Appendix 14: RECENT SPECIALIST STUDIES

Contained in the is Appendix are:

- Groundwater Contamination Assessment for Black Rock Mine Operations Assmang (Pty) Ltd, GPT Reference Number: EEESB-16-1806, January 2017
- Floral Ecological Assessment for the Proposed New Slimes Dam, Scientific Aquatic Services Report Reference: SAS 160054 December 2016
- Waste assessment for land disposal, Mojaterre, Report reference number: PJ160021. January 2017
- Groundwater Assessment for Liner Feasibility for Black Rock Mine Operations, Assmang (Pty) Ltd, GPT Reference number: EEESB-17-2127, February 2017

WASTE ASSESSMENT FOR LAND DISPOSAL

Black Rock Mining Operations – Tailings Facility

Final Document

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January 2017
PJ160021

Limitations, Reliance and Assumption

This report has been exclusively prepared for the Client and the findings presented herein are limited to the scope of work approved by the Client upon acceptance of MojaTerre's proposal (PJ160014).

The report is considered current only for a period of 180 days from the site inspection. Investigation findings presented in this report are based on MojaTerre's professional judgment using information available at the time of the assessment. It is assumed that information sourced by MojaTerre from the Client during the undertaking of this assessment is accurate, current and representative of the site.

Information presented in this report is not intended as legal advice and MojaTerre makes no guarantees about the conditions of the site.

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Author: Renier Pretorius

Designation: Manager

Signature: ______________

Date: January 2017

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List of Abbreviations

As	Arsenic
B	Boron
Ba	Barium
BDL	Below analytical detection limit
BRMO	Black Rock Mining Operation
Cu	Copper
DEA	Department of Environmental Affairs
GNR635	National Norms and Standards for Assessing Wastes for Landfill Disposal developed by the DEA in 2013
GNR636	National Norms and Standards for Disposal of Waste to Landfill developed by the DEA in 2013
H&S	Health & Safety
IWWMP	Integrated Waste and Water Management Plan
LC	Leachable concentrations
TC	Total concentrations
LCT	Leachate concentration threshold value.
Mn	Manganese
MRWDL	Minimum Requirements for Waste Disposal by Landfill developed by the DWAF in 1998.
Pb	Lead
Sb	Antinomy
Se	Selenium
SSV	Soil screening values
TCL	Total concentration threshold value.
ToR	Terms of Reference
TSF	Tailings Storage Facility

1. Introduction

1.1 Terms of Reference

MojaTerre (Pty) Ltd (MojaTerre) was appointed by Envirogistics (Pty) Ltd (Envirogistics) to assess tailings material from the BRMO in accordance with GNR634.

1.2 Project Background

Envirogistics has been appointed by BRMO to undertake numerous environmental specialist work in terms of legislative authorisations and best practice management requirements. In this regard Envirogistics approached MojaTerre to assist with determining the type waste and associated disposal requirements of the BRMO tailings. Tailings from the BRMO process are reportedly stored on-site in an unlined TSF, which is pending some expansion work due to planned production increases.

The BRMO is in the small mining town of Hotazel, which is located approximately 55 km north west of Kuruman and 60 km north of Kathu, all located within the northern portion of the Northern Cape Province. A location map of the facility is provided in ***Annex A***.

The BRMO is an underground manganese mine. Available aerial imagery provided by Google Earth indicates that mining operations within this area have been ongoing since the early 1980's.

Two previous waste assessments were completed for the BRMO (see ***Section 3***). Both studies were completed based on the GNR635 requirements. Previous assessments have characterised the TSF material as a hazardous Type 1 waste which cannot be disposed of, and requires treatment followed by reassessment of the treated waste.

Envirogistics appointed MojaTerre in October 2016 to undertake the required waste assessment, using the technical approached provided in MojaTerre proposal number ***PP150043*** (submitted on 13 September 2016). Due to some sampling difficulties, laboratory analyses were completed between October 2016 and December 2016.

2. Risk Profiling of Waste for Disposal

The South African Legislative framework makes provision for characterising the risks associated with waste materials during handling and storage practices, as well as during disposal.

Regarding disposal to landfill requirements, the DEA has developed the GNR635 and R636 in 2013. GNR635 and GNR636 assist in predicting the conditions to which waste will be exposed during disposal, using generalised assumptions that are applicable to the South African context. Additionally, the GNR635 provides methodologies and criteria for evaluating various waste types during each disposal method to determine the associated disposal risks. Based on the established disposal risks, the GNR635 and GNR636 provide disposal requirements for each identified waste types.

3. Previous Waste Assessments

Two previous waste assessments completed for the BRMO (see ***Section 5.1***) were made available for MojaTerre's review during this project. Both studies were completed based on the GNR635 and NGR636 requirements and include:

- Environmental Management Master Plan, Assmang Ltd., Black Rock Mine Operations: Volume 2: Integrated Water and Waste Management Plan, Prepared by EScience Associates

in October 2012. This assessment focused on the tailings material which is stored in on-site TSFs
- Black Rock Manganese Mine Waste Characterisation Project, prepared by Future Flow Groundwater & Project Management Solutions in June 2016. This study focused on waste rock dumps within the mining footprint.

Previous assessments have characterised the BRMO waste rock material as a hazardous Type 2 waste and the mine tailings as a Type 1 waste. The waste type categories were predominantly influenced by the TC of As, B, Ba, Cu, Mn, Pb, Mn and Se, as well as LC of B, Mn, Sb and Se.

4. Scope of Work

MojaTerre undertook the following Scope of Work to assess the BRMO tailings material:

- Review of available information.
- Sample collection.
- Site visit.
- Laboratory analyses.
- Waste risk profiling for disposal.

5. Our Approach

5.1 Review of Available Information

MojaTerre referred to the following documents during the preparation of this report:

- GNR635 – National Norms and Standards for Assessing Wastes for Landfill Disposal developed by the DEA in 2013
- GNR636 – National Norms and Standards for Disposal of Waste to Landfill developed by the DEA in 2013
- Environmental Management Master Plan, Assmang Ltd., Black Rock Mine Operations: Volume 2: Integrated Water and Waste Management Plan, Prepared by EScience Associates in October 2012.
- Black Rock Manganese Mine Waste Characterisation Project, prepared by Future Flow Groundwater & Project Management Solutions in June 2016.
- Assmang (Pty) Ltd. Black Rock Mine Water Quality Monitoring Report for November 2016, prepared by Aquatico Scientific (Pty) Ltd.

5.2 Sampling Collection

The ToR provided by BRMO stated that one composite TSF sample will be prepared by the mine and that the sample should be collected by a MojaTerre Field Consultant during the site visit.

To maximise the opportunity to obtain a sample which is representative of actual conditions, MojaTerre suggested that (where possible):

- Samples are collected from the TSF discharge area.
- For a physicochemical sample –
    - A small, 50g sample of the waste stream was collected twice a day, daily, for the duration of five days. The collected samples were combined into a ±250g composite laboratory sample collected in plastic container with an airtight seal.
- For an organic compound sample –
    - Two ±125g samples were collected once-off on the final day of sampling. These containers were amber glass jars with airtight seals.
- The laboratory samples were, as far as practically possible, isolated from contact with oxygen.

- The laboratory samples were kept in a cool environment, not in direct sunlight during the sample collection process.

MojaTerre delivered the physicochemical sample to Talbot Laboratories in Pietermaritzburg and the organic compounds samples to Waterlab Laboratory Services for analyses.

5.3 Site Visit

MojaTerre completed a site visit to the BRMO on 26 October 2016. During the site visit, the MojaTerre Field Consultant held interviews with key site personnel. MojaTerre used the interviews as opportunities to gain a better understanding of the processes which generate the tailings material.

After completing the site interviews, MojaTerre requested a short site visit of the waste stream generation and disposal areas. MojaTerre recorded photographs, GPS Coordinates and site observations during the site walkover. The sample location is provided in ***Annex A***.

5.4 Laboratory Analyses

As per the GNR635 requirements, MojaTerre instructed the laboratories to analyse the composite samples for the TC and LC of the constituents listed in ***Annex B***, using the Australian Standard Leaching Procedure (AS4439.1, 4439.2 and 4439.3).

Tailings material is pump to a storage facility in which only tailings are stored. The tailings are not mixed with other waste. In this regards, and in accordance with the GNR635 requirements, a reagent water leachate solution is required for the analytical tests. However, based on existing available information regarding the most abundant chemical species in the tailings material, and for purpose of comparison, MojaTerre requested the following from the laboratories:

- TC using the GNR635 requirements.
- A leach test using reagent water with a pH which was determined by a paste test, followed by analyses of the leach solution for the entire GNR635 constituent list. The paste pH test (1 part solid: 2 parts water) is a method used to determine the in-situ acidic nature of a rock/soil sample. This approach is considered more realistic in terms of actual conditions in the TSF, but also as the worst-case scenario.
- A leach test using normal reagent water as per the GNR635 requirements, followed by analyses of the leach solution for key species identified during the paste test leach test.

5.5 Waste Risk Profiling for Disposal

MojaTerre assessed information obtained during the investigation in accordance with the requirements of GNR635, using the TCT and LCT values stipulated in the document. The GNR635 also provides associated disposal requirements for each identified waste type, which are further supplemented with requirements stipulated in the GNR636.

Table 1 provides a useful summary of the GNR635 and GNR636 requirements.

Table 1 – Waste Type and Landfill Requirement Summary			
TCT and LCT Ranges	**Associated Waste Type**	**Associated Risk Level**	**Required Landfill Design Class**
LC > LCT3 TC > TCT2	Type 0	***Very High Risk*** – • Very high potential for contaminant release. • Requires very high level of control and ongoing management.	• No disposal allowed. • Treatment followed by reassessment is required.
LCT2 < LC ≤ LCT3 TCT1 < TC < TCT2	Type 1	***High Risk*** – • High potential for contaminant release. • Requires high level of control and ongoing management.	• Class A. • Hh:HH landfill as per MRWDL.
LCT1 < LC ≤ LCT2 TCT ≤ TCT1	Type 2	***Moderate Risk*** – • Potential for contaminant release. • Requires proper level of control and ongoing management.	• Class B. • GLB+ landfill as per MRWDL.
LCT0 < LC ≤ LCT1	Type 3	***Low Risk*** – • Low potential for contaminant release. • Requires some level of control and ongoing management.	• Class C. • GLB+ landfill as per MRWDL.
LC ≤ LCT0 TC ≤ TCT0	Type 4	***Low Risk*** – • Low potential for contaminant release. • Requires basic level of control and ongoing management.	• Class D. • GLB+ landfill as per MRWDL.
• Disposal facility design requirements are provided in ***Annex C.***			

6. Results and Findings

6.1 Site Observations

The TSF sample collection point is located at 27°10'32.93"S and 22°54'29.67"E.

The TSF material is dark grey to black, with black material typically having a higher moisture content. The material is loose and similar to fine to coarse sand. The composite sample collected by BRMO had a high moisture content. The sample did not present any obvious odours.

The composite physicochemical sample had an approximate volume of 3L and was stored in an airtight plastic container. The organic compounds sample was collected in an airtight 500mL glass jar.

6.2 Laboratory Results

Laboratory certificates are presented in ***Annex B***. Laboratory results are populated in data evaluation tables, which are also presented on ***Annex B***.

The pH values of the physicochemical and organic compound samples during analyses ranged between 9 and 10.

In terms of detected TC, B, Ba, Cd, Co, Cu and Pb exceed the relevant TCT0 values, whilst exceedance of the TCT2 value is noted for Mn.

In terms of the different leach test scenarios, the paste leach test showed LC exceeding the relevant LCT0 values for B, Ba, Pb and TDS. Mn concentration represents the highest LC within the tested analytical suites, being recorded at a concentration exceeding the LCT1 range.

The normal reagent water leach test indicated low to non-detectable concentrations of the key metals identified during the paste leach test.

6.3 Results Discussion

Due to the significantly high total Mn concentration in the tailings material, the material is categorised as a Type 0 waste in terms of the R635. However, as stipulated in the R635, Type 0 wastes may not be disposed of to landfill (or in this case TSF). Type 0 waste must be treated and reassessed in terms of the R635 before disposal of such waste can be considered.

Due to the geochemical nature of the ore processed at the BRMO, treatment options to address the Mn concentrations within the tailings material is not considered practical and financially feasible. Therefore, it is MojaTerre's perception that the management of tailings material at the BRMO as a Type 1 waste would be the best practical solution for the material. Type 1 wastes require a disposal facility with Class A engineered liners. The associated TSF liner requirements are provided in ***Annex C***.

6.4 Consideration of Alternatives

The Mn within the tailings material is relatively immobile at the pH values measured during this assessment (9.1 to 9.7). This finding is also portrayed within the available water quality information which indicates low to non-detectable Mn concentrations in plant effluents and the surrounding groundwater.

Available water quality data also shows similar results to this waste assessment in terms of pH values, with higher pH values typically associated with processing areas as detected in the plant effluents. This correlation is possibly due to the basic nature of the BRMO ore, increased surface areas associated with processed ore material fines and increased contact time between ore fines and process water, which is similar to the leachate test during which milled sample material is washed in reagent water for several hours.

Available groundwater quality information for monitoring boreholes downgradient of the TSF shows low to non-detectable concentrations of dissolved Mn. This confirms, with limited information available, the immobility of Mn within the current tailings disposal facility as well as no pollution links to the receiving groundwater environment.

The immobility of Mn within the currently unlined TSF further supports MojaTerre's perception that tailings material at the BRMO can be managed as a Type 1 waste.

As indicated in the R635, the TCT values were derived from the SSV developed in the Framework for the Management of Contaminated Land in South Africa (DEA, 2010). The SSV consider total contaminant concentrations and are land use dependant, considering exposure to sensitive receptors through direct inhalation and ingestion as well as groundwater consumption pathways. In this regard, the detected total Mn concentration in the tailings and its immobility during disposal can be considered a greater health and environmental risk in terms of fugitive dust generation as well as material handling, rather than leachate generation and subsurface migration. On this basis, BRMO has a potential case to motivate for further relaxed requirements (management of tailings as a Type 2 waste based on predicted leachate quality) from the regulators in terms of the final TSF liner specifications (Class B liner) for future facility expansions. Such motivation should be supplemented with comprehensive H&S and material handling procedures as well as a dedicated TSF groundwater monitoring programme.

7. Closing Comments

In terms of the R635 requirements and the physicochemical properties of the BRMO tailings, the tailings material is to be considered a Type 1 waste (predominantly due to elevated total Mn concentration). In this regards any expansions of the currently unlined TSF will require an engineered Class A liner. However, based on the relatively immobile nature of Mn in the material, BRMO could motivate for relaxed waste management requirements from the relevant regulators.

Annex A – Maps

Figure 1 – Location Map

Figure 2 – Sample Locality Map

MojaTerre

Project Details:	PJ160021 – Envirogistics Waste Type Assessment (BRMO).
Map Name:	Figure 1 - Site Location Map.
Prepared By:	Renier Pretorius, January 2017.
Source Data:	Google Maps (2017)

MojaTerre

Project Details:	PJ160021 – Envirogistics Waste Type Assessment (BRMO).
Map Name:	Figure 2: Sample Locality Map.
Prepared By:	Renier Pretorius, January 2017.
Source Data:	Google Maps (2017).

Annex B – Laboratory Results

Data Evaluation Tables

Laboratory Certificate

Constituents	Units	TCT0	TCT1	TCT2	Black Rock
# pH at 25°C	pH units				9.1 to 10.1
Metal Ions					
Arsenic, As	mg/kg	5.8	500	2000	2.97
Boron, B	mg/kg	150	15000	60000	441
Barium, Ba	mg/kg	62.5	6250	25000	5020
Cadmium, Cd	mg/kg	7.5	260	1040	0.5
Cobalt, Co	mg/kg	50	5000	20000	50
Chromium, Cr	mg/kg	46000	800000	N/A	6.44
* Hexavalent Chromium, Cr6+	mg/kg	6.5	500	2000	BDL
Copper, Cu	mg/kg	16	19500	78000	65
Mercury, Hg	mg/kg	0.93	160	640	0.13
Manganese, Mn	mg/kg	1000	25000	100000	211718
Molybdenum, Mo	mg/kg	40	1000	4000	15.66
Nickel, Ni	mg/kg	91	10600	42400	7.93
Lead, Pb	mg/kg	20	1900	7600	50
Antimony, Sb	mg/kg	10	75	300	BDL
Selenium, Se	mg/kg	10	50	200	0.09
Vanadium, V	mg/kg	150	2680	10720	1.88
Zinc, Zn	mg/kg	240	160000	640000	61
Iron, Fe	mg/kg				28083
Inorganic anions					
TDS	mg/kg				
Chloride, Cl	mg/kg				
Sulphate, SO4	mg/kg				
Nitrate as nitrigen, NO3 as N	mg/kg				
Total Fluoride	mg/kg	100	10000	40000	3
Total Cyanide	mg/kg	14	10500	42000	0.1
Organis species					
VOC's: Dilution x 20 - µg/kg					
Benzene	mg/kg		10	40	BDL
Carbon Tetrachloride	mg/kg		4	16	BDL
Chlorobenzene	mg/kg		8800	35200	BDL
Chloroform	mg/kg		700	2800	BDL
1,2-Dichlorobenzene	mg/kg		31900	127600	BDL
1,4-Dichlorobenzene	mg/kg		18400	73600	BDL
1,2-Dichloroethane	mg/kg		3.7	15000	BDL
Ethylbenzene	mg/kg		540	2160	BDL
Hexachlorobutadiene	mg/kg		2.8	5.4	BDL
MTBE	mg/kg		1435	5740	BDL
Naphthalene	mg/kg				BDL
Styrene	mg/kg		120	480	BDL
1,1,1,2-Tetrachloroethane	mg/kg		400	1600	BDL
1,1,2,2-Tetrachloroethane	mg/kg		5	20	BDL
Toluene	mg/kg		1150	4600	BDL
1,1,1-Trichloroethane	mg/kg		1200	4800	BDL
1,1,2-Trichloroethane	mg/kg		48	192	BDL
Xylenes total	mg/kg		890	3560	BDL
1,2,4 Trichlorobenzene	mg/kg		Total of 3300	Total of 13200	BDL
1,2,3 Trichlorobenzene	mg/kg				BDL
1,3,5 Trichlorobenzene	mg/kg				BDL
Dichloromethane	mg/kg		16	64	BDL
1,1-Dichloroethylene	mg/kg		150	600	BDL
1,2-Dichloroethylene	mg/kg		3750	15000	BDL
Tetrachloroethylene	mg/kg		200	800	BDL
Trichloroethylene	mg/kg		11600	46400	BDL
Polars Dilution: Dilution x 20 - µg/kg					
2-Butanone (methyl ethyl ketone)	mg/kg		8000	32000	BDL
Vinyl Chloride	mg/kg		1.5	6	BDL
Formaldehyde: Dilution x 10 - µg/kg					
Formaldehyde	mg/kg		2000	8000	839.28
SVOC's: Dilution x 20 - µg/kg					
Benzo(a)pyrene	mg/kg		1.7	6.8	BDL
Di (2 ethylhexyl) Phthalate	mg/kg		40	160	BDL
Nitrobenzene	mg/kg		45	180	BDL
2,4 Dinitrotoluene	mg/kg		5.2	20.8	BDL
Total PAH's	mg/kg		50	200	BDL
PHENOLS: Dilution x20 - µg/kg					
2-Chlorophenol	mg/kg		2100	8400	BDL
2,4-Dichlorophenol	mg/kg		800	3200	BDL
2,4,6-Trichlorophenol	mg/kg		1770	7080	BDL
Phenols (total,non-halogenated)	mg/kg		560	2240	BDL
Pesticides: Dilution x20 - µg/kg					
Aldrin	mg/kg		Total of 1.2	Total of 4.8	BDL
Dieldrin	mg/kg				BDL
DDT	mg/kg		Total of 50	Total of 200	BDL
DDE	mg/kg				BDL
DDD	mg/kg				BDL
Heptachlor	mg/kg		1.2	4.8	BDL
Chlordane	mg/kg		4	16	BDL
2,4 Dichlorophenoxyacetic Acid	mg/kg		120	480	BDL
PCB: Dilution x1 - µg/kg					
Polychlorinated biphenyls	mg/kg		12	48	BDL
TPH: Dilution x1 - µg/kg					
Petroleum H/Cs,C6-C9	mg/kg		650	2600	BDL
Petroleum H/Cs,C10 to C36	mg/kg		10000	40000	BDL
Waste Type Category					***Type 0***

Constituents	Units	LCT0	LCT1	LCT2	LCT3	Black Rock_Paste Test	Black Rock_Reagent Water
# pH at 25°C	pH units					9.7 to 10.1	9.7 to 10.1
Metal Ions							
Arsenic, As	mg/L	0.01	0.5	1	4	0.001	BDL
Boron, B	mg/L	0.5	25	50	200	1.413	0.142
Barium, Ba	mg/L	0.7	35	70	280	0.841	0.281
Cadmium, Cd	mg/L	0.003	0.15	0.3	1.2	BDL	-
Cobalt, Co	mg/L	0.5	25	50	200	0.022	-
Chromium, Cr	mg/L	0.1	5	10	40	0.007	-
* Hexavalent Chromium, Cr6+	mg/L	0.05	2.5	5	20	BDL	-
Copper, Cu	mg/L	2	100	200	800	0.383	-
Mercury, Hg	mg/L	0.006	0.3	0.6	2.4	BDL	-
Manganese, Mn	mg/L	0.5	25	50	200	42	BDL
Molybdenum, Mo	mg/L	0.07	3.5	7	28	0.002	-
Nickel, Ni	mg/L	0.07	3.5	7	28	0.019	-
Lead, Pb	mg/L	0.01	0.5	1	4	0.026	BDL
Antimony, Sb	mg/L	0.02	1	2	8	BDL	-
Selenium, Se	mg/L	0.01	0.5	1	4	0.001	BDL
Vanadium, V	mg/L	0.2	10	20	80	BDL	-
Zinc, Zn	mg/L	5	250	500	2000	0.103	-
Iron, Fe	mg/L					0.147	-
Inorganic anions							
TDS	mg/L	1000	12500	25000	100000	4304	-
Chloride, Cl	mg/L	300	15000	30000	120000	Iron interference	-
Sulphate, SO4	mg/L	250	12500	25000	100000	58	-
Nitrate as nitrigen, NO3 as N	mg/L	11	550	1100	4400	1.07	-
Total Fluoride	mg/L	1.5	75	150	600	0.09	-
Total Cyanide	mg/L	0.07	3.5	7	28	BDL	-
Organis species							
VOC's: Dilution x1 - µg/L							
Benzene	mg/L		0.01	0.02	0.08	BDL	-
Carbon Tetrachloride	mg/L		0.2	0.4	1.6	BDL	-
Chlorobenzene	mg/L		5	10	40	BDL	-
Chloroform	mg/L		15	30	120	BDL	-
1,2-Dichlorobenzene	mg/L		5	10	40	BDL	-
1,4-Dichlorobenzene	mg/L		15	30	120	BDL	-
1,2-Dichloroethane	mg/L		1.5	3	12	BDL	-
Ethylbenzene	mg/L		3.5	7	28	BDL	-
Hexachlorobutadiene	mg/L		0.03	0.06	0.24	BDL	-
MTBE	mg/L		2.5	5	20	BDL	-
Naphthalene	mg/L					BDL	-
Styrene	mg/L		1	2	8	BDL	-
1,1,1,2-Tetrachloroethane	mg/L		5	10	40	BDL	-
1,1,2,2-Tetrachloroethane	mg/L		0.65	1.3	5.3	BDL	-
Toluene	mg/L		35	70	280	BDL	-
1,1,1-Trichloroethane	mg/L		15	30	120	BDL	-
1,1,2-Trichloroethane	mg/L		0.6	1	4	BDL	-
Xylenes total	mg/L		25	50	200	BDL	-
1,2,4 Trichlorobenzene	mg/L		Total of 3.5	Total of 7	Total of 28	BDL	-
1,2,3 Trichlorobenzene	mg/L					BDL	-
1,3,5 Trichlorobenzene	mg/L					BDL	-
Dichloromethane	mg/L		0.25			BDL	-
1,1-Dichloroethylene	mg/L		0.35	0.7	2.8	BDL	-
1,2-Dichloroethylene	mg/L		2.5	5	20	BDL	-
Tetrachloroethylene	mg/L		0.25	0.5	2	BDL	-
Trichloroethylene	mg/L		0.25	2	8	BDL	-
Polars Dilution: Dilution x 1- µg/L							
2-Butanone (methyl ethyl ketone)	mg/L		100	5	20	BDL	-
Vinyl Chloride	mg/L		0.015	0.03	0.12	BDL	-
Formaldehyde: Dilution x 2 - µg/L							
Formaldehyde	mg/L		25	50	200	BDL	-
SVOC's: Dilution x 1 - µg/L							
Benzo(a)pyrene	mg/L		0.035	0.07	0.28	BDL	-
Di (2 ethylhexyl) Phthalate	mg/L		0.5	1	4	BDL	-
Nitrobenzene	mg/L		1	2	8	BDL	-
2,4 Dinitrotoluene	mg/L		0.065	0.13	0.52	BDL	-
Total PAH's	mg/L					BDL	-
Phenols: Dilution x 1 - µg/L							
2-Chlorophenol	mg/L		15	30	120	BDL	-
2,4-Dichlorophenol	mg/L		10	20	80	BDL	-
2,4,6-Trichlorophenol	mg/L		10	20	80	BDL	-
Phenols (total,non-halogenated)	mg/L		7	14	65	BDL	-
Pesticides: Dilution x 1 - µg/L							
Aldrin	mg/L		0.015	0.03	0.03	BDL	-
Dieldrin	mg/L					BDL	-
DDT	mg/L		1	2	2	BDL	-
DDE	mg/L					BDL	-
DDD	mg/L					BDL	-
Heptachlor	mg/L		0.015	0.03	0.03	BDL	-
Chlordane	mg/L		0.05	0.1	0.1	BDL	-
2,4 Dichlorophenoxyacetic Acid	mg/L		1.5	3	3	BDL	-
PCB: Dilution x 1 - µg/L							
Polychlorinated biphenyls	mg/L		0.025	0.05	0.2	BDL	-
TPH: Dilution x 1 - µg/L							
Petroleum H/Cs,C6-C9	mg/L					BDL	-
Petroleum H/Cs,C10 to C36	mg/L					BDL	-
Waste Type Category						***Type 2***	***Type 4***

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CERTIFICATE OF ANALYSES
EXTRACTIONS AS 4439.3

Date received:	**2016-11-25**			**Date completed:**	**2016-12-15**
Project number:	**1000**	**Report number:**	**63647**	**Order number:**	**PO160024**

Client name:	**MojaTerre Pty Ltd**	**Contact person:**	**Renier Pretorius**
Address:	**P O Box 1105, Montana Park, Pretoria, 0159**	**Email:**	**renier.pretorius@mojaterre.com**
Telephone:	**+27 12 743 5725**	**Cell:**	**082 052 9944**

Analyses	BlackRock	
Sample Number	23368	
TCLP / Borax / Distilled Water	Distilled Water	
Ratio*	1:20	
Units	mg/ℓ	LCT0 mg/l
Organics [s]		
VOC's: Dilution x1 - ug/liter		
Benzene	<1	0.01
Carbon Tetrachloride	<5	0.2
Chlorobenzene	<2	5
Chloroform	<5	15
1,2-Dichlorobenzene	<2	5
1,4-Dichlorobenzene	<2	15
1,2-Dichloroethane	<2	1.5
Ethylbenzene	<2	3.5
Hexachlorobutadiene	<2	0.03
MTBE	<5	2.5
Naphthalene	<2	
Styrene	<5	1
1,1,1,2-Tetrachloroethane	<10	5
1,1,2,2-Tetrachloroethane	<10	0.65
Toluene	<10	35
1,1,1-Trichloroethane	<5	15
1,1,2-Trichloroethane	<5	0.6
Xylenes total	<5	25
1,2,4 Trichlorobenzene	<2	3.5
1,2,3 Trichlorobenzene	<2	
1,3,5 Trichlorobenzene	<2	
Dichloromethane	<50	0.25
1,1-Dichloroethylene	<10	0.35
1,2-Dichloroethylene	<10	2.5
Tetrachloroethylene	<10	0.25
Trichloroethylene	<10	0.25
Polars Dilution: Dilution x1 - ug/liter		
2-Butanone (methyl ethyl ketone)	<50	100
Vinyl Chloride	<2	0.015
Formaldehyde: Dilution x2 - ug/liter		
Formaldehyde	<100	25
SVOC's: Dilution x1 - ug/liter		
Benzo(a)pyrene	<0.1	0.035
Di (2 ethylhexyl) Phthalate	<10	0.5
Nitrobenzene	<1	1
2,4 Dinitrotoluene	<5	0.065
Total PAH's	<2	N/A
PHENOLS: Dilution x1 - ug/liter		
2-Chlorophenol	<2	15
2,4-Dichlorophenol	<2	10
2,4,6-Trichlorophenol	<2	10
Phenols (total,non-halogenated)	<20	7
Pesticides: Dilution x1 - ug/liter		
Aldrin	<0.1	0.015
Dieldrin	<0.1	0.015
DDT	<0.1	1
DDE	<0.1	1
DDD	<0.1	1
Heptachlor	<0.1	0.015
Chlordane	<0.1	0.05
2,4 Dichlorophenoxyacetic Acid	UTD	1.5
PCB: Dilution x1 - ug/liter		
Ballsmitters Totals	<5	0.025
TPH: Dilution x1 - ug/liter		
Petroleum H/Cs,C6-C9	<10	N/A
Petroleum H/Cs,C10 to C36	<382	N/A
pH	9.72	

[s]=subcontracted
UTD = Unable to detect

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

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CERTIFICATE OF ANALYSES

Digestion AS 4439.3

Date received:	**2016-11-25**		**Date completed:**	**2016-12-15**
Project number:	**1000**	**Report number: 63647**	**Order number:**	**PO160024**
Client name:	**MojaTerre Pty Ltd**		**Contact person:**	**Renier Pretorius**
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Telephone:	**+27 12 743 5725**		**Cell:**	**0820529944**

Analyses	BlackRock	
Sample Number	23368	TCT0 mg/kg
Total Organics [s]		
VOC's: Dilution x20 - ug/kg		
Benzene	<20	10
Carbon Tetrachloride	<100	4
Chlorobenzene	<40	8800
Chloroform	<100	700
1,2-Dichlorobenzene	<40	31900
1,4-Dichlorobenzene	<40	18400
1,2-Dichloroethane	<40	3.7
Ethylbenzene	<40	540
Hexachlorobutadiene	<40	2.8
MTBE	<100	1435
Naphthalene	<40	
Styrene	<100	120
1,1,1,2-Tetrachloroethane	<200	400
1,1,2,2-Tetrachloroethane	<200	5
Toluene	<200	1150
1,1,1-Trichloroethane	<100	1200
1,1,2-Trichloroethane	<100	48
Xylenes total	<100	890
1,2,4 Trichlorobenzene	<40	3300
1,2,3 Trichlorobenzene	<40	
1,3,5 Trichlorobenzene	<40	
Dichloromethane	<1000	16
1,1-Dichloroethylene	<200	150
1,2-Dichloroethylene	<200	3750
Tetrachloroethylene	<200	200
Trichloroethylene	<200	11600
Polars Dilution: Dilution x20 - ug/kg		
2-Butanone (methyl ethyl ketone)	<1000	8000
Vinyl Chloride	<40	1.5
Formaldehyde: Dilution x10 - ug/kg		
Formaldehyde	839.28	2000
SVOC's: Dilution x20 - ug/kg		
Benzo(a)pyrene	<2	1.7
Di (2 ethylhexyl) Phthalate	<200	40
Nitrobenzene	<20	45
2,4 Dinitrotoluene	<100	5.2
Total PAH's	<40	50
PHENOLS: Dilution x20 - ug/kg		
2-Chlorophenol	<40	2100
2,4-Dichlorophenol	<40	800
2,4,6-Trichlorophenol	<40	1770
Phenols (total,non-halogenated)	<400	560
Pesticides: Dilution x20 - ug/kg		
Aldrin	<2	1.2
Dieldrin	<2	1.2
DDT	<2	50
DDE	<2	50
DDD	<2	50
Heptachlor	<2	1.2
Chlordane	<2	4
2,4 Dichlorophenoxyacetic Acid	UTD	120
PCB: Dilution x1 - ug/kg		
Ballsmitters Totals	<175	12
TPH: Dilution x1 - ug/kg		
Petroleum H/Cs,C6-C9	<200	650
Petroleum H/Cs,C10 to C36	<38000	10000
pH	10.01	

[s] = subcontracted
UTD = Unable to detect

E. Botha ________________
Geochemistry Project Manager

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10th JANUARY 2017

ANALYTICAL REPORT

OUR REF:	**W1766Y16.REP.R1**
	This report replaces W1766Y16.REP
COMPANY NAME:	**MOJATERRE (PTY) LTD**
COMPANY ADDRESS:	**P.O.BOX 1105, MONTANA PARK, PRETORIA**
CONTACT PERSON:	**RENIER PRETORIUS**
QUOTATION NUMBER:	**QU11-0022**
ORDER NUMBER:	**PO160020**
DATE SUBMITTED:	**07/11/2016**

SUMMARY OF RESULTS

From the results outlined below in the assessment, the waste can be assessed as follows:

The Black Rock Sludge is considered to be a Type 0 waste.

From the results outlined below for the Total Concentrations, Boron, Barium, Lead and Copper are greater than Total Concentration Threshold limits (>TCT0) but less than TCT1 (<TCT1), and Manganese is greater than TCT2 (>TCT2). For the Leachable Concentrations, Boron, Barium, Lead and Total Dissolved Solids are greater than Leachable Concentration Threshold limits (>LCT0) but less than LCT1 (<LCT1), and Manganese is greater than LCT1 but less than LCT2 (LCT1<LC<LCT2).

“Wastes with any element or chemical substance concentration above the LCT3 or TCT2 limits (LC>LCT3 or TC>TCT2) are Type 0 Wastes”.

Type 0 wastes may not be disposed to Landfill. The waste needs to be treated and re-assessed in terms of the *Norms and Standards for Assessment of Waste for Landfill Disposal.*

Directors: Dr MMJ- F Talbot, Mr FD Urbaniak- Hedley (British), Mrs VR Talbot, Mr CA Haycock, Mr GM Thompson, Mr CJ Allen
Talbot & Talbot (Pty) Ltd • Company Registration Number: 2000/ 021732/ 07

ANALYTICAL RESULTS FOR THE ASSESSMENT OF WASTE FOR LANDFILL DISPOSAL

One [1] sample was submitted to the laboratory for various analyses. **The results are presented below.**

TOTAL CONCENTRATIONS

Total concentrations were determined as per the National Environmental Management Waste Act 59, 2008, for the National Norms and Standards for the Assessment of Waste for Landfill Disposal.

DETERMINAND	UNITS	RESULTS W1766/16	Total Concentration Threshold (TCT) limits mg/kg		
		BLACK ROCK SLUDGE	TCT0	TCT1	TCT2
# pH at 25°C	pH units	9.1			
* Hexavalent Chromium	mg/kg	<0.10	6.5	500	2000
Total Fluoride	mg/kg	3.00	100	10000	40000
Total Cyanide	mg/kg	0.10	14	10500	42000

Comments: # pH was analysed on the sample filtrate.
* The sample was prepared by a 1:10 aqueous extraction whereby the resultant filtrate was analysed for Hexavalent Chromium. The result was calculated back with mass and volume used in the extraction.
- All determinands fall below the Total Concentration Threshold (TCT0) limits (<TCT0).

METALS

The sample was prepared by an aqua-regia digestion where the resultant digest was analysed for metals by ICP-MS. These results were calculated back with mass and volume used in the digestion.

DETERMINAND	UNITS	RESULTS W1766/16	Total Concentration Threshold (TCT) limits (mg/kg)		
		BLACK ROCK SLUDGE [Aqua-Regia]	TCT0	TCT1	TCT2
Boron, B	mg/kg	441	150	15000	60000
Molybdenum, Mo	mg/kg	15.66	40	1000	4000
Cadmium, Cd	mg/kg	0.50	7.5	260	1040
Antimony, Sb	mg/kg	<0.01	10	75	300
Barium, Ba	mg/kg	5020	62.5	6250	25000
Mercury, Hg	mg/kg	0.13	0.93	160	640
Lead, Pb	mg/kg	50	20	1900	7600
Vanadium, V	mg/kg	1.88	150	2680	10720
Chromium, Cr	mg/kg	6.44	46000	800000	N/A
Manganese, Mn	mg/kg	211718	1000	25000	100000
Iron, Fe	mg/kg	28083			
Cobalt, Co	mg/kg	50	50	5000	20000
Nickel, Ni	mg/kg	7.93	91	10600	42400
Copper, Cu	mg/kg	65	16	19500	78000
Zinc, Zn	mg/kg	61	240	160000	640000
Arsenic, As	mg/kg	2.97	5.8	500	2000
Selenium, Se	mg/kg	0.09	10	50	200

Comment: All metals are below or equal to the Total Concentration Threshold (TCT0) limits (≤TCT0) except Boron, Barium, Lead and Copper which are greater than TCT0 but less than TCT1 (TCT0<TC<TCT1), and Manganese which is greater than TCT2 (>TCT2). Iron does not form part of the required testing but was relatively high and included for reference purposes.

LEACHABLE CONCENTRATIONS

The sample was subjected to an Australian Standard Leaching Procedure (ASLP) as per National Environmental Management Waste Act 59 2008, for the National Norms and Standards for the Assessment of Waste for Landfill Disposal. The resultant leachate was analysed. **The results are presented below.**

DETERMINAND	UNITS	RESULTS W1766/16 BLACK ROCK SLUDGE [ASLP Leachate]	Leachable Concentration Threshold (LCT) limits mg/ℓ			
			LCT0	LCT1	LCT2	LCT3
Hexavalent Chromium	mg/ℓ	<0.01	0.05	2.5	5	20
Total Dissolved Solids	mg/ℓ	4304	1000	12500	25000	100000
Chloride	mg/ℓ	Iron interference	300	15000	30000	120000
Sulphate	mg/ℓ	58	250	12500	25000	100000
Nitrate	mg/ℓ	1.07	11	550	1100	4400
Fluoride	mg/ℓ	0.09	1.5	75	150	600
Cyanide	mg/ℓ	<0.01	0.07	3.5	7	28

Comment: All determinands fall below the Leachable Concentration Threshold (LCT0) limits (<LCT0) except Total Dissolved Solids which is above the Leachable Concentration Threshold Limit (LCT0) but below LCT1 (LCT0<LC<LCT1). Chloride could not be determined due to an iron interference (refer to Metals for the total and leachable Iron concentrations).

METALS

DETERMINAND	UNITS	RESULTS W1766/16 BLACK ROCK SLUDGE [ASLP Leachate]	Leachable Concentration Threshold (LCT) limits mg/ℓ			
			LCT0	LCT1	LCT2	LCT3
Boron, B	mg/ℓ	1.413	0.5	25	50	200
Molybdenum, Mo	mg/ℓ	0.002	0.07	3.5	7	28
Cadmium, Cd	mg/ℓ	<0.001	0.003	0.15	0.3	1.2
Antimony, Sb	mg/ℓ	<0.001	0.02	1.0	2	8
Barium, Ba	mg/ℓ	0.841	0.7	35	70	280
Mercury, Hg	mg/ℓ	<0.001	0.006	0.3	0.6	2.4
Lead, Pb	mg/ℓ	0.026	0.01	0.5	1	4
Vanadium, V	mg/ℓ	<0.001	0.2	10	20	80
Chromium, Cr	mg/ℓ	0.007	0.1	5	10	40
Manganese, Mn	mg/ℓ	42	0.5	25	50	200
Iron, Fe	mg/ℓ	0.147				
Cobalt, Co	mg/ℓ	0.022	0.5	25	50	200
Nickel, Ni	mg/ℓ	0.019	0.07	3.5	7	28
Copper, Cu	mg/ℓ	0.383	2.0	100	200	800
Zinc, Zn	mg/ℓ	0.103	5.0	250	500	2000
Arsenic, As	mg/ℓ	0.001	0.01	0.5	1	4
Selenium, Se	mg/ℓ	0.001	0.01	0.5	1	4

Comment: All metals fall below the Leachable Concentration Threshold (LCT0) limits (<LCT0) except Boron, Barium and Lead which are greater than LCT0 but less than LCT1 (LCT0<LC<LCT1), and Manganese which is greater than LCT1 but less than LCT 2 (LCT1<LC<LCT2). Iron does not form part of the required testing but was relatively high and included for reference purposes.

