Groundwater Complete

NOZALA COAL (PTY) LTD
GRUISFONTEIN COAL PROJECT

REPORT FOR GEOHYDROLOGICAL INVESTIGATION AS PART OF THE WATER USE LICENSE APPLICATION AND ENVIRONMENTAL IMPACT ASSESSMENT

AUGUST 2019

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DECLARATION OF INDEPENDENCE AND SPECIALIST INFORMATION

I, Gerhard Steenekamp and Wiekus du Plessis (Groundwater Complete) declare that:

- We act as independent specialists in this application to Jacana Environmentals;
- We performed the work relating to the application in an objective manner, even if this results in views and findings that are not favorable to the applicant;
- We declare that there were no circumstances that may compromise our objectivity in performing such work;
- We have no vested financial, personal or any other interest in the application;
- We have no, and will not engage in, conflicting interests in the undertaking of the activity;
- We undertake to disclose to the applicant and the competent authority all material information in our 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 ourselves for submission to the competent authority; and
- All the particulars furnished by us in this form are true and correct.

Wiekus du Plessis is a geohydrologist with 10 years' experience in all consulting aspects of geohydrology. He holds a Master's degree in Geohydrology and is registered with the South African Council for Natural Scientific Professions as a Water Resource Science Professional (registration number 400148/15).

He provides groundwater consulting service to the whole spectrum of geohydrological related projects, from groundwater supply, management plans, monitoring, interpretation, groundwater quality management and remediation of groundwater pollution for projects ranging from diamond, coal, platinum, chromium, anthracite, base mineral and metal mining to power stations. He also has experience in performing numerical modeling and calculations for mine closure purposes and post closure planning.

Gerhard Steenekamp
Pr.Sci.Nat. 400385/04

Wiekus du Plessis
Pr.Sci.Nat. 400148/15

August 2019

LEGAL REQUIREMENTS FOR ALL SPECIALIST STUDIES CONDUCTED

Legal Requirement		Relevant Section in Specialist study
(1)	A specialist report prepared in terms of these Regulations must contain-	
(a)	details of-	
	(i) the specialist who prepared the report; and	Page 1
	(ii) the expertise of that specialist to compile a specialist report including a curriculum vitae	Page 1
(b)	a declaration that the specialist is independent in a form as may be specified by the competent authority;	Page 1
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	Sections 1 & 3
(cA)	an indication of the quality and age of base data used for the specialist report;	Section 4.1
(cB)	a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	Section 7.9
(d)	the duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Section 4.2
(e)	a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	Sections 3 & 4
(f)	details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	N/A
(g)	an identification of any areas to be avoided, including buffers;	N/A
(h)	a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	N/A
(i)	a description of any assumptions made and any uncertainties or gaps in knowledge;	Section 7.1
(j)	a description of the findings and potential implications of such findings on the impact of the proposed activity or activities;	Section 8
(k)	any mitigation measures for inclusion in the EMPr;	Section 8
(l)	any conditions for inclusion in the environmental authorisation;	None

Legal Requirement		Relevant Section in Specialist study
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Section 9
(n)	a reasoned opinion:	
	whether the proposed activity, activities or portions thereof should be authorised;	None
	regarding the acceptability of the proposed activity or activities; and	None
	if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	Section 8
(o)	a description of any consultation process that was undertaken during the course of preparing the specialist report;	Section 4.2
(p)	a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	None
(q)	any other information requested by the competent authority.	None

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GRUISFONTEIN COAL PROJECT: REPORT ON GEOHYDROLOGICAL INVESTIGATION AS PART OF THE WATER USE LICENSE APPLICATION AND ENVIRONMENTAL IMPACT ASSESSMENT, AUGUST 2019

EXECUTIVE SUMMARY:

Groundwater Complete was contracted by Jacana Environmentals CC to conduct a geohydrological study and report on findings as specialist input to the Water Use License Application (WULA), Environmental Impact Assessment (EIA) and other environmental authorizations for the proposed Gruisfontein Coal Mining Project – hereinafter only referred to as Gruisfontein.

The project has a life-of-mine (LOM) of approximately 16 years during which the coal reserves will be extracted using the conventional truck and shovel opencast mining method. Mining related infrastructure includes a processing plant, temporary and long-term discard dumps, overburden dumps, product stockpile, water management and other supporting infrastructure. The processed product will be transported via road to the Medupi or/and Matimba power station. The discard and overburden material generated over the LOM will be placed back into the pit during the closure/decommissioning phase.