Vanessa Talbot
TECHNICAL DIRECTOR

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Annex C – R636 Disposal Facility Design Requirements

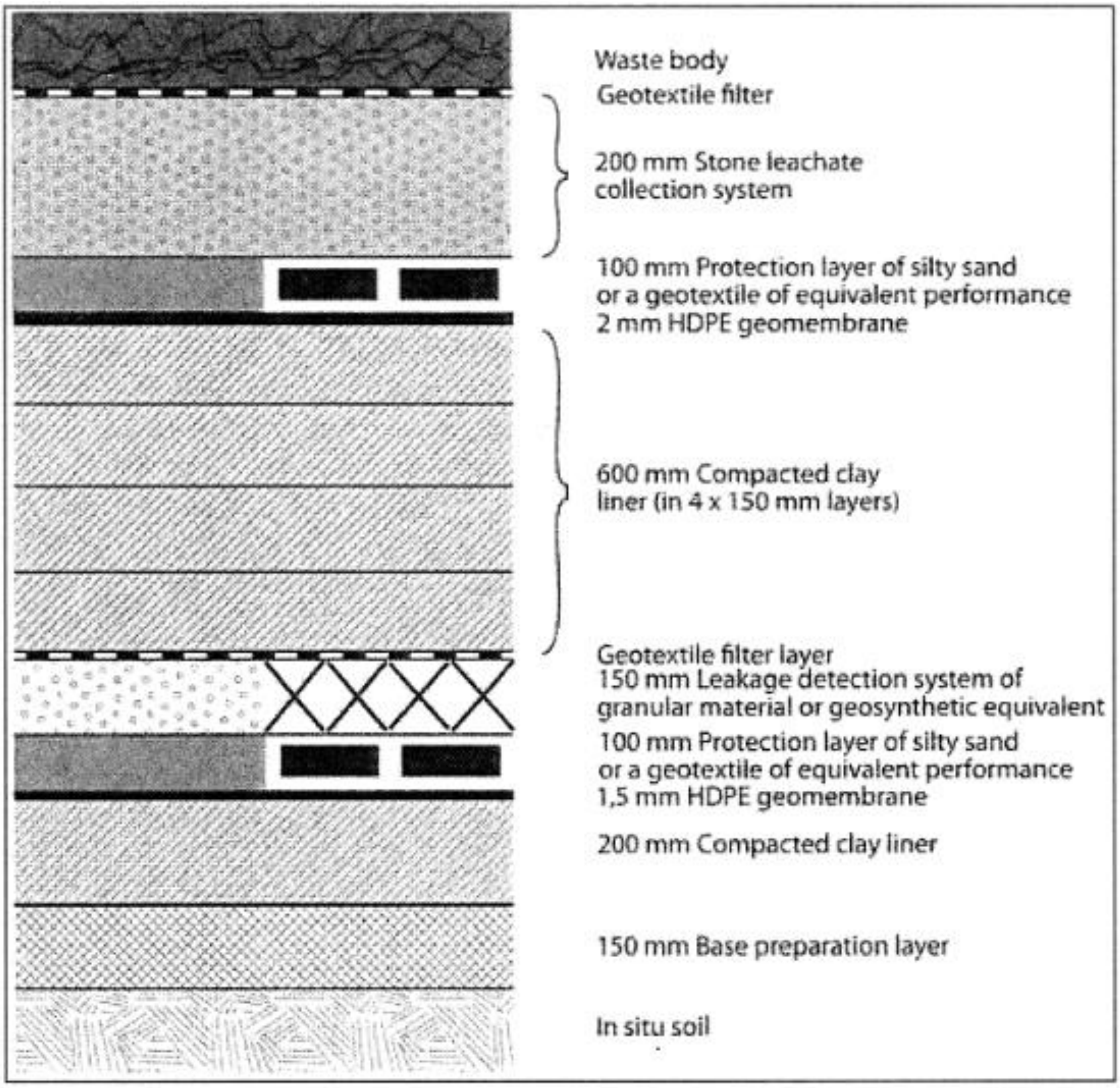
Class A Disposal Facilities

Class B Disposal Facilities

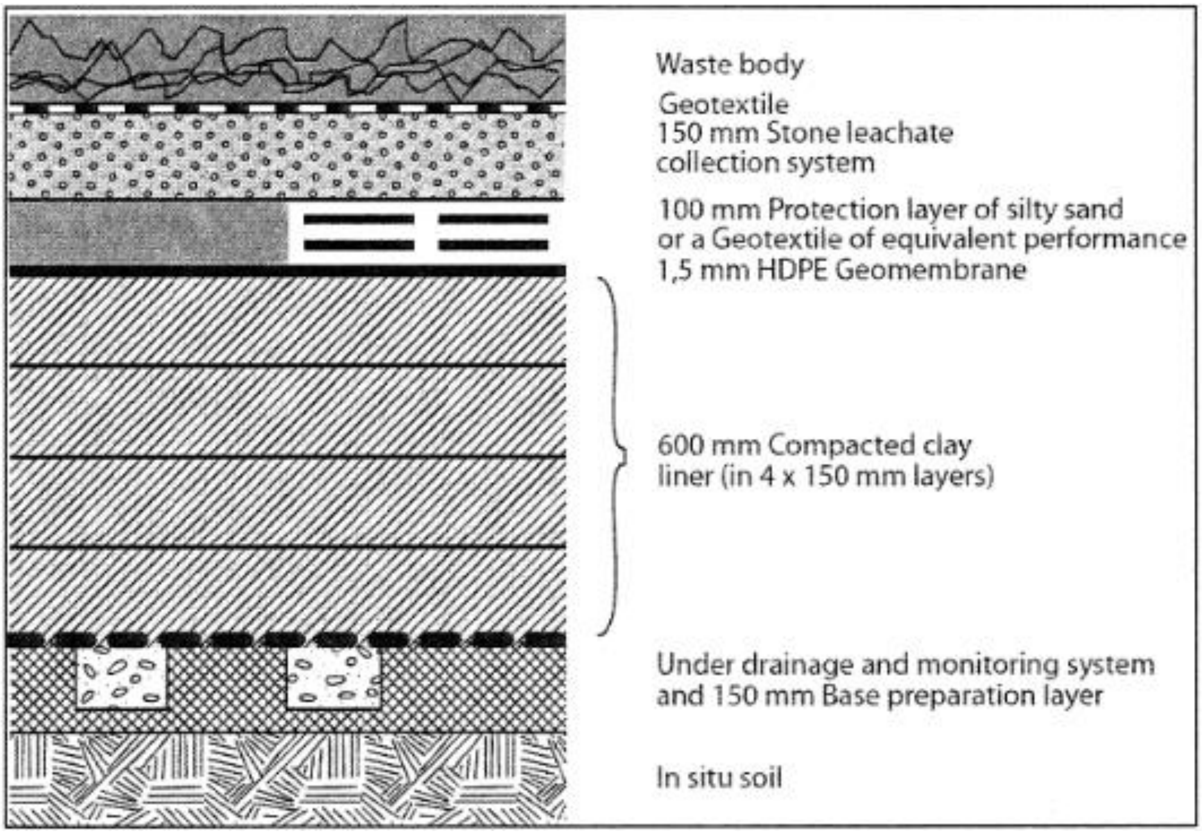
Class C Disposal Facilities

Class D Disposal Facilities

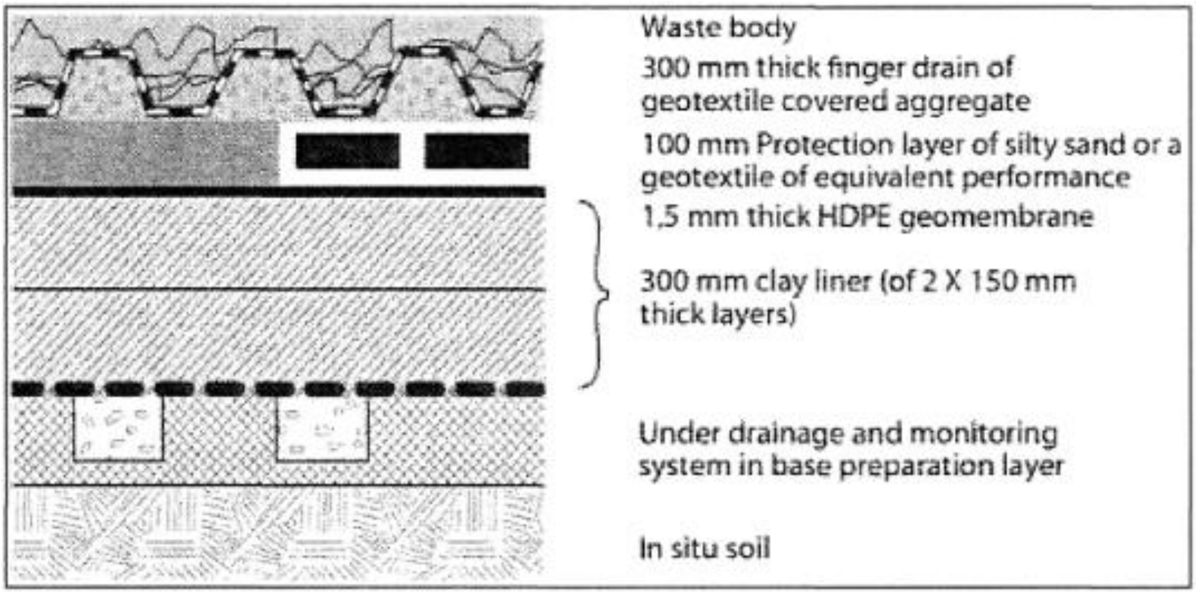
Class A Disposal Facilities



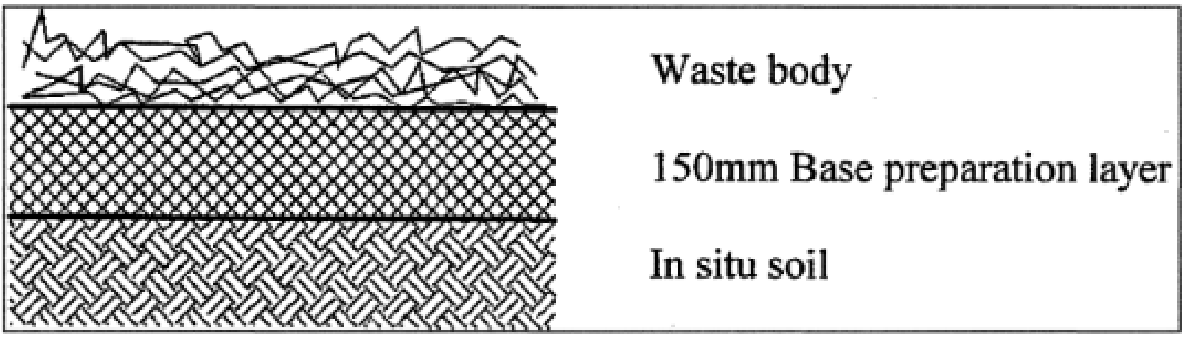
Class B Disposal Facilities



Class C Disposal Facilities



Class D Disposal Facilities



GROUNDWATER ASSESSMENT FOR LINER FEASIBILITY

FOR

BLACK ROCK MINE OPERATIONS

ASSMANG (PTY) LTD

GPT Reference Number:	EEESB-17-2127
Client Reference Number:	Click here to enter text.
Version:	Final Version 1.0
Date:	February 2017

Compiled for:

ESCIENCE ASSOCIATES (PTY) LTD

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Report Type:	Groundwater Assessment For Liner Feasibility
Project Title:	Black Rock Mine Operations Assmang (Pty) Ltd.
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Reviewed By:	M. Burger, M.Sc., Pr.Sci.Nat.
GPT Reference:	EEESB-17-2127
Version:	Final Ver 1.0
Date:	February 2017
Distribution List (Current Version):	• EScience Associates (PTY) Ltd o Mr. A. Ebrahim (abdul@escience.co.za)

Disclaimer:

The results and conclusions of this report are limited to the Scope of Work agreed between GPT and the Client for whom this investigation has been conducted. All assumptions made and all information contained within this report and its attachments depend on the accessibility to and reliability of relevant information, including maps, previous reports and soft information, from the Client and Contractors. All work conducted by GPT is done in accordance with the GPT Standard Operating Procedures. GPT is an ISO 9001 accredited Company.

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Declaration:

I hereby declare:

1. I have no vested interest (present or prospective) in the project that is the subject of this report as well as its attachments. I have no personal interest with respect to the parties involved in this project.
2. I have no bias with regard to this project or towards the various stakeholders involved in this project.
3. I have not received, nor have I been offered, any significant form of inappropriate reward for compiling this report.

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This report was reviewed by:

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Professional Natural Scientist (No 400296/12)

Customer Satisfaction:

Feedback regarding the technical quality of this report (i.e. methodology used, results discussed and recommendations made), as well as other aspects, such as timeous completion of project and value of services rendered, can be posted onto GPT's website at address: http://www.gptglobal.com/feedback.htm.

EXECUTIVE SUMMARY

Geo Pollution Technologies – Gauteng (Pty) Ltd (GPT) was appointed by EScience Associates (Pty) Ltd (Escience) to prepare a risk based assessment specifically to inform liner requirements for the proposed expansion of the Nchwaning II tailings storage facility. The risk assessment approach aims to describe and define the relationship between the cause (source) and the effect on the receptor, through the groundwater pathway. In the absence of any one of the three components, it can be conclude that groundwater risk does not exist (Framework for the Management of Contaminated Land, May 2010).

The results of the risk assessment are listed below by independently assessing the three components of the source-pathway-receptor model:

1. Source

The source of potential contamination is the *extension of the existing* tailings facility at the Nchwaning mine.

The results of the leach testing of tailings material indicate that the discard material has a low contamination potential. Only boron, barium, manganese and lead were found in a concentration above the lower Leachable Concentration Threshold (LCT) limits. However, these elements are not present in the groundwater in concentrations exceeding the LCT0 concentration (with the exception of boron) thus indicating that the tailings are not currently leaching to the groundwater to any significant degree. Boron is a naturally occurring compound associated with manganese ore and can reach natural concentrations in the ore of 0.5 to 1.1% (Varentsov, 1996).

It is concluded that the source presents a low contamination risk at worst, and the concentration of contaminants in the groundwater is actually a reflection of what is already found naturally, as detected in groundwater hydraulically upgradient of the site.

2. Pathway

The pathway applicable to this study is unsaturated seepage through the Kalahari Formation to the groundwater below.

The groundwater level in the area is exceptionally deep. Average depth of water below surface was found to be about 60 metres below surface. At the site of the proposed tailings dam the groundwater is even deeper at an average of 73 metres (GPT03 and GPT04). At borehole GPT03 closest to the proposed tailings, the groundwater is at 100 metres below surface. This means that the vertical thickness of the unsaturated pathway below the tailings is at least 70 metres, but could well be as much as 100 m, which is immense. This also renders aquifer vulnerability very low.

During this very long pathway, there are at least three factors to consider:

- Time of travel. Recharge into the Kalahari Sands is very low, as little as 1 mm/year. Even taking extreme unsaturated flow conditions into account, the vertical velocity should not exceed 100 mm/a. It would thus take thousands of years for contamination to reach the permanent groundwater level. This slow transport velocity has also been illustrated by numerous tritium studies in the Kalahari (Xu Y., 2003).

- Diffusion during travel. During transport the water is constantly diffused by factors such as different path lengths and retardation, for instance. The result of this diffusion is that a contamination pulse will reach the subsurface groundwater as a spread out diffuse cloud. This will inevitably reduce the contamination levels by orders of magnitude, rendering the contribution to groundwater compounds immeasurably small.

- Temporary perching: The Kalahari sands and the calcrete/clay layers form a vertically and laterally complex network of flow and perching regimes. This temporary perching before infiltration is a prominent factor in retarding vertical flow, and increases diffusion and dilution of dissolved compounds.

3. Receptor(s)

Based on current available information, only proposed abstraction borehole BRMO – 23 is a possible sensitive receptor. BRMO is in the process of investigating abstraction at this point for domestic purposes. However, it has been shown in a previous investigation that the travel time to this borehole is at least five years and that the concentration will be reduced to only about 1% of the input concentration of chemical compounds that might reach the bottom of the unsaturated zone. It must thus be concluded that even if any contaminant should be able to reach the saturated aquifer, no sensitive receptors will be affected.

Taking into account that:

- The contribution of the new proposed tailings as a source of contamination is very unlikely and statistically insignificant;
- The pathway through the unsaturated zone is not a viable pathway on life-of-mine timescales, and is probably relatively impermeable to groundwater infiltration;
- No sensitive receptors are currently present in the area of mining; and,
- Based on a previous study, no environmental benefit is expected from installing a liner beneath a new tailings facility adjacent to an unlined tailings facility;

It is concluded that the source-receptor linkage is incomplete in the mining area, and that "*(the) risk of seepage entering the groundwater environment and reaching receptors with no lining using existing leach results for Life of TSF, 20 years, 50 years and 100 years*" is indeed negligible .

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
ARD	Acid Rock Drainage
BPG	Best Practice Guidelines
CMS	Catchment Management Strategy
CSM	Conceptual Site Model
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Programme/Plan
IWRMP	Integrated Water Resources Management Plan
IWRM	Integrated Water Resources Management
Km^2	Square Kilometre
L/s	Litres per second
mamsl	Metres above mean sea level
Mbgl	Metres below ground level
Ml/d	Megalitres per day
m	Meter
mm	Millimetre
mm/a	Millimetres per annum
mS/m	Millisiemens per metre
m^3	Cubic metre
MAP	Mean Annual Precipitation
MPRDA	Mining and Petroleum Resources Development Act (Act No. 73 of 2002) 1989)
NEMA	National Environmental Management Act (Act No. 107 of 1998)
NWA	National Water Act (Act No. 36 of 1998)
ppm	Parts per million
RDM	Resource Directed Measures
RQO	Resource Quality Objective
RWQO	Resource Water Quality Objective
TDS	Total Dissolved Solids
WMA	Water Management Area
WMP	Water Management Plan

DEFINITIONS

Definition	Explanation
Aquiclude	A geologic formation, group of formations, or part of formation through which virtually no water moves
Aquifer	A geological formation which has structures or textures that hold water or permit appreciable water movement through them. Source: National Water Act (Act No. 36 of 1998).
Borehole	Includes a well, excavation, or any other artificially constructed or improved underground cavity which can be used for the purpose of intercepting, collecting or storing water in or removing water from an aquifer; observing and collecting data and information on water in an aquifer; or recharging an aquifer. Source: National Water Act (Act No. 36 of 1998).
Boundary	An aquifer-system boundary represented by a rock mass (e.g. an intruding dolerite dyke) that is not a source of water, and resulting in the formation of compartments in aquifers.
Cone of Depression	The depression of hydraulic head around a pumping borehole caused by the withdrawal of water.
Confining Layer	A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers; it may lie above or below the aquifer.
Dolomite Aquifer	See “Karst” Aquifer
Drawdown	The distance between the static water level and the surface of the cone of depression.
Fractured Aquifer	An aquifer that owes its water-bearing properties to fracturing.
Groundwater	Water found in the subsurface in the saturated zone below the water table.
Groundwater Divide or Groundwater Watershed	The boundary between two groundwater basins which is represented by a high point in the water table or piezometric surface.
Groundwater Flow	The movement of water through openings in sediment and rock; occurs in the zone of saturation in the direction of the hydraulic gradient.
Hydraulic Conductivity	Measure of the ease with which water will pass through the earth's material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (m/d).
Hydraulic Gradient	The rate of change in the total hydraulic head per unit distance of flow in a given direction.
Infiltration	The downward movement of water from the atmosphere into the ground.

Definition	Explanation
Intergranular Aquifer	A term used in the South African map series referring to aquifers in which groundwater flows in openings and void spaces between grains and weathered rock.
Monitoring	The regular or routine collection of groundwater data (e.g. water levels, water quality and water use) to provide a record of the aquifer response over time.
Observation Borehole	A borehole used to measure the response of the groundwater system to an aquifer test.
Phreatic Surface	The surface at which the water level is in contact with the atmosphere: the water table.
Piezometric Surface	An imaginary or hypothetical surface of the piezometric pressure or hydraulic head throughout all or part of a confined or semi-confined aquifer; analogous to the water table of an unconfined aquifer.
Porosity	Porosity is the ratio of the volume of void space to the total volume of the rock or earth material.
Production Borehole	A borehole specifically designed to be pumped as a source of water supply.
Recharge	The addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.
Recharge Borehole	A borehole specifically designed so that water can be pumped into an aquifer in order to recharge the ground-water reservoir.
Saturated Zone	The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.
Specific Capacity	The rate of discharge from a borehole per unit of drawdown, usually expressed as m3/d•m.
Specific Yield	The ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.
Transmissivity	Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.
Unsaturated Zone (Vadose Zone)	That part of the geological stratum above the water table where interstices and voids contain a combination of air and water.
Vulnerability	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

Definition	**Explanation**
Watershed	Catchment in relation to watercourse or watercourses or part of a watercourse means the area from which any rainfall will drain into the watercourses or part of a watercourse through surface flow to a common point or points. Source: National Water Act (Act No. 36 of 1998).
Water Table	The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is equal to that of the atmosphere.

GROUNDWATER ASSESSMENT FOR LINER FEASIBILITY

BLACK ROCK MINE OPERATIONS

1. INTRODUCTION

Geo Pollution Technologies – Gauteng (Pty) Ltd (GPT) was appointed by EScience Associates (Pty) Ltd (Escience) to do a risk based contamination assessment for the extension of the Nchwaning II tailings facility for the Black Rock Mining Operations (BRMO) near Hotazel, Northern Cape. The risk assessment approach aims to describe and define the relationship between the cause (source) and the effect on the receptor, through the groundwater pathway. In the absence of any one of the three components, it is possible to conclude that groundwater risk does not exist (Framework for the Management of Contaminated Land, May 2010).

To assess potential impacts of the proposed tailings on the receiving groundwater environment, the potential sources of contamination, pathways and receptors were identified; as will be discussed in this report.

BRMO consists of the following mining areas: the Black Rock Mine on the farm Nchwaning 267, the Nchwaning Mine on the farm Nchwaning 267 and the Gloria Mine on Gloria 266. A comprehensive groundwater monitoring network for the entire BRMO was developed and implemented in 2011. This was followed by a hydrogeological impact assessment in 2015 for the tailings expansion at the Nchwaning Mine.

1.1 Project Description

Risk based assessment undertaken specifically to inform liner requirements for the proposed expansion of the Nchwaning II TSF.

1.2 Scope of Work

This groundwater study aims to describe and evaluate the sources of contamination, pathways and receptors; specifically for the planned tailings expansion. The purpose was to determine whether the proposed tailings expansion poses any risk to any receiver in the area, and thus whether it will be essential to line the tailings based on a scientific perspective.

2. PROJECT METHODOLOGY

The potential impacts of the tailings were investigated through a desk study based upon previous investigations and available data which include preliminary waste screening assessments and numerical modelling.

3. DESK STUDY

A desk study was performed on all available information pertaining to the groundwater situation at the Black Rock Mine, Nchwaning II Mine, Nchwaning III Mine and Gloria Mine at the Black Rock Mining Operations (BRMO), as detailed below.

3.1 Information Reviewed

The following information sources were reviewed:

- Geological Map (Scale 1:250 000) published by the Council for Geosciences.
- National Groundwater Archive (NGA) information managed by DWA (2005).
- Aquatico Scientific (PTY) Ltd. (December 2016). Assmang Black Rock Mining Operations: Water Quality Monitoring Report. Water Monitoring Report.
- Geo Pollution Technologies – Gauteng (Pty) Ltd. (2011). Evaluation of the Hydrocensus at Black Rock Mining Operations and Its Surroundings. Hydrogeological Assessment Report.
- Geo Pollution Technologies – Gauteng (Pty) Ltd. (2015). Hydrogeological Impact Assessment for the Assmang Nchwaning II Manganese Mine Tailings Facility Expansion, Assmang (PTY) Ltd.
- Geo Pollution Technologies – Gauteng (Pty) Ltd. (2016). Groundwater Contamination Assessment, Assmang (Pty) Ltd.
- MojaTerre (Pty.) Ltd. – (January 2017). – Screening Waste Type Assessment Black Rock Mining Operations – Tailings Facility

3.2 Normative references

The following documents are normative references to this report and should be used as such:

- Geo Pollution Technologies – Gauteng (Pty) Ltd. (2016). Groundwater Contamination Assessment, Assmang (Pty) Ltd.
- MojaTerre (Pty.) Ltd. – (January 2017). - Screening Waste Type Assessment Black Rock Mining Operations – Tailings Facility
- Aquatico Scientific (PTY) Ltd. (December 2016). Assmang Black Rock Mining Operations: Water Quality Monitoring Report. Water Monitoring Report.

4. REGIONAL INFORMATION

A description of the regional area information is described under the headings below.

4.1 Site Location

BRMO is comprised of four mining localities/operations, viz. Black Rock, Gloria, Nchwaning II and Nchwaning III mine. The mines are located approximately 80 km north-west of the town of Kuruman and 16 km north-west of the village of Hotazel.

All source activities at BRMO are located on the farms Nchwaning 267, Gloria 266 and Belgravia 264.

4.2 Regional Water Management Setting and Sensitivity

BRMO is situated in the Lower Vaal Water Management Area (WMA), in quaternary catchment D41M and D41K. The regional climate is arid with limited surface water resources. The Kuruman River and its tributary the Ga-Mogara River are both ephemeral streams. The mean annual precipitation is given as 250 mm/annum and mean annual evaporation as 3000 mm/annum.

4.2.1 Present ecological status

Based on the Provincial Water Resources Assessments for the National Water Balance of 1999, the sensitivity, and present ecological status for the D41M-D41K quaternary catchment is given as D (Largely modified).

4.3 Regional Geology

The investigated area falls within the 2722 Kuruman 1:250 000 geology series maps and is situated approximately 16 km north-west of Hotazel, Northern Cape. An extract of the map is shown in Figure 1.

The lithostratigraphic sequence from the surface to the mined Hotazel Formation is as follows:

- Quartenary sands, clay and calcrete of the Kalahari Formation, Karoo Supergroup.
- Tillite/diamictite of the Dwyka Group, Karoo Supergroup.
- Quartzite and shale of the Mapedi Formation, Olifantshoek Group.
- The Hotazel Formation, Postmasburg Group, Transvaal Supergroup.

A regional thrust fault, the Blackridge Thrust Fault is located between the Black Rock Mine and the Nchwaning II and III mines[1].

4.4 Regional Hydrogeology

As previously discussed, the site is underlain by the Kalahari formation. This formation at BRMO consists of a top layer of aeolian sands followed by calcrete of tertiary age. If weathered, the calcareous sands have high porosity and permeability values relative to bedrock in the area. There is limited surface runoff in the Kalahari area (high infiltration rates during precipitation).

[1] Gutzmer, J. And Beukes, N. J. (1996). Mineral Paragenesis of the Kalahari Manganese Field, South Africa. *Ore Geology Reviews* 11: 405 – 428.

The potential of groundwater occurrence will depend on the presence of secondary alteration and fracturing in the calcrete. Weathering and fracturing may increase the aquifer potential, thus zones of weathering and fracturing within the calcrete will act as targets for potential groundwater exploration.

The arithmetic average depth of the water levels below surface in the boreholes found at BRMO is 69.6 mbgl with a maximum depth of 110 mbgl. If the depth of the Kalahari formation is considered with the water levels found in the hydrocensus, it can be concluded that the farmers tap their water from this weathered/fractured calcrete aquifer. The average recharge value assigned to calcrete is ± 10 % of the mean annual precipitations (MAP) (Groundwater Decision Tool). The natural/background water quality is within SANS241: 2015 target drinking water quality limits.

4.4.1 Shallow, weathered aquifer

Surficial deposits comprise of calcrete, clay and quaternary sands and can be as thick as 40 m. Calcrete is a product of alteration and weathering of carbonate rocks by precipitation of calcium carbonate from groundwater in soil during long periods of precipitation deficits in arid climates. Calcrete/clay complexes are found to generally have low transmissivities and form extensive aquitards in outcrop areas. The sandy soil horizon is expected to allow for rapid infiltration into the unsaturated (vadose) zone during precipitation events. High intensity, low volume rainfall is common in arid regions.

The main source of recharge into the shallow alluvial aquifer is rainfall that infiltrates the aquifer through the vadose zone. Vertical movement of water is faster than lateral movement in this system as water moves predominantly under the influence of gravity. Groundwater recharge was estimated to be an average of 10% of mean annual precipitation. Recharge occurs mainly by diffuse recharge as infiltration rates are expected to be high. The climate of the region is arid and the presence of calcrete above the bedrock suggests long dry spells.

With advanced clay lens development, perched aquifers are expected to form across the site following high precipitation events. The hydraulic conductivity of this aquifer ranges between 10^{-4} and 1 m/day.

4.4.2 Weathered/fractured aquifer

Dwyka diamictite is thought to have been folded and fractured due to tectonic activity related to the formation of the Cape Fold Belt, occurs between 40 and 68 mbgl. Dwyka Formation tillite is generally massive with little jointing but may be stratified. Primary porosity is virtually inexistent and the presence of water is generally limited to secondary structures, i.e. fractures.

Both the porosity[2] and the hydraulic conductivity[3] of these aquifers are known to be low. The commonly expected values of porosity and hydraulic conductivity are 0.05 and 10^{-5} m/day, respectively. Movement of groundwater in this aquifer occurs primarily in secondary structures such as faults and fractures.

The Dwyka Formation tillites are low-yielding aquifers as they have a low groundwater development potential. The underlying Mapedi Formation quartzite aquifer is also considered a low-yielding or non-aquifer.

2 The ratio of the volume of void space to the total volume of the rock or earth material

3 Measure of the ease with which water will pass through the earth's material; defined as the rate of flow through a cross-section of one square meter under a unit hydraulic gradient at right angles to the direction of flow (m/d).

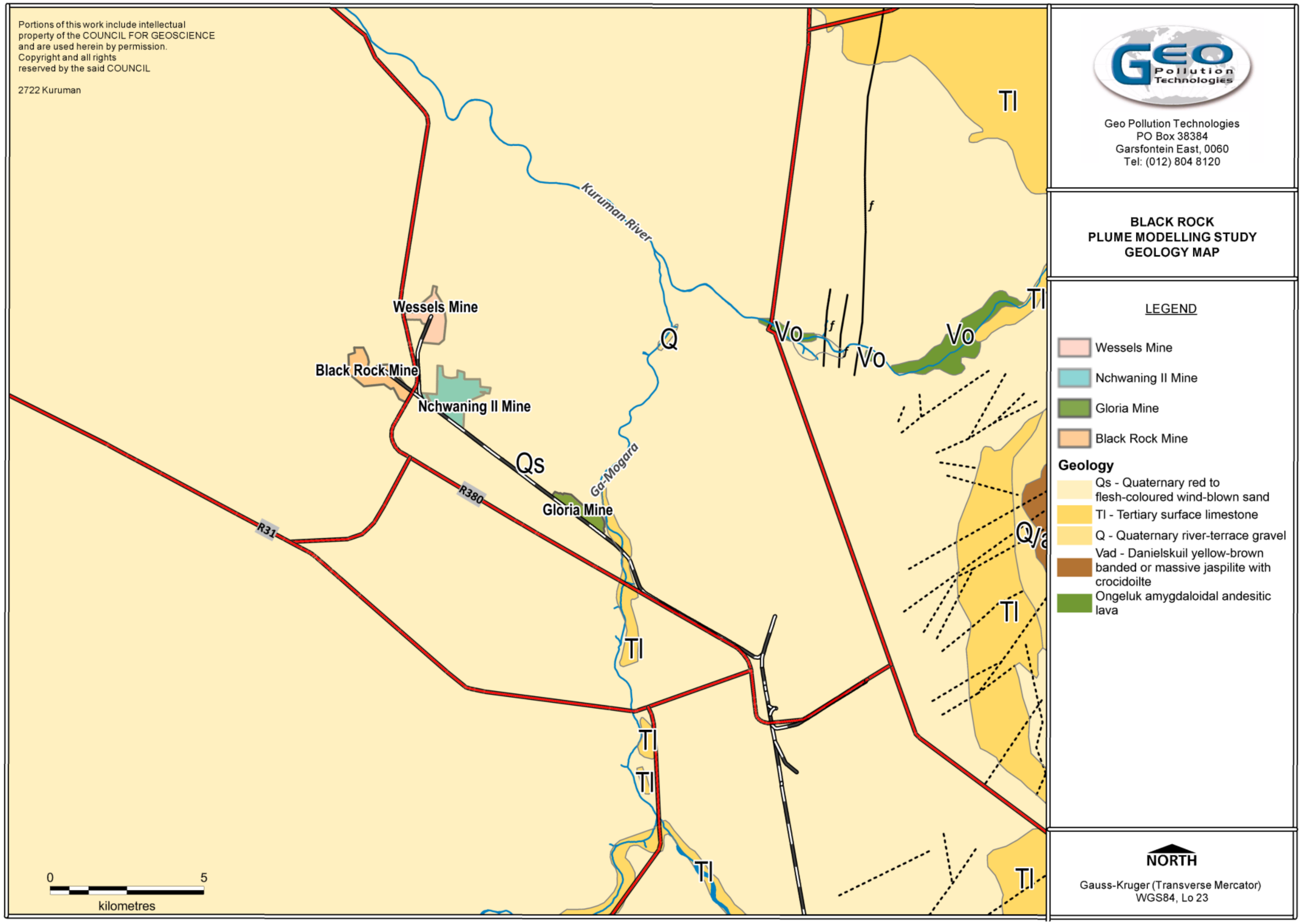

Figure 1: Regional Geology Map (1:250 000 geology series map)

5. HYDROGEOLOGICAL SETTING

The backbone of any groundwater impact prediction or management system is to understand the hydrogeological setting and how the potential stresses will influence the natural groundwater conditions. The hydrogeological setting is described under the headings below.

5.1 Site Topography and Drainage

The topography can normally be used as a good first approximation of the hydraulic gradient in the unconfined aquifer. The area is characterised by an irregular topography and in the area of the mining site the slope is more or less in the order of 1%.

Locally drainage is towards the Kuruman River which flows westwards, to the east lies the Ga-Mogara River which is a tributary to the Kuruman River. Both rivers are ephemeral streams/rivers and flow in these water bodies is periodical. The area is characterised by low rainfall, high potential evapotranspiration and high infiltration rates.

5.2 Water Levels

The latest water level monitoring data from the nine (9) monitoring boreholes showed that groundwater levels varied between a minimum of 37.94 and a maximum of 100 mbgl with an average of 59.3 mbgl (See Figure 3 and Table 1).

Table 1: Groundwater monitoring points (Nov 2016)

ID	Location	Latitude	Longitude	Water level (mbgl)
GPT01	Gloria Mine	-27.17560	22.90210	37.94
GPT02	Gloria Mine	-27.16790	22.91040	70.93
GPT03	Nchwnaning I and II	-27.14900	22.85820	100.00
GPT04	Nchwnaning I and II	-27.12430	22.86380	46.37
GPT07	Sinter plant and slimes dam complex	-27.14980	22.89320	48.87
GPT05	Black Rock Mine	-27.13540	22.84430	40.89
GPT06	Black Rock Mine	-27.12500	22.84330	-
GPT08		-27.13082	22.83625	38.27
GPT09		-27.12573	22.83689	>100

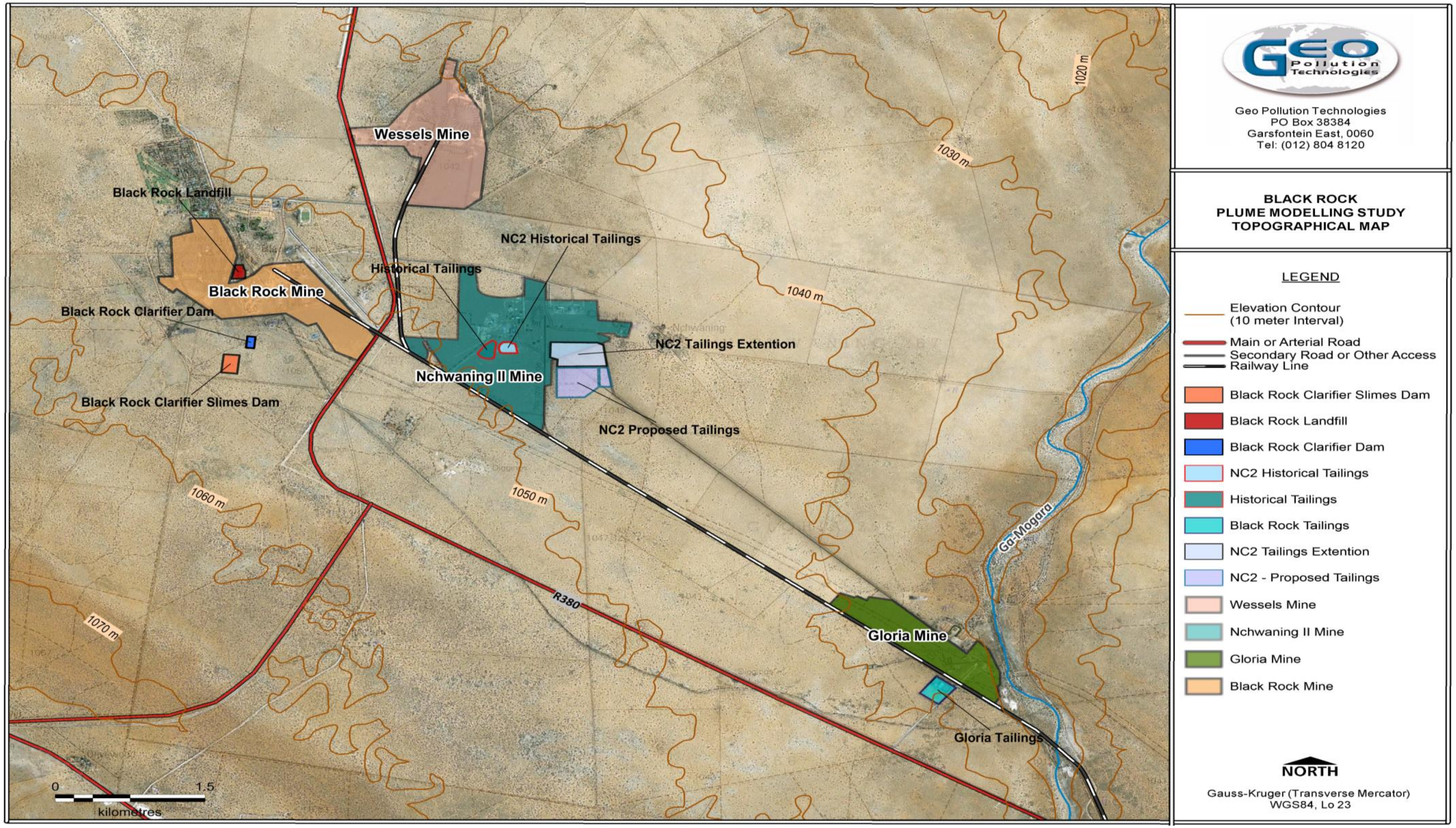

Figure 2: Site topography

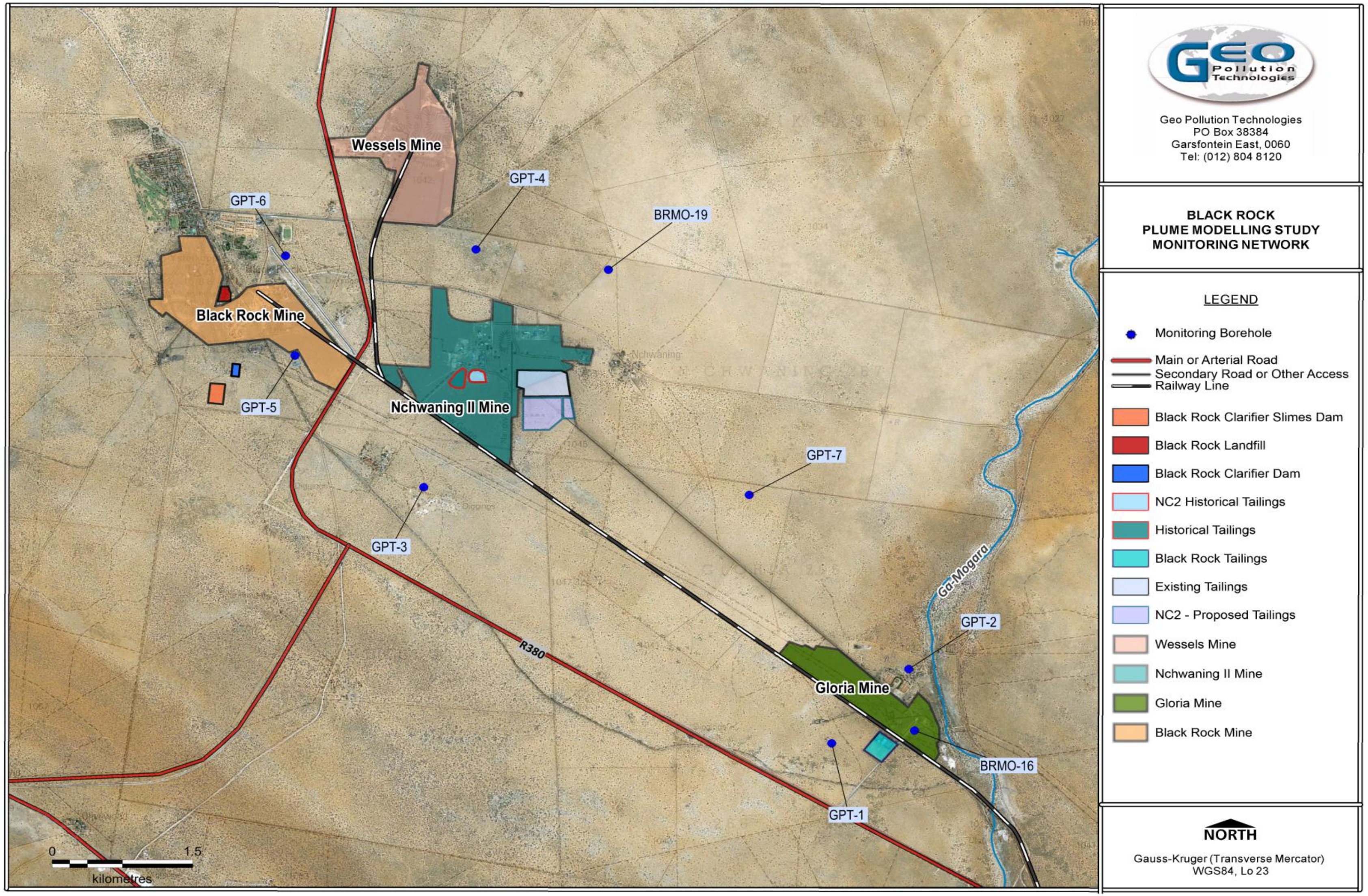

Figure 3: Monitoring boreholes

5.3 Preliminary Screening Waste Classification.

Based on the waste classification done in January 2017 (Mojaterre, 2017) the constituents elevated above the Leachable Concentration Threshold (LCT) limits are (see Table 2):

- Boron
- Barium
- Manganese
- Lead
- Total Dissolved Solids

If this is correlated to monitored groundwater qualities (Aquatico, 2016) only Boron is exceeded (see Table 3). Boron is a natural occurring compound associated with manganese ore and can reach natural concentrations in the ore of 0.5 to 1.1% (Varentsov, 1996).

Note that groundwater concentrations presented in Table 3 are for borehole GPT03 which is hydraulically upstream of the Nchwaning facilitates. This implies that the elevated levels of Boron are associated with background concentrations rather than contribution from BRMO activities.

Table 2: Results of the Chemical Leaching Analysis

Constituent		Units	Tailings Material	Date	Leachable Concentration Threshold (LCT) limits			
					LCT0	LCT1	LCT2	LCT3
Boron	B	mg/l	1.413	10-Jan-17	0.5	25	50	200
Barium	Ba	mg/l	0.841	10-Jan-17	0.7	35	70	280
Manganese	Mn	mg/l	42	10-Jan-17	0.5	25	50	200
Lead	Pb	mg/l	0.026	10-Jan-17	0.01	0.5	1	4
Total Dissolved Solids	TDS	mg/l	4304	10-Jan-17	1000	12500	25000	100000

Table 3: Groundwater quality vis LCT

Constituent		Units	Water quality		Leachable Concentration Threshold (LCT) limits			
			GPT03	GPT04	LCT0	LCT1	LCT2	LCT3
Boron	B	mg/l	1.57	0.243	0.5	25	50	200
Manganese	Mn	mg/l	<0.001	<0.001	0.5	25	50	200
Lead	Pb	mg/l	<0.009	<0.009	0.01	0.5	1	4
Total Dissolved Solids	TDS	mg/l	548	908	1000	12500	25000	100000

5.4 Groundwater Quality

The groundwater quality results from the July 2016 monitoring report[4] supplied by the client were compared with the South African National Standard for Drinking Water, SANS 241-1:2015. SANS 241-1 is applicable to all water services institutions and sets numerical limits for specific determinants to provide the minimum assurance necessary that the drinking water is deemed to present an acceptable health risk for lifetime consumption.

5.4.1 Groundwater quality against SANS241:2015 limits

From Table 4 the following can be deduced:

- Nitrate and Fluoride are above the limits

[4] Aquatico Scientific Pty (Ltd). (2016). Assmang (Pty) LtdBlack Rock Water Quality Monitoring Report July 2016.

Table 4: December 2016 Groundwater quality compared to SANS 241: 2015.

Parameter		Unit	SANS 241: 2015 Recommended Limits	Risk	Results GPT03
Physical & Aesthetic determinands					
Electrical conductivity at 25^{0}C	EC	mS/m	≤ 170	Aesthetic	93.1
Total Dissolved Solids	TDS	mg/litre	≤ 1200	Aesthetic	548
Turbidity		NTU	Operational ≤1; Aesthetic ≤5	Aesthetic/Operational	
pH at 25^{0}C		pH units	≥ 5 to ≤9.7	Aesthetic	8.8
Chemical Determinands - Macro determinands					
Combined Nitrate & Nitrite	NO3 as N	mg/litre	≤ 0.9	Acute Health	2.4
Sulphate	SO_4	mg/litre	Acute Health ≤500; Aesthetic ≤250	Acute Health/Aesthetic	36.2
Fluoride	F	µg/litre	≤1500	Chronic Health	1880
Ammonia as N	NH_3	mg/litre	≤ 1.5	Aesthetic	
Chloride	Cl	mg/litre	≤ 300	Aesthetic	92.7
Sodium	Na	mg/litre	≤ 200	Aesthetic	155
Zinc	Zn	µg/litre	≤5000	Aesthetic	5
Chemical Determinands - Micro determinands					
Boron	B	µg/litre	≤ 2400	Chronic Health	1570
Copper	Cu	µg/litre	≤ 2000	Chronic Health	5
Total Iron	Fe	mg/litre	Acute Health ≤ 2.0; Aesthetic ≤0.3	Acute/Aesthetic	0.009
Lead	Pb	µg/litre	≤ 10	Chronic Health	0.009
Total manganese	Mn	mg/litre	Acute Health ≤0.4; Aesthetic ≤0.1	Acute/Aesthetic	0.001
Aluminium	Al	µg/litre	≤ 300	Operational	5
Concentration deemed to present an unacceptable health risk for lifetime consumption.					

6. GROUNDWATER RISK ASSESSMENT

The groundwater risk assessment methodology is based on defining and understanding the three basic components of risk, i.e. the source of the risk (source term), the pathway along which the potential risk propagates, and finally the receptor that experiences the risk (receptor). The risk assessment approach is therefore aimed at describing and defining the relationship between cause and effect. In the absence of any one of the three components, it is possible to conclude that groundwater risk does not exist (Framework for the Management of Contaminated Land, May 2010).

6.1 Source Term(s)

The potential source of contamination for this study is the proposed Nchwaning 2 tailings expansion. In defining the source, a leach test was conducted by Future Flow in 2015, as shown in Table 5 below.

Table 5: Tailings Material Leach Concentrations of Potential Significance

Constituent		Units	Tailings Material	LCT0
Boron	B	mg/l	1.413	0.5
Barium	Ba	mg/l	0.841	0.7
Manganese	Mn	mg/l	22	0.5
Lead	Pb	mg/l	0.026	0.01
Total Dissolved Solids	TDS	mg/l	4304	1000

The results of the leach testing of tailings material indicate that the discard material has a low contamination potential, i.e. it poses a low to moderate risk to the groundwater environment. Only boron, barium, manganese and lead were found in a concentration marginally above the LCT0 limit. However, these elements are not present in the groundwater in concentrations exceeding the LCT0 concentration (with the exception of boron for most boreholes) thus indicating that the tailings are not currently leaching to the groundwater to any significant degree.

Boron is a naturally occurring compound associated with manganese ore and can reach natural concentrations in the ore of 0.5 to 1.1% (Varentsov, 1996). Due to the long contact time of groundwater with manganese ore, boron is leached from the ore. As a result, groundwater in the area also contains high concentrations of boron as listed in the table

below. If this is compared to the SANS 241: 2015 standard of 2.4 mg/l, it is evident that the groundwater already contains significant boron concentrations.

Table 6: Average constitution concentration in groundwater (all boreholes)

Constituent		Units	Natural Concentration	LCT0
Boron	B	mg/l	1.525	0.500
Manganese	Mn	mg/l	0.001	0.500
Lead	Pb	mg/l	0.009	0.010
Total Dissolved Solids	TDS	mg/l	564.600	1000.000

It can thus be concluded that boron is prevalent in the manganese ore fields and that the associating aquifer contains significant boron in the natural state.

6.2 Pathways

With respect to potential impacts on the water resource, the groundwater pathways through which contaminants could move are flow through the vadose (unsaturated) zone.

The groundwater level in the area is exceptionally deep. During a hydrocensus in November 2014, the average depth of water below surface was found to be about 60 metres below surface (Table 7). At the site of the proposed Nchwnaning tailings dam the groundwater is even deeper at an average of 73 metres (GPT03 and GPT04). At the borehole GPT03, closest to the proposed tailings, the groundwater is at 100 metres below surface. This means that the length of the unsaturated pathway below the tailings is at least 70 metres, but could well be as much as 100 m, which is immense considering that the groundwater is typically about 10 m deep in the higher rainfall areas of South Africa.

Table 7: Depth to the Groundwater

ID	Location	Latitude	Longitude	Water level (mbgl)
GPT01	Gloria Mine	-27.17560	22.90210	37.94
GPT02	Gloria Mine	-27.16790	22.91040	70.93
GPT03	Nchwnaning I and II	-27.14900	22.85820	100.00
GPT04	Nchwnaning I and II	-27.12430	22.86380	46.37
GPT07	Sinter plant and slimes dam complex	-27.14980	22.89320	48.87
GPT05	Black Rock Mine	-27.13540	22.84430	40.89
GPT06	Black Rock Mine	-27.12500	22.84330	-
GPT08		-27.13082	22.83625	38.27
GPT09		-27.12573	22.83689	>100

During this very long pathway, there are at least three factors to consider:

1. Time of travel. Recharge into the Kalahari Sands is very low, as little as 1 mm/year. If the field capacity of the soil is taken as 10%, typical unsaturated vertical flow velocity would be in the order of 10 mm/a. Although there are factors that could increase vertical flow (e.g. piping in sands), there are similarly factors retarding flow (e.g. perching, absorption etc.). Even taking extreme conditions into account, the vertical velocity should not exceed 100 mm/a. It would thus take thousands of years for contamination to reach the permanent groundwater level. This slow transport velocity has also been illustrated by numerous tritium studies in the Kalahari (Xu Y., 2003).

2. Diffusion during travel. During transport the water is constantly diffused by factors such as different path lengths and retardation, for instance. The result of this diffusion is that a contamination pulse will reach the subsurface groundwater as a spread out diffuse cloud. This will inevitably reduce the contamination levels by orders of magnitude, rendering the contribution to groundwater compounds immeasurably small.

3. Temporary perching: The Kalahari sands and the calcrete/clay layers form a vertically and laterally complex network of flow and perching regimes. This temporary perching before infiltration is a prominent factor in retarding vertical flow and increases diffusion and dilution of dissolved compounds.

Another important factor to be considered is the dilution of leached source material during travel through the pathway:

A previous modelling study (GPT EEESB-16-1806, 2016) has shown that a dilution factor of at least two orders of magnitude will be encountered when chemical compounds reach the aquifer below. The leaching concentrations will thus be reduced to at least a tenth of those shown in Table 6 when the constituents reach the aquifer. This will render the concentrations well below LCT0, with the exception of manganese.

The area of the proposed new Nchwaning tailings facility is about 15 ha. If this is compared to the roughly 16 ha of the existing tailings dam against which it will be build and the 5 ha of the historical tailings, it is apparent that the new tailings will contribute only about 50% of the contaminant flow at Nchwaning. Furthermore, the combined footprint of all tailings and control water dams at all BRMO sites add up to a total 44.3 ha, reducing the contribution of the new tailings in comparison to existing facilities to 25%. Thus, lining the new tailings will reduce the leaching to the subsurface by about 20% at best. But this percentage could even be much less. It will be argued later that lining a tailings facility next to an unlined tailings will not reduce the seepage to the subsurface at all.

A further factor to consider is dilution over the extent of the aquifer. The area of the aquifer is about 47 000 ha. The percentage area of the proposed tailings compared to the aquifer is thus in the order of 0.03%. Thus, in the long term after mixing has occurred, the contribution of the talings will be unmeasurable. It is thus concluded that the Kalahari Formation serves as an extensive protection for the aquifer below, and is an effective filter for contaminants. Coupled with low precipitation and high evaporation rates the transportation of dissolved contaminants from the source areas is foreseen to present a very low risk to the groundwater environment.

6.3 Receptors

As the final component of the risk assessment, the receptors in the context of the water resource would be users of the water resource itself. The following potential receptors (proposed future groundwater users) were found:

- BRMO-19 - Nchwaning II Manganese Mine proposed water abstraction from borehole BRMO-19 for process use.
- BRMO-23 – Proposed Groundwater abstraction from BRMO-23 for domestic and agricultural use.

All other users are outside of the BRMO boundaries and this significantly further from the source.

The borehole BRMO-19 is not intended to be used for human consumption, clean potable water is alternatively provided.

Thus only BRMO – 23 is a possible sensitive receptor. However, it has been shown in a previous investigation (Assmang Nchwaning II Manganese Mine Tailings Facility Expansion GPT Report ESBlack-15-293) that the travel time to this borehole is at least five years and that the concentration will be reduced to only about 1% of the input concentration of chemical compounds that might reach the bottom of the unsaturated zone. Therefore it is clear, from the assessment of BRMO 23, that the potential impact on receptors outside of the BRMO boundary would be negligible as well.

It is notable that the assessment undertaken (Assmang Nchwaning II Manganese Mine Tailings Facility Expansion GPT Report ESBlack-15-293) followed a precautionary approach assuming that contaminants were modelled as tracer fluids. Therefore the assessment does not take into account the potential for adsorption, perching and any other factors that may reduce hydraulic conductivity and/or increase dispersion of the contaminants.

It must thus be concluded that even if any contaminant be able to reach the saturated aquifer, no sensitive receptors will be affected.

6.4 Practical Aspects

It can be envisaged that lining a tailings dam adjacent to an unlined tailings facility, has no benefit. Vertical flow through the tailings will perch on the liner and then just flow horizontally into the lower water level of the adjacent tailings and then proceed to the subsurface unhindered. In such a scenario no environmental benefit will be gained by installing a liner.

7. CONCLUSION

Taking into account that:

- The contribution of the new proposed tailings as a source of contamination is very unlikely and statistically insignificant,
- The pathway through the unsaturated zone is not a viable pathway on life-of-mine timescales, and is probably impermeable to groundwater infiltration.
- No sensitive receptors are present in the area of the mine.
- Based on a previous study, no environmental benefit is expected from installing a liner beneath a new tailings facility adjacent to an unlined tailings facility.

It is concluded that the source-receptor linkage is incomplete in the mining area, and that "*(the) risk of seepage entering the groundwater environment and reaching receptors with no lining using existing leach results for Life of TSF, 20 years, 50 years and 100 years*" is indeed negligible .

8. REFERENCES

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GROUNDWATER CONTAMINATION ASSESSMENT

FOR

BLACK ROCK MINE OPERATIONS

ASSMANG (PTY) LTD

GPT Reference Number: EEESB-16-1806
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Customer Satisfaction:

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EXECUTIVE SUMMARY

Geo Pollution Technologies – Gauteng (Pty) Ltd (GPT) was appointed by EScience Associates (Pty) Ltd (Escience) to construct both a conceptual and numerical groundwater model using the latest available data, techniques and software for the Black Rock Mining Operations (BRMO) near Hotazel, Northern Cape. In order to comply with the water use license (No. 10/D41M/ABEGJ/3490) for the site Blackrock Mine Operations was instructed in the WUL under Appendix IV point 4 to address the following:

"*4.14. The Licensee is to ensure that an additional Geohydrological assessment is conducted within one (1) year of issuance of this licence which encompasses all of the information indicated above. The report must also contain an accurate assessment of source, pathways and receptors; and must provide the mitigation measures against pollution. It must include the monitoring network and its implementation plan.*" Page 20 of 26.

The WUL instruction was addressed by performing the following actions:

- Accurate assessment of the source (waste classification), pathway (plume modelling) and receptors (monitoring network and plume modelling).
- Calibrate the model against monitoring data(quality & water levels) to determine the groundwater contamination plumes.
- To determine the rate of movement of the groundwater contamination plumes from various potential groundwater contamination sources.
- To predict the long term groundwater contamination plume positions using calculated contaminant loads that may be released by each waste stream.
- To determine the impact on the receiving environment & associated water resources.
- To supply data for closure cost estimates as a result of existing & predicted contamination plumes from various contamination sources.

Completed Work

The following was done to address potential groundwater impacts:

- Review of available groundwater data
- Numerical Modelling
- Risk Assessment
- Impact Predictions
- Water Management Options

Conceptual Site Model

The site is underlain by the Kalahari formation. This formation at BRMO consists of a top layer of aeolian sands followed by calcrete of tertiary age. If weathered, the calcareous sands have high porosity and permeability values relative to bedrock in the area. There is limited surface runoff in the Kalahari area (high infiltration rates during precipitation).

The arithmetic average depth of the water levels below surface in the boreholes found at BRMO is 59.29 mbgl with a maximum depth of 99.77m below surface. If the depth of the Kalahari formation is considered with the water levels found in the hydrocensus, it can be concluded that the farmers tap their water from this weathered/fractured calcrete aquifer.

Flow predominantly takes place in north to north north-easterly directions towards the Ga-Mogara River which flows into the Kuruman River from the Nchwaning II Mine; however this path is intersected by mechanical discharge points downstream of the mine where flow is redirected towards the abstraction boreholes, i.e borehole BRMO-19.

From the water quality information the background water quality as represented by borehole GPT03 located upstream of the Nchwaning II Manganese Mine is within regulatory limits. Downstream of the mine elevated concentrations of Mg can be observed and this is attributed to water-rock interaction. Mg has an aesthetic effect on the water but no definite health risks are known.

Numerical Flow and Transport Model

It follows from this conceptual model that if contamination emanates from the facilities at the mining area it could be transported as follows:

- Transport through the unsaturated zone
- Transport through the saturated zone.

Transport through the unsaturated zone

Flow through the unsaturated zone is expected to be slow, and contamination emanating from the mining activities could take decades to reach the groundwater level due to unsaturated vertical hydraulic conductivity. It can also be expected that the concentration of contamination will be reduced during such transport due to dilution and adsorption to the aquifer.

Transport through the saturated zone

Within the limitations of the numerical model assumptions the following was calculated:

- The modelled leachate plume emanating from the mining facilities is calculated to migrate northeast towards the Ga-mogara River. However, the river is not a receptor, as the groundwater levels are well below the riverbed and only episodic flow occurs and disconnection was, therefore, assumed.
- The original 100 mg/ℓ assumed at the source, was calculated to lower to 1 mg/ℓ over the entire modelling period.
- No privately owned boreholes (receptors) are likely to be affected by the pollution plume.

It is thus concluded that contaminants emanating from the mining area could result in downstream pollution, but the concentration is likely to lower below domestic groundwater standards. This conclusion will also be true for many other contaminants that behave as non-reacting tracers, as well as other sources of pollution in this mining area. The results of the modelling are thus generic for the area.

Risk Assessment

Based on the numerical model it is evident that no human health effects are likely to occur at any monitoring boreholes within the assumed 100 year mining scenario. From the previous studies and the monitoring reports it can be seen that none of the water samples exceeded the screening values indicated by the DWS water quality guidelines for domestic use. Leachate from the tailings material samples was also found not to exceed any of the screening values indicated by the DEA Waste Classification Screening Values.

The potential sources of contamination were identified as the Existing Nchwaning Tailings, Gloria Tailings, Gloria Historical Waste Storage, Nchwaning Historical Tailings, Nchwaning Proposed Tailings, Black Rock Tailings, Black Rock Landfill, Historical Tailings and Nchwaning Proposed Tailings.

It has been displayed through leach testing of tailings material and other waste rock material that the materials have a low contamination potential, i.e. it poses a low risk to the groundwater environment (GPT, 2015).

Coupled with low precipitation and high evaporation rates, lack of groundwater users and the ~70m thick unsaturated zone underlying the site, the transportation of contaminants sourced from the solid and liquid waste areas is foreseen as a low risk to the groundwater environment.

Water management options

Pollution source management should be based on passive management principles, i.e. the need for ongoing intervention and active management is minimal, but not non-existent. Examples of passive measures include storm water diversion berms and drains, lining of pollution control dams, finger drains under tailings disposal facilities and toe paddocks around such facilities, etc. Passive pollution prevention measures are essentially based on good planning and design to prevent a pollution problem from arising, rather than relying on active intervention to intercept and treat contaminated water. However, situations are often encountered where active impact minimisation management measures are required to supplement the passive pollution prevention measures.

Tailings deposits and pollution control dams

The following tailings management options are available to Black Rock:

- Mine tailings deposition is expected to result in large volumes of waste water discharge which should be directed to and contained in sanitarily designed evaporation or slimes dam as planned.
- Prevent the erosion or leaching of materials from the tailings deposit and contain material or substances so eroded or leached in such areas by providing suitable barrier dams, evaporation dams or any other effective measures to prevent this material or substance from leaching into the subsurface.
- Potentially contaminated water that has been in contact with discarded material must be kept within the confines of an evaporation dam until evaporated, treated to rendered acceptable for release, or re-used in some other way.

Waste rock deposits and pollution control dams

The following waste rock management options are available to Black Rock:

- Monitoring of water storage facilities, particularly pollution control dams is imperative to manage the risk of spillage from the dams. Stage-storage (elevation-capacity) curves are useful tools to monitor the remaining capacity within a water storage facility.
- Prevent the erosion or leaching of materials from any residue deposit or stockpile from any area and contain material or substances so eroded or leached in such area by providing suitable barrier dams, evaporation dams or any other effective measures to prevent this material or substance from entering and polluting any water resources.
- Water quantity and quality data should be collected on a regular, ongoing basis during mine operations. These data will be used to recalibrate and update the mine water management model, to prepare monitoring and audit reports, to report to the regulatory authorities against the requirements of the IWMP and other authorisations and as feedback to stakeholders in the catchment, perhaps via the CMA.
- Water that has been in contact with residue, and must therefore be considered polluted, must be kept within the confines of the MRD until evaporated, treated to rendered acceptable for release, or re-used in some other way.
- All water that falls within the catchment area of the MRD must be retained within that area. For most MRDs the catchment can be divided into component catchments, as follows:
- The top area of the MRD together with any return water storage dams which have been connected to the top area of the MRD by means of an outfall penstock, and
- The faces of the MRD together with the catchment paddocks provided to receive run-off from the faces and any additional catchment dams associated with the faces and catchment paddocks.
- The design, operation and closure of MRDs should incorporate consideration of the risk of changes in the mining and plant operations, and hence the mine water balance, through the life cycle of the mine.
- A system of storm water drains must be designed and constructed to ensure that all water that falls outside the area of the MRD is diverted clear of the deposit. Provision must be made for the maximum precipitation to be expected over a period of 24 hours with a probability of once in one hundred years. A freeboard of at least 0.5 m must be provided throughout the system above the predicted maximum water level. This requirement applies to all MRDs, both fine and coarse-grained MRDs.
- Ensure that the water use practices on and around the MRD do not result in unnecessary water quality deterioration, e.g. use of the return water dam for storage of poorer quality water.

Monitoring Programme

The following groundwater monitoring programme is recommended:

- The current groundwater network consists of nine boreholes strategically placed upstream and downstream of the three mining areas that encompass the BRMO (See Table 7 and Figure 14). These boreholes are sampled on a monthly basis in accordance with the WUL for the BRMO site.
- As it was found in this study that the BRMO does not pose a direct risk to the groundwater environment, the current monitoring network is considered adequate, especially considering the waste classification results.

Recommendations

The following recommendations are put forward:

- Bi-annual water level and quality monitoring should be implemented. Monitoring data should be used to recalibrate and update the mine water management plan, to prepare monitoring and audit reports, to report to the regulatory authorities against the requirements of the IWMP and other authorisations and as feedback to stakeholders in the catchment.
- Update the existing numerical model against monitored data every 5 years, during operations.
- The hydrocensus and risk assessment should be updated when mining activities change or new receptors are identified.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
ARD	Acid Rock Drainage
BPG	Best Practice Guidelines
CMS	Catchment Management Strategy
CSM	Conceptual Site Model
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Programme/Plan
IWRMP	Integrated Water Resources Management Plan
IWRM	Integrated Water Resources Management
Km^2	Square Kilometre
L/s	Litres per second
mamsl	Meters above mean sea level
Mbgl	Meters below ground level
Ml/d	Megalitres per day
m	Meter
mm	Millimetre
mm/a	Millimetres per annum
mS/m	Millisiemens per metre
m^3	Cubic metre
MAP	Mean Annual Precipitation
MPRDA	Mining and Petroleum Resources Development Act (Act No. 73 of 2002) 1989)
NEMA	National Environmental Management Act (Act No. 107 of 1998)
NWA	National Water Act (Act No. 36 of 1998)
ppm	Parts per million
RDM	Resource Directed Measures
RQO	Resource Quality Objective
RWQO	Resource Water Quality Objective
TDS	Total Dissolved Solids
WMA	Water Management Area
WMP	Water Management Plan

DEFINITIONS

Definition	Explanation
Aquiclude	A geologic formation, group of formations, or part of formation through which virtually no water moves
Aquifer	A geological formation which has structures or textures that hold water or permit appreciable water movement through them. Source: National Water Act (Act No. 36 of 1998).
Borehole	Includes a well, excavation, or any other artificially constructed or improved underground cavity which can be used for the purpose of intercepting, collecting or storing water in or removing water from an aquifer; observing and collecting data and information on water in an aquifer; or recharging an aquifer. Source: National Water Act (Act No. 36 of 1998).
Boundary	An aquifer-system boundary represented by a rock mass (e.g. an intruding dolerite dyke) that is not a source of water, and resulting in the formation of compartments in aquifers.
Cone of Depression	The depression of hydraulic head around a pumping borehole caused by the withdrawal of water.
Confining Layer	A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers; it may lie above or below the aquifer.
Dolomite Aquifer	See “Karst” Aquifer
Drawdown	The distance between the static water level and the surface of the cone of depression.
Fractured Aquifer	An aquifer that owes its water-bearing properties to fracturing.
Groundwater	Water found in the subsurface in the saturated zone below the water table.
Groundwater Divide or Groundwater Watershed	The boundary between two groundwater basins which is represented by a high point in the water table or piezometric surface.
Groundwater Flow	The movement of water through openings in sediment and rock; occurs in the zone of saturation in the direction of the hydraulic gradient.
Hydraulic Conductivity	Measure of the ease with which water will pass through the earth's material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (m/d).
Hydraulic Gradient	The rate of change in the total hydraulic head per unit distance of flow in a given direction.
Infiltration	The downward movement of water from the atmosphere into the ground.

Definition	Explanation
Intergranular Aquifer	A term used in the South African map series referring to aquifers in which groundwater flows in openings and void spaces between grains and weathered rock.
Monitoring	The regular or routine collection of groundwater data (e.g. water levels, water quality and water use) to provide a record of the aquifer response over time.
Observation Borehole	A borehole used to measure the response of the groundwater system to an aquifer test.
Phreatic Surface	The surface at which the water level is in contact with the atmosphere: the water table.
Piezometric Surface	An imaginary or hypothetical surface of the piezometric pressure or hydraulic head throughout all or part of a confined or semi-confined aquifer; analogous to the water table of an unconfined aquifer.
Porosity	Porosity is the ratio of the volume of void space to the total volume of the rock or earth material.
Production Borehole	A borehole specifically designed to be pumped as a source of water supply.
Recharge	The addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.
Recharge Borehole	A borehole specifically designed so that water can be pumped into an aquifer in order to recharge the ground-water reservoir.
Saturated Zone	The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.
Specific Capacity	The rate of discharge from a borehole per unit of drawdown, usually expressed as m3/d•m.
Specific Yield	The ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.
Transmissivity	Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.
Unsaturated Zone (Vadose Zone)	That part of the geological stratum above the water table where interstices and voids contain a combination of air and water.
Watershed	Catchment in relation to watercourse or watercourses or part of a watercourse means the area from which any rainfall will drain into the watercourses or part of a watercourse through surface flow to a common point or points. Source: National Water Act (Act No. 36 of 1998).
Water Table	The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is equal to that of the atmosphere.

GROUNDWATER CONTAMINATION ASSESSMENT

BLACK ROCK MINE OPERATIONS

1. INTRODUCTION

Geo Pollution Technologies – Gauteng (Pty) Ltd (GPT) was appointed by EScience Associates (Pty) Ltd (Escience) to construct both a conceptual and numerical groundwater model using the latest available data, techniques and software for the Black Rock Mining Operations (BRMO) near Hotazel, Northern Cape.

BRMO consists of the following mining areas: the Black Rock Mine on the farm Nchwaning 267, the Nchwaning Mine on the farm Nchwaning 267 and the Gloria Mine on Gloria 266. A comprehensive groundwater monitoring network for the entire BRMO was developed and implemented in 2011. This was followed by a hydrogeological impact assessment in 2015 for the tailings expansion at the Nchwaning Mine.

The impacts on the groundwater environment associated with BRMO are related to effluent discharge, as well *ad hoc* solid and liquid waste management. To assess potential impacts on the receiving groundwater environment and to propose management and mitigation measures, the potential sources of contamination, pathways and receptors were identified; a conceptual model developed to illustrate the relationships; and a numerical groundwater model constructed.

1.1 Project Description

In order to comply with the water use license for the site Blackrock Mine Operations was instructed to address the following:

"*The licensee shall ensure that additional geohydrological assessments needs to be conducted within one (1) of issuance of this licence which encompasses all of the information indicated above. The report must also contain an accurate assessment of source, pathway and receptors and must provide the mitigation measures against pollution. It must include the monitoring network and implementation plan.*"

1.2 Scope of Work

Within the scope of work the groundwater study aimed to address the following:

- Conceptual site model based on the source-pathway-receptor model.
- Numerical modelling of the impact of the sources on the groundwater regime.
- Risk assessment on the potential impacts.
- A short report summarising the findings of the study and commenting on the potential impact of the solid and liquid source areas specified in the WUL on the groundwater environment.

2. PROJECT METHODOLOGY

The impact of effluent discharge, as well ad hoc solid and liquid waste management areas were investigated through a desk study, previous field investigations, data analyses and the use of a numerical model. The work completed for the purposes of compiling the groundwater report is discussed in the following paragraphs.

2.1 Desk Study

This entailed the gathering of information through the collation, scrutiny and evaluation of available and relevant meteorological, geographical, geological, geochemical, hydrogeological and water quality data.

2.2 Conceptual Site Model

A Groundwater Conceptual Site Model (CSM) was constructed as a descriptive representation of the groundwater system that incorporates an interpretation of the geological and hydrological conditions.

2.3 Numerical Modelling

The finite difference numerical model was created using the AquaVeo's Groundwater Modelling System (GMS10.1) as Graphical User Interface (GUI) for the well-established Modflow and MT3DMS numerical codes.

MODFLOW is a 3D, cell-centred, finite difference, saturated flow model developed by the United States Geological Survey. MODFLOW can perform both steady state and transient analyses and has a wide variety of boundary conditions and input options. It was developed by McDonald and Harbaugh of the US Geological Survey in 1984 and underwent eight overall updates since. The latest update (Modflow NWT) incorporates several improvements extending its capabilities considerably, the most important being the introduction of the new Newton formulation and solver, vastly improving the handling of dry cells that has been a problem in Modflow previously.

Transport modelling was done using MT3DMS. MT3DMS is a 3-D model for the simulation of advection, dispersion, and chemical reactions of dissolved constituents in groundwater systems. MT3DMS uses a modular structure similar to the structure utilized by MODFLOW, and is used in conjunction with MODFLOW in a two-step flow and transport simulation. Heads are computed by MODFLOW during the flow simulation and utilized by MT3DMS as the flow field for the transport portion of the simulation.

2.4 Risk Assessment

The groundwater risk assessment was performed by defining the three components, which are the source, the pathway and the receptor. The risk assessment approach is therefore aimed at describing and defining the relationship between cause (source) through the groundwater pathway and the effect to the receptor. In the absence of any one of the three components, it is possible to conclude that groundwater risk does not exist.

2.5 Mitigation and Management Measures

The groundwater management measures were developed by taking in consideration the National Water Act, Act 36 of 1998 (NWA) and, to a lesser extent, the Mineral and Petroleum Resources Development Act, Act No. 28 of 2002 (MPRDA) and the National Environmental Management Act, Act 107 of 1998 (NEMA). Chapter 4 of the NWA addresses the use of water.

The Department of Water and Sanitation (DWS), has recognised the challenges facing both the water user and the authorities in managing groundwater in an integrated manner. This recognition has resulted in a number of guideline documents that provide the mining industry with an opportunity to marry together legislation and best practice into useable tools of implementation.

The management measures discussed in this report were based on these Best Practice Guidelines (BPG) series (DWA, 2008). The relevant guidelines for this report are listed below:

- Activity Series Guidelines
    - BPG A2. Water Management for Mine Residue Deposits
    - BPG A4. Pollution Control Dams
- Hierarchy Series Guidelines
    - H1. Pollution prevention
    - H2. Minimisation of impacts
    - H3. Water reuse and reclamation
    - H4. Water treatment
- General Series Guidelines
    - G1. Storm water management
    - G3. Water monitoring systems
    - G4. Impact prediction

3. DESK STUDY

A desk study was performed on all available information pertaining to the groundwater situation at the Black Rock Mine, Nchwaning II Mine, Nchwaning III Mine and Gloria Mine at the Black Rock Mining Operations (BRMO), as detailed below.

3.1 Information Reviewed

The following information sources were reviewed:

- Geological Map (Scale 1:250 000) published by the Council for Geosciences.
- National Groundwater Archive (NGA) information managed by DWA (2005).
- Aquatico Scientific (PTY) Ltd. (2014). Assmang Black Rock Mining Operations: Water Quality Monitoring Report. Water Monitoring Report.
- Geo Pollution Technologies – Gauteng (PTY) Ltd. (2011). Evaluation of the Hydrocensus at Black Rock Mining Operations and It Surroundings. Hydrogeological Assessment Report.
- Geo Pollution Technologies – Gauteng (PTY) Ltd. (2015). Hydrogeological Impact Assessment for the Assmang Nchwaning II Manganese Mine Tailings Facility Expansion, Assmang (PTY) Ltd.

3.2 Activity Description

BRMO has been in operation since 1940. All activity at the BRMO mines are located on the farms Belgravia 264, Nchwaning 267 and Gloria 266 including the solid and liquid waste management areas.

The surface infrastructure consists of the following:

- Existing Nchwaning II Tailings
- Gloria Tailings
- Gloria Historical Waste Storage

- Nchwaning II Historical Tailings
- Nchwaning II Proposed Tailings
- Black Rock Tailings
- Black Rock Landfill
- Historical Tailings
- Nchwaning II Proposed Tailings.

3.3 Summary of Previous Findings

A summary of the findings of the above mentioned reports are discussed under the headings below.

3.3.1 Conceptual site model

All the elements of a conceptual site model exist at BRMO, i.e. source-pathway-receptor linkage however some may not be relevant. The conceptual groundwater model for BRMO is described in detail below.

3.3.2 Potential sources

The potential sources of contamination were identified as the Existing Nchwaning Tailings, Gloria Tailings, Gloria Historical Waste Storage, Nchwaning Historical Tailings, Nchwaning Proposed Tailings, Black Rock Tailings, Black Rock Landfill, Historical Tailings and Nchwaning Proposed Tailings.

3.3.3 Groundwater pathways

It was assumed that potential contaminants are primarily mobilised as runoff and/or leach into the soil horizon. Thereafter the contaminants will infiltrate into the unsaturated zone and finally reach the groundwater table as dissolved constituents in recharging waters. Once the contaminated infiltrating water reaches the underlying aquifer as recharge it will follow the surface topography towards the Kuruman River and the private abstraction boreholes.

3.3.4 Sensitive receptors

The main receptors were identified as groundwater users on the farm Nchwaning. As of March 2011 two abstraction boreholes were located within 2 km downstream of BRMO. The Kuruman River and its tributary the Ga-Mogara River were not regarded as receptors as groundwater in the region does not contribute to baseflow based on episodic flow and deep water levels.

3.3.5 Potential impacts

Nitrate concentrations are elevated above the regulatory limits for human consumption. The elevated nitrate concentrations detected in effluent on site can be attributed to concentrating of the endemic nitrate during manganese processing at BRMO.

3.3.6 Recommended management measures

It was suggested that the current quarterly groundwater monitoring programme be maintained and the monitoring network was considered sufficient.

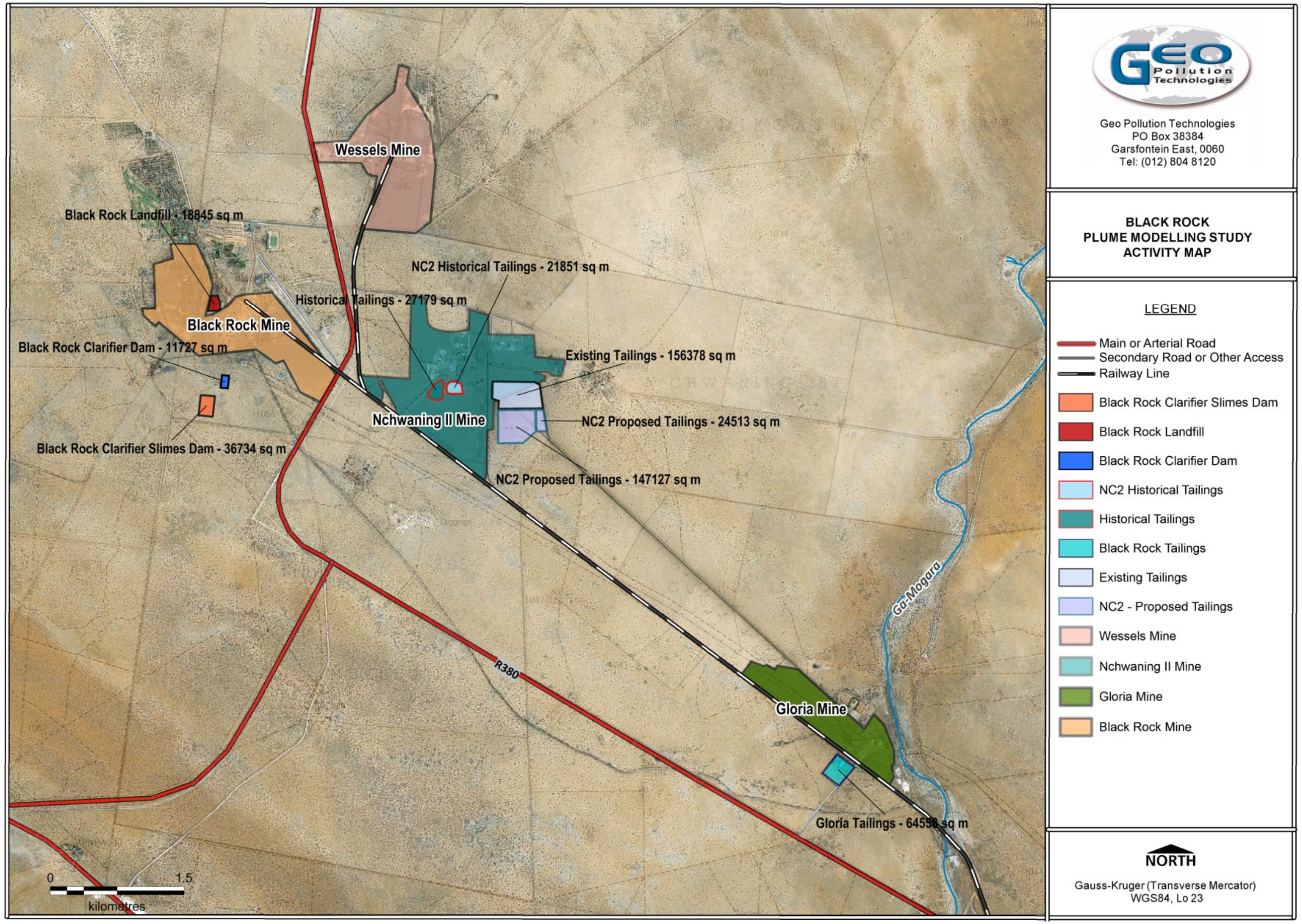

Figure 1: Activity map

4. REGIONAL INFORMATION

A description of the regional area information is described under the headings below.

4.1 Site Location

BRMO comprises four mining localities/operations, viz. Black Rock, Gloria, Nchwaning II and Nchwaning III mines as shown in Figure 1. The mines are located approximately 80 km north-west of the town of Kuruman and 16 km north-west of the village of Hotazel.

All source activities at BRMO are located on the farms Nchwaning 267, Gloria 266 and Belgravia 264.

4.2 Regional Water Management Setting and Sensitivity

BRMO is situated in the Lower Vaal Water Management Area (WMA), in quaternary catchment D41Mand D41K. The regional climate is arid with limited surface water resources. The Kuruman River and its tributary the Ga-Mogara River are ephemeral streams. The mean annual precipitation is given as 250 mm/annum and mean annual evaporation as 3000 mm/annum.

4.2.1 Present ecological status

The present ecological status category (PESC) is the practicality of restoring a system following an assessment of the changes that have occurred, to arrive at an attainable ecological management. The PESC status is defined as follows:

- Category A: Unmodified natural
- Category B: Largely natural
- Category C: Moderately modified
- Category D: Largely modified

Based on the Provincial Water Resources Assessments for the National Water Balance of 1999, the sensitivity, and present ecological status for the D41M-D41K quaternary catchment is given as D.

4.3 Site History

The site history is discussed under the headings below.

4.3.1 Historic water qualities

Based on the previous hydrogeological studies the natural/background water quality was described as calcium/magnesium-bicarbonate waters, i.e. freshly recharged unpolluted groundwater. Some groundwater samples showed signs of chloride and nitrate enrichment. The available data is detailed in Table 1below.

Table 1: Historic water qualities of the area

Sample No.	BRMO 1	BRMO 2	BRMO 4	BRMO 5	BRMO 6	BRMO 7	BRMO 8	BRMO 9	BRMO 10	BRMO 11	BRMO 12	BRMO 13	BRMO 15	BRMO 16	BRMO 18
Data source	GPT	GPT	GPT	GPT	GPT	GPT	GPT	GPT	GPT	GPT	GPT	GPT	GPT	GPT	GPT
Sample date	Feb-11	Feb-11	Feb-11	Feb-11	Feb-11	Feb-11	Feb-11	Feb-11	Feb-11	Feb-11	Feb-11	Feb-11	Feb-11	Feb-11	Feb-11
Ca [mg/l]	105	14	38	40	71	39	64	70	23	83	85	5	74	70	76
Mg [mg/l]	64	13	24	25	77	35	31	31	20	42	43	2.9	45	72	53
Na [mg/l]	65	149	86	79	47	114	48	55	52	57	56	154	11	38	25
K [mg/l]	9.9	4.5	6.4	6.7	5.2	10.2	7.9	8.5	8.7	9.8	9.9	14.9	2.3	2.9	3
Mn [mg/l]	0	0	0	0	0	0	0	0	0	0	0	0	0.039	0	0
Fe [mg/l]	0	0	0	1.34	0	0	0	0	0.04	0.043	0	0.114	0.045	0	0
F [mg/l]	0	0.9	0.3	0.3	0	0.6	0	0	0.3	0	0	0.3	0	0	0
NO_3 [mg/l]	33	4.2	8.2	8.5	3.8	3.9	10	23	3.6	9.9	8.7	8.8	2.8	6.3	3.1
Cl [mg/l]	177	75	62	61	143	95	84	68	37	170	180	36	25	118	41
SO_4 [mg/l]	38	89	50	43	60	51	29	48	29	36	36	32	14	56	21
Alkalinity [mg/l $CaCO_3$]	336	236	252	248	372	328	256	264	216	260	256	320	400	416	440
pH	7.7	8.8	7.6	7.7	7.8	7.6	7.7	7.9	8.3	7.5	7.5	8.1	7.6	7.5	7.3
EC [mS/m]	131	87.6	79	77.4	113	100	81.8	85.3	55.8	116	115	84.9	68	103	81.3
Cat/An Bal. %	4.5	3.8	4	3.1	3.8	2.7	4.6	6.5	5.7	5	4.9	6.9	3.3	5.9	17

4.3.2 Historic contamination

Historic contaminants

The historical contaminants as a result of previous activities are listed below:

Nitrates reported as NO_3 as N, were elevated above the regulatory target water quality range concentration of <6 mg/l.