The main aim or objective of this study was to determine the potential groundwater quality and water level impacts associated with the proposed new opencast coal mining and related activities.

The following conclusions and recommendations are based on the findings of the groundwater investigation that was conducted for Gruisfontein.

Conclusions – Geohydrological Environment:

- There is no documented surface drainage feature in the immediate vicinity of Gruisfontein. The flat topography and deep sandy soils result in a very low run-off component in the area. The dominant surface drainage feature is the perennial Limpopo River, which flows from south-west to north-east and passes about 6.5 km to the north-west of Gruisfontein.
- The MRA area receives on average approximately 408 mm of rainfall annually.
- A hydrocensus/groundwater user survey was conducted on and around Gruisfontein by Aquatico Scientific in November 2018 during which a total of 33 boreholes or other groundwater localities were located. The equipped private user boreholes were found to be used for domestic and/or livestock watering, or a combination of the two.
- Recharge to the fractured rock aquifer underlying the MRA area was estimated to be in the region of 1.5% of the mean annual rainfall.
- The MRA area is generally underlain by sedimentary rocks of the Karoo Supergroup, more specifically shale and sandstone of the Vryheid Formation (Ecca Group) and mudstones of the Beaufort Group. All seams/coal zones are covered by some 30 m to 100 m of non-coal bearing superficial deposits referred to as overburden.

- Geological structures in the form of faults are known to cut through the Gruisfontein MRA area, which generally trend east-west with mostly sub-vertical displacement. Fractures and discontinuities have the potential to store and transmit significant volumes of groundwater and are therefore of significant geohydrological importance.
- Based on the findings of geochemical tests that were conducted for the nearby Temo Coal Project, all material (overburden, inter burden and discard) is potentially acid generating over the long term.
- Based on the exploration drilling results and widespread water level measurements, the unsaturated zone is predominantly composed of sandy soil followed by mudstone and shale. The average thickness of the unsaturated zone (where no impacts from groundwater abstraction occur) is in the order of 18 to 20 meters.
- Constant rate pumping tests were performed on all four user boreholes located within the Gruisfontein MRA area. A mean matrix transmissivity of 1.0 m^2/d was calculated and an average hydraulic conductivity of approximately 0.033 m/d.
- Groundwater level depths vary between approximately 9 and 31 meters below surface (mbs), while elevations of between 805 and 856 meters above mean sea level (mamsl) were observed. Groundwater flow from the MRA area is towards the west/north-west in the direction of the perennial Limpopo River.
- Groundwater from most user boreholes is suitable for human consumption and domestic use according to the South African National Standards *(SANS 241:2015)*. Exceptions do however occur with some elevated inorganic salinities (TDS, chloride, sodium) exceeding the maximum concentrations allowed in drinking water. The highest risk borehole in terms of drinking water for humans and even livestock is WB28 with a nitrate content of 162 mg/l.
- The aquifer underlying the MRA area scored a groundwater vulnerability rating of 8 and is therefore regarded as having a medium vulnerability.
- Two aquifer systems are present, namely a shallow aquifer (minor/non-aquifer) composed of soil and weathered bedrock, and a deeper fractured rock aquifer (minor/sole-aquifer) hosted within the sedimentary rocks of the Karoo Supergroup.
- The GQM rating for Gruisfontein calculates to 12, which indicates a very high level of protection where strictly no groundwater degradation is allowed. The high score is a direct result of the aquifer's classification as a sole-source aquifer.

Conclusions – Numerical Groundwater Modelling:

The potential groundwater quality and water level impacts associated with the proposed new opencast mining and related activities were simulated/predicted with a numerical groundwater flow and contaminant transport model and the results are summarised below:

- The pit floor was simulated to intersect the groundwater level throughout the entire life of mine and the model simulated groundwater inflow volumes for each year are as follows:

Stress period/Year	Volume (m^3/d)	Volume (l/s)
1	290	3.4
2	450	5.2
3	480	5.6
4	570	6.6

Stress period/Year	Volume (m^3/d)	Volume (l/s)
5	520	6.0
6	520	6.0
7	560	6.5
8	600	6.9
9	620	7.2
10	640	7.4
11	600	6.9
12	660	7.6
13	610	7.1
14	660	7.6
15	620	7.2
16	670	7.8