Activities that lead to contamination

The vegetation cover is predominantly legumes, this family of plants are known to fix nitrogen, i.e. convert it to nitrate. Nitrates are highly mobile and are thus easily detected in groundwater samples across the site. Additionally, recirculation of water for processing purposes is likely to concentrate contaminants at a single source which includes nitrate.

The extent of contamination

The hydrochemical signature of groundwater samples within 10 km of the BRMO mining sites indicated that the water was sourced from a single aquifer with a single recharge source. Thus, nitrate contamination was considered to be historically prevalent throughout the Hotazel area.

4.4 Regional Geology

The investigated area falls within the 2722 Kuruman 1:250 000 geology series maps and is situated approximately 16 km north-west of Hotazel, Northern Cape. An extract of the map is shown in Figure 2.

The lithostratigraphic sequence from the surface to the mined Hotazel Formation is as follows:

- Quartenary sands, clay and calcrete of the Kalahari Formation, Karoo Supergroup.
- Tillite/diamictite of the Dwyka Group, Karoo Supergroup.
- Quartzite and shale of the Mapedi Formation, Olifantshoek Group.
- The Hotazel Formation, Postmasburg Group, Transvaal Supergroup.

A regional thrust fault, the Blackridge Thrust Fault is located between the Black Rock Mine and the Nchwaning II and III mines[1].

4.5 Regional Hydrogeology

As discussed, the site is underlain by the Kalahari formation. This formation at BRMO consists of a top layer of aeolian sands followed by calcrete of tertiary age. If weathered, the calcareous sands have high porosity and permeability values relative to bedrock in the area. There is limited surface runoff in the Kalahari area (high infiltration rates during precipitation).

The potential of groundwater occurrence will depend on the presence of secondary alteration and fracturing in the calcrete. Weathering and fracturing may increase the aquifer potential, thus zones of weathering and fracturing within the calcrete will act as targets for potential groundwater

[1] Gutzmer, J. And Beukes, N. J. (1996). Mineral Paragenesis of the Kalahari Manganese Field, South Africa. *Ore Geology Reviews* 11: 405 – 428.

exploration. The arithmetic average depth of the water levels below surface in the boreholes found at BRMO is 69.6 mbgl with a maximum depth of 110m below surface. If the depth of the Kalahari formation is considered with the water levels found in the hydrocensus, it can be concluded that the farmers tap their water from this weathered/fractured calcrete aquifer. The average recharge values assigned to calcrete is ± 10 % of the mean annual precipitations (MAP) (Groundwater Decision Tool). The natural/background water quality is within target water quality limits.

4.5.1 Shallow, weathered aquifer

Surficial deposits comprise of calcrete, clay and quaternary sands and can be as thick as 40 m. Calcrete is a product of alteration and weathering of carbonate rocks by precipitation of calcium carbonate from groundwater in soil during long periods of precipitation deficits in arid climates. Calcrete/clay complexes are found to generally have low transmissivities and form extensive aquitards in outcrop areas. The sandy soil horizon is expected to allow for rapid infiltration into the vadose zone during precipitation events. High intensity, low volume rainfall is common in arid regions.

The main source of recharge into the shallow alluvial aquifer is rainfall that infiltrates the aquifer through the unsaturated (vadose) zone. Vertical movement of water is faster than lateral movement in this system as water moves predominantly under the influence of gravity. Groundwater recharge was estimated to be an average of 10% of mean annual precipitation. Recharge occurs mainly by diffuse recharge as infiltration rates are expected to be high. The climate of the region is arid and the presence of calcrete above the bedrock suggests long dry spells.

With advanced clay lens development, perched aquifers are expected to form across the site following high precipitation events. The hydraulic conductivity of this aquifer ranges between 10^{-4} and 1 m/day.

4.5.2 Weathered/fractured aquifer

Dwyka diamictite is thought to have been folded and fractured due to tectonic activity related to formation of the Cape Fold Belt, occurs between 40 and 68 mbgl. Dwyka Formation tillite is generally massive with little jointing but may be stratified. Primary porosity is virtually inexistent and the presence of water is generally limited to secondary structures, i.e. fractures.

Both the porosity[2] and the hydraulic conductivity[3] of these aquifers are known to be low. The commonly expected values of porosity and hydraulic conductivity are 0.05 and 10^{-5} m/day, respectively. Movement of groundwater in this aquifer occurs primarily in secondary structures such as faults and fractures. Previous studies show that water sourced from this aquifer is stagnant old water of a sodium chloride type.

The Dwyka Formation tillites are low-yielding aquifers as they have a low groundwater development potential. The underlying Mapedi Formation quartzite aquifer is also considered a low-yielding or non-aquifer.

[2] The ratio of the volume of void space to the total volume of the rock or earth material

[3] Measure of the ease with which water will pass through the earth's material; defined as the rate of flow through a cross-section of one square meter under a unit hydraulic gradient at right angles to the direction of flow (m/d).

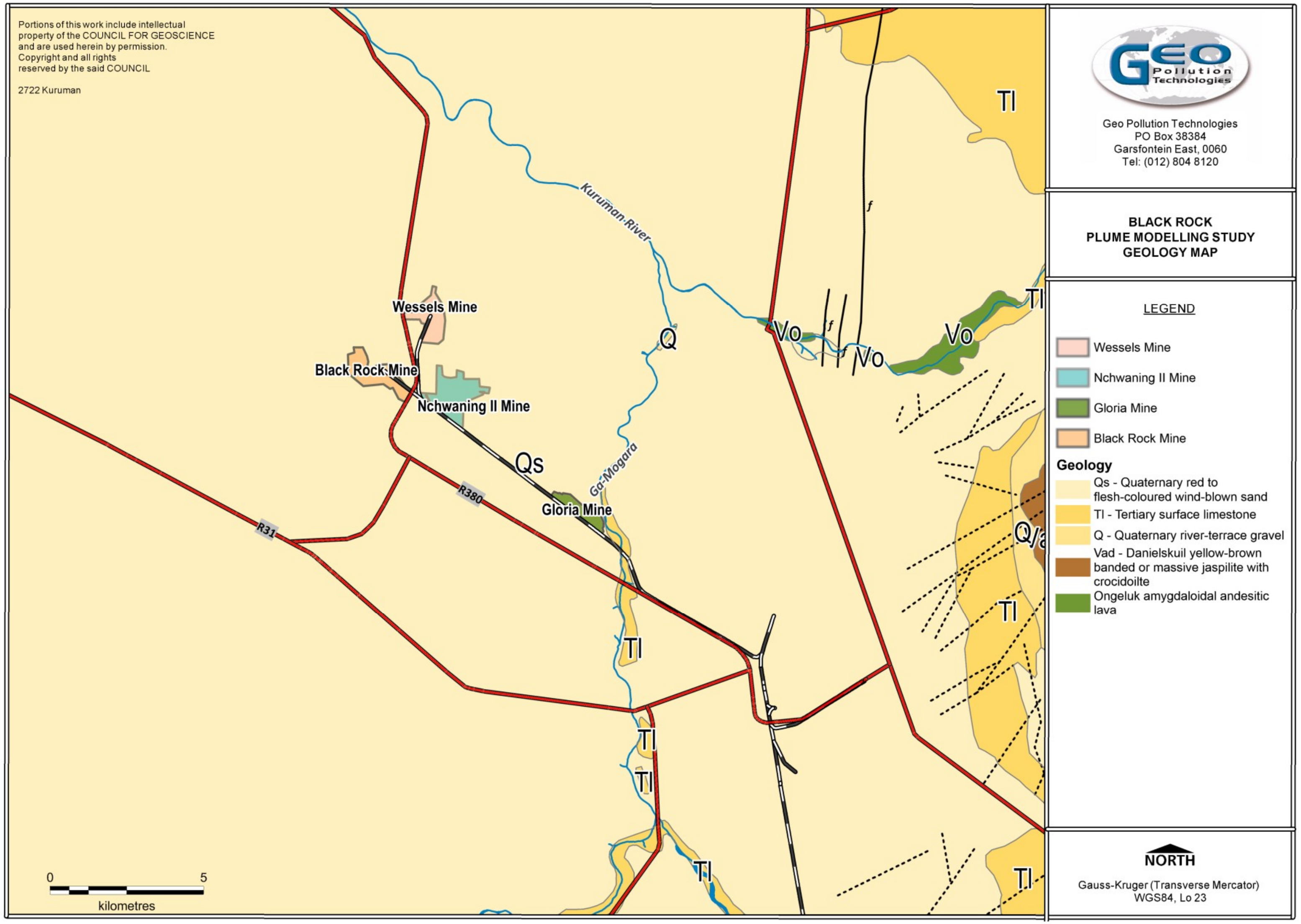

Figure 2: Regional Geology Map (1:250 000 geology series map)

5. HYDROGEOLOGICAL SETTING

The backbone of any groundwater impact prediction or management system is to understand the hydrogeological setting and how the potential stresses will influence the natural groundwater conditions. The hydrogeological setting is described under the headings below.

5.1 Site Topography and Drainage

The topography (Figure 3) can normally be used as a good first approximation of the hydraulic gradient in the unconfined aquifer. The area is characterised by an irregular topography and in the area of the mining site the slope is more or less in the order of 1%.

Locally drainage is towards the Kuruman River which flows westwards, to the east lies the Ga-Mogara River which is a tributary to the Kuruman River. Both rivers are ephemeral streams/rivers and flow in these water bodies is periodical. The area is characterised by low rainfall, high potential evapotranspiration and high infiltration rates.

5.1.1 Groundwater monitoring network

Quarterly water monitoring is conducted by Aquatico Scientific, the groundwater monitoring programme includes water level and quality monitoring at nine (9) groundwater monitoring points.

5.2 Water Levels

The latest water level monitoring data from the nine (9) monitoring boreholes showed that groundwater levels varied between a minimum of 37.1 and a maximum of 99.77 mbgl with an average of 59.29 mbgl (Table 2).

Table 2: Groundwater monitoring points (July 2016)

ID	Location	Latitude	Longitude	Date sampled	Water level (mbgl)
GPT01	Gloria Mine	-27.17560	22.90210	2014/11/11 09:50	37.71
GPT02	Gloria Mine	-27.16790	22.91040	2014/11/11 10:12	70.83
GPT03	Nchwnaning I and II	-27.14900	22.85820	2014/11/11 07:51	99.77
GPT04	Nchwnaning I and II	-27.12430	22.86380	2014/11/11 11:14	46.47
GPT07	Sinter plant and slimes dam complex	-27.14980	22.89320	2014/11/11 10:33	48.52
GPT05	Black Rock Mine	-27.13540	22.84430	2014/11/11 12:40	39.64
GPT06	Black Rock Mine	-27.12500	22.84330	2014/11/11 11:58	-
GPT08		-27.13082	22.83625	2014/11/11 12:22	37.85
GPT09		-27.12573	22.83689	2014/11/11 11:32	93.53

5.3 Waste water quality

The results of the waste water analytical results were made available and are herein compared to the WUL limits for waste water in Table 3. The constituents in the waste water monitoring points found to be above the SANS 2015 limits during the July 2016 monitoring event are:

- EC, TDS, NO_3 as N, SO_4, Cl, Na, Mn, Total Coliforms and E.Coli.
- The elevated nature of these constituents may be related to processing activities at BRMO, anthropologic activities as well as the high evapotranspiration rates in the area.

Table 3: Results of the analysis for waste water at BRMO compared with the SANS 2015 limits (July 2016).

Parameter		Unit	SANS 241: 2015 Recommended Limits	Risk	Results					
					Black Rock Mine Sewage treatment plant	Wastewater Treatment Plant	Gloria Mine Sewage Treatment Plant	Gloria Mine TSF RWD	Nchwaning 2 TSF RWD	Nchwaning Sewage Treatment Plant
Physical & Aesthetic determinants										
Electrical conductivity at 25^0C	EC	mS/m	≤ 170	Aesthetic	112	297	67.9	471	304	132
Total Dissolved Solids	TDS	mg/liter	≤ 1200	Aesthetic	687	2011	405	3127	2212	767
pH at 25^0C		pH units	≥ 5 to ≤9.7	Aesthetic	8.45	8.36	7.92	8.08	8.06	8.01
Chemical Determinants - Macro determinants										
Nitrate as N	NO_3	mg/liter	≤ 11	Acute Health	19.3	52.7	3.01	77.7	85.5	2.92
Sulphate	SO_4	mg/liter	Acute Health ≤500; Aesthetic ≤250	Acute Health/Aesthetic	39.7	529	45.1	847	775	39.4
Fluoride	F	µg/liter	≤1500	Chronic Health	0	0.673	0	0.671	0	0
Ammonia as N	NH_3	mg/liter	≤ 1.5	Aesthetic	0.016	0.019	0.15	0.113	0.343	0.54
Chloride	Cl	mg/liter	≤ 300	Aesthetic	97	466	29.6	862	377	100
Sodium	Na	mg/liter	≤ 200	Aesthetic	90.6	338	37.6	669	287	106
Zinc	Zn	µg/liter	≤5000	Aesthetic						
Chemical Determinants - Micro determinants										
Boron	B	µg/liter	≤ 2400	Chronic Health	0	3	0	3.21	2.52	0
Total Iron	Fe	mg/liter	Acute Health ≤ 2.0; Aesthetic ≤0.3	Acute/Aesthetic	0	0	0	0	0	0
Total manganese	Mn	mg/liter	Acute Health ≤0.4; Aesthetic ≤0.1	Acute/Aesthetic	0	0	0	0	0	1.81

Parameter		Unit	SANS 241: 2015 Recommended Limits	Risk	Results					
					Black Rock Mine Sewage treatment plant	Wastewater Treatment Plant	Gloria Mine Sewage Treatment Plant	Gloria Mine TSF RWD	Nchwaning 2 TSF RWD	Nchwaning Sewage Treatment Plant
Aluminium	Al	µg/liter	≤ 300	Operational	0	0	0	0	0	0
Chemical Determinants - Organic determinants										
Total coliforms		colonies per 100ml	≤ 10	Chronic Health	**0**	**4**	**107000**	**38000**	**990**	**111000**
E.coli		colonies per 100ml	0	Chronic Health	**0**	**0**	**34000**	**600**	**56**	**104000**
Concentration deemed to present an unacceptable health risk for lifetime consumption.										

5.4 Material Leachate Quality

According to the concentration thresholds of waste classification of the analysed samples, the waste material generated on site is Type 4 bar Mn at the sewage sludge , therefore the waste material can be classified as non-hazardous, (see Table 4).

Table 4: Results of the Chemical Leaching Analysis compared with the Screening Values proposed in the Regulations for Waste Classification (DEA, 2013)

Parameter	Leachable Concentration Threshold (LCT)								
	Unit	NW Sewage Sludge	NW Tailings NW	NW Slimes Dam 1 SW	NM historic tailings next to lined dam	LCT0	LCT1	LCT2	LCT3
As as Arsenic	mg/l	0.14	0	0	0	0.01	0.5	1	4
B as Boron	mg/l	0.43	0.051	0.052	0.47	0.5	25	50	200
Ba as Barium	mg/l	17	0.39	0.6	0.09	0.7	35	70	280
Cd as Cadmium	mg/l	0.047	0	0	0	0.003	0.15	0.3	1.2
Chloride as Cl	mg/l	0	6.5	0.87	150	300	15000	30000	120000
Co as Cobalt	mg/l	0.12	0	0	0	0.5	25	50	200
Cr as Total Chromium	mg/l	0.37	0	0	0.0075	0.1	5	10	40
Cu as Copper	mg/l	1.7	0	0	0	2	100	200	800
F as Fluoride	mg/l	0	0.65	0	0	1.5	75	150	600
Hg as Mercury	mg/l	0	0	0	0	0.006	0.3	0.6	2.4
Mn as Managanese	mg/l	900	0.064	0	0.55	0.5	25	50	200
Mo as Molybdenum	mg/l	0	0	0	0	0.07	3.5	7	28
Ni as Nickel	mg/l	0.087	0	0	0	0.07	3.5	7	28
Nitrate as N	mg/l	0	0.64	0.16	9.8	11	550	1100	4400
Pb as Lead	mg/l	0.03	0	0	0	0.01	0.5	1	4
Se as Selenium	mg/l	0.7	0	0	0	0.01	0.5	1	4
Sulphate as SO4	mg/l	0	16	9.9	390	250	12500	25000	100000
V as Vanadium	mg/l	0.019	0	0	0	0.2	10	20	80
Zn as Zinc	mg/l	140	0	0	0	5	250	500	2000
TDS	mg/l	10920	108	72	1092	1000	12500	25000	100000
NA: Not applicable/Below Threshold									
TCT0 limits based on screening values for the protection of water resources contained in the Framework for the Management of Contaminated Land (DEA, March 2010);	LCT1 limits derived by multiplying LCT0 values by a Dilution Attenuation Factor (DAF) of 50, as proposed by the Australian State of Victoria;								
TCT1 limits derived from land remediation values for commercial/industrial land	LCT2 limits derived by multiplying LCT1 values by a factor of 2;								
TCT2 limits derived by multiplying the TCT1 values by a factor of 4, as used by the Environmental Protection Agency, Australian State of Victoria. Environmental Protection Agency,	LCT3 limits derived by multiplying the LCT2 values by a factor of 4.								
Waste Type 0				Not allowed					
Waste Type 1				Class A or Hh:HH landfill					
Waste Type 2				Class B or GLB+ landfill					
Waste Type 3				Class C or GLB- landfill					
Waste Type 4				Class D or GLB- landfill					

5.5 Groundwater Quality

The groundwater quality results from the July 2016 monitoring report[4] supplied by the client were compared with the South African National Standard for Drinking Water, SANS 241-1:2015. SANS 241-1 is applicable to all water services institutions and sets numerical limits for specific determinants to provide the minimum assurance necessary that the drinking water is deemed to present an acceptable health risk for lifetime consumption. The results from these analyses were plotted as pie diagrams (Figure 4), stiff diagrams (Figure 5) and piper diagram (Figure 6). The laboratory certificate of analyses and monitoring data can be seen attached as Appendix B.

The pie diagrams show both the individual ions present in a water sample and the total ion concentrations in meq/l or mg/l. The scale for the radius of the circle represents the total ion concentrations, while the subdivisions represent the individual ions. It is very useful in making quick comparisons between waters from different sources and presents the data in a convenient manner for visual inspection.

A Stiff pattern is basically a polygon created from four horizontal axes using the equivalent charge concentrations (meq/l) of cations and anions. The cations are plotted on the left of the vertical zero axis and the anions are plotted on the right. Stiff diagrams are very useful in making quick comparisons between waters from different sources.[5]

On the piper diagram the cation and anion compositions of many samples can be represented on a single graph. Certain trends in the data can be discerned more visually, because the nature of a given sample is not only shown graphically, but also show the relationship to other samples. The relative concentrations of the major ions in mg/l are plotted on cation and anion triangles, and then the locations are projected to a point on a quadrilateral representing both cation and anions.

5.5.1 Hydrochemical characterisation

From the tables and figures the following can be deduced:

- The major cations in the groundwater samples are calcium and sodium.
- The major anions in the groundwater samples are bicarbonate, chloride and sulphate.
- The water quality in the vicinity of BRMO can be considered independently as the hydrochemical signatures vary spatially across the three mining areas:
  - Black Rock: Ca^{2+}-Mg^{2+}/HCO_3^-.
  - Nchwaning: Na^+/HCO_3^- (upstream) and Na^+-Mg^{2+}/Cl^- (downstream).
  - Gloria: Mg^{2+}/Cl^- (upstream) and Na^+-Mg^{2+}/HCO_3^- (downstream).
- The groundwater types show evidence of mixing and characteristic of dynamic groundwater regimes. A dynamic regime with bicarbonate-rich waters undergoing mixing and enrichment in sodium, chloride and sulphate

[4] Aquatico Scientific Pty (Ltd). (2016). Assmang (Pty) LtdBlack Rock Water Quality Monitoring Report July 2016.

[5] Hiscock, K. M. (2005). Chapter 2: Chemical Hydrogeology. *Hydrogeology: Principles and Practice. pp. 74 - 117.* Blackwell Science Ltd. Oxford.

5.5.2 Groundwater quality against DWS guidelines

From Table 5 the following can be deduced:

- The constituents above the DWS guidelines for domestic use are EC, NO_3, Cl and Na.

The elevation of the constituents mentioned above can be interpreted as follows:

- NO_3 concentrations are elevated possibly due to nutrient overloading in the soil due to agricultural practices and effluent from human activities, nitrogen fixation by legumes, and animal excreta mixing with infiltrating waters. Further NO_3 contamination is limited to the Black Rock mining area.
- Elevated EC, Cl and Na enrichment is to be expected in deep-lying groundwater with high residence times increasing the advent of water-rock interaction.

Table 5: July 2016 Groundwater quality compared to SANS 241: 2015.

Parameter		Unit	SANS 241: 2015 Recommended Limits	Risk	Results						
					GPT01	GPT02	GPT03	GPT04	GPT05	GPT06	GPT08
Physical & Aesthetic determinants											
Electrical conductivity at 25^0C	EC	mS/m	≤ 170	Aesthetic	166	192	101	170	127	169	150
Total Dissolved Solids	TDS	mg/liter	≤ 1200	Aesthetic	976	1134	566	908	744	934	892
pH at 25^0C		pH units	≥ 5 to ≤9.7	Aesthetic	7.85	7.76	8.47	8.45	7.82	7.84	7.3
Chemical Determinants - Macro determinants											
Nitrate as N	NO_3	mg/liter	≤ 11	Acute Health	43.7	13.2	3.46	2.86	44.3	62.3	53.1
Sulphate	SO_4	mg/liter	Acute Health ≤500; Aesthetic ≤250	Acute Health/Aesthetic	110	179	33.7	84.9	14.9	40.8	47.3
Fluoride	F	µg/liter	≤1500	Chronic Health	0.602	0.552	1.82	0	0.83	0	0
Chloride	Cl	mg/liter	≤ 300	Aesthetic	284	264	93.2	344	97.8	156	119
Sodium	Na	mg/liter	≤ 200	Aesthetic	132	298	178	201	41.2	77.6	49
Zinc	Zn	µg/liter	≤5000	Aesthetic	0	0	0	0	0	0	0
Chemical Determinants - Micro determinants											
Boron	B	µg/liter	≤ 2400	Chronic Health	0.697	1.78	1.68	0.243	0.064	0.179	0.062
Copper	Cu	µg/liter	≤ 2000	Chronic Health	0	0	0	0	0	0	0
Total Iron	Fe	mg/liter	Acute Health ≤ 2.0; Aesthetic ≤0.3	Acute/Aesthetic	0	0	0	0	0	0	0
Lead	Pb	µg/liter	≤ 10	Chronic Health	0	0	0	0	0	0	0
Total manganese	Mn	mg/liter	Acute Health ≤0.4; Aesthetic ≤0.1	Acute/Aesthetic	0	0	0	0	0	0	0
Aluminium	Al	µg/liter	≤ 300	Operational	0	0	0	0	0	0	0
Chemical Determinands - Organic determinands											

Parameter		Unit	SANS 241: 2015 Recommended Limits	Risk	Results						
					GPT01	GPT02	GPT03	GPT04	GPT05	GPT06	GPT08
Total coliforms		colonies per 100ml	≤ 10	Chronic Health	0	0	0	0	0	0	0
E.coli		colonies per 100ml	0	Chronic Health	0	0	0	0	0	0	0
Concentration deemed to present an unacceptable health risk for lifetime consumption.											

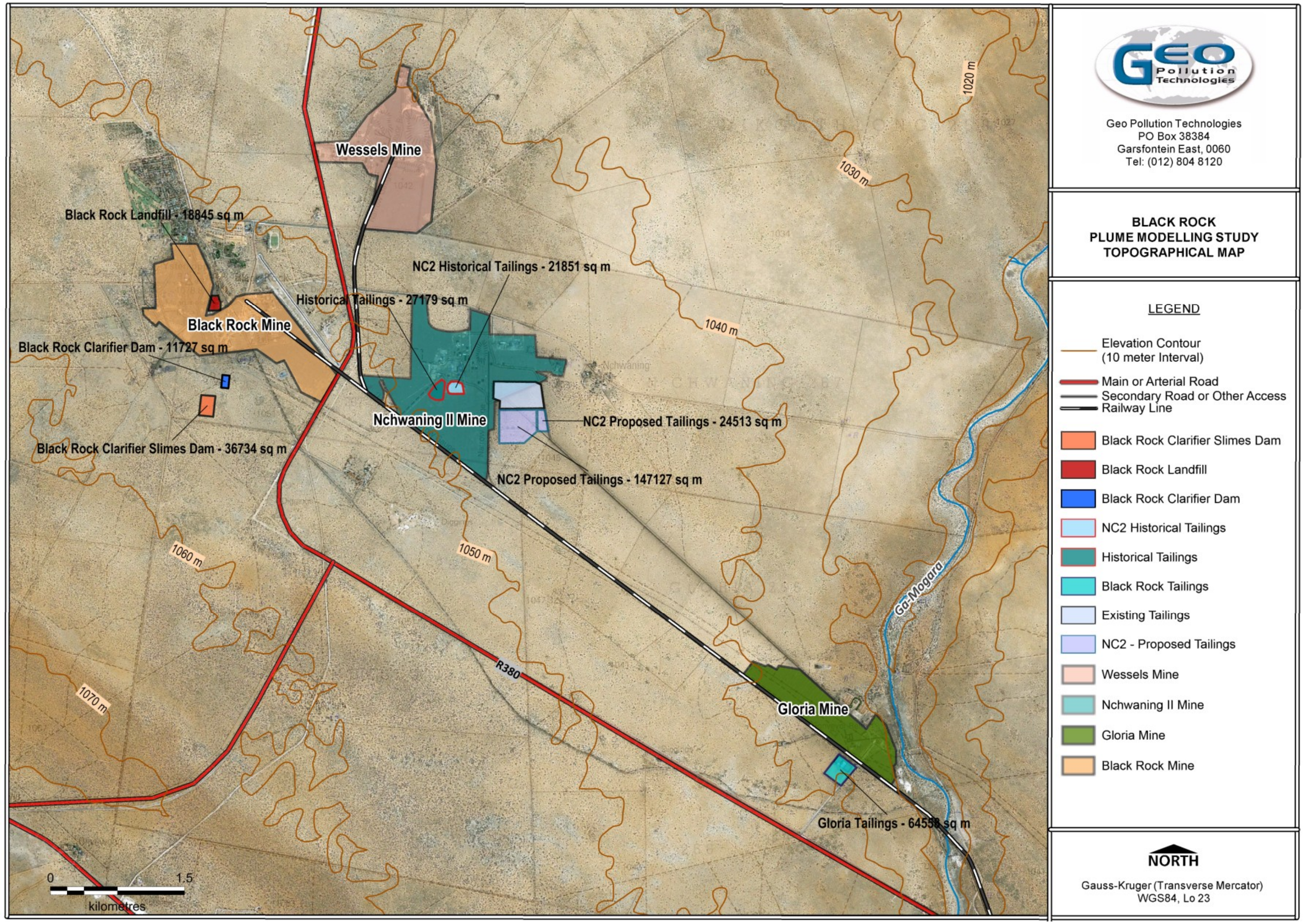

Figure 3: Site topography

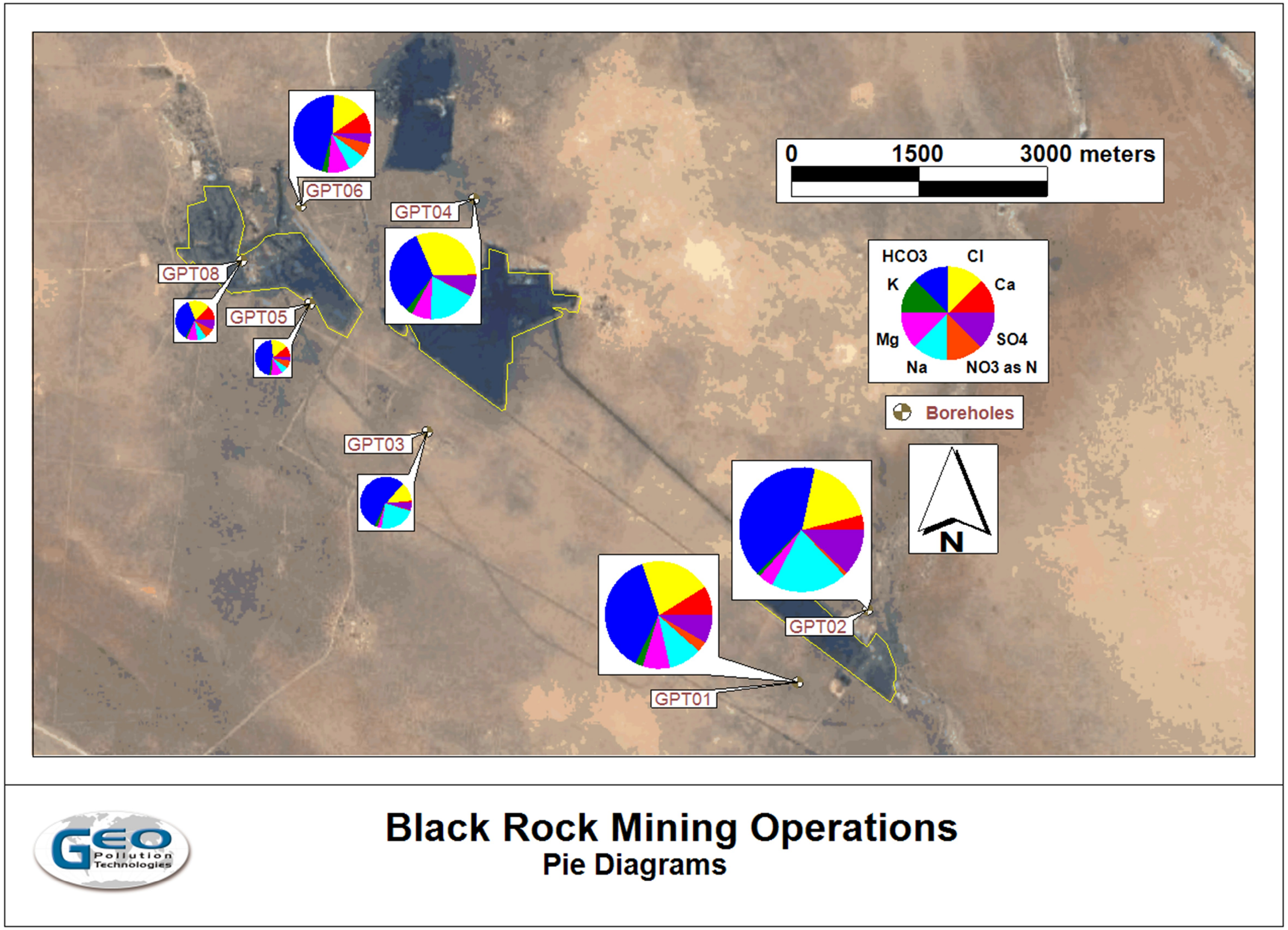

Figure 4: Pie diagrams (July 2016)

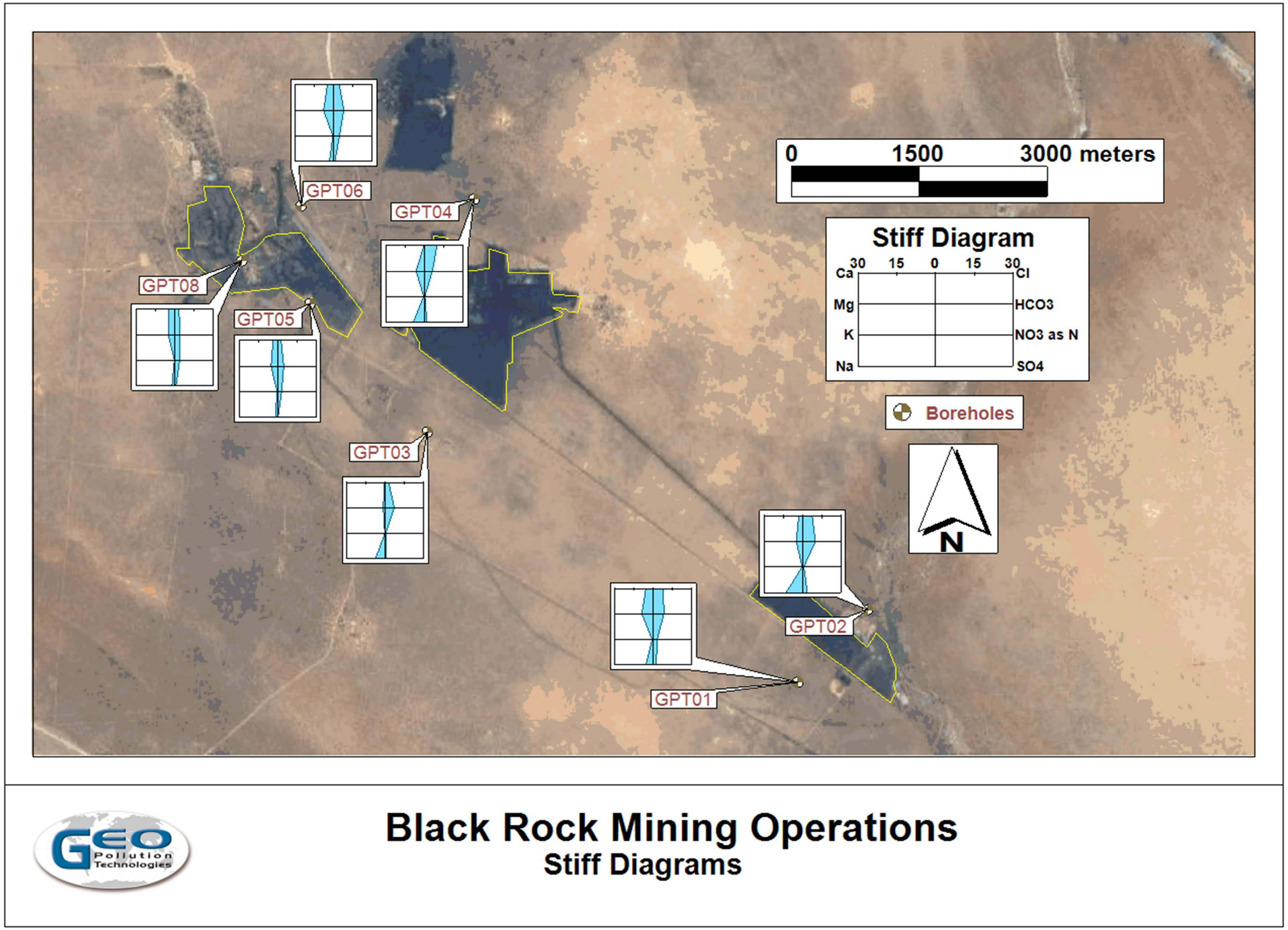

Figure 5: Stiff diagrams (July 2016)

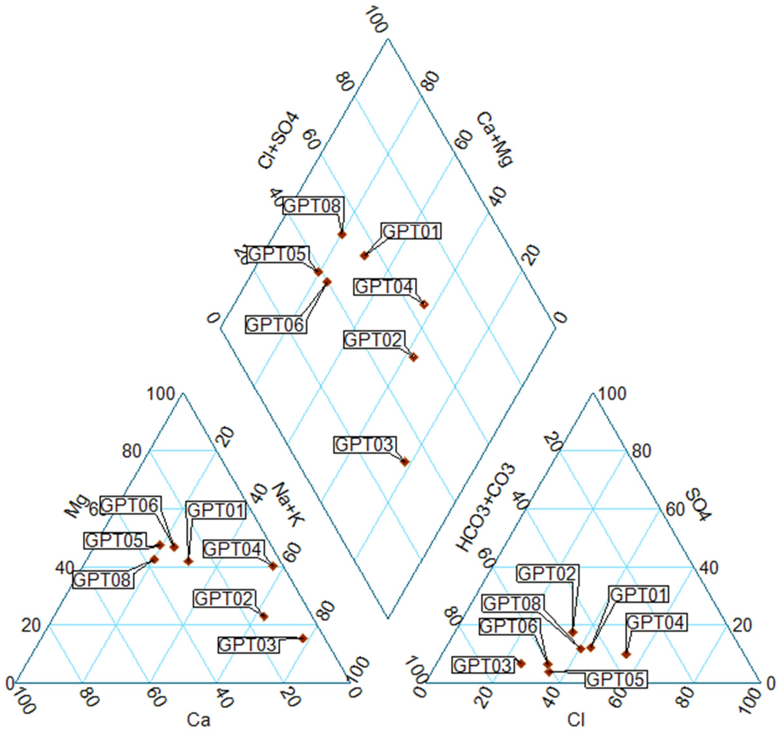

Figure 6: Piper diagram (July 2016)

6. CONCEPTUAL SITE MODEL

From the results of the desk study, field investigations and laboratory analyses, a conceptual hydrogeological model was compiled for BRMO.

The site is underlain by the Kalahari formation, which consists of a top layer of aeolian sands, followed by calcrete. The maximum depth of the Kalahari formation is +/- 125m. The average depth of the water levels below surface in the boreholes found at BRMO is 70m below surface with a maximum depth of 110m below surface. If this is compared with the water levels found in the hydrocensus, it can be concluded that the surrounding water users tap their water from this sand/calcrete aquifer. The calcareous sand also has high values of porosity and permeability relative to the fractured aquifer and is expected to be high-yielding with regards to groundwater.

There is limited surface runoff in the Kalahari area (high infiltration rates during precipitation). The average recharge value is ± 10 % of the mean annual precipitations (MAP).

Locally, drainage is towards the Kuruman River which flows westwards, to the east lies the Ga-Mogara River which is a tributary to the Kuruman River. Both rivers are ephemeral streams/rivers and flow in these water bodies is periodical. The area is characterised by low rainfall, high potential evapotranspiration and high infiltration rates.

The conceptual hydrogeological model for BRMO is illustrated schematically in Figure 8 by considering lithological cross-sections through the existing Nchwaning tailings facility and the entire Nchwaning II Mine. The position and orientation of the cross-section trace is shown in Figure 7. The cross-section extends from south-west of the current Nchwaning mine infrastructure, through the mine to the Kuruman River and intersects a number of boreholes.

6.1 Water Levels

The groundwater table does not mimic the topography. Three flow regimes were identified corresponding to the three mining areas and N-S cross-cutting fault systems. The fault zones act as barriers to flow between the three mining areas, i.e. Black Rock, Nchwaning and Gloria.

Flow predominantly takes place in directions north to north north-easterly towards the Ga-Mogara River and the Kuruman River from the Nchwaning II Mine; however this path is intersected by abstraction points downstream of the mine where flow is redirected towards the abstraction boreholes, i.e borehole BRMO-19.

6.2 Contaminant Levels

From the water quality information presented in Table 5 the background water quality is represented by borehole GPT03 located upstream of the Nchwaning II Manganese Mine is within regulatory limits. The elevated pH cannot be attributed to any activity. Downstream of the mine as represented by borehole GPT04 elevated concentrations of Mg can be observed and this is attributed to water-rock interaction. Mg has an aesthetic effect on the water but no definite health risks are known.

Analysed leachate from the tailings material samples were found not to exceed any of the screening values indicated by the DEA regulations. It can therefore be concluded that the input of the leachate produced by ore processing waste material on site, will not have any significant effects on groundwater quality, but should have a similar effect as the local underlying geology.