- The affected area (i.e. groundwater depression cone) was simulated to increase throughout the life of mine from approximately 0.27 km^2 during year 1 to ±3.43 km^2 at the end of the 16th and final year of mining.
- **Note that the water level impacts were simulated to remain within the MRA area. The water levels of outside user boreholes are consequently expected to remain unaffected by the proposed opencast mining at Gruisfontein.**
- The maximum water level drawdown was simulated to increase from more or less 39 meters to a maximum of ±90 meters at mine closure.
- Water levels were simulated not to have fully recovered from the impacts of pit dewatering after a post closure simulation time of 50 years. The backfilled pit is consequently expected to remain a groundwater/contamination sink long after mine closure.
- Residual contamination from the rehabilitated surface source areas was simulated to migrate towards the pit, while contamination generated by the pit was simulated to remain restricted to its borders.
- The maximum plume concentrations were simulated to increase from approximately 20% at mine closure to ±60% at 50 years post closure, or 600 mg/l to 1 800 mg/l respectively if the source had a constant sulphate concentration of 3 000 mg/l.
- **Note that the groundwater quality impacts (i.e. contamination plumes) were simulated to remain within the MRA area and more specifically concentrated at the pit position. The water quality of outside user boreholes is consequently expected to remain unaffected by the proposed opencast mining and related activities.**

Conclusions – Decant Predictions:

- The expected time it will take the backfilled Gruisfontein pit to fill with water was calculated with the use of volume/recharge calculations to be in the region of 160 years post closure.
- Post closure decanting of the rehabilitated pit is expected to occur at a surface elevation of ±856 meters above mean sea level (mamsl) and at an estimated rate of approximately 150 m^3/d, or 1.7 l/s. Given the topography, geological profile and

climate of the area it is our opinion that this water is not expected to daylight as actual decant.
- The pit water is expected to be of poor quality due to the high potential of the backfill material to generate sulphuric acid over the long term.

Recommendations:
- Post closure recharge to the backfilled opencast pit is expected to be more or less seven times higher (10% of MAP) than the pre-mining figure of approximately 1.5%. The aquifer's response to this increase should be monitored and a dedicated water level monitoring borehole should ideally be drilled into the backfilled pit for this purpose.
- Groundwater monitoring (i.e. sampling and water level measurements) should be conducted at quarterly intervals and the schedule re-assessed by a qualified geohydrologist at a later stage in terms of stability of water levels and quality. If the sampling program requires changes, it should be done so in consultation with the appropriate authorities.
- Groundwater samples should be analysed at a SANAS accredited laboratory for chemical and physical constituents normally associated with a coal mining environment.
- Site specific geochemical tests should be conducted at Gruisfontein for confirmation of the acid generating potential of the underlying Karoo rocks.
- Twelve dedicated source monitoring boreholes are deemed necessary.
- Borehole positions should be finalised with the aid of a geophysical survey, preferably not magnetic.
- A borehole depth of 30 meters is usually sufficient in a coal mining environment. Steel casing should be inserted well through the loose weathered zone, and perforated PVC casing the full length/depth of the borehole. A concrete collar should be constructed around the completed borehole, which will help support the steel casing and prevent surface water runoff from flowing into the borehole.
- Boreholes should be completed with a lockable cap to prevent vandalism, and clearly marked in the field with a nameplate.

BH	Coordinates *(WGS 84)*		Elevation (mamsl)	Depth (m)	Comment
	South	East			
GRU01	-23.5804	27.2724	862	37	Existing borehole downgradient from proposed stockpiles
MBH01	-23.5605	27.2830	856	30	Downgradient from pollution control dam
MBH02	-23.5634	27.2817	856	30	Downgradient from hard overburden dump
MBH03	-23.5634	27.2850	857	30	Downgradient from discard dump
MBH04	-23.5749	27.2855	862	30	Downgradient from discard dump
MBH05	-23.5843	27.2700	862	30	Downgradient from plant area

BH	Coordinates *(WGS 84)*		Elevation (mamsl)	Depth (m)	Comment
	South	East			
MBH06	-23.5801	27.2676	860	30	Downgradient from 3-year temporary discard dump
MBH07	-23.5798	27.2651	860	30	Downgradient from pollution control dam
MBH08	-23.5663	27.2700	856	30	Downgradient from potential pit decant position

1 INTRODUCTION AND OBJECTIVE

Groundwater Complete was contracted by Jacana Environmentals CC to conduct a geohydrological study and report on findings as specialist input to the Water Use License Application (WULA), Environmental Impact Assessment (EIA) and other environmental authorizations for the proposed Gruisfontein Coal Mining Project – hereinafter only referred to as Gruisfontein.

The mining rights application (MRA) area is located on the farm Gruisfontein 230-LQ situated approximately 50 kilometers north-west of Lephalale, 15 km north of Steenbokpan and just 8 km south of the Limpopo River. A map showing the location of the farm Gruisfontein is provided in **Figure 1**.

The project has a life-of-mine (LOM) of approximately 16 years during which the coal reserves will be extracted using the conventional truck and shovel opencast mining method. Mining related infrastructure includes a processing plant, temporary and long-term discard dumps, overburden dumps, product stockpile, water management and other supporting infrastructure. The processed product will be transported via road to the Medupi or/and Matimba power station. The discard and overburden material generated over the LOM will be placed back into the pit during the closure/decommissioning phase.

The main aim or objective of this study was to determine the potential groundwater quality and water level impacts associated with the proposed new opencast coal mining and related activities.

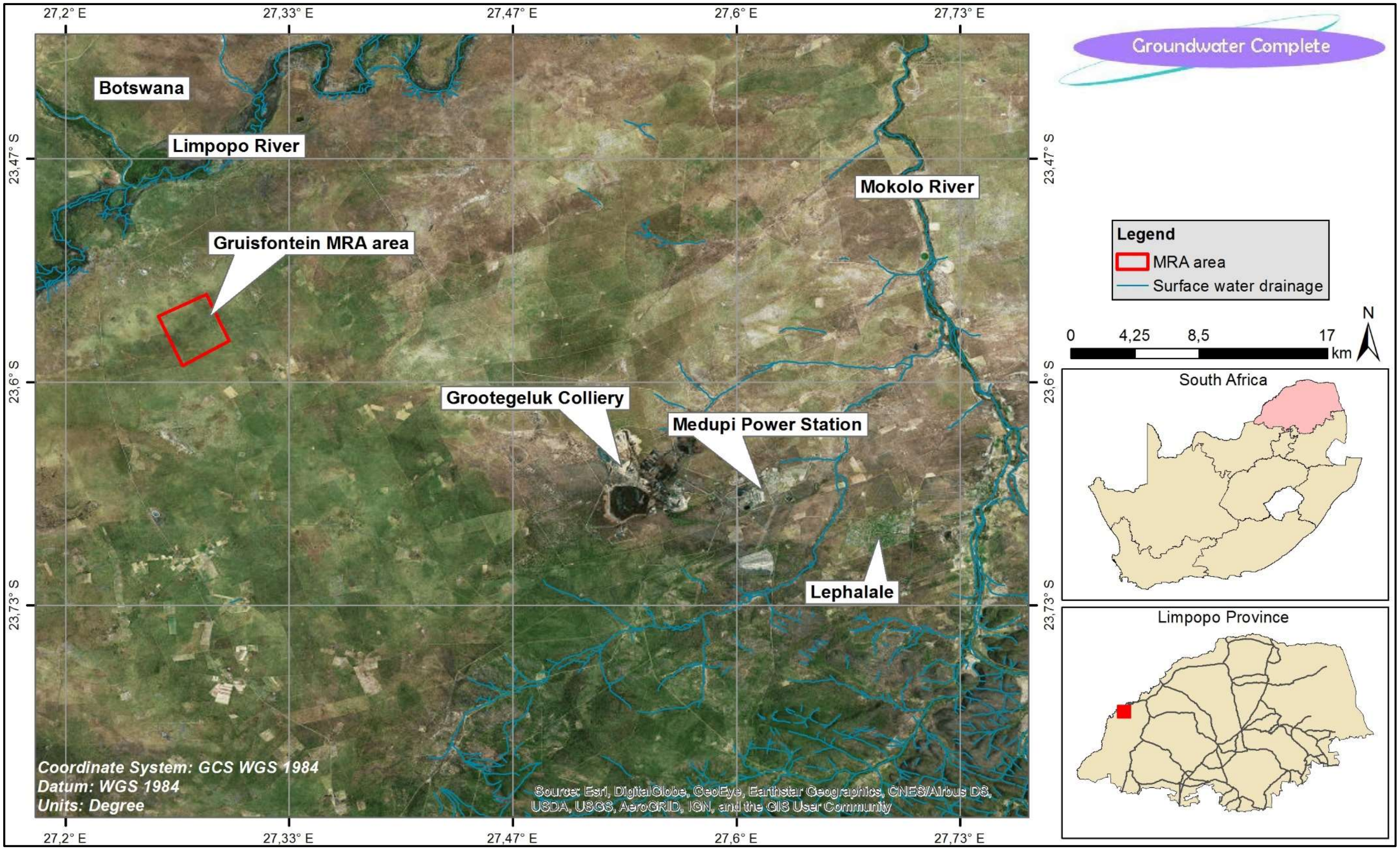

Figure 1: Locality map of the Gruisfontein project area

2 GEOGRAPHICAL SETTING

2.1 SURFACE TOPOGRAPHY AND WATER COURSES

The surface topography around Gruisfontein can be described as being relatively flat with a very slight and gentle slope of approximately 0.4% towards the north-west. Surface elevations vary between approximately 870 meters above mean sea level (mamsl) in the south and ± 840 mamsl **(Figure 2)** in the north.