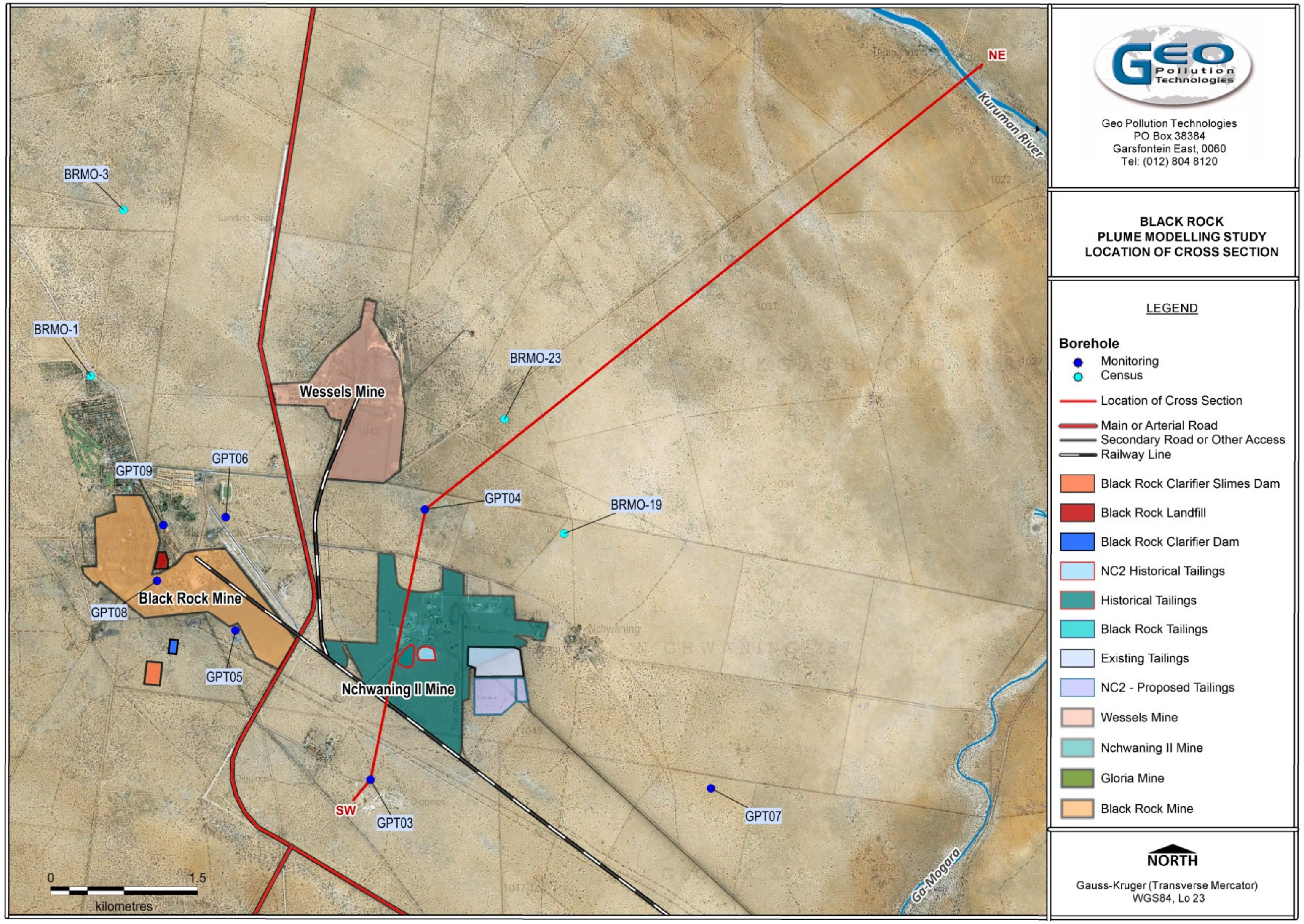

Figure 7: Position and orientation of the cross-section trace through the BRMO used for the conceptual hydrogeological model

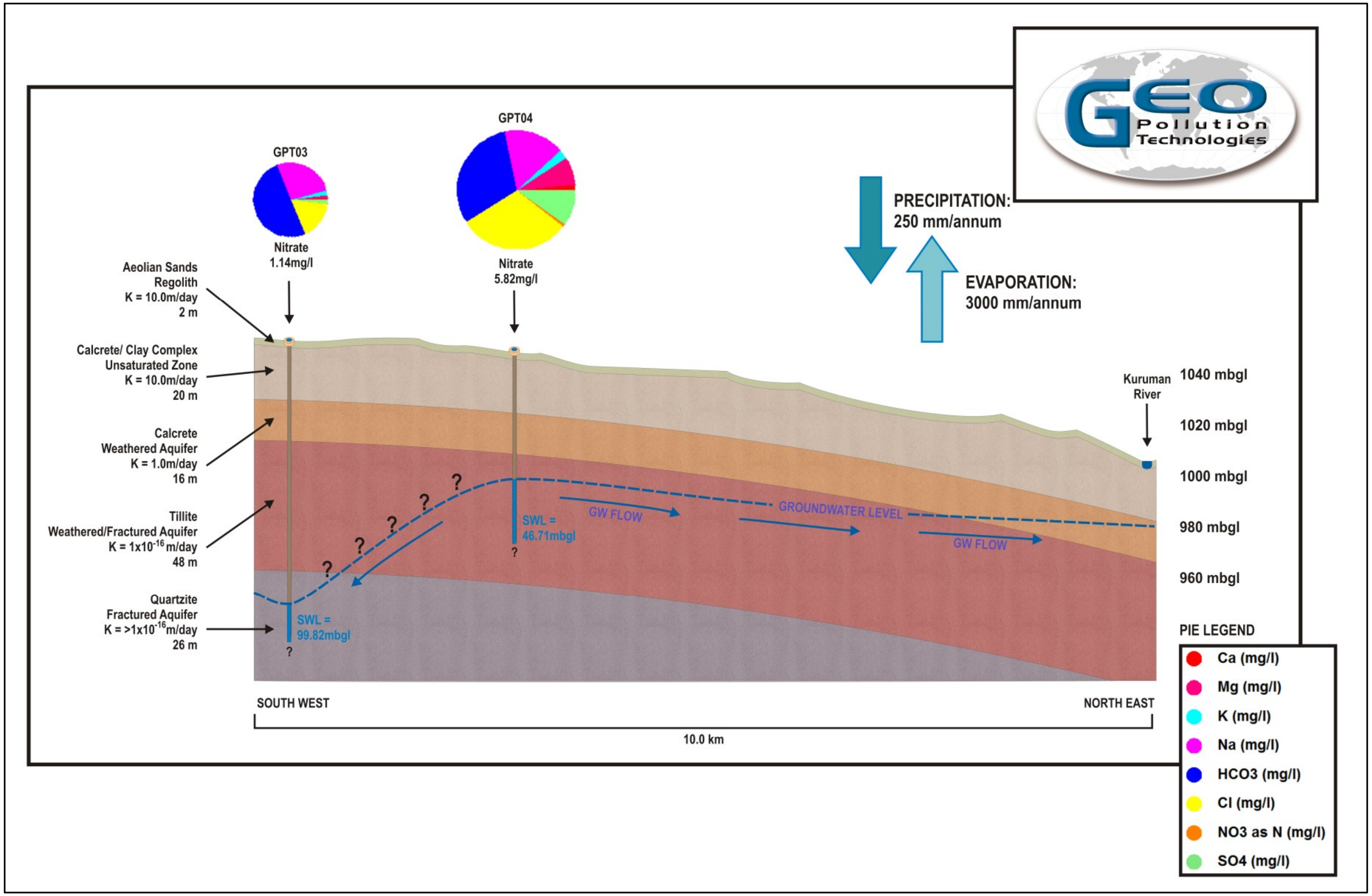

Figure 8: Conceptual hydrogeological model

7. GROUNDWATER FLOW AND TRANSPORT MODELLING

The groundwater flow and transport model is constructed and simulated to aid in decision making processes and environmental management.

The groundwater regime of the study area is rather complex, characterised by intricate layering containing highly permeable sand as well as virtual aquitards such as the numerous calcrete and clay layers in the Kalahari Formation. Underneath the recently deposited sediment, the bedrock is highly heterogeneous due to complex faulting and intrusions, which ultimately influence the groundwater flow patterns. Constructing a groundwater flow model with all the detail is close to impossible; however, assumptions are made based on known data and used to simulate different worst case scenarios to conclude with management protocol.

Therefore, the purpose of the model is to develop a tool than can be used to assess the worst case impact associated with potential pollution sources.

7.1 Objectives

The aim of the groundwater model is to simulate the groundwater system to determine the potential pollution impact of the various sources, if any. The aim of the model is to gain an understanding of the groundwater flow dynamics and will be used to estimate the rate of flow and contaminant transport in the unsaturated zone, as well as the subsequent dilution where seeping contamination reaches the permanent groundwater level.

As stated earlier in this report, the unsaturated zone is of extensive depth and is therefore expected to play an important role in the protection of the underlying aquifer.

7.2 Conceptual model input

For the purpose of this study, the subsurface was envisaged to consist of the following hydrogeological units.

- The upper few tens of meters (typical 50 – 100 m) below surface mostly consist of unconsolidated sediments of the Kalahari Formation. This layer consists of sand, calcrete and clay layer(s) of whom the hydraulic characteristics are mostly unknown. It is anticipated to have a reasonably high hydraulic conductivity, but in general unsaturated. However, seasonal aquifers perched on the clay and calcrete probably do form in this layer, especially after high rainfall events. For the purpose of this model the layer was considered as homogeneous with mostly sandy silt characteristics. This is the worst case scenario that is aimed for in impact prediction.
- The next few tens of meters (typically about 100 m) comprising slightly weathered, highly fractured bedrock with a low hydraulic conductivity. A permanent groundwater level resides in this unit. The groundwater flow direction was accepted to be influenced by regional topography and for the site flow would be in general from high lying areas to the Ga-Mogara and Kuruman Rivers.
- Below a few tens of meters the fracturing of the aquifer is less frequent and fractures less significant due to increased pressure. This results in an aquifer of lower hydraulic conductivity and very slow groundwater flow velocities. For all practical purposes, this section was considered impermeable and not modelled.

It follows from this conceptual model that contamination emanating from the facilities at the mining area could move through the following potential pathways:

1. Transport through the unsaturated zone
2. Transport through the saturated zone.

Both pathways are prominent in this area and will be discussed separately below.

7.3 Flow in the Unsaturated Zone

Various studies have indicated that the recharge in the Kalahari is in the order of 30mm per annum[6]. If the residual water content of the soil is taken as an illustrative value of 3%, this amount of recharge will wet an area of 1 meter. Assuming piston flow, it follows that contamination will take about 70 years to reach the saturated zone if it is to behave as a tracer fluid.

But piston flow is not necessarily correct, as preferred pipe-flow structures can develop below sources of water such as unlined tailings and dams. The presence of such structures could reduce the travel time to the saturated zone considerably, but it still would take several decades to reach the groundwater level.

Despite this, the numerical groundwater model assumes an immediate transfer of contaminants to the saturated zone with no dilution or retardation, to reflect a worst-case scenario.

7.4 Numerical modelling in the Saturated Zone

Numerical groundwater modelling is considered to be the most reliable method of anticipating and quantifying the likely impacts on the groundwater regime.

The finite difference numerical model was created using the AquaVeo's Groundwater Modelling System (GMS10.1) as Graphical User Interface (GUI) for the well-established Modflow and MT3DMS numerical codes.

MODFLOW is a 3D, cell-centred, finite difference, saturated flow model developed by the United States Geological Survey. MODFLOW can perform both steady state and transient analyses and has a wide variety of boundary conditions and input options. It was developed by McDonald and Harbaugh of the US Geological Survey in 1984 and underwent eight overall updates since. The latest update (Modflow NWT) incorporates several improvements extending its capabilities considerably, the most important being the introduction of the new Newton formulation and solver, vastly improving the handling of dry cells that has been a problem in Modflow previously.

Transport modelling was done using MT3DMS. MT3DMS is a 3-D model for the simulation of advection, dispersion, and chemical reactions of dissolved constituents in groundwater systems. MT3DMS uses a modular structure similar to the structure utilized by MODFLOW, and is used in conjunction with MODFLOW in a two-step flow and transport simulation. Heads are computed by MODFLOW during the flow simulation and utilized by MT3DMS as the flow field for the transport portion of the simulation.

7.5 Fixed aquifer parameters

The following fixed assumptions and input parameters were used for the numerical model of this area:

- Recharge = 30 mm/a ≈ 0.00001 m/d. This value was based on extensive studies in the semi-arid region of the Northern Cape[6].
- The specific storage over the area was taken as 0.000001. This is a typical value for a sandy material bedrock.
- Horizontal Hydraulic Permeability of the bedrock = 0.1 m/d, a typical for a sandy/clayey aquifer.
- Vertical Hydraulic Anisotropy (KH/KV) of the primarily aquifer = 10. By nature of the pronounced horizontal layering, this value is commonly used in sedimentary layers.
- The effective porosity value of the bedrock was taken as 0.1. This value could not be determined directly and was taken as typical of semi-consolidated sand.
- Longitudinal dispersion was taken as 50 metres, which is about 10% of expected plume dimensions, as recommended in various modelling guidelines.
- Transverse and vertical dispersion was taken as 5 metres and 0.5 metre respectively as recommended in various textbooks, being about 10% of the expected plume dimensions.

7.6 Model Boundaries and Discretisation

Boundaries were chosen to include the area where the groundwater pollution plume could reasonably be expected to spread and simultaneously be far enough removed from mining boundaries not to be affected by groundwater abstraction in the mine.

For this particular site, an upstream constant head boundary was created to the southwest of the mine at an elevation of 1 000 mamsl, as well as a downstream constant head boundary of 940 mamsl underneath the Ga-mogara River, as depicted in Figure 9. These boundaries resulted in an area of about 3 to 10 km around the mining area, which is considered far enough for the expected groundwater effects not to be influenced by boundaries.

The modelling area was discretised by a 400 by 500 grid, refined at the mining areas as depicted in Figure 10 and Figure 11, resulting in finite difference elements of about 25 by 25 meters at the mining areas and up to 500 meters at the edges of the model. All modelled features, like mining areas etc., are sizably larger than these dimensions, and the grid is thus adequate for the purpose.

7.7 Modelling Scenarios

The contaminant source was assumed to be nitrate, as this was the element with the highest exceedances of relevant screening criteria measured in the groundwater and in the leachate of the tailings. It is highly likely that the nitrate is of natural origin and could even accumulate in the tailings through recirculation of process water used on the mine. The Kalahari is known to have brackish water with high nitrate content due to nitrate fixation by the thorn trees. Nevertheless, for the sake of the impact prediction, it was assumed as a contaminant originating from the mine at a concentration of 100 mg/ℓ.

7.8 Predicted Groundwater Impacts

The results of the model are illustrated in Figure 12 below. The migration of contaminated water from the mining area has been modelled as described, and the results are presented in Figure 12 in

[6] Bredenkamp D. B. et al: Manual on the Quantitative Estimation of Groundwater Recharge and Aquifer Storativity. Water Research Commission June 1995. Report TT 73/95

terms of the extent of the pollution plume 10, 25, 50 and 100 years after the operations have started, as required by DWS.

As stated previously, the results must be viewed with caution as a homogeneous aquifer has been assumed. Heterogeneities in the aquifer are unknown and the effect of this cannot be predicted. Furthermore, no chemical interaction of the leachate with the minerals in the surrounding bedrock has been assumed. As there must be some interaction and retardation of the plume, this calculation will represent a worst-case scenario.

The source concentration was set at a constant of 100 mg/l for nitrate, which is not adsorbed or retarded in the subsurface and thus behaves as a tracer. This is in accordance with measured values of leachate from the tailings as well as effluent water on the site.

Within the limitations of the abovementioned assumptions, it can be estimated from these figures that:

- The leachate plume emanating from the mining facilities is calculated to migrate northeast towards the Ga-mogara River. However, the river is not a receptor, as the groundwater levels are well below the riverbed and only episodic flow occurs and disconnection was, therefore, assumed.
- The original 100 mg/ℓ assumed at the source, was calculated to lower to 1 mg/ℓ over the entire modelling period.
- No privately owned boreholes (receptors) are likely to be affected by the pollution plume.

It is thus concluded that contaminants emanating from the mining area could result in downstream pollution, but the concentration is likely to lower below domestic groundwater standards. This conclusion will also be true for many other contaminants that behave as non-reacting tracers, as well as other sources of pollution in this mining area. The results of the modelling are thus generic for the area.

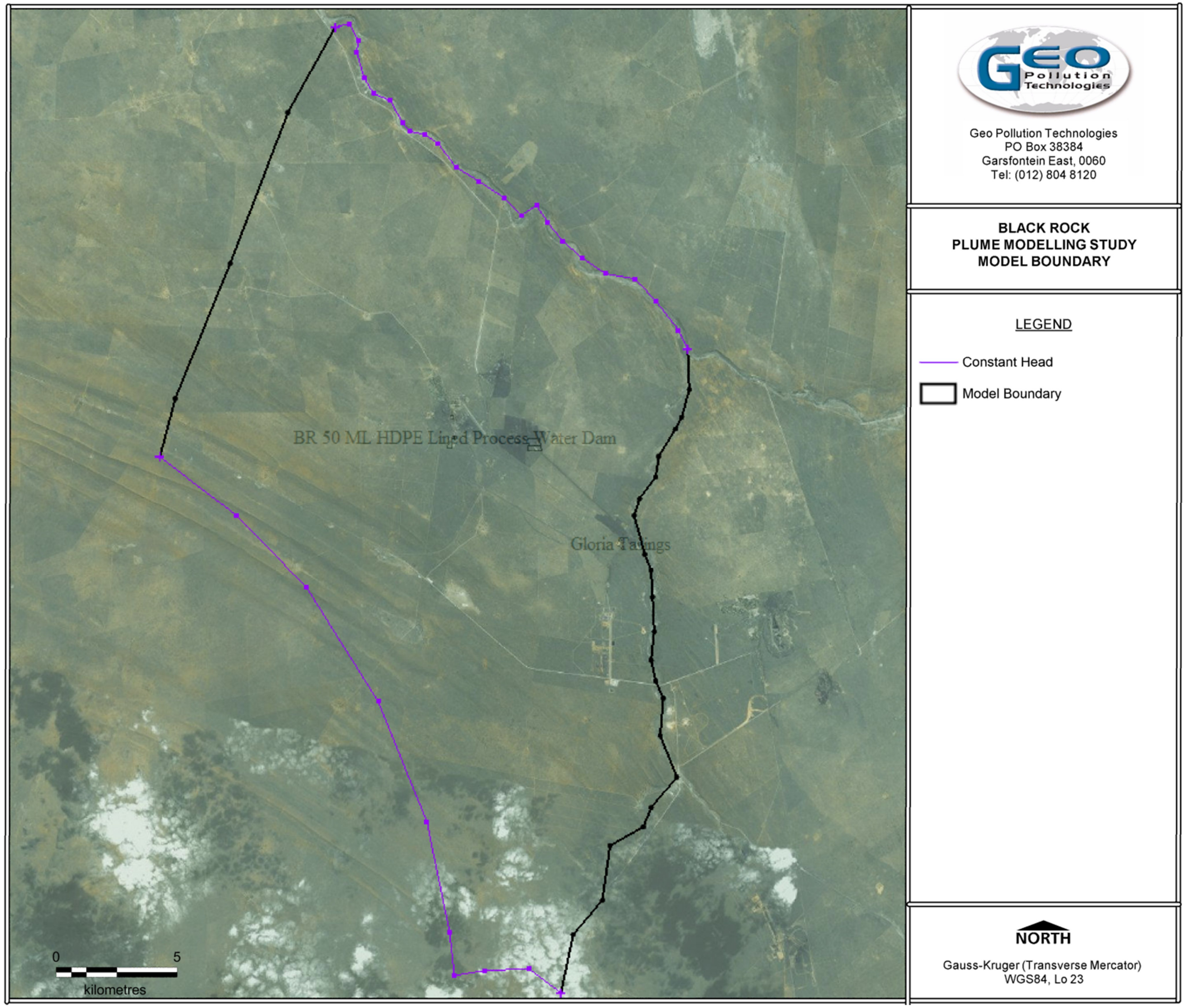

Figure 9: Model Boundaries

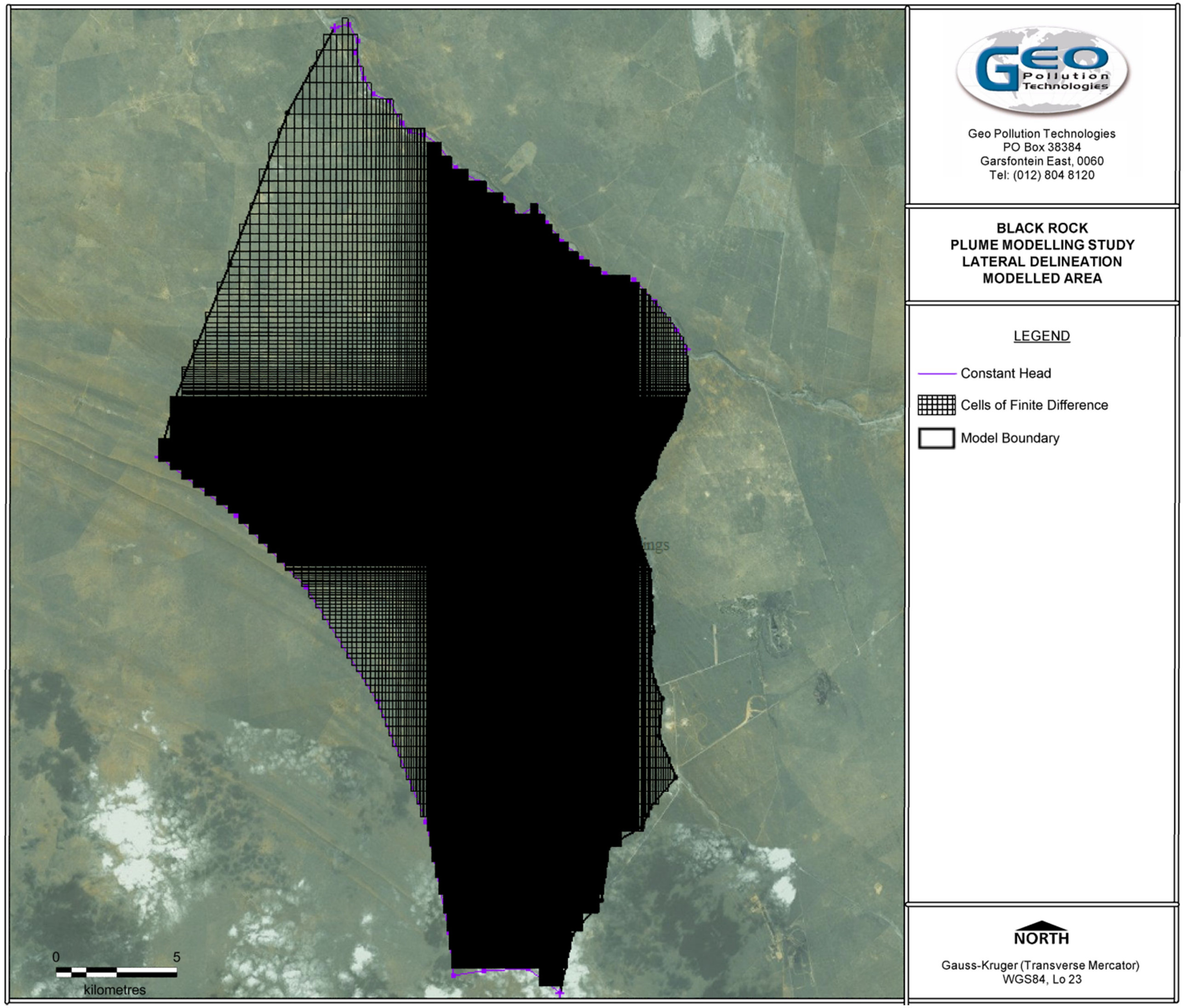

Figure 10: Model Grid

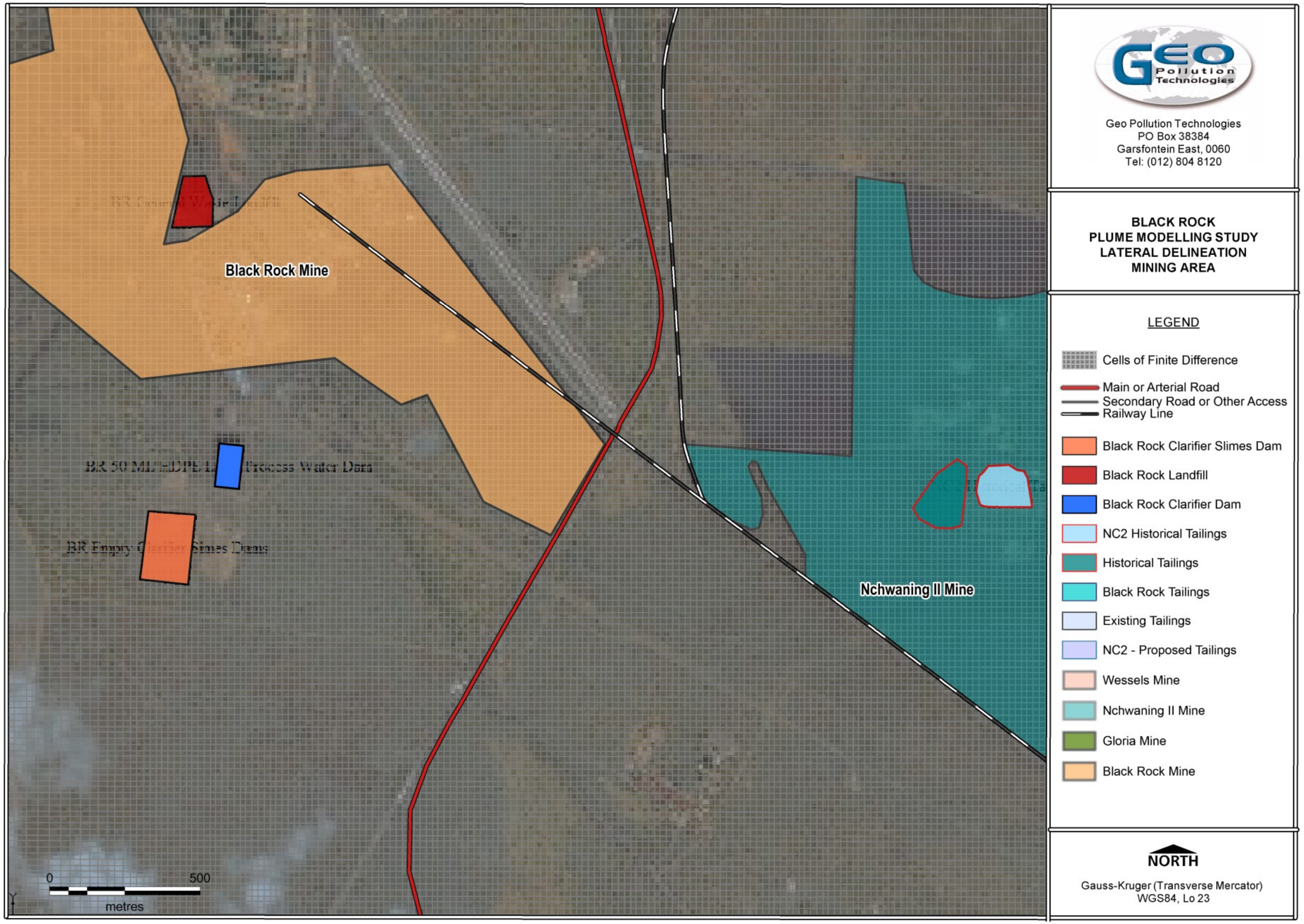

Figure 11: Model Grid at Black Rock

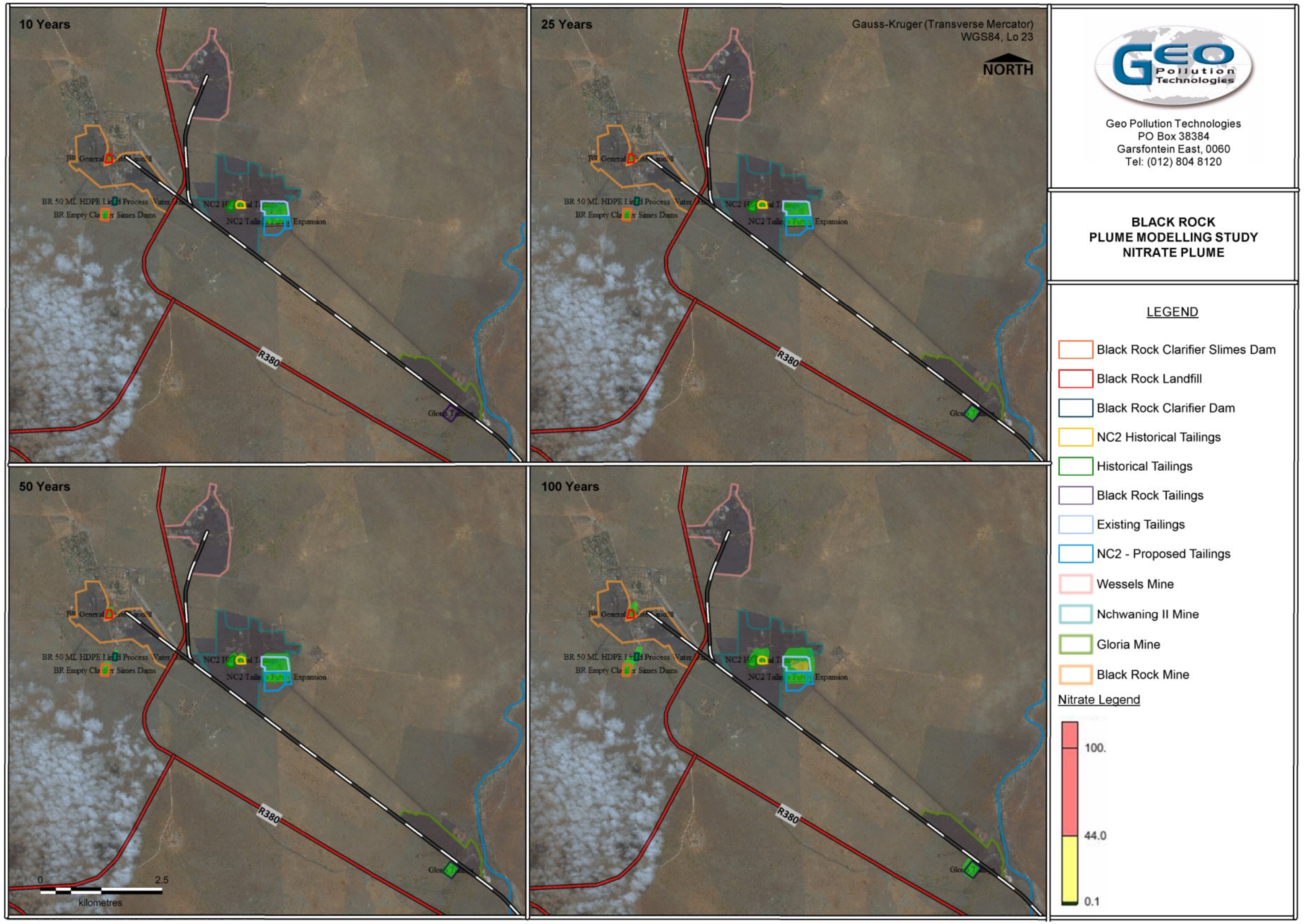

Figure 12: Predicted Groundwater Contamination

7.8.1 Cumulative effects

Based on the above generic modelling, the cumulative pollution impacts of all current and historic sources should be similar in nature. Due to the distances between mines at Hotazel, very little cumulative effects are thus possible.

7.9 Assumptions and Limitations

The modelling was done within the limitations of the scope of work of this study and the amount of data available. Although all efforts have been made to base the model on sound assumptions and has been calibrated to observed data, the results obtained from this exercise should be considered in accordance with the assumptions made. Especially the assumption that a fractured aquifer will behave as a homogeneous porous medium can lead to error. However, on a large enough scale (bigger than the REV, Representative Elemental Volume) this assumption should hold reasonable well.

8. GROUNDWATER RISK ASSESSMENT

The groundwater risk assessment methodology is based on defining and understanding the three basic components of risk, i.e. the source of the risk (source term), the pathway along which the risk propagates, and finally the target that experiences the risk (receptor). The risk assessment approach is therefore aimed at describing and defining the relationship between cause and effect. In the absence of any one of the three components, it is possible to conclude that groundwater risk does not exist.

Based on the numerical model it is evident that no human health effects are likely to occur at any monitoring boreholes within the assumed 100 year mining scenario. From the previous studies and the monitoring reports it can be seen that none of the water samples exceeded the screening values indicated by the DWS water quality guidelines for domestic use and produced leachate from the tailings material samples was also found not to exceed any of the screening values indicated by the DEA Waste Classification Screening Values. It can therefore be concluded that the input of the leachate produced by mining waste material on site, will not have any significant effects on groundwater quality, but should have a similar effect as the local underlying geology. Another contributing factor to the protection of the underlying fractured aquifer is the thickness of the unsaturated zone which could retard the flow of any possible contamination generated on site, into the groundwater environment.

8.1 Source Term(s)

The potential sources of contamination were identified as the Existing Nchwaning Tailings, Gloria Tailings, Gloria Historical Waste Storage, Nchwaning Historical Tailings, Nchwaning Proposed Tailings, Black Rock Tailings, Black Rock Landfill, Historical Tailings and Nchwaning Proposed Tailings.

It has been displayed through leach testing of tailings material and other waste rock material that the discard material has a low contamination potential, i.e. it poses a low risk to the groundwater environment.

8.2 Pathways

With respect to potential impacts on the water resource, the groundwater pathways through which contaminants could move are the following:

- Movement through the vadose (unsaturated) zone;
- Movement through an aquifer;
- Surface runoff.

Within the context of defining the pathways it is important to note that the pathways may have the following features:

- Hydraulic conduit (pathway) for the mobilization and movement of the contaminants of concern from the source term to the receptor.
- Attenuation of contaminants, release of new contaminants and alteration of the chemistry of the discharge from the source term through a variety of chemical reactions.
- Habitat for receptors.

Kalahari sands and the calcrete/clay complex form a vertically and laterally extensive filter for contaminants. Coupled with low precipitation and high evaporation rates the transportation of dissolved contaminants sourced from the source areas is foreseen to present a low risk to the groundwater environment.

8.3 Receptors

As the final component of the risk assessment, the receptors in the context of the water resource would be users of the water resource itself. The following receptors were found:

- Groundwater users downstream of BRMO:
  - Nchwaning II Manganese Mine abstracting process water through borehole BRMO-19 (Appendix I).
  - Groundwater user abstracting through BRMO-23 for domestic and agricultural use (Appendix I).
  - The borehole BRMO-19 is not used for human consumption, clean potable water is alternatively provided.

Table 6: Source-Pathway-Receptor Evaluation

Potential Sources	Transport Mechanism	Exposure Pathway	Available Monitoring Points	Potential Receptors	Available Monitoring Points	Pathway Complete		Significance of risk
						Yes/No	Current/Potential in Future	
Existing Nchwaning Tailings	Leaching, Unsaturated Flow, Groundwater Transport and Surface Water	Possible abstraction	GPT4, GPT7	None	None	No	NA	Low
Gloria Tailings	Leaching, Unsaturated Flow, Groundwater Transport and Surface Water	Possible abstraction	GPT1, GPT2	BRMO-16	BRMO-16	Potential	Future	Low
Gloria Historical Waste Storage	Leaching, Unsaturated Flow, Groundwater Transport and Surface Water	Possible abstraction	GPT1, GPT3	None	None	No	NA	Low
Nchwaning II Historical Tailings	Leaching, Unsaturated Flow, Groundwater Transport and Surface Water	Possible abstraction	GPT4, GPT7, BRMO-19	None	None	No	NA	Low
Nchwaning II Proposed Tailings	Leaching, Unsaturated Flow, Groundwater Transport and Surface Water	Possible abstraction	GPT4, GPT7, BRMO-19	None	None	No	NA	Low
Black Rock Tailings	Leaching, Unsaturated Flow, Groundwater Transport and Surface Water	Possible abstraction	GPT5, GPT6, GPT4	None	None	No	NA	Low
Black Rock Landfill	Leaching, Unsaturated Flow, Groundwater Transport and Surface Water	Possible abstraction	GPT5, GPT6, GPT4	None	None	No	NA	Low
Historical Tailings	Leaching, Unsaturated Flow, Groundwater Transport and Surface Water	Possible abstraction	GPT4, GPT7, BRMO-19	None	None	No	NA	Low
Nchwaning II Proposed Tailings	Leaching, Unsaturated Flow, Groundwater Transport and Surface Water	Possible abstraction	GPT4, GPT7, BRMO-19	None	None	No	NA	Low

9. MANAGEMENT OPTIONS

Water management options are subdivided into actions that:

- Address surface- and groundwater quality issues;
- Address waste water discharge.

At the solid and liquid waste management areas the waste material will be subject to weathering and evaporation. These physical and chemical processes will alter the geochemistry and hydrochemistry of the discarded material. The leaching of waste management areas is controlled by the amount of water available to facilitate chemical reactions, which depends on precipitation and evaporation. At Hotazel the MAP is given as 250 mm/annum while MAE is given as 3000 mm/annum. Thus, there is limited water available to allow for the leaching.

It has been displayed through leach testing of tailings material and other waste rock material that the discard material has a low contamination potential, i.e. it poses a low risk to the groundwater environment.

Kalahari sands and the calcrete/clay complex form a vertically and laterally extensive filter for contaminants. Coupled with low precipitation and high evaporation rates the transportation of dissolved contaminants sourced from the TSF is foreseen to present a low risk to the groundwater environment.

Potential receptors identified downstream of BRMO were the Nchwaning mine itself abstracting groundwater through BRMO-19 and a groundwater user abstracting groundwater through BRMO-23 for domestic and agricultural use. However, based on the modelling, these receptors are unlikely to be affected.

Pollution source management should be based on passive management principles, i.e. the need for ongoing intervention and active management is minimal, but not non-existent. Examples of passive measures include storm water diversion berms and drains, lining of pollution control dams and toe paddocks around such facilities, etc. Passive pollution prevention measures are essentially based on good planning and design to prevent a pollution problem from arising, rather than relying on active intervention to intercept and treat contaminated water. However, situations are often encountered where active impact minimisation management measures are required to supplement the passive pollution prevention measures.

9.1.1 Tailings deposits and slimes dams

- Mine tailings deposition is expected to result in large volumes of waste water discharge which should be directed to and contained in sanitarily designed evaporation or slimes dam as planned.
- Prevent the erosion or leaching of materials from the tailings deposit and contain material or substances so eroded or leached in such area by providing suitable barrier dams, evaporation dams or any other effective measures to prevent this material or substance from leaching into the subsurface.
- Potentially contaminated water that has been in contact with discarded material must be kept within the confines of an evaporation dam until evaporated, treated to rendered acceptable for release, or re-used in some other way.

9.1.2 Waste rock deposits and pollution control dams

- Monitoring of water storage facilities, particularly pollution control dams, is imperative to manage the risk of spillage from the dams. Stage-storage (elevation-capacity) curves are useful tools to monitor the remaining capacity within a water storage facility.
- Prevent the erosion or leaching of materials from any residue deposit or stockpile from any area and contain material or substances so eroded or leached in such area by providing suitable barrier dams, evaporation dams or any other effective measures to prevent this material or substance from entering and polluting any water resources.
- Water quantity and quality data should be collected on a regular, ongoing basis during mine operations. These data will be used to recalibrate and update the mine water management model, to prepare monitoring and audit reports, to report to the regulatory authorities against the requirements of the IWMP and other authorisations and as feedback to stakeholders in the catchment, perhaps via the CMA.
- Water that has been in contact with residue, and must therefore be considered polluted, must be kept within the confines of the MRD until evaporated, treated to rendered acceptable for release, or re-used in some other way.
- All water that falls within the catchment area of the MRD must be retained within that area. For most MRDs the catchment can be divided into component catchments, as follows:
- The top area of the MRD together with any return water storage dams which have been connected to the top area of the MRD by means of an outfall penstock, and
- The faces of the MRD together with the catchment paddocks provided to receive run-off from the faces and any additional catchment dams associated with the faces and catchment paddocks.
- The design, operation and closure of MRDs should incorporate consideration of the risk of changes in the mining and plant operations, and hence the mine water balance, through the life cycle of the mine.
- A system of storm water drains must be designed and constructed to ensure that all water that falls outside the area of the MRD is diverted clear of the deposit. Provision must be made for the maximum precipitation to be expected over a period of 24 hours with a probability of once in one hundred years. A freeboard of at least 0.5 m must be provided throughout the system above the predicted maximum water level. This requirement applies to all MRDs, both fine and coarse-grained MRDs.
- Ensure that the water use practices on and around the MRD do not result in unnecessary water quality deterioration, e.g. use of the return water dam for storage of poorer quality water

10. MONITORING PROGRAMME

The current groundwater network consists of nine boreholes strategically placed upstream and downstream of the three mining areas that encompass the BRMO (See Table 7 and Figure 13). These boreholes are sampled on a monthly basis in accordance with the WUL for the BRMO site and are reported.

The sampling methodology and analyses as well as comparisons with the relevant standards can be found in the water quality monitoring report compiled by Aquatico Scientific Pty (Ltd)[7].

[7] Aquatic Scientific Pty (Ltd). (2016). Assmang (Pty) Ltd Black Rock Water Quality Monitoring Report July 2016

As it was found in this study that the BRMO does not pose a direct risk to the groundwater environment, the current monitoring network is considered adequate for the purpose.

Table 7: WUL ground water monitoring points

Monitoring point	X-coordinate	Y-coordinate	Monitoring purpose	Monitoring frequency
BRMO-16	22.91103	-27.1743	Impact monitoring	Bi-annually
BRMO-19	22.87807	-27.1264	Impact monitoring	Bi-annually
GPT-1	22.90212	-27.1756	Impact monitoring	Bi-annually
GPT-2	22.91043	-27.1679	Impact monitoring	Bi-annually
GPT-3	22.85819	-27.149	Impact monitoring	Bi-annually
GPT-4	22.86381	-27.1243	Impact monitoring	Bi-annually
GPT-5	22.8443	-27.1354	Impact monitoring	Bi-annually
GPT-6	22.84328	-27.125	Impact monitoring	Bi-annually
GPT-7	22.89323	-27.1498	Impact monitoring	Bi-annually

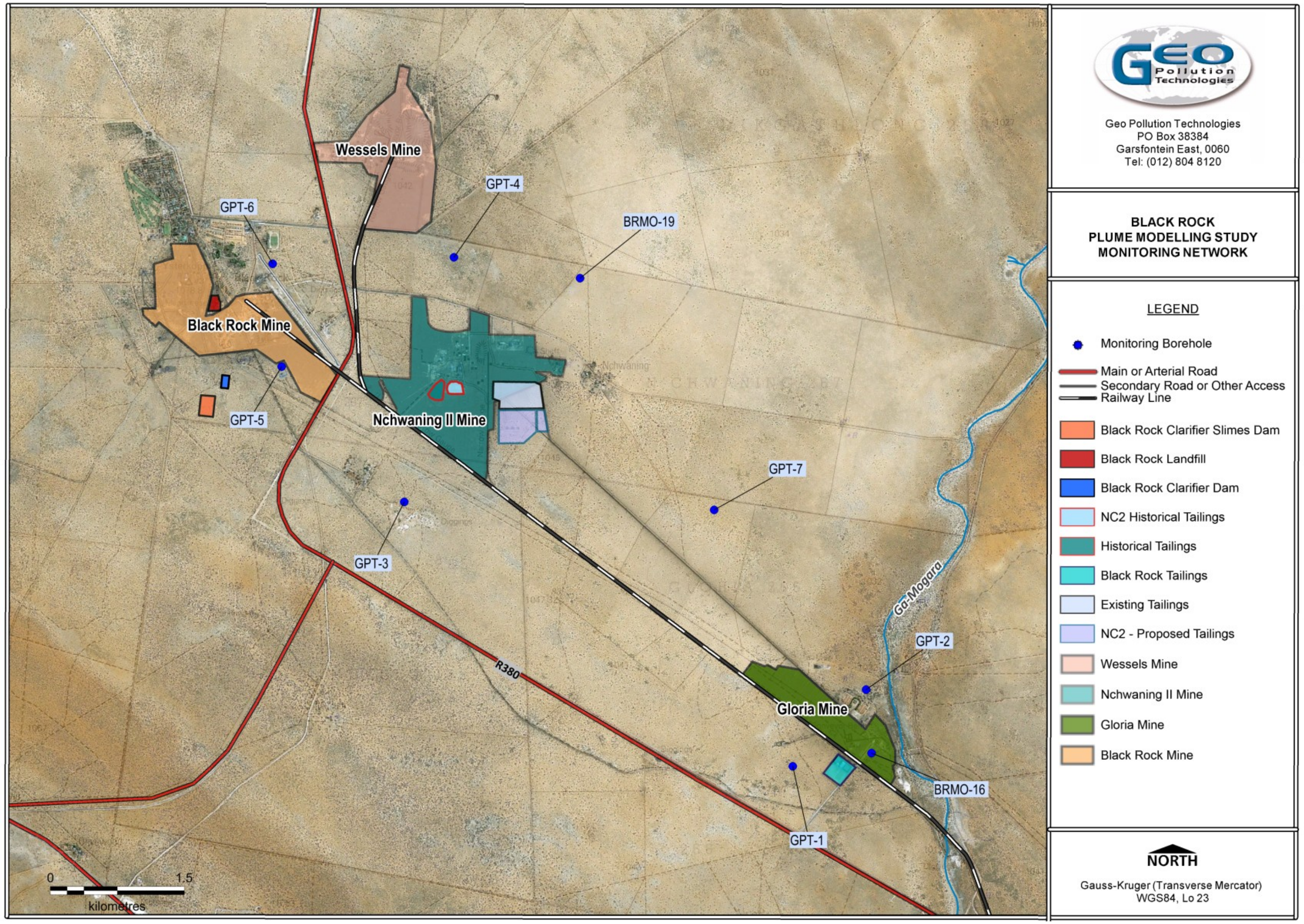

Figure 13: WUL groundwater monitoring points

11. CONCLUSIONS AND RECOMMENDATIONS

This report was not intended to be an exhaustive description of the project, but rather as a specialist interim hydrogeological study to evaluate the hydrogeological impact that the various mining related sources of contamination at the BRMO might have on the receiving groundwater environment. This section will briefly summarise the current groundwater conditions in the area, the expected impacts of the proposed tailings facility extension on the groundwater and the recommendations to minimise the effect of mining waste storage on the groundwater regime.