There is no documented surface drainage feature in the immediate vicinity of Gruisfontein. The flat topography and deep sandy soils result in a very low run-off component in the area. The dominant surface drainage feature is the Limpopo River, which flows from south-west to north-east and passes about 6.5 km to the north-west of Gruisfontein. The Limpopo River also forms the boundary between South Africa and Botswana. The Gruisfontein project area is located within the A41E quaternary catchment, which covers an area of nearly 1 950 km^2. Surface elevations and water courses for the project area are indicated in **Figure 2**.

Note that there is no drainage in the immediate vicinity of Gruisfontein and surface water is therefore not considered to be a sensitive receptor of groundwater impacts that may potentially originate from the proposed coal mining and related activities.

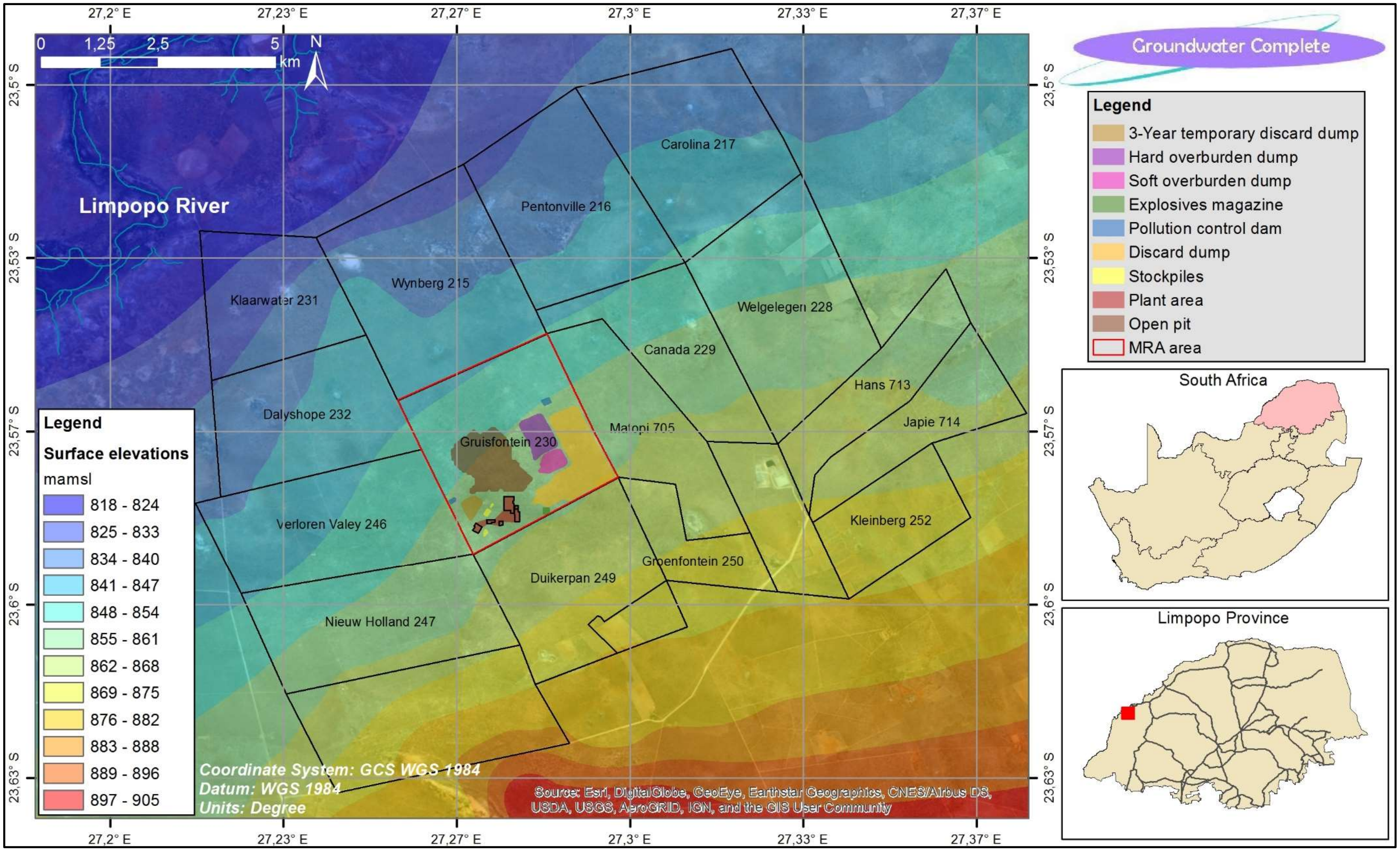

Figure 2: Surface elevations and water courses in the Gruisfontein project area

2.2 CLIMATIC CONDITIONS

The project area is located within a summer rainfall region that receives 88% of its annual rainfall during the warm summer months of November through to March **(Figure 3)**. On average the project area receives an annual rainfall of 408 mm. This data was obtained from a rainfall station close by Gruisfontein, however rainfall records are only available for 4 years. The internet site *Climate-data.org* states the average rainfall as 437 mm/y and average temperatures as indicated in **Figure 4**.

The nearest rainfall station from the SA Weather Service is station A4E007 situated at the Mokolo Dam approximately 60 km south-east of Gruisfontein has an average rainfall of 677 mm per annum. This is however on the Waterberg plateau where the rainfall is significantly higher and not representative of Gruisfontein.

The climate is generally hot to very hot in summer with mild winters. Average monthly temperatures (*Climate-data.org*) vary from more than 32 ^{0}C in the summer to ± 14 ^{0}C in the winter **(Figure 4)**. The area is thus characterised by hot to very hot summers and mild winters.

Evapotranspiration is estimated to vary between 1 800 and 2 000 mm/year *(Surface Water Resources of South Africa, 1990)*, resulting in a significant environmental moisture deficit throughout the year.

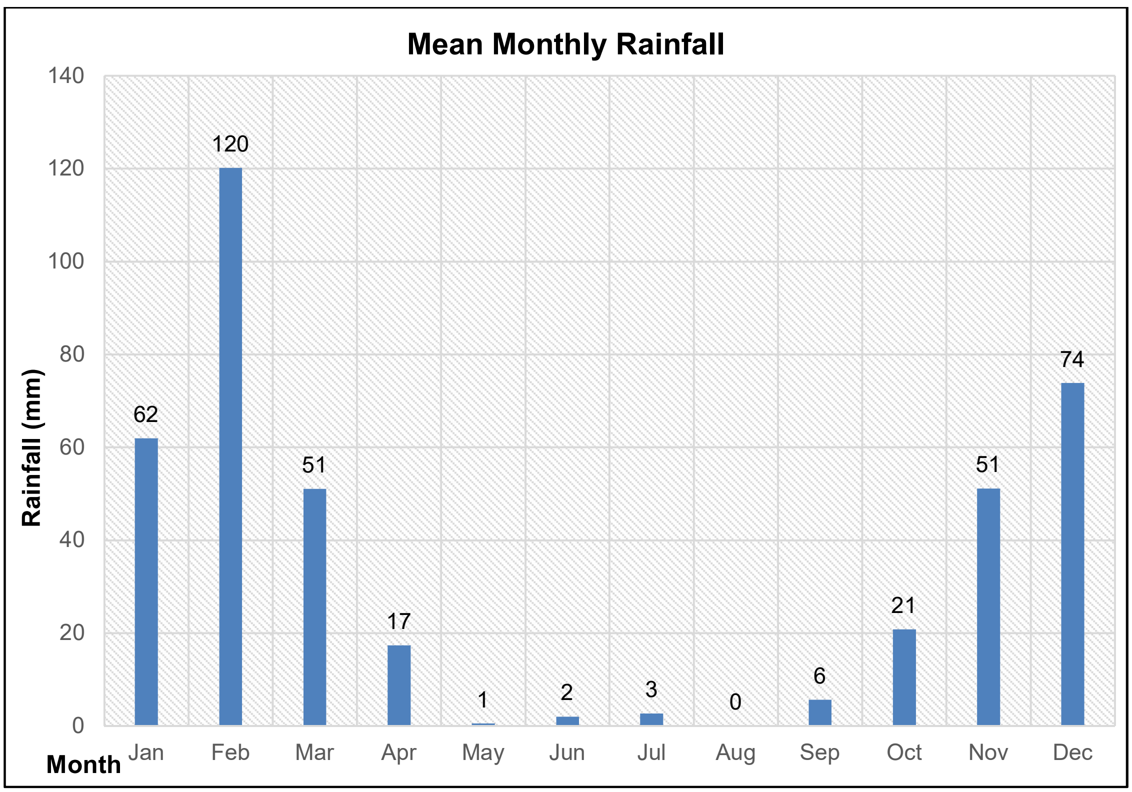

Figure 3: Average monthly rainfall for the Gruisfontein project area

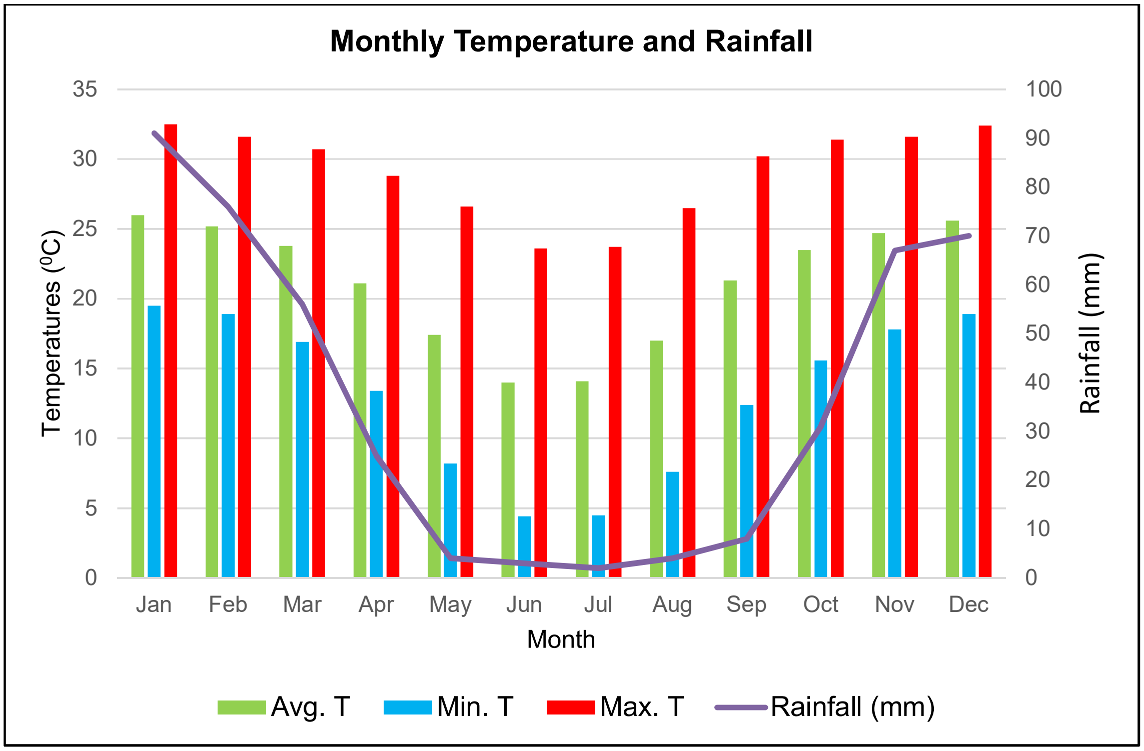

Figure 4: Average monthly temperatures and rainfall for the Gruisfontein project area

3 SCOPE OF WORK AND REPORT STRUCTURE

The methodology that was followed and structure of the report can be summarised as follows:

- Topographic maps were consulted and used in the general description of the surface topography and water courses located within the immediate vicinity of the MRA area *(Section 2.1)*.
- Climatic conditions were evaluated and discussed *(Section 2.2)*.
- All available groundwater and related studies and associated information were assessed and used accordingly throughout the investigation where applicable *(Section 4.1)*.
- A hydrocensus/groundwater user survey was conducted on and around Gruisfontein by Aquatico Scientific in November 2018. Groundwater users within the survey area were identified, boreholes were surveyed in terms of positions and water levels, water quality and water uses were determined *(Section 4.2)*.
- A pilot geophysical test survey was conducted on Gruisfontein to determine if the faults and dykes in the area are picked up by magnetic methods *(Section 4.3)*.
- No additional monitoring boreholes were drilled for the purpose of this groundwater investigation *(Section 4.4)*.
- Aquifer testing in the form of constant rate pumping tests were performed on four user boreholes located within the Gruisfontein MRA area *(Section 4.5)*.