11.1 Project Objectives

Within the scope of work the groundwater study aims to address the following:

- Conceptual site model based on the source-pathway-receptor model.
- Numerical modelling of the impact of the sources on the groundwater regime.
- Risk assessment on the potential impacts.
- A short report summarising the findings of the study and commenting on the potential impact of the solid and liquid source areas specified in the WUL on the groundwater environment.

11.2 Desk Study

BRMO has been in operation since 1940. All activity at the BROM mines are located on the farms Belgravia 264, Nchwaning 267 and Gloria 266 including the solid and liquid waste management areas.

The surface infrastructure consists out of the following:

- Existing Nchwaning II Tailings
- Gloria Tailings
- Gloria Historical Waste Storage
- Nchwaning II Historical Tailings
- Nchwaning II Proposed Tailings
- Black Rock Tailings
- Black Rock Landfill
- Historical Tailings
- Nchwaning II Proposed Tailings

11.3 Hydrogeological Setting

11.3.1 Topography and drainage

- The Black Rock Mines are situated in the Lower Vaal Water Management Area (WMA), in quaternary catchment D41M and D41K.
- The present ecological status for the quaternary catchments is given as D, i.e. largely modified.
- The average annual rainfall (measured over a period of 70 years) is approximately 250 mm, with the high rainfall months between November and April.

- The mines are underlain by Quartenary sands, clay and calcrete of the Kalahari Formation; Dwyka Formation tillite; Mapedi Formation quartzite; and the exploited Hotazel Formation BIF and manganese deposits.
- The Wessels-type Mn mineralisation is characterised by N-S cross-cutting faults which were responsible for the high-grade mineralisation by hydrothermal fluids.
- The area is characterised by a irregular topography and in the area of the mining site the slope is more or less in the order of 1%
- Surface drainage is towards the Kuruman River which flows westwards, to the east lays the Ga-Mogara River which is a tributary to the Kuruman River. Both rivers are ephemeral streams/rivers and flow in these water bodies is periodical. The area is characterised by low rainfall, high potential evapotranspiration and high infiltration rates.
- The latest water level monitoring data from the nine (9) monitoring boreholes showed that groundwater levels varied between a minimum of 34 and a maximum of 99 mbgl. These are well below the streams in the area, and thus both the Ga-Mogara and Kuruman Rivers are not connected to the groundwater, but rather loose water to the subsurface. Generally, most boreholes were found to have anomalous groundwater levels due to disturbances or heterogeneities.

11.3.2 Site geology

The BRMO is located on the northern edge of the Kalahari Manganese Field, and is characterised by a Wessels-type ore mineralisation which is highly enriched in Mn. The BRMO mines rocks of the Hotazel Formation of the Transvaal super group, viz. banded iron formation (BIF) and hematite lutite intercalated with three beds of Mn lutite. The northern part of the deposit is cut by N-S striking faults that facilitated hydrothermal alteration and upgrading of Mn in the Mn lutite beds.

The lithostratigraphic sequence from the surface to the mined Hotazel Formation is as follows:

- Quartenary sands, clay and calcrete of the Kalahari Formation, Karoo Supergroup.
- Tillite/diamictite of the Dwyka Group, Karoo Supergroup.
- Quartzite and shale of the Mapedi Formation, Olifantshoek Group.
- The Hotazel Formation, Postmasburg Group, Transvaal Supergroup.

11.3.3 Groundwater monitoring network

Quarterly water monitoring is conducted by Aquatico Scientific, the groundwater monitoring programme includes water level and quality monitoring at nine (9) groundwater monitoring points.

11.3.4 Geophysics

The water use license stipulates the following:

"*Additional geophysical investigation need to be conducted by the Licensee, especially close to potential contaminant sources in order to ascertain preferential flow paths and to assist in the establishment of an effective groundwater monitoring network which needs to be submitted to the responsible authority within one (1) of issuance of this licence*."

A geophysics study was than in 2011, however due to the thickness of the unsaturated zone the methods employed were not ideal. Furthermore based on the limited risk posed by the site in terms waste leachate generation, the pathway to the saturated groundwater table being buffered by the thick unsaturated zone (>34 m) and the lack of receptors, the WUL statement should be reconsidered as the current monitoring network is deemed sufficient.

11.3.5 Water levels

- The latest water level monitoring data from the nine (9) monitoring boreholes showed that groundwater levels varied between a minimum of 34 and a maximum of 99 mbgl.
- Most monitoring boreholes were found to have anomalous groundwater levels due to disturbances or heterogeneities.
- In the vicinity of the BRMO groundwater flow is north to north-north-easterly from the mine.

11.3.6 Water quality

The results of the waste water analytical results were made available and compared to the WUL limits for waste water. The constituents in the waste water for all water handling facilities are generally within the SANS 2011 limits for disposed water except elevated concentrations of NO_3 as N in sewage effluent and slimes dam waste water discharge.

The leachate analysed of the tailings did not exceed the maximum recommended concentrations according to the SSV1 Guidelines, indicating that the probability of a health risk to humans, in terms of the inorganic constituents analysed, for the samples collected, is low

- The constituents in the waste water for all water handling facilities are generally within the SANS 2011 limits except elevated concentrations of NO_3 as N in sewage effluent and old slimes dam waste water discharge.
- The major cations in the groundwater samples are calcium and sodium.
- The major anions in the groundwater samples are bicarbonate, chloride and sulphate.
- The water quality in the vicinity of the Nchwaning mine can be considered independently as the hydrochemical signatures vary spatially across the three mining areas:
    - Black Rock: Ca^{2+}-Mg^{2+}/HCO_3^-.
    - Nchwaning: Na^+/HCO_3^- (upstream) and Na^+-Mg^{2+}/Cl^- (downstream).
    - Gloria: Mg^{2+}/Cl^- (upstream) and Na^+-Mg^{2+}/HCO_3^- (downstream).
- The groundwater types show evidence of mixing and characteristic of dynamic groundwater regimes. A dynamic regime with bicarbonate-rich waters undergoing mixing and enrichment in sodium, chloride and sulphate.
- The constituents above the DWA guidelines are Ca, Mg, NO_3 as N, Na and TDS.

The elevation of the constituents mentioned above can be interpreted as follows:

- Ca and Mg concentrations are elevated due to the complete alteration and weathering of carbonate rocks into calcrete.
- NO_3 concentrations are elevated possibly due to nutrient overloading in the soil due to agricultural practices, nitrogen fixation by legumes, and effluent from human and animal excreta mixing with infiltrating waters.

11.4 Conceptual Site model

From the results of the field investigations and laboratory analyses, a conceptual hydrogeological model was compiled for BRMO.

The site is underlain by the Kalahari formation, which consists of a top layer of aeolian sands, followed by calcrete. The maximum depth of the Kalahari formation is +/- 125m. The average depth of the water levels below surface in the boreholes found at BRMO is 70m below surface with a maximum depth of 110m below surface. If this is compared with the water levels found in the hydrocensus, it can be concluded that the farmers tap their water from this sand/calcrete aquifer. The calcareous sand also has high characteristics of porosity and permeability and is expected to be a good aquifer.

There is limited surface runoff in the Kalahari area (high infiltration rates during precipitation). The average recharge value is ± 10 % of the mean annual precipitations (MAP).

Locally, drainage is towards the Kuruman River which flows westwards, to the east lays the Ga-Mogara River which is a tributary to the Kuruman River. Both rivers are ephemeral streams/rivers and flow in these water bodies is periodical. The area is characterised by low rainfall, high potential evapotranspiration and high infiltration rates.

11.4.1 Water levels

The latest water level monitoring data from the nine (9) monitoring boreholes showed that groundwater levels varied between a minimum of 34 and a maximum of 99 mbgl. The groundwater table does not mimic the topography. These are well below the streams in the area, and thus both the Ga-Mogara and Kuruman Rivers are not connected to the groundwater, but rather loose water to the subsurface. Generally, most boreholes were found to have anomalous groundwater levels due to disturbances or heterogeneities.

Flow predominantly takes place in directions north to north north-easterly towards the Kuruman River from the Nchwaning II Mine; however this path is intersected by mechanical discharge points downstream of the mine where flow is redirected towards the abstraction boreholes, i.e. borehole BRMO-19.

11.4.2 Contaminant levels

From the water quality information presented, the background water quality is represented by borehole GPT03, located upstream of the Nchwaning II Manganese Mine, is within regulatory limits. The elevated pH cannot be attributed to any activity. Downstream of the mine as represented by borehole GPT04 elevated concentrations of Mg can be observed and this is attributed to water-rock interaction. Mg has an aesthetic effect on the water but no definite health risks are known.

Analysed leachate from the tailings material samples were found not to exceed any of the screening values indicated by the DEA regulations. It can therefore be concluded that the input of the leachate produced by ore processing waste material on site, will not have any significant effects on groundwater quality, but should have a similar effect as the local underlying geology.

11.5 Numerical Flow and Transport Model

It follows from this conceptual model that contamination emanating from the facilities at the mining area that the pathway for chemicals would entail:

1. Transport through the unsaturated zone

2. Transport through the saturated zone.

11.5.1 Transport through the unsaturated zone

Flow through the unsaturated zone is expected to be slow, and contamination emanating from the mining activities could take decades to reach the groundwater level. It can also be expected that the concentration of contamination will be reduced drastically during such transport due to dilution and absorption to aquifer materials.

11.5.2 Transport through the saturated zone

Within the limitations of the numerical model assumptions, it was estimated that:

- The leachate plume emanating from the mining facilities is calculated to migrate northeast towards the Ga-mogara River. However, the river is not a receptor, as the groundwater levels are well below the riverbed and only episodic flow occurs and disconnection was, therefore, assumed.
- The original 100 mg/ℓ assumed at the source, was calculated to lower to 1 mg/ℓ over the entire modelling period.
- No privately owned boreholes (receptors) are likely to be affected by the pollution plume.

It is thus concluded that contaminants emanating from the mining area could result in downstream pollution, but the concentration is likely to lower below domestic groundwater standards. This conclusion will also be true for many other contaminants that behave as non-reacting tracers, as well as other sources of pollution in this mining area. The results of the modelling are thus generic for the area.

11.6 Groundwater Risk Assessment

Based on the numerical model it is evident that no human health effects are likely to occur at any monitoring boreholes within the assumed 100 year mining scenario. From the previous studies and the monitoring reports it can be seen that none of the water samples exceeded the screening values indicated by the DWS water quality guidelines for domestic use and produced leachate from the tailings material samples was also found not to exceed any of the screening values indicated by the DEA Waste Classification Screening Values.

The potential sources of contamination were identified as the Existing Nchwaning Tailings, Gloria Tailings, Gloria Historical Waste Storage, Nchwaning Historical Tailings, Nchwaning Proposed Tailings, Black Rock Tailings, Black Rock Landfill, Historical Tailings and Nchwaning Proposed Tailings.

It has been displayed through leach testing of tailings material and other waste rock material that the material has a low contamination potential, i.e. it poses a low risk to the groundwater environment.

Coupled with low precipitation and high evaporation rates, lack of groundwater users and the 70m thick unsaturated zone underlying the site, the transportation of contaminants sourced from the solid and liquid waste areas is foreseen as a low risk to the groundwater environment.

11.7 Management Options

At the solid and liquid waste management areas the waste material will be subject to weathering and evaporation. These physical and chemical processes will alter the geochemistry and hydrochemistry of the discarded material. The leaching of waste management areas is controlled by the amount of water available to facilitate chemical reactions, which depends on precipitation and evaporation. At Hotazel the MAP is given as 250 mm/annum while MAE is given as 3000 mm/annum. Thus, there is limited water available to allow for leaching.

It has been displayed through leach testing of tailings material and other waste rock material that the discard material has a low contamination potential, i.e. it poses a low risk to the groundwater environment.

Kalahari sands and the calcrete/clay complex form a vertically and laterally extensive filter for contaminants. Coupled with low precipitation and high evaporation rates the transportation of dissolved contaminants sourced from the TSF is foreseen to present a low risk to the groundwater environment.

Potential receptors identified downstream of BRMO were the Nchwaning mine itself abstracting groundwater through BRMO-19 and a groundwater user abstracting groundwater through BRMO-23 for domestic and agricultural use. However, the model shows that impacts of these receptors are unlikely.

Pollution source management should be based on passive management principles, i.e. the need for ongoing intervention and active management is minimal, but not non-existent. Examples of passive measures include storm water diversion berms and drains, lining of pollution control dams and toe paddocks around such facilities, etc. Passive pollution prevention measures are essentially based on good planning and design to prevent a pollution problem from arising, rather than relying on active intervention to intercept and treat contaminated water. However, situations are often encountered where active impact minimisation management measures are required to supplement the passive pollution prevention measures.

11.7.1 Tailings deposits and pollution control dams

- Mine tailings deposition is expected to result in large volumes of waste water discharge which should be directed to and contained in sanitarily designed evaporation or slimes dam as planned.
- Prevent the erosion or leaching of materials from the tailings deposit and contain material or substances so eroded or leached in such area by providing suitable barrier dams, evaporation dams or any other effective measures to prevent this material or substance from leaching into the subsurface.
- Potentially contaminated water that has been in contact with discarded material must be kept within the confines of an evaporation dam until evaporated, treated to rendered acceptable for release, or re-used in some other way.

11.7.2 Waste rock deposits and pollution control dams

- Monitoring of water storage facilities, particularly pollution control dams, is imperative to manage the risk of spillage from the dams. Stage-storage (elevation-capacity) curves are useful tools to monitor the remaining capacity within a water storage facility.
- Prevent the erosion or leaching of materials from any residue deposit or stockpile from any area and contain material or substances so eroded or leached in such area by providing suitable barrier dams, evaporation dams or any other effective measures to prevent this material or substance from entering and polluting any water resources.
- Water quantity and quality data should be collected on a regular, ongoing basis during mine operations. These data will be used to recalibrate and update the mine water management

model, to prepare monitoring and audit reports, to report to the regulatory authorities against the requirements of the IWMP and other authorisations and as feedback to stakeholders in the catchment, perhaps via the CMA.

- Water that has been in contact with residue, and must therefore be considered polluted, must be kept within the confines of the MRD until evaporated, treated to rendered acceptable for release, or re-used in some other way.
- All water that falls within the catchment area of the MRD must be retained within that area. For most MRDs the catchment can be divided into component catchments, as follows:
- The top area of the MRD together with any return water storage dams which have been connected to the top area of the MRD by means of an outfall penstock, and
- The faces of the MRD together with the catchment paddocks provided to receive run-off from the faces and any additional catchment dams associated with the faces and catchment paddocks.
- The design, operation and closure of MRDs should incorporate consideration of the risk of changes in the mining and plant operations, and hence the mine water balance, through the life cycle of the mine.
- A system of storm water drains must be designed and constructed to ensure that all water that falls outside the area of the MRD is diverted clear of the deposit. Provision must be made for the maximum precipitation to be expected over a period of 24 hours with a probability of once in one hundred years. A freeboard of at least 0.5 m must be provided throughout the system above the predicted maximum water level. This requirement applies to all MRDs, both fine and coarse-grained MRDs.
- Ensure that the water use practices on and around the MRD do not result in unnecessary water quality deterioration, e.g. use of the return water dam for storage of poorer quality water.

11.8 Water Monitoring

- The current groundwater network consist of seven boreholes strategically place upstream and downstream of the three mining areas that encompass the BRMO (See Table 7 and Figure 14). These boreholes are sampled on a monthly basis in accordance with the WUL for the BRMO site and are reported on diligently.
- The sampling methodology and analyses as well as comparisons with the relevant standards can be found in the water quality monitoring report compiled by Aquatico Scientific Pty (Ltd).
- As it was found in this study that the BRMO does not pose a direct risk to the groundwater environment, the current monitoring network is considered adequate for the purpose.

11.9 Recommendations

The following recommendations are put forward:

- Bi-annual water level and quality monitoring should be implemented. Monitoring data should be used to recalibrate and update the mine water management plan, to prepare monitoring and audit reports, to report to the regulatory authorities against the requirements of the IWMP and other authorisations and as feedback to stakeholders in the catchment.
- Update the existing numerical model against monitored data every 5 years, during operations.
- The hydrocensus and risk assessment should at least be repeated once before closure to evaluate any impacts.

APPENDIX I: BOREHOLE CENSUS INFORMATION

Borehole name	Farm name	Owner	Tel. Nr	Latitude	Longitude	Elevation (mamsl)	Water level (mbgl)	Borehole depth (mbgl)	Use
BRMO-1	Cornish	HJ Lampbrecht	0796655444	-27.11209	22.82945	1045	unable	unable	Stock farming, domestic
BRMO-2				-27.09059	22.80084	1040	96.82	110	Stock farming, domestic
BRMO-3				-27.09685	22.83279	1033	103	113	Stock farming
BRMO-4	Harefield	WP van der Walt	0737881068	-27.08478	22.75076	1054	unable	unable	Stock farming, domestic
BRMO-5	Harefield	WP van der Walt	0737881069	-27.08272	22.73704	1042	87.8	unable	Stock farming, domestic
BRMO-7	Boerdraai	GJ Stolz	0828866629	-27.03925	22.84162	1003	110	115	Stock farming, domestic
BRMO-6	Mecca	HJ Lampbrecht	0796655444	-27.04621	22.75911	1031	91.5	110	Stock farming, domestic
BRMO-8	Olivewood	K Theart	0724984415	-27.18443	22.82148	1051	49.5	70	Stock farming, domestic
BRMO-9	Drakenstein	L Bylsma		-27.1506	22.7587	1070	unable	unable	Stock farming, domestic
BRMO-10	Tigerpan	PA vd Merwe		-27.18162	22.71055	1066	unable	unable	Stock farming, domestic
BRMO-11	Olivepan	LP vd Walt	0832975038	-27.21062	22.82467	1062	49.8	70	Stock farming, domestic
BRMO-12	Olivepan	LP vd Walt	0832975038	-27.21095	22.82465	1066	37.8	70	Stock farming, domestic
BRMO-13	Umtu	LP vd Walt	0832975039	-27.19389	22.88436	1058	unable	unable	Game farming
BRMO-14	East	PC van Jaarsveld		-27.16625	22.91368	1011	dry	unable	
BRMO-15				-27.17332	22.91641	1024			
BRMO-16	Nchwaning	JL Reynecke	0837019499	-27.16911	22.87752	1042	unable	unable	Stock farming, domestic
BRMO-17	Lehating	S van der Walt	0829206832	-27.05661	22.87486	1002	20.7	30	Stock farming, domestic
BRMO-18	Rhodes	GJ Smit		-27.1084	22.93807	1009	18.8	40	Stock farming, domestic
BRMO-19	Nchwaning	S van der Walt	0829206834	-27.1265	22.87809	1044	dry	86	
BRMO-20	Gloria mine			-27.17417	22.91106	1038	74.6	unable	mining
BRMO-21	Gloria mine			-27.17393	22.91078	1039	unable	unable	mining
BRMO-22	Boerdraai	GJ Stolz	0829206837	-27.05839	22.79427	1032	93.7	unable	Stock farming, domestic
BRMO-23	Nchwaning	JL Reynecke	0837019499	-27.11602	22.87196	1041	unable	unable	Stock farming, domestic

FLORAL ECOLOGICAL ASSESSMENT AS PART OF THE ENVIRONMENTAL ASSESSMENT AND AUTHORISATION PROCESS FOR THE PROPOSED NEW SLIMES DAM AT THE ASSMANG LTD. BLACK ROCK MINE OPERATIONS IN THE VICINITY OF HOTAZEL, NORTHERN CAPE PROVINCE

Prepared for

eScience Associates (Pty) Ltd

December 2016

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EXECUTIVE SUMMARY

From the assessment, it was found that the majority of the study area is comprised of Open Bushveld Habitat Unit, with an overall moderate ecological sensitivity, mostly due to the high number of *Vachellia erioloba* and *V. haematoxylon*, protected under the National Forest Act (Act 84 of 1998) present, as well as the overall moderate PES of the study area with largely intact habitat. It is however important to note that portions of the study area, particularly in the vicinity of disturbances have undergone vegetation transformation and loss of habitat structure and that the habitat type is considered well represented within the region surrounding the study area. The proposed development of a slimes dam within the study area is therefore not expected to significantly impact on floral conservation in the region. In addition, the project footprint (±17ha) is relatively small and is located immediately adjacent to existing mining infrastructure to the north and west.

It is recommended that the project be considered favorably, provided that all mitigation and management measures as outlined in this report be adhered to, with specific reference to obtaining permits under the National Forests Act (Act 84 of 1998) for the removal of *V. erioloba* and *V. haematoxylon* trees and protected floral species (*Boophane disticha* and *Euphorbia* spp.) within the study area.

Scientific Aquatic Services (SAS) was appointed to conduct a floral ecological assessment as part of the environmental assessment and authorisation process for the proposed development of a new slimes dam of approximately 17ha in extent at the Assmang Ltd., Black Rock Mine Operations, hereafter referred to as the "study area". The proposed new slimes dam is located approximately 80km northwest of Kuruman, 11km to the northwest of the town of Hotazel, 2km to the east of the R380 roadway and immediately to the south of an existing slimes dam within the Northern Cape Province. Existing mining activity is also present immediately to the west of the study area.

The ecological assessment was confined to the study area and its immediate surrounds and did not include an ecological assessment of surrounding properties. The surrounding area was however considered as part of the desktop assessment of the area.

<u>Specific outcomes required from this report include the following:</u>

- To conduct a desktop study to gain background information on the physical habitat and potential floral biodiversity associated with the study area and surrounding region;
- To conduct a Red Data Listed (RDL) species assessment as well as an assessment of other Species of Conservation Concern (SCC), including potential for such species to occur within the study area;
- To provide inventories of floral species as encountered within the study area;
- To determine and describe habitat types, communities and the ecological state of the study area and to rank each habitat type based on conservation importance and ecological sensitivity;
- To describe the spatial significance of the study area with regards to surrounding natural areas;
- To identify and consider all sensitive landscapes including rocky ridges, wetlands and/ or any other special features; and
- To determine the environmental impacts of the proposed development activity on the floral ecology within the study area and to development mitigation and management measures.

In order to achieve the objectives of the report, the following assessment procedure/methodology was used:

- A desktop study to gain background information on the physical habitat, as well as generating potential floral biodiversity lists for the study area and surrounding region;
- Aerial photographs and digital satellite imagery were consulted prior to the field assessment to guide priority areas for ground truthing;
- The site visit was initiated by means of an initial visual, on-site assessment of the study are;
- A field assessment that identified the tree, forb, grass and alien floral species that occur within the study area;
- A description of the sensitivity of the project footprint;
- Data analyses and reporting of all findings; and
- Impact assessment according to a predefined impact assessment methodology provided by the Environmental Assessment Practitioner (EAP).

The following general conclusions were drawn upon completion of the literature review and desktop analysis:

- According to the Mining Biodiversity Guidelines (2012) the study area does not fall within an area indicated to be of increased biodiversity importance.
- According to the National List of Threatened Terrestrial Ecosystems (2011) the study area is not located within a threatened terrestrial ecosystem;
- According to the National Protected Areas Expansion Strategy (NPAES; 2008) database, the study area does not fall within an area earmarked as an NPAES area;
- According to the National Biodiversity Assessment (NBA; 2011) database, the study area is not located within a formally or informally protected area, with the entire study area falling within an area that is currently not protected. The Land Cover data indicates that the study area largely falls within a natural area, with mining activity located to the north and west;
- According to the Northern Cape Provincial Spatial Development Framework (PSDF; 2012), the study area is located within the Griqualand West Centre of Endemism (GWC), however, the study area is not located within a Critical Biodiversity Area (CBA), within a Biodiversity Priority Area or within a protected area as identified by the PSDF (2012);
- The Municipal Biodiversity Summary (MBS; 2010) for the Kgalagadi District Municipality didn't indicate any sensitivities for this study area; and
- The study area falls within the Savanna Biome, the Eastern Kalahari Bushveld Bioregion and within the Kathu Bushveld vegetation type (Mucina & Rutherford, 2006). The study area is situated within the 2722BB Quarter Degree Square (QDS).

The following general conclusions were drawn upon completion of the field assessment:

- A single broad habitat unit was identified within the 17ha study area namely the Open Bushveld Habitat Unit, which is well represented within the region surrounding the study area;
- Although the study area is considered to be in a moderate Present Ecological Sate (PES) and having moderate ecological sensitivity due to the high number of *Vachellia erioloba* and *V. haematoxylon* trees (protected under the National Forest Act (Act 84 of 1998) within the study area, with largely intact habitat present, portions of the study area in the vicinity of disturbances have undergone vegetation transformation and loss of habitat structure;
- Due to the relatively small development footprint and the location of the proposed slimes dam adjacent to existing mining infrastructure to the north and west, which will further limit the disturbance footprint area, the proposed project is not expected to significantly impact on floral conservation in the region;
- No floral Species of Conservation Concern (SCC) listed by the International Union for the Conservation of Nature (IUCN) or listed under the National Environmental Management: Biodiversity Act (NEMBA; Act 10 of 2004) Threatened or Protected Species (TOPS; 2013) list were encountered within the study area;

- Two species listed by the South African National Biodiversity Institute (SANBI) as 'Declining' have been encountered within the study area, namely *Boophane disticha* and *Vachellia erioloba;*
- Two floral SCC listed as protected under the National Forest Act (Act 84 of 1998) were encountered within the study area, namely *V. erioloba* and *V. haematoxylon;*
- A single species protected under the Northern Cape Nature Conservation Act, 2009 (Act 9 of 2009) was encountered within the study area, namely *Euphorbia duseimata* and another *Euphorbia* species;
- A low diversity of alien species occurs within the study area. The Category 1b invasive species, *Echinonopsis schickendantzii* requires mandatory eradication; and
- A relatively low abundance of medicinal species was encountered during the field assessment. Apart from *Boophane disticha and V. erioloba,* these medicinal species are all commonly occurring species, and are not confined to the study area.

The following general conclusions were drawn upon completion of the impact assessment:
Based on the above impact assessment it is evident that there are three possible impacts on the floral and faunal ecology respectively within the study area. The tables below summarise the findings, indicating the significance of the impacts before management takes place and the likely impact if management and mitigation takes place. From the table, it is evident that after mitigation, all potential floral impacts may be reduced from Medium-High and Medium-Low to Medium-Low and Low significance levels.

Summary of the results obtained from the assessment of floral ecological impacts

Impact	Unmanaged	Managed
1: Impact on habitat for floral species	Medium-Low	Low
2: Impact on floral diversity	Medium-Low	Low
3: Impact on floral SCC	Medium-High	Medium-Low

Cumulative Impacts
Development of the proposed slimes dam within the study area will contribute to the cumulative loss of Kathu Bushveld within the region. However, due to the relatively small development footprint and due to the study area being located immediately adjacent to an existing slimes dam, whereby edge effects have already impacted to some degree on the ecological integrity of the northern portions of the study area, the cumulative impact of the development is not considered to be significant.

No-Go Alternative
Should the development of a slimes dam within the study area not take place, no direct loss of habitat within the study area will occur and the *Vachellia erioloba* and *V. haematoxylon* trees present will remain intact. It is however important to note, that even if no development of the study area takes place, its location immediately adjacent to existing mining activity in the north and west is likely to lead to habitat deterioration over time as a result of edge effects.

It is recommended that the following essential mitigation measures are adhered to during the various development phases:
Development Footprint
- The boundaries of the development footprint areas are to remain as small as possible, be clearly defined and it should be ensured that all activities remain within defined footprint areas.
- Placement of temporary roads and access routes should be limited to existing roads or should be placed immediately adjacent to the proposed slimes dam footprint.
- Vehicles should be restricted to travelling only on designated and existing roadways to limit the ecological footprint of the proposed development activities.

Edge effects (erosion and alien species)

- Edge effects of all construction activities, such as erosion and alien plant species proliferation, which may affect floral habitat, need to be strictly managed in adjacent natural areas. Alien species should be eradicated and controlled to prevent their spread beyond the mine development footprint areas. Specific mention is made of *Echinopsis schickendantzii* as encountered in the study area, as well as *Prosopis glandulosa* and *Verbesina encelioides* known to occur in the region, and the prevention and control *Senegalia mellifera* subsp *detinens* encroachment.
- To prevent the erosion of top soils, management measures may include berms, soil traps, hessian curtains and stormwater diversion away from any areas susceptible to erosion.
- Ongoing management of edge effects such as erosion and alien vegetation control and monitoring must take place during the operational phase, as well as control of soil contamination, as salinisation of soils could severely affect floral and faunal habitat.

Waste material, discharge and contamination

- It must be ensured that construction related waste do not affect surrounding natural areas.
- It must be ensured that the mine process water system is managed in such a way as to prevent discharge to the receiving environment.
- If any soils are contaminated, it should be stripped and disposed of at a registered hazardous waste dumping site.

Stormwater

- Adequate stormwater management must be incorporated into the design of the proposed development throughout all phases in order to prevent erosion of topsoil and the loss of adjacent floral habitat. In this regard, special mention is made of containment of runoff of the facilities.

Vehicles

- In the event of a vehicle breakdown, maintenance of vehicles must take place with care and the recollection of spillage should be practiced near the surface area to prevent ingress of hydrocarbons into topsoil and subsequent habitat loss.

Soils

- All soils compacted as a result of construction activities falling outside of development footprint areas should be ripped and profiled.

Fires

- Informal fires in the vicinity of development construction areas should be prohibited.

Rehabilitation

- All disturbed surrounding habitat areas, including temporary access roads and other impacted areas not required for the operations of the slimes dam must be rehabilitated (ripped, scarified and re-vegetated with suitable indigenous grass species that will aid in soil stabilisation) as soon as possible.

Floral SCC

- Floral SCC encountered within the development footprint, are to be relocated as appropriate. This specifically relates to *Boophane disticha*, *Euphorbia duseimata* and another *Euphorbia* species which can be successfully rescued and relocated under the supervision of a qualified botanist.
- Floral SCC are to be handled with care and the relocation of these plant species to suitable similar habitat is to be overseen by a botanist.
- Permit to relocate floral SCC protected under NCNCA (Act 9 of 2009) are to be obtained from relevant departments for their removal or relocation.
- Permits are to be obtained for the destruction of approximately 1470 *Vachellia erioloba* and 2089 *V. haematoxylon* under the National Forests Act (Act 84 of 1998).
- No *Vachellia erioloba* or *V. haematoxylon* are to be needlessly destroyed and such activities must strictly be limited to specimens falling directly within the project footprint.

- It is recommended that, should such permits be obtained, the wood from felled *Vachellia erioloba* and *V. haematoxylon* be made available for use by local communities.
- Harvesting of floral species by mining and operational personnel within adjacent areas should be strictly prohibited.
- Monitoring of relocation success of *Boophane disticha* and *Euphorbia duseimata* should continue during the operational phase.

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GLOSSARY OF TERMS

Alien vegetation	Plants that do not occur naturally within the area but have been introduced either intentionally or unintentionally. Vegetation species that originate from outside of the borders of the biome -usually international in origin.
Biodiversity	The number and variety of living organisms on earth, the millions of plants, animans and micro-organisms, the genes they contain, the evolutionary history and potential they encompass and the ecosystems, ecological processes and landscape of which they are integral parts.
Ecoregion	An ecoregion is a "recurring pattern of ecosystems associated with characteristic combinations of soil and landform that characterise that region".
Indigenous vegetation	Vegetation occurring naturally within a defined area.
SCC	The term Species of Conservation Concern (SCC) in the context of this report refers to all Red Data Listed (RDL) and International Union for the Conservation of Nature (IUCN) listed species as well as protected species of relevance to the project.
Red Data Listed	Organisms that fall into the Extinct in the Wild (EW), critically endangered (CR), Endangered (EN), Vulnerable (VU) categories of ecological status.

LIST OF ACRONYMS

°C	Degrees Celsius
BGIS	Biodiversity Geographic Information Systems
DMR	Department of Mineral Resources
DWA	Department of Water Affairs
EAP	Environmental Assessment Practitioner
EIA	Environmental Impact Assessment
EVC	Extent of Vegetation Cover (used in VIS calculations)
GIS	Geographic Information System
GPS	Global Positioning System
GWC	Griqualand West Centre of Endemism
ha	Hectares
IUCN	International Union for the Conservation of Nature
m	Metres
MAP	Mean Annual Precipitation
MAT	Mean Annual Temperature
MBS	Municipal Biodiversity Summaries (2010)
MEA	Millennium Ecosystem Assessment
mm	Millimetre
MPRDA	Mineral and Petroleum Resources Development Act (Act 28 of 2002)
NBA	National Biodiversity Assessment (2011)
NCNCA	Northern Cape Nature Conservation Act (Act 9 of 2009)
NEMA	National Environmental Management Act (Act 107 of 1998)
NEMBA	National Environmental Management: Biodiversity Act (Act 10 of 2004)
NPAES	National Protected Areas Expansion Strategy (2008)
NWA	National Water Act (Act 36 of 1998)
PES	Present Ecological State
POC	Probability of Occurrence.
PRECIS	Pretoria Computer Information Systems
PVC	Percentage Vegetation Cover of indigenous species (used in VIS calculations)
QDS	Quarter Degree Square (1:50,000 topographical mapping references)
RIS	Recruitment of Indigenous species (used in VIS calculations)
SANBI	South African National Biodiversity Institute
SAS	Scientific Aquatic Services CC
SI	Structural Intactness (used in VIS calculations)
TSP	Threatened Species Programme

1 INTRODUCTION

1.1 Background

Scientific Aquatic Services (SAS) was appointed to conduct a floral ecological assessment as part of the environmental assessment and authorisation process for the proposed development of a new slimes dam of approximately 17ha in size at the Assmang Ltd., Black Rock Mine Operations, hereafter referred to as the "study area" (Figures 1 & 2). The proposed new slimes dam is located approximately 80km northwest of Kuruman, 11km to the northwest of the town of Hotazel, 2km to the east of the R380 roadway and immediately to the south of an existing slimes dam within the Northern Cape Province. Existing mining activity is also present immediately to the north and west of the study area.

The ecological assessment was confined to the study area and did not include an ecological assessment of surrounding properties. The surrounding area was however considered as part of the desktop assessment.

This report, after consideration and the description of the ecological integrity of the study area, must guide the Environmental Assessment Practitioner (EAP), regulatory authorities and mining proponent, by means of the presentation of results and recommendations, as to the ecological viability of the proposed development activities.

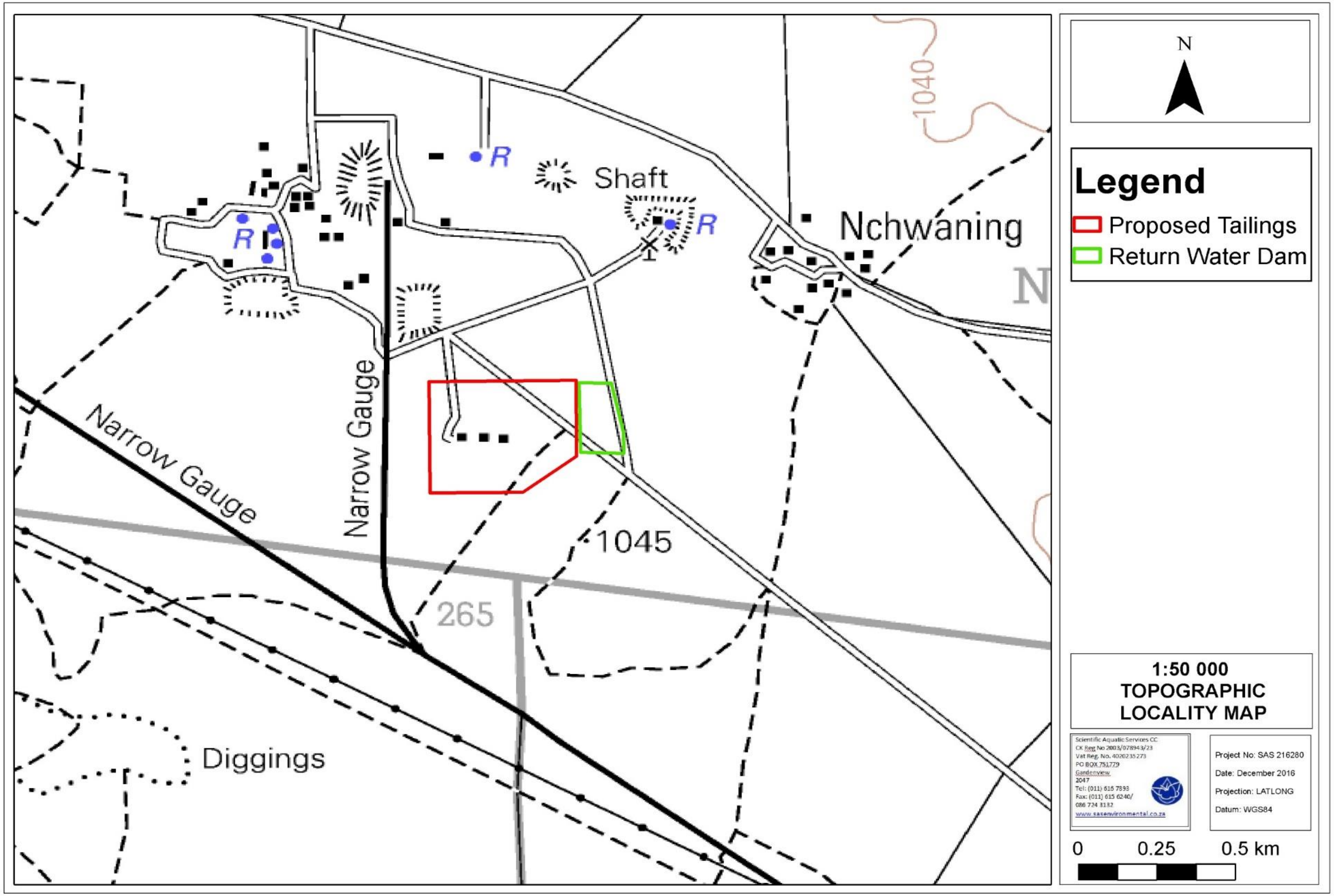


Figure 1: The study area depicted on a 1:50 000 topographical map in relation to its surrounding area.

Figure 2: Digital Satellite image depicting the location of the study area in relation to surrounding areas.

1.2 Project Scope

Specific outcomes in terms of this report are outlined below.

- To conduct a desktop study to gain background information on the physical habitat and potential floral biodiversity associated with the study area and surrounding region;
- To conduct a Red Data Listed (RDL) species assessment as well as an assessment of other Species of Conservation Concern (SCC), including potential for such species to occur within the study area;
- To provide inventories of floral species as encountered within the study area;
- To determine and describe habitat types, communities and the Present Ecological State (PES) of the study area and to rank each habitat type based on conservation importance and ecological sensitivity;
- To describe the spatial significance of the study area with regards to surrounding natural areas;
- To identify and consider all sensitive landscapes including rocky ridges, wetlands and/ or any other special features; and
- To determine the environmental impacts of the proposed slimes dam development activity on the terrestrial ecology within the study area and to development mitigation and management measures.

1.3 Assumptions and Limitations

The following assumptions and limitations are applicable to this report:

- The floral assessment is confined to the study area and does not include the neighbouring and adjacent properties; these were however considered as part of the desktop assessment;
- With ecology being dynamic and complex, some aspects (some of which may be important) may have been overlooked. It is, however, expected that most floral communities have been accurately assessed and considered;
- Sampling by its nature, means that not all individuals are assessed and identified. Some species and taxa on the study area may therefore been missed during the assessment; and
- A field assessment was undertaken during June 2015 and November 2016 (updated study area) to determine the ecological status of the study area. Although not considered ideal for the identification of the full suite of floral species, this time of year still allowed for the majority of floral species to be accurately identified. Although considered sufficient, a more accurate assessment would require that assessments take place in all seasons of the year. In addition, SAS has conducted a number of ecological assessments within the larger region and has sound knowledge of the floral ecology of the area.

1.4 Legislation Requirements

The following legislative requirements were considered during the assessment:

- National Environmental Management Act (NEMA; Act 107 of 1998);
- Minerals and Petroleum Resource Development Act (MPRDA; Act 22 of 2002);

- National Environmental Management: Biodiversity Act (NEMBA; Act 10 of 2004);
- National Forests Act (Act 84 of 1998); and
- Northern Cape Nature Conservation Act (NCNCA; Act 9 of 2009).

The details of each of the above, as they pertain to the study, is provided in Appendix A of this report.

2 ASSESSMENT APPROACH

2.1 General Approach

In order to accurately determine the PES of the study area and capture comprehensive data with respect to floral taxa, the following methodology was used:

- Maps, aerial photographs and digital satellite images were consulted prior to the field assessment in order to determine broad habitats, vegetation types and potential sites of high or increased ecological sensitivity. An initial visual on-site assessment of the study area was made in order to confirm the assumptions made during consultation of the maps;
- A literature review with respect to habitats, vegetation types and species distribution was conducted;
- Relevant databases considered during the assessment of the study area included:
  - The South African National Biodiversity Institute (SANBI) Threatened Species Programme (TSP);
  - The National Environmental Management Biodiversity Act (NEMBA, Act 10 of 2004);
  - Threatened or Protected Species (TOPS, 2013);
  - The Pretoria Computer Information Systems (PRECIS);
  - The Northern Cape Municipal Biodiversity Summaries (MDS, 2010);
  - Mucina and Rutherford (2006); and
  - National Biodiversity Assessment (NBA) (2011).
- A reconnaissance 'walkabout' was undertaken to determine the general habitat types found throughout the study area and, following this, specific study sites were selected that were considered to be representative of the habitats found within the area, with special emphasis being placed on areas that may potentially support RDL and other SCC species. Sites were investigated on foot in order identify the occurrence of the dominant plant species and habitat diversities.

2.2 Floral Species of Conservation Concern (SCC)

Prior to the field assessment, a record of South African RDL floral species and their habitat requirements was acquired from SANBI for the Quarter Degree Square (QDS) 2722BB (available on request). According to the SANBI database, no RDL floral species are listed for this QDS and therefore the Probability of Occurrence (POC) for RDL floral species has not been determined.

2.3 Vegetation Surveys

Vegetation surveys were undertaken by first identifying different habitat units and then analysing the floral species composition. Vegetation analyses were conducted within areas that were perceived to best represent the various floral communities. Species were recorded and a species list was compiled for each habitat unit. These species lists were also compared with the vegetation expected to be found within the relevant vegetation type as described in Section 4.3, which serves to provide an accurate indication of the ecological integrity and conservational value of each habitat unit.

2.4 Sensitivity Mapping

All the floral features of the study area were considered and sensitive areas were delineated with the use of a Global Positioning System (GPS). In addition, identified locations of floral SCC were also marked by means of GPS. A Geographic Information System (GIS) was used to project these features onto aerial photographs and topographic maps. The sensitivity map should guide the design and layout of the proposed development.

3 LAND USE AND CONSERVATION CHARACTERISTICS OF THE STUDY AREA

The following sections contain data accessed as part of the desktop assessment. It is important to note, that although all data sources used provide useful and often verifiable high quality data, the various databases used not always provide an entirely accurate indication of the study area's actual site characteristics. This information is however considered to be useful as background information to the study. Thus, this data was used as a guideline to inform the assessment and areas where increased conservation importance is indicated were paid attention to.

3.1 Importance According to the Mining and Biodiversity Guideline (2012)

The Mining Biodiversity Guideline (2012) provides explicit direction in terms of where mining-related impacts are legally prohibited, where biodiversity priority areas may present high risks for mining projects, and where biodiversity may limit the potential for mining. The Guideline distinguishes between four categories of biodiversity priority areas in relation to their importance from a biodiversity and ecosystem service point of view as well as the implications for mining. These categories include: Legally Protected Areas, Highest Biodiversity Importance, High Biodiversity Importance and Moderate Biodiversity Importance.

According to the Mining Biodiversity Guidelines the study area does not fall within an area indicated to be of increased biodiversity importance.

3.2 National List of Threatened Terrestrial Ecosystems for South Africa (2011)

The NEMBA (Act 10 of 2004) provides for listing of threatened or protected ecosystems, in one of four categories: critically endangered, endangered, vulnerable or protected. Threatened ecosystems are listed in order to reduce the rate of ecosystem and species extinction by preventing further degradation and loss of structure, function and composition of threatened ecosystems. The purpose of listing protected ecosystems is primarily to conserve sites of exceptionally high conservation value (SANBI, Biodiversity Geographic Information Systems (BGIS)).

According to the National List of Threatened Terrestrial Ecosystems (2011) the study area is not located within a threatened terrestrial ecosystem.

3.3 NPAES Focus Areas for Protected Area Expansion (2008)

The goal of the National Protected Area Expansion Strategy (NPAES; 2008) is to achieve cost effective protected area expansion for ecological sustainability and adaptation to climate change. The NPAES sets targets for protected area expansion, provides maps of the most important areas for protected area expansion, and makes recommendations on mechanisms for protected area expansion. It deals with land-based and marine protected areas across all of South Africa's territory (SANBI, BGIS).

According to the NPAES database, the study area does not fall within an area earmarked as an NPAES area.

3.4 National Biodiversity Assessment (NBA, 2011)

The latest NBA (2011) provides an assessment of South Africa's biodiversity and ecosystems, including headline indicators and national maps for the terrestrial, freshwater, estuarine and marine environments. The NBA 2011 was led by the South African National Biodiversity Institute (SANBI) in partnership with a range of organisations. It follows on from the National Spatial Biodiversity Assessment 2004, broadening the scope of the assessment to include key thematic issues as well as a spatial assessment. The NBA 2011 includes a summary of spatial biodiversity priority areas that have been identified through systematic biodiversity plans at national, provincial and local levels (SANBI, BGIS).

According to the NBA (2011), the study area is not located within a formally or informally protected area, with the entire study area falling within an area that is currently not protected (Figure 3). The Land Cover data indicates that the study area largely falls within a natural area, with mining activity located to the north and west (Figure 4).

3.5 Northern Cape Provincial Spatial Development Framework

According to the Northern Cape PSDF (2012), the study area is located within the Griqualand West Centre of Endemism (GWC), however, the study area is not located within a Critical Biodiversity Area (CBA), within a Biodiversity Priority Area or within a protected area as identified by the PSDF (2012).

3.6 Importance According to the Municipality Biodiversity Summaries (MBS, 2010)

A MBS has been developed for each municipality in the Northern Cape Province. The summary provides a standard, national set of biodiversity information for each municipality (BGIS, 2015), which provides data, such as the National Land Cover, Wetland habitat and buffers and vegetation status. The study area is located within the Kgalagadi District Municipality and the MBS didn't indicate any sensitivities for the study area.

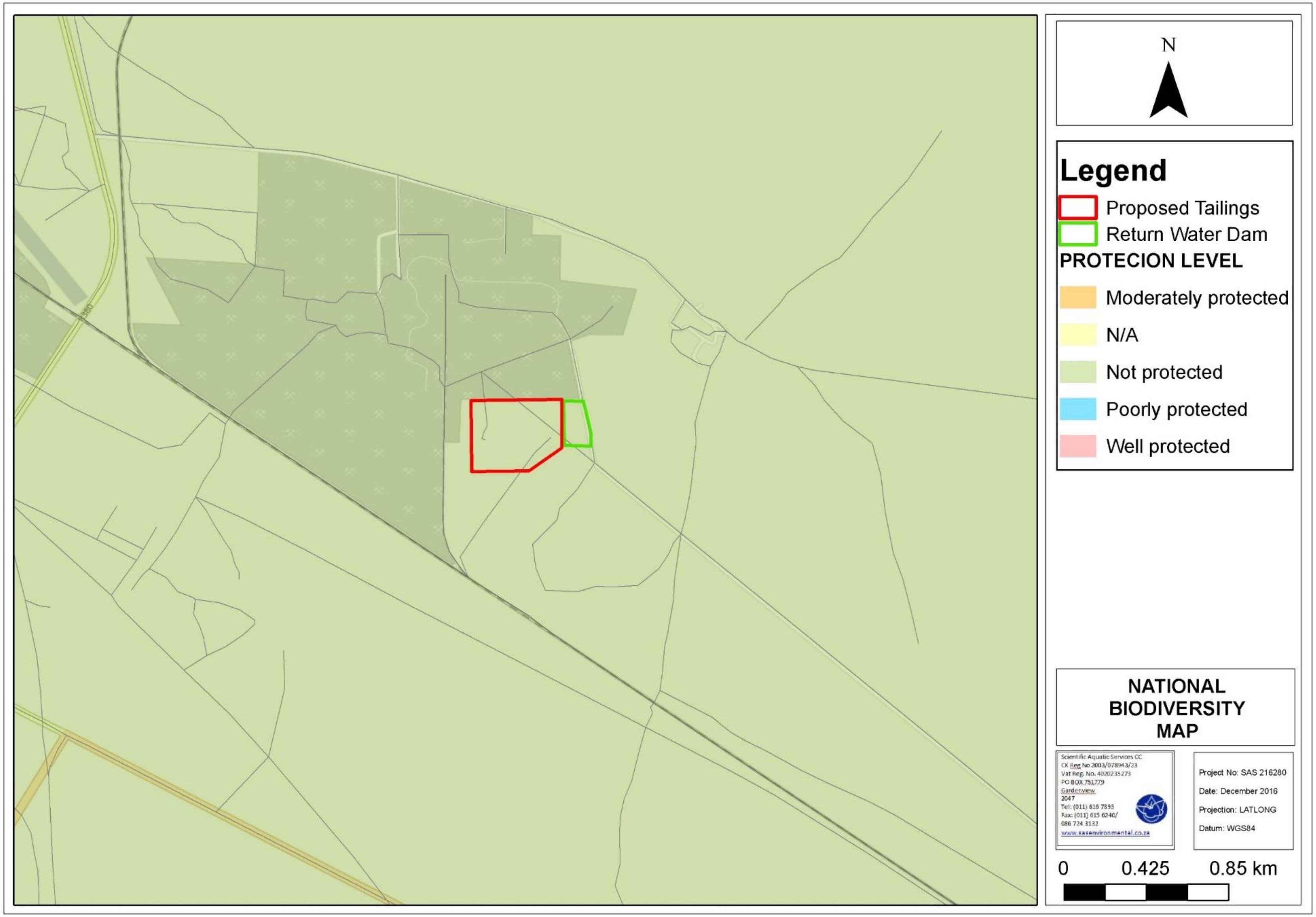


Figure 3: Level of ecosystem protection according to the National Biodiversity Assessment (2011).

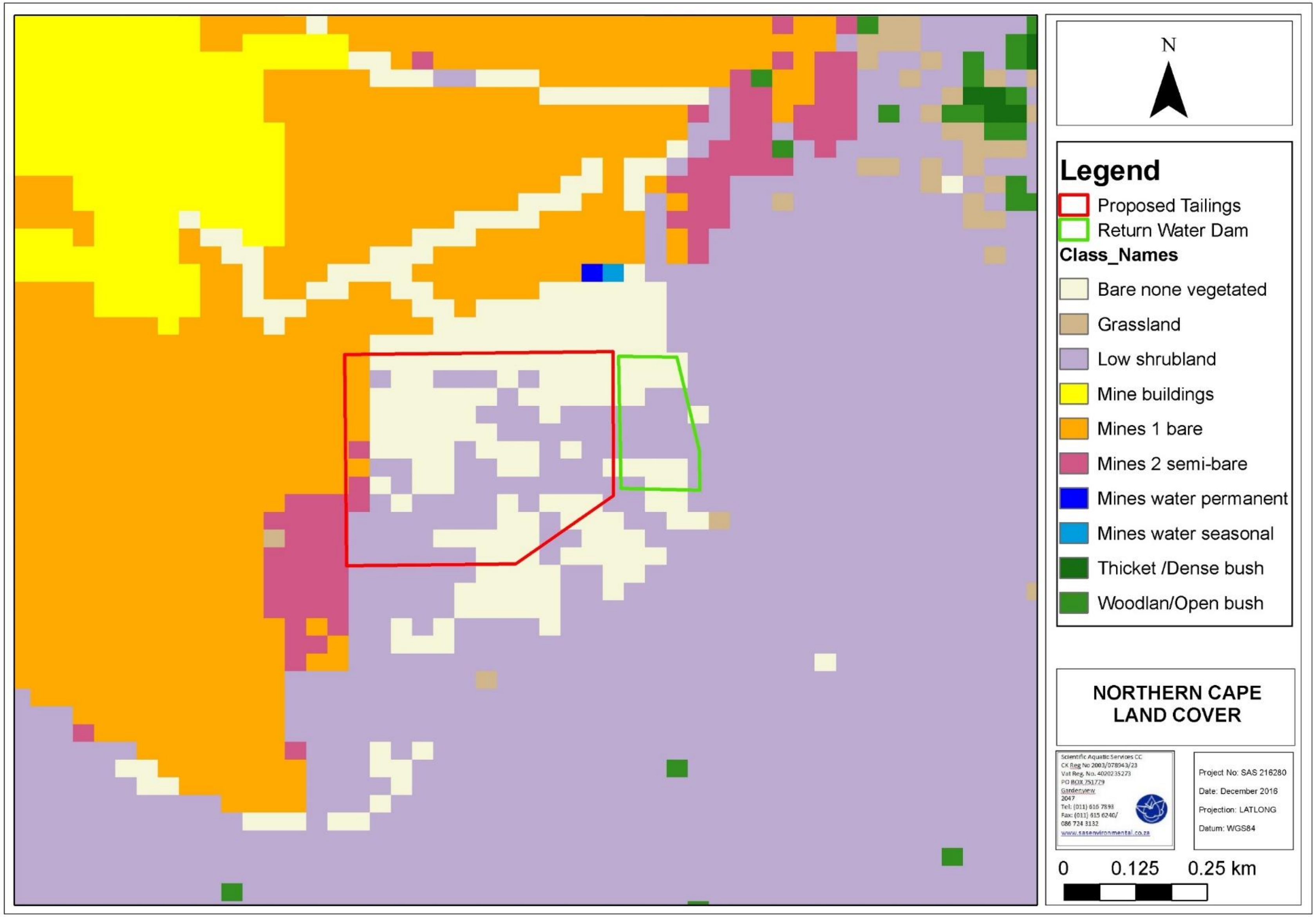


Figure 4: Land cover uses associated with the study area (NBA, 2011).

4 FLORAL DESCRIPTION

4.1 Biome and Bioregion

Biomes are broad ecological units that represent major life zones extending over large natural areas (Rutherford, 1997). The study area under assessment falls within the Savanna biome (Figure 5) (Rutherford & Westfall, 1994). Biomes are further divided into bioregions, which are spatial terrestrial units possessing similar biotic and physical features, and processes at a regional scale. This study area is situated within the Eastern Kalahari Bushveld Bioregion (Mucina & Rutherford, 2006).

4.2 Griqualand West Centre of Endemism (GWC)

The study area is located within the Griqualand West Centre of Endemism (GWC), an area comprising the Hay District and parts of the Barkly West District in the Northern Cape Province. The core area of the GWC coincides with the surface outcrops of the Ghaap Plateau and Olifantshoek Supergroup. In floristic terms, however, the outer boundaries of the centre are rather diffuse, as several of the GWC floristic elements spill over onto related substrates, especially alkaline one's rich in calcium. The mountainous western parts of the GWC are covered by Kalahari Mountain Bushveld, and the eastern plateau area is covered by Kalahari Plateau Bushveld, both endemic to the centre (Van Wyk & Smith, 2001).

According to Van Wyk & Smith (2001), the vegetation within the GWC is still fairly intact, although extremely poorly conserved. The Kalahari Plateau Bushveld is, for instance, the only vegetation type which is not represented in any sizeable nature reserve. Bush encroachment, by the indigenous *Senegalia mellifera*, which is due to inappropriate veld management practices (mainly overgrazing by domestic livestock), is a major problem in many parts of the region.

4.3 Vegetation Type and Landscape Characteristics

While biomes and bioregions are valuable as they describe broad ecological patterns, they provide limited information on the actual species that are expected to be found in an area. Knowing which vegetation type an area belongs to provides an indication of the floral composition that would be found if the study area was in a pristine condition, which can then be compared to the observed floral list and so give an accurate and timely description of the ecological integrity of the assessment site. When the boundary of the study area is superimposed on the vegetation types of the surrounding area, it is clear that the study area falls within the Kathu Bushveld vegetation type (Mucina & Rutherford, 2006).

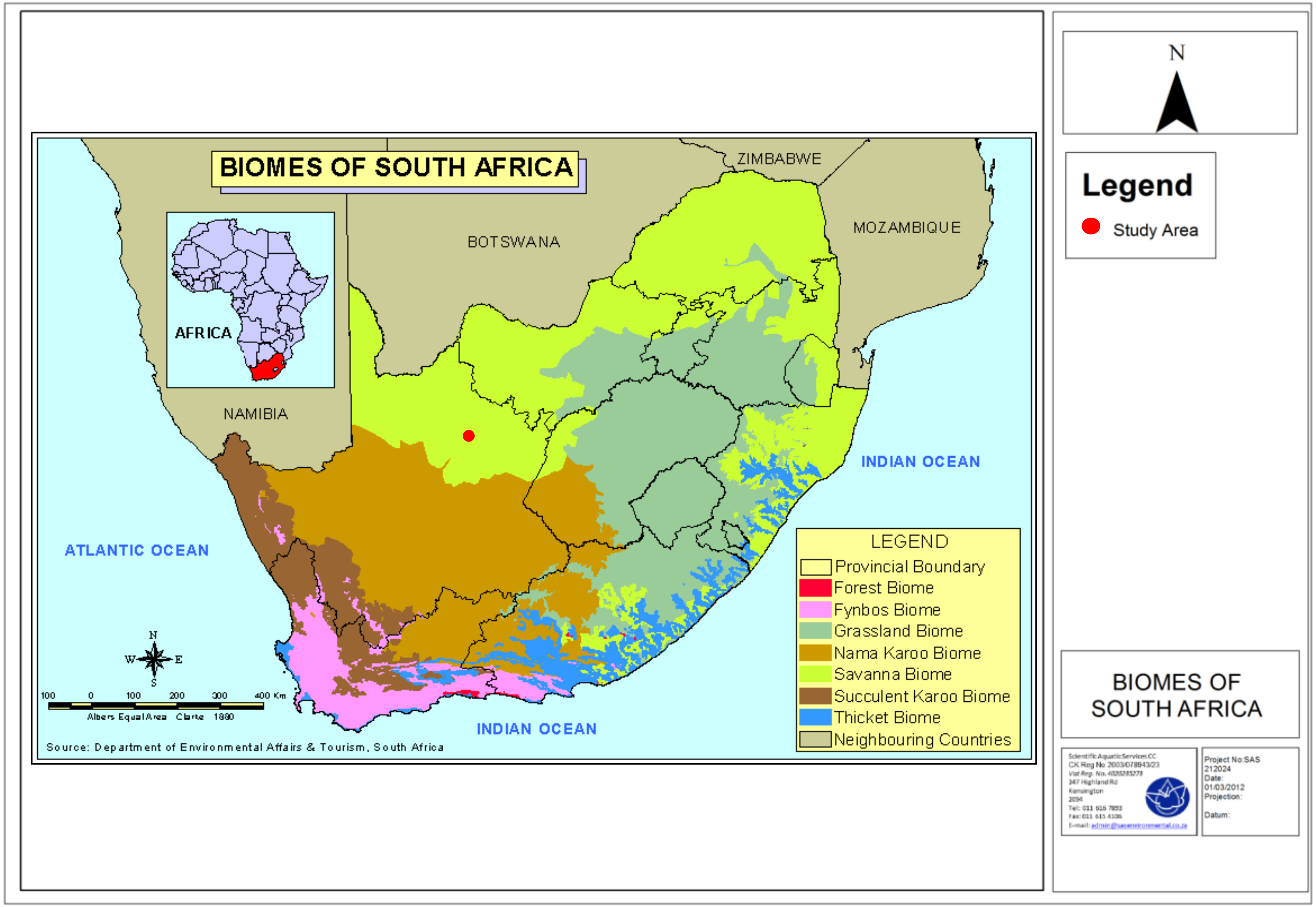


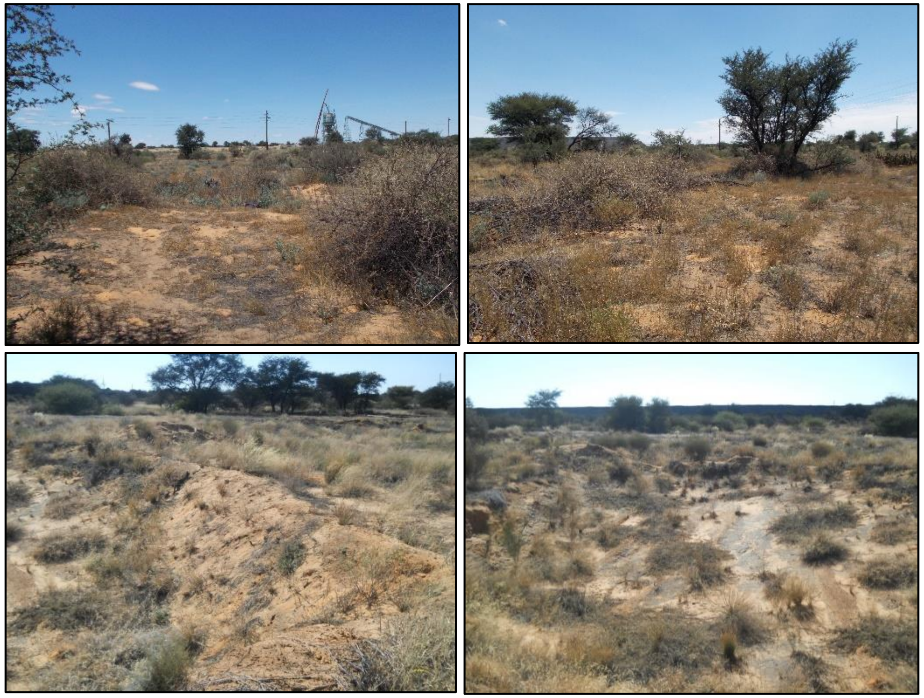
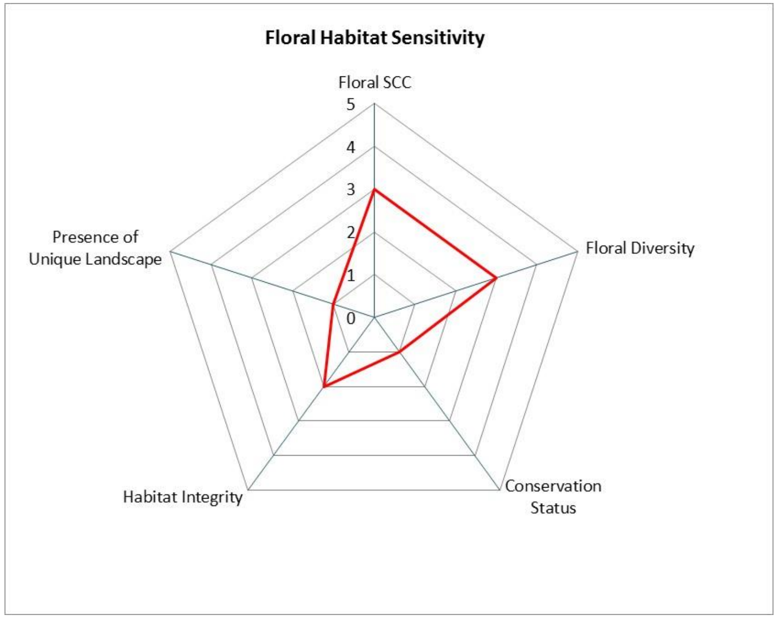
Figure 5: Biomes of South Africa, with the approximate location of the study area indicated with a red circle.

5 RESULTS OF THE FLORAL INVESTIGATION

5.1 Habitat Unit 1: Open Bushveld Habitat Unit

One broad habitat unit was identified within the 17ha study area namely the Open Bushveld Habitat Unit. The study area is located immediately to the south of an existing slimes dam and to the east of existing mining activities, with edge effects from such activities being evident in the northern and western portion of the habitat unit, particularly in the form of topographic disturbance and stockpiling. Another portion towards the centre of the study rea, towards the centre of the study area, has also been affected by road development and historical excavation activities. Apart from these areas, the Open Bushveld Habitat Unit is considered to be in a largely natural state, with basic ecological processes still evident.

Table 1: Summary of results of the floral assessment.

<table>
<tr><td rowspan="2">Habitat Unit:
Open Bushveld Habitat</td><td>Floral Habitat Sensitivity</td><td>Moderately Low</td><td colspan="2" rowspan="3"></td></tr>
<tr><td colspan="2">Notes on Photograph: The Open Bushveld Habitat Unit identified within the study area. The top images show the open bushveld habitat assessed during November 2016. The bottom images show a limited area where historical excavations have taken place (July 2015)</td></tr>
<tr><td colspan="3" rowspan="3">Floral Habitat Sensitivity Graph:

</td></tr>
<tr><td>Conservation Status of Vegetation Type/Ecosystem</td><td>Habitat integrity/Alien and Invasive species</td></tr>
<tr><td>Falls within the Kathu Bushveld vegetation type Least Concern with a conservation target of 16%. Grass species encountered within the study area are mostly indicative of the expected Kathu Bushveld vegetation type and include Aristida meridionalis, A. congesta, Eragrostis lehmanniana, E. pallens, Schmidtia</td><td>Habitat disturbance and edge effects from mining activities have resulted in a moderately low habitat integrity for this habitat unit. Limited alien floral species were encountered within the study area. Chenopodium album occurs scattered within more disturbed areas, while a single population of Echinopsis schickendantzii</td></tr>
</table>

<table>
<tr>
<td rowspan="3">**Floral Species of Conservation Concern (SCC)**</td>
<td rowspan="3">The woody layer is dominated by *Vachellia erioloba* and *V. haematoxylon* (previously known as *Acacia erioloba* and *A. haematoxylon* respectively), both species that are protected under the National Forests Act (Act 84 of 1998). Two floral SCC were encountered, namely *Boophane disticha* (listed by SANBI as 'Declining') and *Euphorbia duseimata* (indicated to be protected under the Northern Cape Nature Conservation Act (Act 9 of 2009).

It is however recommended that permits for the removal or relocation of all floral SCC protected in terms of the National Forests Act (Act 84 of 1998), the Northern Cape Nature Conservation Act (NCNCA; Act 9 of 2009) and species listed by SANBI as being of conservation importance, be obtained.</td>
<td>*pappophoroides* and S.*kalahariensis*. Of these species, *S. pappophoroides* was the dominant graminoid species present during the time of assessment, occurring throughout the study area.</td>
<td>is located along the eastern boundary of the study area</td>
</tr>
<tr>
<td colspan="2">**Floral Diversity**</td>
</tr>
<tr>
<td colspan="2">The vegetation associated with the Open Bushveld Habitat Unit is largely homogeneous. The woody layer is dominated by *Vachellia erioloba* and *V. haematoxylon* (previously known as *Acacia erioloba* and *A. haematoxylon* respectively), both species that are protected under the National Forests Act (Act 84 of 1998). These species occur scattered throughout the extent of the study area. *Senegalia mellifera* subsp. *detinens* was also present within the study area, but did not show signs of forming dense, impenetrable thickets. This species has the potential to be a bush encroacher species and is listed as such in the Northern Cape Province (Bromilow, 2001).
The forb layer within the study area is not continuous, and is characterised a moderate diversity of forbs and low shrub species including *Lycium hirsutum, Aptosimum lineare, Pentzia incana, Pollicha campestris* and *Helichrysum cerastioides*.</td>
</tr>
<tr>
<td>**Presence of Unique Landscapes**</td>
<td>No unique landscapes important to flora were present.</td>
<td>**General comments:**
The vegetation within the study area is well represented within the region surrounding the study area and the majority of species being typical of the region. In addition, the relatively small development footprint and the location of the proposed slimes dam adjacent to existing mining activities and infrastructure, will further limit the disturbance footprint area.</td>
<td>**Business Case, Conclusion and Mitigation Requirements:**
Although the study area is considered to be in a moderate PES, with largely intact habitat present and a high number of floral SCC present, portions of the study area, particularly in the vicinity of disturbances have undergone vegetation transformation and loss of habitat structure. It is however recommended that permits for the removal or relocation of all floral SCC protected in terms of the National Forests Act (Act 84 of 1998), and the Northern Cape Nature Conservation Act (NCNCA; Act 9 of 2009), be obtained.</td>
</tr>
</table>

5.2 Floral SCC Assessment

An assessment considering the presence of any floral RDL species and other floral SCC, as well as suitable habitat to support any such species, was undertaken. No floral SCC listed by the IUCN or listed as being of conservation importance under the NEMBA (Act 10 of 2004) TOPS (2013) list were encountered within the study area.

The complete Pretoria Computer Information Systems (PRECIS) RDL floral lists for the QDS reference 2722BB were acquired from SANBI whereby it was found that no RDL species were listed for the QDS. However, approximately 23 specimens of *Boophane disticha* (Figure 6), listed by SANBI as 'Declining', were encountered within the study area, while *Vachellia erioloba and Vachellia haematoxylon*, of which approximately 3559 individual trees were counted, is also listed as 'Declining' (www.redlist.sanbi.org). Permits are to be obtained for the destruction of approximately 1470 *Vachellia erioloba* and 2089 *V. haematoxylon* under the National Forests Act (Act 84 of 1998).

Figure 6: *Boophane disticha* found within the study area.

As previously mentioned, two floral SCC listed as protected under the National Forest Act (Act 84 of 1998) were encountered within the study area, namely *Vachellia erioloba* and *V. haematoxylon* (previously known as *Acacia erioloba* and *A. haematoxylon* respectively). In terms of Regulation GN 908 (2014) of this Act, protected tree species may not be cut, disturbed, damaged or destroyed and their products may not be possessed, collected, removed, transported, exported, donated, purchased or sold, except under licence granted by the Department of Agriculture, Forestry and Fisheries (DAFF) or a delegated authority. Applications for such activities should be made to the responsible official in each province.

In addition to the above, a single species was encountered within the study area, namely *Euphorbia duseimata* is protected under the Northern Cape Nature Conservation Act, 2009 (Act 9 of 2009), whereby all *Euphorbia* spp. are listed as protected. In order to transport and relocate this species, an application for a permit should be submitted to the relevant Northern Cape Department and it is recommended that the relocation of this species is overseen by a suitably qualified botanist.


Figure 7: *Euphorbia spp. and Euphorbia duseimata* found within the study area.

No other floral SCC, specifically those species listed by the IUCN, SANBI and the TOPS (2013) species regulations, have been encountered within the study area after a thorough search and, as such, have a limited probability to occur within the study area.

5.3 Alien and Invasive Floral Species

Alien and invasive floral species are floral species s that are of exotic origin and are invading previously pristine areas or ecological niches (Bromilow, 2001). Not all weeds are exotic in origin but, as these exotic plant species have very limited natural "check" mechanisms within the natural environment, they are often the most opportunistic and aggressively growing species within the ecosystem. Therefore, they are often the most dominant and noticeable within an area. Disturbances of the ground through trampling, excavations or landscaping often leads to the dominance of exotic pioneer species that rapidly dominate the area. Under natural conditions, these pioneer species are overtaken by sub-climax and climax species through natural veld succession. This process, however, takes many years to occur, with the natural vegetation never reaching the balanced, pristine species composition prior to the disturbance. There are many species of indigenous pioneer plants, but very few indigenous species can out-compete their more aggressively growing exotic counterparts.
Alien vegetation invasion causes degradation of the ecological integrity of an area, causing (Bromilow, 2001):

- A decline in species diversity;
- Local extinction of indigenous species;
- Ecological imbalance;
- Decreased productivity of grazing pastures; and
- Increased agricultural input costs.

During the floral assessment, all alien and weed species were identified and are listed in the table below.

Table 2: Dominant alien vegetation species identified during the general area assessment.

Species	English name	Origin	CARA Category*	NEMBA Category*
Trees/ shrubs				
Echinopsis schickendantzii	Torch cactus	Argentina	1	1b
Forbs				
Chenopodium album	White goosefoot	Europe	N/C	N/C

N/A = Not Categorised
***Conservation of Agricultural Resources Act (Act 43 of 1983)**
**** National Environmental Management: Biodiversity Act (Act 10 of 2004): Alien and Invasive Species Regulations, GN R598 of 2014**

Category 1a – Invasive species that require compulsory control.
Category 1b – Invasive species that require control by means of an invasive species management programme.
Category 2 – Commercially used plants that may be grown in demarcated areas, provided that there is a permit and that steps are taken to prevent their spread.
Category 3 – Ornamentally used plants that may no longer be planted. Existing plants may remain, except within the flood line of watercourses and wetlands, as long as all reasonable steps are taken to prevent their spread (Bromilow, 2001).

From the table above it is clear that a low diversity of alien species occurs within the study area. *Chenopodium album,* an uncategorised alien species, occurs scattered but in low abundance throughout the study area, while a single population of *Echinonopsis schickendantzii* (Figure 8), listed as a Category 1 invasive species and therefore requiring mandatory eradication, was encountered. *E.schickendantzii* competes with indigenous species and as it grows under trees, prevents access to shade for domestic and wild animals. Where it has started forming infestations it reduces the carrying capacity of the land and its many spines can cause injuries to grazing animals (Bromilow, 2001).

Figure 8: *Echinonopsis schickendantzii* within the study area.

5.4 Medicinal Floral Species

Medicinal plant species are not necessarily indigenous species, with many of them regarded as alien invasive weeds.

The table below presents a list of plant species with traditional medicinal value, plant parts traditionally used and their main applications, which were identified during the field assessment. Apart from *Boophane disticha* and *V. erioloba*, these medicinal species are all commonly occurring species and are not confined to the study area.

Table 3: Traditional medicinal plants identified during the field assessment. Medicinal applications and application methods are also presented (van Wyk, Oudtshoorn, Gericke, 2009).

Species	Name	Plant parts used	Medicinal uses
Boophane disticha	Bushman poison bulb	Bulb scales	Dry outer scales of the bulb are used as an outer dressing after circumcision and are applied to boils or septic wounds to alleviate pain. Weak decoctions are administered by mouth or as and enema for various complaints such as headaches, abdominal pain, weakness and eye conditions.
Dicoma capensis	Koorsbossie	Leaves and twigs, sometimes roots	The plant is widely used to treat fever, an upset stomach and numerous other ailments, including influenza, high blood pressure and even cancer. In addition to the use of aboveground parts, the roots are ground and snuffer as a treatments for colds, or a decoction of it in gin has been used to treat haemorrhoids and fever.
Helichrysum sp.	Everlasting	Leaves and twigs, sometimes roots	Many ailments are treated, including coughs, colds, fever, headache and menstrual pain. Also used in wound dressing.
Vachellia erioloba	Camel Thorn	Pods, gum, roots	Dry powdered pods can be used to treat ear infections. The gum can be used for the treatment of gonorrhoea and the pulverized, burned bark can be used to treat headaches. The root can be used to treat toothache. To treat tuberculosis, the root is boiled for a few minutes and the infusion is swirled around in the mouth and spat out (http://www.plantzafrica.com/plantab/acaciaeriol.htm)

6 SENSITIVITY MAPPING

From the assessment, it was found that the majority of the study area is comprised of Open Bushveld Habitat Unit, with an overall moderate ecological sensitivity, mostly due to the high number of *Vachellia erioloba* and *V. haematoxylon*, protected under the National Forest Act (Act 84 of 1998) present, as well as the overall moderate PES of the study area with largely intact habitat present. It is however important to note that portions of the study area, particularly in the vicinity of disturbances have undergone vegetation transformation and loss of habitat structure and that the habitat type is considered well represented within the region surrounding the study area. The proposed project is therefore not expected to significantly impact on floral conservation in the region.

It is recommended that permits be obtained to remove or relocate the various floral SCC within the study area. *Vachellia erioloba* and *V. haematoxylon* occur scattered throughout the study area and is therefore not indicated on the site sensitivity map below. The locations of *Boophane disticha* and *Euphorbia duseimata* are however indicated.

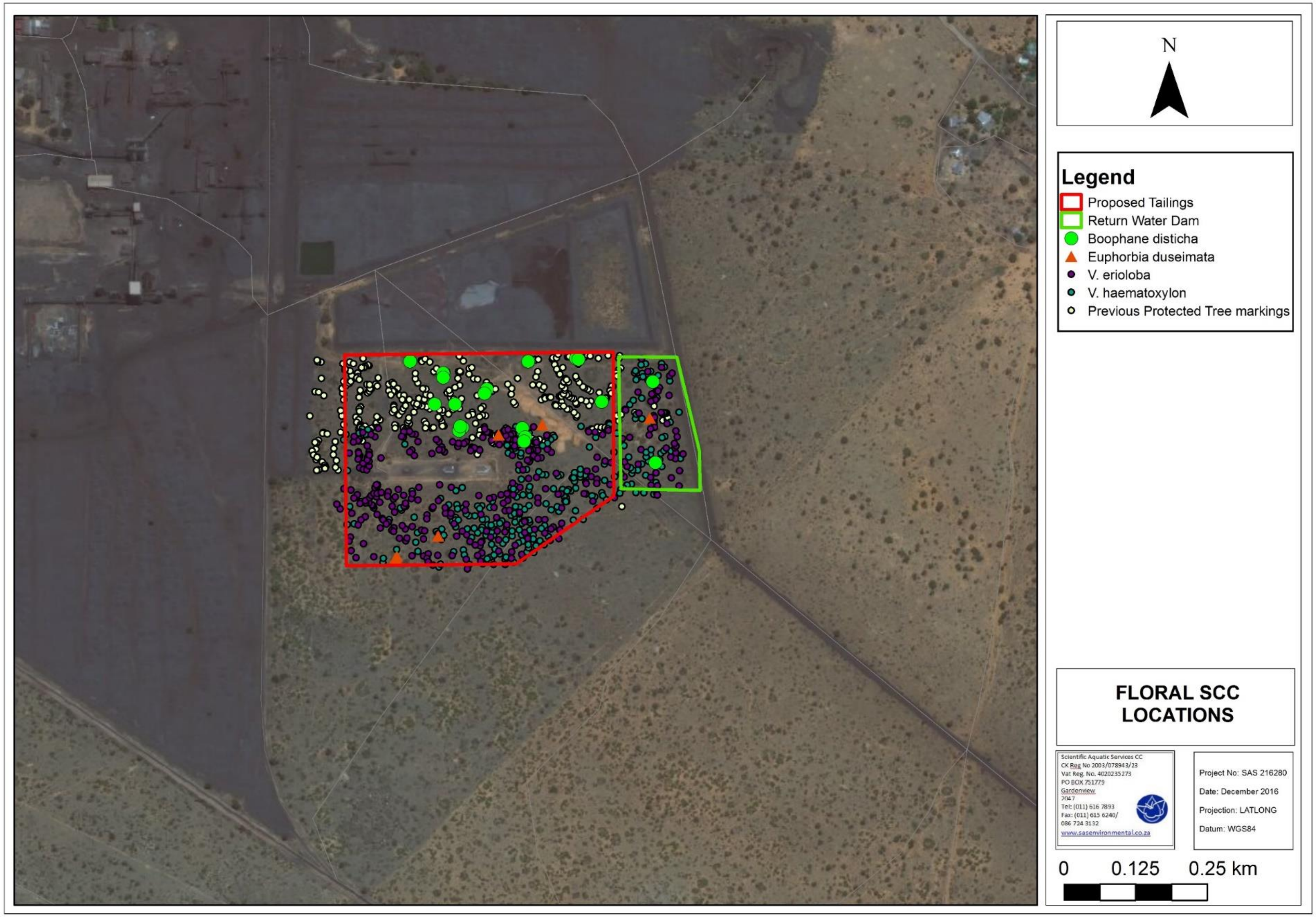


Figure 9: Sensitivity map for the study area.

7 IMPACT ASSESSMENT

7.1 Impact Assessment Results

The impact tables below serve to summarise the significance of perceived impacts on the floral biodiversity of the study area. The tables present the impact assessment according to the method described in Appendix C and also indicate the mitigation measures required to minimise the impacts. In addition, an assessment of the significance of the perceived impacts is presented, taking into consideration the available mitigating measures assuming that they are fully implemented.

7.1.1 IMPACT 1: Impact on habitat for floral species

Activities leading to impact

Pre-Construction	Construction	Operational
Design of infrastructure, leading to a larger than expected infrastructure footprint	Site clearing and the removal of vegetation leading to a loss of floral habitat	Ongoing disturbance of soils with general operational activities
	Encroachment of construction activities beyond the extent of the proposed project footprint	Increased introduction and proliferation of alien plant species and further transformation of natural habitat due to disturbance during
	Site clearing and the disturbance of soils leading to loss of floral habitat	Edge effects such as erosion and alien species proliferation leading to loss of floral habitat in the surrounding
	Movement of construction vehicles and access road construction beyond the project footprint leading to a loss of floral habitat	
	Dumping of material within open veld areas leading to a loss of floral habitat	
	Compaction of soils due to construction activities	
	Edge effects such as erosion and alien species proliferation leading to loss of floral habitat in the surrounding areas	
	Increased fire frequency during construction leading to a loss of adjacent floral habitat	
	Dust generation during construction leading to a loss of floral habitat	

Without Management	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
	5	2	3	2	5	7	10	70 (Medium-Low)

Essential construction phase mitigation measures

- The boundaries of the development footprint areas are to remain as small as possible, be clearly defined and it should be ensured that all activities remain within defined footprint areas.
- Placement of temporary roads and access routes should be limited to existing roads or should be placed immediately adjacent to the proposed slimes dam footprint.
- Vehicles should be restricted to travelling only on designated and existing roadways to limit the ecological footprint of the proposed development activities.
- Edge effects of all construction activities, such as erosion and alien plant species proliferation, which may affect floral habitat, need to be strictly managed in adjacent natural areas. Alien species should be eradicated and controlled to prevent their spread beyond the mine development footprint areas. Specific mention is made of *Echinopsis schickendantzii* as encountered in the study area, as well as *Prosopis glandulosa* and *Verbesina encelioides* known to occur in the region (but not encountered in the study area), and the prevention and control of *Senegalia mellifera* subsp *detinens* encroachment.
- It must be ensured that construction related waste do not affect surrounding natural areas.
- It must be ensured that the mine process water system is managed in such a way as to prevent discharge to the receiving environment.
- Adequate stormwater management must be incorporated into the design of the proposed development throughout all phases in order to prevent erosion of topsoil and the loss of adjacent floral habitat. In this regard, special mention is made of containment of runoff of the facilities.
- In the event of a vehicle breakdown, maintenance of vehicles must take place with care and the recollection of spillage should be practiced near the surface area to prevent ingress of hydrocarbons into topsoil and subsequent habitat loss.
- If any soils are contaminated, it should be stripped and disposed of at a registered hazardous waste dumping site.
- All soils compacted as a result of construction activities falling outside of development footprint areas should be ripped and profiled.
- To prevent the erosion of top soils, management measures may include berms, soil traps, hessian curtains and stormwater diversion away from any areas susceptible to erosion.
- Informal fires in the vicinity of development construction areas should be prohibited.

Recommended construction phase mitigation measures

- It must be ensured that all temporary access roads and construction areas are regularly sprayed with water in order to curb dust generation, if deemed necessary.
- Mining and construction personnel, should be informed about fire control and prevention measures to reduce the frequency of uncontrolled veld fires in areas surrounding and within the study area.
- It is recommended that all construction personnel be educated in environmental awareness.

Essential operation phase mitigation measures

- All disturbed surrounding habitat areas, including temporary access roads and other impacted areas not required for the operation of the slimes dam must be rehabilitated (ripped, scarified and re-vegetated with suitable indigenous grass species that will aid in soil stabilisation) as soon as possible.
- Ongoing management of edge effects such as erosion and alien vegetation control must take place, as well as control of soil contamination, as salinisation of soils could severely affect habitat.

With Management	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
	3	2	2	1	5	5	8	35 (Low)

Probable latent impacts

- Loss of floral habitat may lead to altered floral biodiversity.
- Permanent loss of floral habitat may take place.

7.1.2 IMPACT 2: Impact on floral diversity

Activities leading to impact

Pre-Construction	Construction	Operational
Failure to initiate a rehabilitation plan and alien floral control plan during the pre-construction phase	Site clearing and the removal of vegetation for development of a slimes dam leading to a loss of floral diversity	On-going disturbance of soils due to operational activities leading to altered floral diversity
Insufficient design of infrastructure leading to pollution of soils and ground water	Loss of surrounding floral biodiversity through invasion of alien species in disturbed areas	Increased introduction and proliferation of alien plant species and further transformation of floral diversity
	Erosion as a result of smiles dam development and storm water runoff leading to a loss of floral diversity	Risk of discharge, spillage and contamination from operational facilities may pollute receiving environment leading to altered floral diversity
	Movement of construction vehicles and access road construction through surrounding floral habitat	Seepage affecting soils and the groundwater regime leading to altered floral diversity
	Compaction of soils reducing efficiency of floral re-establishment in surrounding areas	On-going disturbance may lead to erosion and sedimentation
		Indiscriminate movement of operational vehicles through adjacent open veld areas

Without Management	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
	4	2	3	2	4	6	9	54 (Medium-Low)

Essential construction phase mitigation measures

- All development footprint areas and areas affected by the proposed slimes dam development should remain as small as possible.
- Removal of the alien and invasive floral species, with specific emphasis on Category 1 alien species, encountered within the study area and immediate surrounds must take place in order to comply with existing legislation (amendments to the regulations under the Conservation of Agricultural Resources Act, (Act 43 of 1983, Section 28 of the National Environmental Management Act (Act 107 of 1998) and the National National Environmental Management: Biodiversity Act (No. 10 of 2004). Removal of species should commence during the pre-construction and construction phases.
- Species specific and area specific eradication recommendations:
  - Care should be taken with the choice of herbicide to ensure that no additional impact and loss of indigenous plant species occurs due to the herbicide used. The use of herbicides must be limited and only be used under strict control and when no other alternative exists.
  - Footprint areas should be kept as small as possible when removing alien plant species.
- Also refer to mitigation measures listed under Section 7.1.1.

Essential operation phase mitigation measures

- Temporary access roads and other impacted areas not required for operations of the slimes dam are to be rehabilitated as soon as possible, in order to reduce the risk of erosion and further impacts on local flora.
- Removal of alien vegetation should continue and be continuously monitored for the duration the operational phase.

With Management	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
	3	2	3	2	3	5	8	40 (Low)

Probable latent impacts

- Proliferation of alien and invasive species in disturbed areas will lead to loss of floral biodiversity within the area surrounding the study area.
- Loss of floral habitat may lead to permanently altered floral biodiversity.
- A decrease in floral species diversity may occur throughout the study area due to habitat transformation as a result of development activities.
- Ineffective rehabilitation may lead to permanent loss of floral biodiversity within the area.

7.1.3 IMPACT 3: Impact on floral SCC

Activities leading to impact

Pre-Construction	Construction	Operational
Infrastructure placement and design leading to overall loss of floral SCC and medicinal species	Site clearance and removal of vegetation leading to a direct loss of floral SCC and medicinal species and fragmentation of populations	An increase in alien plant species leading to loss of floral SCC and medicinal species by outcompeting these species
Inadequate design of infrastructure leading to pollution of soils and ground water which may lead to a loss of floral SCC and medicinal	Construction of infrastructure and access roads through sensitive habitat leading to a loss of floral SCC and medicinal species	Erosion and sedimentation as a result of operational activities leading to a loss of floral SCC, including medicinal species
	Vehicles accessing site through sensitive habitat leading to direct loss of floral species of conservation concern	Ongoing edge effects from developed areas on surrounding more natural areas leading to impacts on protected floral species within the natural veld areas surrounding the study area
	Poor control of vehicular movement and management of edge effects leading to impacts on protected floral species within the natural veld areas surrounding the study area	

Without Management	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
	5	3	3	2	5	8	10	80 (Medium-High)

Essential construction phase mitigation measures

- Floral SCC encountered within the development footprint, are to be relocated as appropriate. This specifically relates to *Boophane disticha* and *Euphorbia* species which can be successfully rescued and relocated.
- Floral SCC are to be handled with care and the relocation of these plant species to suitable similar habitat is to be overseen by a botanist.
- A permit to relocate floral SCC protected under NCNCA (Act 9 of 2009) must be obtained from relevant departments for their removal or relocation prior to the construction phase.
- Permits must be obtained for the destruction of approximately 1470 (no.) *Vachellia erioloba* and 2089 (no.) *V. haematoxylon* under the National Forests Act (Act 84 of 1998) prior to the construction phase.
- No *Vachellia erioloba* or *V. haematoxylon* are to be needlessly destroyed and such activities must strictly be limited to specimens falling directly within the project footprint.
- It is recommended that, should such permits be obtained, the wood from felled *Vachellia erioloba* and *V. haematoxylon* be made available for use by local communities.

Essential operation phase mitigation measures

- Harvesting of floral species by mining and operational personnel within adjacent areas should be strictly prohibited.
- Monitoring of relocation success of *Boophane disticha* and *Euphorbia species* should continue during the operational phase.

With Management	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
	5	3	2	1	4	8	7	56 (Medium-Low)

Probable latent impacts

- A decrease in floral SCC numbers and diversity may lead to a loss of species richness over time within the region.
- Permanent loss of floral SCC habitat may occur.

7.2 Impact Assessment Conclusion

Based on the above impact assessment it is evident that there are three possible impacts on the floral ecology associated with the study area. The table below summarise the findings, indicating the significance of the impacts before management takes place and the likely impact if management and mitigation takes place. From the table, it is evident that after mitigation, all potential floral impacts may be reduced from Medium-High and Medium-Low to Medium-Low and Low significance levels.

Table 4: Summary of the results obtained from the assessment of floral ecological impacts.

Impact	Unmanaged	Managed
1: Impact on habitat for floral species	Medium-Low	Low
2: Impact on floral diversity	Medium-Low	Low
3: Impact on floral SCC	Medium-High	Medium-Low

7.3 Cumulative Impacts

Development of the proposed slimes dam within the study area will contribute to the cumulative loss of Kathu Bushveld within the region. However, due to the relatively small development footprint and due to the study area being located immediately adjacent to an existing slimes dam, whereby edge effects have already impacted to some degree on the ecological integrity of the northern portions of the study area, the cumulative impact of the development is not considered to be significant.

7.4 No-Go Alternative

Should the development of a slimes dam within the study area not take place, no direct loss of habitat within the study area will occur and the *Vachellia erioloba* and *V. haematoxylon* trees present will remain intact. It is however important to note, that even if no development of the study area takes place, its location immediately adjacent to existing mining activity in the north and west is likely to lead to habitat deterioration over time because of edge effects.

8 SUMMARY OF MITIGATION MEASURES

After conclusion of this ecological assessment, it is the opinion of the ecologists that the proposed slimes dam development be considered favourably provided that the following essential mitigation measures as listed below are adhered to:

Development Footprint

- The boundaries of the development footprint areas are to remain as small as possible, be clearly defined and it should be ensured that all activities remain within defined footprint areas.
- Placement of temporary roads and access routes should be limited to existing roads or should be placed immediately adjacent to the proposed slimes dam footprint.
- Vehicles should be restricted to travelling only on designated and existing roadways to limit the ecological footprint of the proposed development activities.

Edge effects (erosion and alien species)

- Edge effects of all construction activities, such as erosion and alien plant species proliferation, which may affect floral habitat, need to be strictly managed in adjacent natural areas. Alien species should be eradicated and controlled to prevent their spread beyond the mine development footprint areas. Specific mention is made of *Echinopsis schickendantzii* as encountered in the study area, as well as *Prosopis glandulosa* and *Verbesina encelioides* known to occur in the region (but not encountered in the study area), and the prevention and control *Senegalia mellifera* subsp *detinens* encroachment.
- To prevent the erosion of top soils, management measures may include berms, soil traps, hessian curtains and stormwater diversion away from any areas susceptible to erosion.
- Ongoing management of edge effects such as erosion and alien vegetation control and monitoring must take place during the operational phase, as well as control of soil contamination, as salinisation of soils could severely affect floral and faunal habitat.

Waste material, discharge and contamination

- It must be ensured that construction related waste does not affect surrounding natural areas.
- It must be ensured that the mine process water system is managed in such a way as to prevent discharge to the receiving environment.
- If any soils are contaminated, it should be stripped and disposed of at a registered hazardous waste dumping site.

Stormwater

- Adequate stormwater management must be incorporated into the design of the proposed development throughout all phases in order to prevent erosion of topsoil and the loss of adjacent floral habitat. In this regard, special mention is made of containment of runoff of the facilities.

Vehicles

- In the event of a vehicle breakdown, maintenance of vehicles must take place with care and the recollection of spillage should be practiced near the surface area to prevent ingress of hydrocarbons into topsoil and subsequent habitat loss.

Soils

- All soils compacted as a result of construction activities falling outside of development footprint areas should be ripped and profiled.

Fires

- Informal fires in the vicinity of development construction areas should be prohibited.

Rehabilitation

- All disturbed surrounding habitat areas, including temporary access roads and other impacted areas not required for the mining operations must be rehabilitated (ripped, scarified and re-vegetated with suitable indigenous grass species that will aid in soil stabilisation) as soon as possible.

Floral SCC

- Floral SCC encountered within the development footprint, are to be relocated as appropriate. This specifically relates to *Boophane disticha* and *Euphorbia* species which can be successfully rescued and relocated.
- Floral SCC are to be handled with care and the relocation of these plant species to suitable similar habitat is to be overseen by a botanist.

- A permit to relocate floral SCC protected under NCNCA (Act 9 of 2009) are to be obtained from relevant departments for their removal or relocation.
- Permits are to be obtained for the destruction of approximately 1470 *Vachellia erioloba* and 2089 *V. haematoxylon* under the National Forests Act (Act 84 of 1998).
- No *Vachellia erioloba* or *V. haematoxylon* are to be needlessly destroyed and such activities must strictly be limited to specimens falling directly within the project footprint.
- It is recommended that, should such permits be obtained, the wood from felled *Vachellia erioloba* and *V. haematoxylon* be made available for use by local communities.
- Harvesting of floral species by mining and operational personnel within adjacent areas should be strictly prohibited.
- Monitoring of relocation success of *Boophane disticha* and *Euphorbia species* should continue during the operational phase.

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APPENDIX A - Legislative Requirements

National Environmental Management Act (NEMA; Act 107 of 1998)

The National Environmental Management Act (NEMA; Act 107 of 1998) and the associated Environmental Impact Assessment (EIA) Regulations (GN R982 of 2014) and well as listing notices 1, 2 and 3 (GN R983, R984 and R985 of 2014), state that prior to any development taking place which triggers any activity as listed within the abovementioned regulations, an environmental authorisation process needs to be followed. This could follow either the Basic Assessment process or the EIA process depending on the nature of the activity and scale of the impact.

Mineral and Petroleum Resources Development Act (MPRDA; Act 22 of 2002)

The primary environmental objective of the Minerals and Petroleum Resource Development Act (MPRDA; Act 22 of 2002) is to give effect to the environmental right contained in the South African Constitution. Furthermore, Section 37(2) of the MPRDA (Act 22 of 2002) states that “any prospecting or mining operation must be conducted in accordance with generally accepted principles of sustainable development by integrating social, economic and environmental factors into the planning and implementation of prospecting and mining projects in order to ensure that exploitation of mineral resources serves present and future generations”.

Note that legislation and guidelines specifically applicable to floral SCC is included in Section 2.2.

National Environmental Management: Biodiversity Act (NEMBA; Act 10 of 2004) National Threatened or Protected Species Regulations, 2013

Chapter 4, Part 2 of the National Environmental Management: Biodiversity Act (NEMBA; Act 10 of 2004) provides for listing of Threatened or Protected Species (TOPS). If a species is listed as threatened, it must be further classified as critically endangered, endangered or vulnerable. The Act defines these classes as follows:
Critically Endangered species: any indigenous species facing an extremely high risk of extinction in the wild in the immediate future;
Endangered species: any indigenous species facing a high risk of extinction in the wild in the near future, although it is not a critically endangered species;
Vulnerable species: any indigenous species facing an extremely high risk of extinction in the wild in the medium-term future; although it is not a critically endangered species or an endangered species.
Protected species: “any species which is of such high conservation value or national importance that it requires national protection”. Species listed in this category will include, among others, species listed in terms of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Certain activities, known as Restricted Activities, are regulated on listed species using permits by a special set of regulations published under the Act. Restricted activities regulated under the act are keeping, moving, having in possession, importing and exporting, and selling.

National Forests Act (Act 84 of 1998) Protected Tree Species

In terms of Section 15(1) the National Forests Act (Act 84 of 1998) an amended list of protected tree species has been published November 2014. According to this Act protected tree species may not be cut, disturbed, damaged or destroyed and their products may not be possessed, collected, removed, transported, exported, donated, purchased or sold - except under licence granted by the Department of Water and Sanitation (DWS) or a delegated authority. Applications for such activities should be made to the responsible official in each province. Each application is evaluated on merit (including site visits) before a decision is taken whether or not to issue a licence (with or without conditions). Such decisions must be in line with national policy and guidelines.

Northern Cape Nature Conservation Act (NCNCA; Act 9 of 2009)

According to the NCNCA (2009) the following are applicable in terms of protected floral species, as listed in Schedules, 1- 3 and 6 of the Act.

Restricted activities involving specially protected plants:
49 (1) No person may, without a permit-

- Pick;
- Import;
- Export;
- Transport;
- Possess;
- Cultivate; or
- Trade in, a specimen of a specially protected plant

Restricted activities involving protected plants
50 (1) Subject to the provision of section 52, no person may, without a permit-

- Pick;
- Import;
- Export;
- Transport;
- Cultivate; or
- Trade in, a specimen of a protected plant.

APPENDIX B - Floral Method of Assessment

Floral Species of Conservational Concern Assessment

Prior to the field visit, a record of floral SCC and their habitat requirements was acquired from SANBI for the Quarter Degree Square in which the study area is situated, as well as relevant regional, provincial and national lists. Throughout the floral assessment, special attention was paid to the identification of any of these SCC as well as the identification of suitable habitat that could potentially support these species.

The Probability of Occurrence (POC) for each floral SCC was determined using the following calculations wherein the distribution range for the species, specific habitat requirements and level of habitat disturbance were considered. The accuracy of the calculation is based on the available knowledge about the species in question, with many of the species lacking in-depth habitat research.

Each factor contributes an equal value to the calculation.

Distribution						
	Outside of known distribution range					**Inside known distribution range**
Site score						
EVC 1 score	0	1	2	3	4	5
Habitat availability						
	No habitat available					**Habitat available**
Site score						
EVC 1 score	0	1	2	3	4	5
Habitat disturbance						
	0	**Very low**	**Low**	**Moderate**	**High**	**Very high**
Site score						
EVC 1 score	5	4	3	2	1	0

[Distribution + Habitat availability + Habitat disturbance] / 15 x 100 = POC%

Floral Habitat Sensitivity

The floral habitat sensitivity of each habitat unit was determined by calculating the mean of five different parameters which influence floral communities and provide an indication of the overall floristic ecological integrity, importance and sensitivity of the habitat unit. Each of the following parameters are subjectively rated on a scale of 1 to 5 (1 = lowest and 5 = highest):

- **Floral SCC:** The confirmed presence or potential for floral SCC or any other significant species, such as endemics, to occur within the habitat unit;
- **Unique Landscapes:** The presence of unique landscapes or the presence of an ecologically intact habitat unit in a transformed region;
- **Conservation Status:** The conservation status of the ecosystem or vegetation type in which the habitat unit is situated based on local, regional and national databases;
- **Floral Diversity:** The recorded floral diversity compared to a suitable reference condition such as surrounding natural areas or available floristic databases; and
- **Habitat Integrity:** The degree to which the habitat unit is transformed based on observed disturbances which may affect habitat integrity.

Each of these values contribute equally to the mean score, which determines the floral habitat sensitivity class in which each habitat unit falls. A conservation and land-use objective is also assigned to each sensitivity class which aims to guide the responsible and sustainable utilization of the habitat unit in question. In order to present the results use is made of spider diagrams to depict the significance of each aspect of floral ecology for each vegetation type. The different classes and land-use objectives are presented in the table below:

Table B1: Floral habitat sensitivity rankings and associated land-use objectives.

Score	Rating significance	Conservation objective
1> and <2	Low	Optimise development potential.
2> and <3	Moderately low	Optimise development potential while improving biodiversity integrity of surrounding natural habitat and managing edge effects.
3> and <4	Intermediate	Preserve and enhance biodiversity of the habitat unit and surrounds while optimising development potential.
4> and <5	Moderately high	Preserve and enhance the biodiversity of the habitat unit limit development and disturbance.
5	High	Preserve and enhance the biodiversity of the habitat unit, no-go alternative must be considered.

APPENDIX C – Impact Assessment Methodology

In order for the EAP to allow for sufficient consideration of all environmental impacts, impacts were assessed using a common, defensible method of assessing significance that will enable comparisons to be made between risks/ impacts and will enable authorities, stakeholders and the client to understand the process and rationale upon which risks/ impacts have been assessed. The method to be used for assessing risks/ impacts is outlined in the sections below.

The first stage of risk/ impact assessment is the identification of environmental activities, aspects and impacts. This is supported by the identification of receptors and resources, which allows for an understanding of the impact pathway and an assessment of the sensitivity to change. The definitions used in the impact assessment are presented below.

- An **activity** is a distinct process or task undertaken by an organisation for which a responsibility can be assigned. Activities also include facilities or infrastructure possessed by an organisation.
- An **environmental aspect** is an 'element of an organizations activities, products and services which can interact with the environment'[1]. The interaction of an aspect with the environment may result in an impact.
- **Environmental risks/impacts** are the consequences of these aspects on environmental resources or receptors of particular value or sensitivity, for example, disturbance due to noise and health effects due to poorer air quality. In the case where the impact is on human health or wellbeing, this should be stated. Similarly, where the receptor is not anthropogenic, then it should, where possible, be stipulated what the receptor is.
- **Receptors** can comprise, but are not limited to, people or human-made systems, such as local residents, communities and social infrastructure, as well as components of the biophysical environment such as wetlands, flora and riverine systems.
- **Resources** include components of the biophysical environment.
- **Frequency of activity** refers to how often the proposed activity will take place.
- **Frequency of impact** refers to the frequency with which a stressor (aspect) will impact on the receptor.
- **Severity** refers to the degree of change to the receptor status in terms of the reversibility of the impact; sensitivity of receptor to stressor; duration of impact (increasing or decreasing with time); controversy potential and precedent setting; threat to environmental and health standards.
- **Spatial extent** refers to the geographical scale of the impact.
- **Duration** refers to the length of time over which the stressor will cause a change in the resource or receptor.

The significance of the impact is then assessed by rating each variable numerically according to the defined criteria. Refer to the below. The purpose of the rating is to develop a clear understanding of influences and processes associated with each impact. The severity, spatial scope and duration of the impact together comprise the consequence of the impact and when summed can obtain a maximum value of 15. The frequency of the activity and the frequency of the impact together comprise the likelihood of the impact occurring and can obtain a maximum value of 10. The values for likelihood and consequence of the impact are then read off a significance rating matrix and are used to determine whether mitigation is necessary[2].

[1] The definition has been aligned with that used in the ISO 14001 Standard.

[2] Some risks/impacts that have low significance will however still require mitigation

The assessment of significance is undertaken twice. Initial significance is based only natural and existing mitigation measures (including built-in engineering designs). The subsequent assessment takes into account the recommended management measures required to mitigate the impacts. Measures such as demolishing infrastructure, and reinstatement and rehabilitation of land, are considered post-mitigation.

The model outcome of the impacts was then assessed in terms of impact certainty and consideration of available information. The Precautionary Principle is applied in line with South Africa's National Environmental Management Act (No. 108 of 1997) (NEMA) in instances of uncertainty or lack of information by increasing assigned ratings or adjusting final model outcomes. In certain instances where a variable or outcome requires rational adjustment due to model limitations, the model outcomes have been adjusted.

LIKELIHOOD DESCRIPTORS

Table C1: Criteria for assessing significance of impacts

Probability of impact	**RATING**
Highly unlikely	1
Possible	2
Likely	3
Highly likely	4
Definite	5
Sensitivity of receiving environment	**RATING**
Ecology not sensitive/important	1
Ecology with limited sensitivity/importance	2
Ecology moderately sensitive/ /important	3
Ecology highly sensitive /important	4
Ecology critically sensitive /important	5

CONSEQUENCE DESCRIPTORS

Severity of impact	**RATING**
Insignificant / ecosystem structure and function unchanged	1
Small / ecosystem structure and function largely unchanged	2
Significant / ecosystem structure and function moderately altered	3
Great / harmful/ ecosystem structure and function largely altered	4
Disastrous / ecosystem structure and function seriously to critically altered	5
Spatial scope of impact	**RATING**
Activity specific/ < 5 ha impacted / Linear features affected < 100m	1
Development specific/ within the site boundary / < 100ha impacted / Linear features affected <	2
Local area/ within 1 km of the site boundary / < 2000ha impacted / Linear features affected < 3000m	3
Regional within 5 km of the site boundary / < 5000ha impacted / Linear features affected < 10 000m	4
Entire habitat unit / Entire system/ > 5000ha impacted / Linear features affected > 10 000m	5
Duration of impact	**RATING**
One day to one month	1
One month to one year	2
One year to five years	3
Life of operation or less than 20 years	4
Permanent	5

Table C2: Significance rating matrix

LIKELIHOOD (Frequency of activity + Frequency of impact)	CONSEQUENCE (Severity + Spatial Scope + Duration)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45
	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90
	7	14	21	28	35	42	49	56	63	70	77	84	91	98	105
	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
	9	18	27	36	45	54	63	72	81	90	99	108	117	126	135
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150

Table C3: Positive/Negative Mitigation Ratings

Significance Rating	Value	Negative Impact Management Recommendation	Positive Impact Management Recommendation
Very high	126-150	Critically consider the viability of proposed projects Improve current management of existing projects significantly and immediately	Maintain current management
High	101-125	Comprehensively consider the viability of proposed projects Improve current management of existing projects significantly	Maintain current management
Medium-high	76-100	Consider the viability of proposed projects Improve current management of existing projects	Maintain current management
Medium-low	51-75	Actively seek mechanisms to minimise impacts in line with the mitigation hierarchy	Maintain current management and/or proposed project criteria and strive for continuous improvement
Low	26-50	Where deemed necessary seek mechanisms to minimise impacts in line with the mitigation hierarchy	Maintain current management and/or proposed project criteria and strive for continuous improvement
Very low	1-25	Maintain current management and/or proposed project criteria and strive for continuous improvement	Maintain current management and/or proposed project criteria and strive for continuous improvement

The following points were considered when undertaking the assessment:

- Risks and impacts were analysed in the context of the project's area of influence encompassing:
  - Primary project site and related facilities that the client and its contractors develops or controls;
  - Areas potentially impacted by cumulative impacts for further planned development of the project, any existing project or condition and other project-related developments; and
  - Areas potentially affected by impacts from unplanned but predictable developments caused by the project that may occur later or at a different location.
- Risks/ Impacts were assessed for all stages of the project cycle including:
  - Pre-construction;

- Construction; and
- Operation.
- If applicable, transboundary or global effects were assessed;
- Individuals or groups who may be differentially or disproportionately affected by the project because of their disadvantaged or vulnerable status were assessed.
- Particular attention was paid to describing any residual impacts that will occur after rehabilitation.

Mitigation Measure Development

According to the Department of Mineral Resources (DMR; 2013) “Rich biodiversity underpins the diverse ecosystems that deliver ecosystem services that are of benefit to people, including the provision of basic services and goods such as clean air, water, food, medicine and fibre; as well as more complex services that regulate and mitigate our climate, protect people and other life forms from natural disaster and provide people with a rich heritage of nature-based cultural traditions. Intact ecological infrastructure contributes significant savings through, for example, the regulation of natural hazards such as storm surges and flooding by which is attenuated by wetlands”.

According to the DMR (2013), ecosystem services can be divided into four (4) main categories:

- Provisioning services are the harvestable goods or products obtained from ecosystems such as food, timber, fibre, medicine, and fresh water;
- Cultural services are the non-material benefits such as heritage landscapes and seascapes, recreation, ecotourism, spiritual values and aesthetic enjoyment;
- Regulating services are the benefits obtained from an ecosystem’s control of natural processes, such as climate, disease, erosion, water flows, and pollination, as well as protection from natural hazards; and
- Supporting services are the natural processes such as nutrient cycling, soil formation and primary production that maintain the other services.

Loss of biodiversity puts aspects of the economy, wellbeing and quality of life at risk, and reduces socio-economic options for future generations. This is of particular concern for the poor in rural areas who have limited assets and are more dependent on common property resources for their livelihoods. The importance of maintaining biodiversity and intact ecosystems for ensuring on-going provision of ecosystem services, and the consequences of ecosystem change for human well-being, were detailed in a global assessment entitled the Millennium Ecosystem Assessment (MEA, 2005), which established a scientific basis for the need for action to enhance management and conservation of biodiversity.

Sustainable development is enshrined in South Africa’s Constitution and laws. The need to sustain biodiversity is directly or indirectly referred to in a number of Acts, not least the National Environmental Management: Biodiversity Act (NEMBA) (No. 10 of 2004) and is fundamental to the notion of sustainable development. In addition, International guidelines and commitments as well as national policies and strategies are important in creating a shared vision for sustainable development in South Africa (DMR, 2013).

The primary environmental objective of the Minerals and Petroleum Resource Development Act (MPRDA; Act 22 of 2002) is to give effect to the environmental right contained in the South African Constitution. Furthermore, Section 37(2) of the MPRDA (Act 22 of 2002) states that “any prospecting or mining operation must be conducted in accordance with generally accepted principles of sustainable development by integrating social, economic and environmental factors into the planning and implementation of prospecting and mining projects in order to ensure that exploitation of mineral resources serves present and future generations”.

Pressures on biodiversity are numerous and increasing. According to the DMR (2013), loss of natural habitat is the single biggest cause of biodiversity loss in South Africa and much of the world. The most severe transformation of habitat arises from the direct conversion of natural habitat for human requirements, including[3]:

- Cultivation and grazing activities;
- Rural and urban development;
- Industrial and mining activities, and
- Infrastructure development.

Impacts on biodiversity can largely take place in four ways (DMR 2013):

- **Direct impacts:** are impacts directly related to the project including project aspects such as site clearing, water abstraction and discharge of water from riverine resources;
- **Indirect impacts:** are impacts associated with a project that may occur within the zone of influence in a project such as surrounding terrestrial areas and downstream areas on water courses;
- **Induced impacts:** are impacts directly attributable to the project but are expected to occur due to the activities of the project. Factors included here are urban sprawl and the development of associated industries; and
- **Cumulative impacts:** can be defined as the sum of the impact of a project as well as the impacts from past, existing and reasonably foreseeable future projects that would affect the same biodiversity resources. Examples include numerous mining operations within the same drainage catchment or numerous residential developments within the same habitat for faunal or floral species.

Given the limited resources available for biodiversity management and conservation, as well as the need for development, efforts to conserve biodiversity need to be strategic, focused and supportive of sustainable development. This is a fundamental principle underpinning South Africa's approach to the management and conservation of its biodiversity and has resulted the definition of a clear mitigation strategy for biodiversity impacts.

'Mitigation' is a broad term that covers all components of the 'mitigation hierarchy' defined hereunder. It involves selecting and implementing measures – amongst others – to conserve biodiversity and to protect, the users of biodiversity and other affected stakeholders from potentially adverse impacts as a result of mining or any other landuse. The aim is to prevent adverse impacts from occurring or, where this is unavoidable, to limit their significance to an acceptable level. Offsetting of impacts is considered to be the last option in the mitigation hierarchy for any project.

The mitigation hierarchy in general consists of the following in order of which impacts should be mitigated (DMR 2013):

- **Avoid/prevent impact:** can be done through utilising alternative sites, technology and scale of projects to prevent impacts. In some cases if impacts are expected to be too high the "no project" option should also be considered, especially where it is expected that the lower levels of mitigation will not be adequate to limit environmental damage and eco-service provision to suitable levels;
- **Minimise impact:** can be done through utilisation of alternatives that will ensure that impacts on biodiversity and ecoservices provision are reduced. Impact minimisation is considered an essential part of any development project;
- **Rehabilitate impact:** is applicable to areas where impact avoidance and minimisation are unavoidable where an attempt to re-instate impacted areas and return them to conditions which are ecologically similar to the pre-project condition or an agreed post project land use,

[3] North West Province Environment Outlook. A Report on the State of the Environment, 2008. Chapter 4.

for example arable land. Rehabilitation can however not be considered as the primary mitigation tool as even with significant resources and effort rehabilitation that usually does not lead to adequate replication of the diversity and complexity of the natural system. Rehabilitation often only restores ecological function to some degree to avoid ongoing negative impacts and to minimise aesthetic damage to the setting of a project. Practical rehabilitation should consist of the following phases in best practice:

- **Structural rehabilitation** which includes physical rehabilitation of areas by means of earthworks, potential stabilisation of areas as well as any other activities required to develop a long terms sustainable ecological structure;
- **Functional rehabilitation** which focuses on ensuring that the ecological functionality of the ecological resources on the study area supports the intended post closure land use. In this regard special mention is made of the need to ensure the continued functioning and integrity of wetland and riverine areas throughout and after the rehabilitation phase;
- **Biodiversity reinstatement** which focuses on ensuring that a reasonable level of biodiversity is re-instated to a level that supports the local post closure land uses. In this regard special mention is made of re-instating vegetation to levels which will allow the natural climax vegetation community of community suitable for supporting the intended post closure land use; and
- **Species reinstatement** which focuses on the re-introduction of any ecologically important species which may be important for socio-cultural reasons, ecosystem functioning reasons and for conservation reasons. Species re-instatement need only occur if deemed necessary.

➢ **Offset impact:** refers to compensating for latent or unavoidable negative impacts on biodiversity. Offsetting should take place to address any impacts deemed to be unacceptable which cannot be mitigated through the other mechanisms in the mitigation hierarchy. The objective of biodiversity offsets should be to ensure no net loss of biodiversity. Biodiversity offsets can be considered to be a last resort to compensate for residual negative impacts on biodiversity.

The significance of residual impacts should be identified on a regional as well as national scale when considering biodiversity conservation initiatives. If the residual impacts lead to irreversible loss or irreplaceable biodiversity the residual impacts should be considered to be of very high significance and when residual impacts are considered to be of very high significance, offset initiatives are not considered an appropriate way to deal with the magnitude and/or significance of the biodiversity loss. In the case of residual impacts determined to have medium to high significance, an offset initiative may be investigated. If the residual biodiversity impacts are considered of low significance no biodiversity offset is required.[4]

In light of the above discussion the following points present the key concepts considered in the development of mitigation measures for the proposed development.

➢ Mitigation and performance improvement measures and actions that address the risks and impacts[5] are identified and described in as much detail as possible.

➢ Measures and actions to address negative impacts will favour avoidance and prevention over minimisation, mitigation or compensation.

➢ Desired outcomes are defined, and have been developed in such a way as to be measurable events with performance indicators, targets and acceptable criteria that can be tracked over defined periods, with estimates of the resources (including human resource and training requirements) and responsibilities for implementation wherever possible.

[4] Provincial Guideline on Biodiversity Offsets, Western Cape, 2007.
[5] Mitigation measures should address both positive and negative impacts

APPENDIX D - Vegetation Type

Kathu Bushveld Vegetation Type

Distribution
The Kathu Bushveld vegetation type occurs within the Northern Cape Province on plains from Kathu and Dibeng in the south, through Hotazel, in the vicinity of Frylinckspan and up to the Botswana border roughly between Van Zylsrus and McCarthysrus on altitudes varying from 960-1300m (Mucina & Rutherford, 2006).

Climate
The region is characterised by summer and autumn rainfall with very dry winters. The Mean Annual Temperature (MAP) is about 220-380mm, with frost frequently occurring in winter. The mean monthly maximum and minimum temperatures for are Sishen 37.0°C and -2.2°C for December and July, respectively (Mucina & Rutherford, 2006).

Geology and Soils
The vegetation type is characterised by aeolian red sand and surface calcrete and deep sandy soils (>1.2m) of Hutton and Clovelly soil forms. The land types present include mainly Ah and Ae, with some Ag (Mucina & Rutherford, 2006).

Conservation
In terms of conservation, the Kathu Bushveld vegetation type is considered Least Concern with a conservation target of 16%. The vegetation type is not represented in statutory conservation areas and more than 1% is already transformed, including the manganese ore mining locality at Sishen, one of the biggest open-cast mines in the world. Erosion is very low (Mucina & Rutherford, 2006).

Dominant Floral Taxa
The Kathu Bushveld vegetation type is characterised by a medium-tall layer with Vachellia erioloba in places, but mostly open and including Boscia albitrunca as the prominent trees. The shrub layer is generally most important with, for example *Senegallia mellifera, Diospyros lycioides* and *Lycium hirsutum*. The grass layer is variable in cover.

Dominant floral species associated with this vegetation type include:

- **Tall trees**: *Vachellia erioloba* (d*);
- **Small trees**: *Senegalia mellifera subsp. detinens (d), Boscia albitrunca (d), Terminalia sericea*;
- **Tall shrubs**: *Diospyros lycioides* subsp *lycioides (d), Dichrostachys cinerea, Grewia flava, Gymnosporia buxifolia, Rhigozum brevispinosum*;
- **Low shrubs**: *Aptosimum decumbens, Grewia retinervis, Nolletia arenosa, Sida cordifolia, Tragia dioica;*
- **Graminoids**: *Aristida meridionalis (d), Brachiaria nigropedata (d), Centropodia glauca (d), Eragrostis lehmanniana (d), Schmidtia pappophoroides (d), Stipagrostis ciliata (d), Aristida congesta, Eragrostis biflora, E. chloromelas, E. heteromera, E. pallens, Melinis repens, Schmidtia kalahariensis, Stipagrostis uniplumis, Tragus berteronianus*;
- **Herbs**: *Acrotome inflata, Erlangea misera, Gisekia africana, Heliotropium ciliatum, Hermbstaedtia fleckii, H. odorata, Limeum fenestratum, L. viscosum, Lotononis platycarps, Senna italica subsp. arachoides, Tribulus terrestris*.

*d: dominant species of the vegetation type

APPENDIX E – Vegetation List

Table E1: Dominant floral species encountered in the Open Bushveld Habitat Unit. Alien species are indicated with an asterisk and floral SCC are indicated in bold

Grass species	Forb species	Tree/Shrub Species
Aristida bipartita	**Chenopodium album*	*Asparagus laricinus*
Aristida congesta	**Echinopsis schickendantzii*	*Diospyros lycioides*
Aristida meridionalis	*Abutilon sp.*	*Grewia flava*
Aristida stipitata	*Aptosimum elongatum*	*Senegalia mellifera subsp. detinens*
Cenchrus ciliaris	*Berkeya* sp.	***Vachallia erioloba***
Digitaria eriantha	***Boophane disticha***	***Vachellia haematoxylon***
Enneapogon cenchroides	*Crotalaria orientalis*	*Vachellia hebeclada*
Eragrostis lehmanniana	*Chrycosoma ciliata*	
Eragrostis pallens	*Cucumis zeyheri*	
Fingerhuthia afriacana	*Dicoma capensis*	
Heteropogon contortus	*Dimorpotheca zeyheri*	
Schmidtia kalihariensis	***Euphorbia duseimata***	
Schmidtia pappophoroides	*Felicia muricata*	
Stipagrostis zeyheri	*Gnidia polycephala*	
	Helichrysum cerastioides	
	Hermannia comosa	
	Hirpidium sp.	
	Hoffmannreggia burchellii	
	Lycium hirsutum	
	Lycium sp.	
	Melolobium candicans	
	Monechma distichotrichum	
	Pentzia globosa	
	Pollicha campestris	
	Pteronia glauca	
	Senna italica subsp. *arachoides*	
	Tribulus zeyheri	

APPENDIX F - Declaration and Specialists CV’s

Declaration

Declaration that the specialist is independent in a form as may be specified by the competent authority

I, Nelanie Cloete, declare that –

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the relevant legislation and any guidelines that have relevance to the proposed activity;
- I will comply with the applicable legislation;
- I have not, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct.

Signature of the Specialist

SCIENTIFIC AQUATIC SERVICES (SAS) – SPECIALIST CONSULTANT

INFORMATION

CURRICULUM VITAE OF NELANIE CLOETE

PERSONAL DETAILS

Position in Company	Ecologist, Botanist specialist
Date of Birth	6 June 1983
Nationality	South African
Languages	English, Afrikaans
Joined SAS	2011

MEMBERSHIP IN PROFESSIONAL SOCIETIES

Professional member of the South African Council for Natural Scientific Professions (SACNASP 400503/14) - 2014
Member of the South African Association of Botanists (SAAB) - 2010
Member of the International Affiliation for Impact Assessments (IAIAsa) South Africa group - 2010
Member of the Grassland Society of South Africa (GSSA) - 2010
Member of the Botanical Society of South Africa (BotSoc) - 2016

EDUCATION

Qualifications

MSc Environmental Management (University of Johannesburg)	2013
MSc Botany (University of Johannesburg)	2007
BSc (Hons) Botany (University of Johannesburg)	2005
BSc (Botany and Zoology) (Rand Afrikaans University)	2004

Short Courses

Certificate – Department of Environmental Science in Legal context of Environmental Management, Compliance and Enforcement (UNISA)	2009
Introduction to Project Management - Free online course by the University of Adelaide	2016

COUNTRIES OF WORK EXPERIENCE

South Africa – Gauteng, Mpumalanga, North West, Limpopo, KwaZulu-Natal, Northern Cape
Democratic Republic of the Congo

SELECTED PROJECT EXAMPLES

Floral Assessments

- Floral assessment as part of the environmental assessment and authorisation process for the proposed Mzimvubu water project at Maclear, Eastern Cape.
- Floral assessment as part of the environmental authorisation process for the proposed Assmang Iron Ore Black Rock, Northern Cape Province.
- Floral assessment as part of the environmental authorisation process for the proposed Bloemwater Knellpoort water project pipeline assessment, Free State Province.
- Terrestrial ecological scan as part of the environmental authorisation process for the proposed Sappi Pipeline, Gauteng.
- Floral assessment as part of the proposed Setlagole Mall development, North West Province.

Wetland Assessments

- Consideration of potential wetland features on the proposed residential development on Vlakfontein Portion 50, Gauteng.

- Riparian Vegetation Index determination and wetland delineation for the proposed Doornkloof infrastructure, Gauteng.
- Wetland assessment along the proposed Powerline route, Delareyville, North West Province.
- Wetland delineation in the vicinity of a proposed mining development site, New Denmark Mine, Mpumalanga Province.

Basic Assessment (BA) and Environmental Impact Assessment (EIA) Reports

- EIA and Scoping report for the proposed new township development near Lubumbashi, DRC (4000ha).
- Basic Assessment report and process for a mixed use development, New Redruth, Gauteng.
- EIA and Scoping report for the proposed Lesotho border road, Free State Province (in progress).

Environmental and Ecological Management Plans

- External audits for the Environmental Management Plan for Bokoni Platinum Mine, Limpopo Province.
- Biodiversity Action plans for African Exploration, Mining and Finance Corporation in line with the NEMBA requirements.
- Biodiversity Action plans for Twickenham Platinum mining operations in line with the NEMBA requirements, Limpopo Province.
- Biodiversity Action plans for Bokoni Platinum mining operations in line with the NEMBA requirements, Limpopo Province.
- Environmental management plan for Erf 1086 New Redruth Extension 6, Gauteng Province.

Permit applications for protected tree and floral species

- Permit application for the removal of protected tree species for the Bushbuckridge Shopping Mall development within the Mpumalanga Province.
- Permit application for the removal and propagation of protected tree species for the Open Cast Operations within Bokoni Platinum Mine in the Limpopo Province.
- Permit application for the removal of protected tree species for Modikwa Mine within the Limpopo Province.
- Permit application for the removal of protected tree species for the Umfolozi Power line within the Kwa-Zulu Natal Province.

Water Use License Applications (WULA) and Risk Assessments

- External Water Use License audits for Bokoni Platinum Mine, Limpopo Province.
- General Authorisation for the commercial development of Erf 1086 New Redruth Extension 6, Gauteng Province.
- A Water Use License Application for the mixed development on the Gillimead Agricultural Holdings, Gauteng Province.
- A Water Use License Application for the Riba Cross Shopping Centre development, Limpopo Province.
- A Water Use License Application for the proposed upgrade of the Lesotho border road, Free State Province (in progress).
- A Risk Assessment for the proposed residential development in Fourways, Gauteng Province.
- A Water Use License Application for the proposed development of the Bylsbridge project, Centurion, Gauteng Province (in progress).