- The groundwater sampling protocol and chemical analysis of water samples were discussed *(Section 4.6).*
- Dedicated groundwater recharge studies were consulted in the assessment of the aquifer recharge rate *(Section 4.7)*.
- Numerical groundwater flow and contaminant transport models were constructed to simulate the potential groundwater quantity and quality impacts associated with the proposed new opencast mining and related activities *(Section 4.8)*.
- The 1:250 000 scale geological map of the MRA area was consulted in the assessment and discussion of the underlying geology *(Section 5.1)*.
- The acid generating potential of the underlying rock material was assessed based on the findings of geochemical tests that were conducted for the neighbouring Temo Coal Project *(Section 5.2)*.
- The hydrogeology of the MRA area was assessed in terms of the unsaturated zone, saturated zone and aquifer hydraulic conductivity *(Section 5.3)*.
- Information collected during the hydrocensus/user survey of November 2018 was used in the assessment of the groundwater level depths, elevations and gradients *(Section 5.4)*.
- Potential sources of groundwater contamination were identified and discussed in more detail *(Section 5.5)*.
- Geological maps and previously conducted groundwater and related studies were used in the identification of preferred pathways that may possibly conduce/assist the flow of contamination *(Section 5.6).*
- All potential receptors were identified with the help of hydrocensus/user survey information *(Section 5.7).*
- The results of chemical and physical analyses that were conducted on groundwater samples collected from the immediate groundwater user boreholes were assessed and discussed *(Section 5.8)*.
- The *Groundwater Vulnerability Classification System* was used to determine the aquifer's vulnerability or susceptibility to groundwater contamination *(Section 6.1)*.
- Geological information combined with the findings of a DWA study that involved the hydrogeological mapping of South Africa were used to identify and characterise the aquifers underlying the MRA area *(Section 6.2)*.
- The underlying aquifer was assessed in terms of the degree of protection it requires from contamination typically associated with coal mining and related activities *(Section 6.3)*.
- The surface topography in combination with major faults and dyke structures were used to roughly delineate the aquifer system underlying MRA area *(Section 6.4)*.
- With the numerical groundwater model only being a simplified representation of the very complex and highly heterogeneous aquifer system/s, certain model restrictions and limitations inevitably do exist and were discussed briefly *(Section 7.1)*.
- The choice of modelling software used to simulate the geohydrological environment was discussed in detail *(Section 7.2)*.
- Model dimensions, boundaries and aquifer parameters used in the construction and calibration of the model were discussed in detail *(Section 7.3)*.

- Groundwater elevations and gradients achieved through the steady state calibration of the numerical groundwater flow model were discussed in detail *(Section 7.4)*.
- The geometric structure of the model (i.e. number and thickness of model layers, number of rows and columns and dimensions of cells) was discussed in detail *(Section 7.5)*.
- The groundwater sources and sinks were assessed and simulated in the numerical groundwater model *(Section 7.6)*.
- All groundwater and related information were used in the formulation of a sound conceptual model, which was discussed in detail and illustrated by means of a vertical cross-section through the MRA area *(Section 7.7)*.
- The model simulations and results were discussed in detail and indicated with the use of contour maps *(Sections 7.8 and 7.9)*.
- The actual rating of the potential groundwater related impacts was aided by the findings of the numerical groundwater flow and contaminant transport models *(Section 8)*.
- A groundwater monitoring plan/protocol was proposed and discussed in detail *(Section 9)*.
- The groundwater environmental management program was discussed in detail *(Section 10)*.
- Conclusions and recommendations resulting from the groundwater investigation were clearly stated *(Section 11)*.

4 METHODOLOGY

4.1 DESK TOP STUDY

All available groundwater and related studies and associated information were assessed and used accordingly throughout the investigation where applicable. The following studies formed part of the assessment:

- Gruisfontein progress report to DMR, February 2018;
- Gruisfontein Cronimet concept study, March 2018;
- Evaluation of acid rock drainage potential in the Waterberg Coalfield, 2014;
- Several environmental management programs for projects in the area such as for Exxaro Grootegeluk Colliery, Eskom Medupi Power Station, Smitspan and others.
- Data from Anglo Coal, Sasol operations and Exxaro projects in the vicinity.

Groundwater information was obtained from various open sources as well as dedicated information gathering for this study as well as supporting information from the exploration program.

4.2 RESULTS OF THE HYDROCENSUS/USER SURVEY

A hydrocensus/groundwater user survey was conducted on and around Gruisfontein by Aquatico Scientific in November 2018. The time of year or season in which the survey was conducted is not expected to influence its outcome. The main objectives of a hydrocensus field survey can be summarised as follows:

- To locate all interested and affected parties (I&APs) with respect to groundwater – most notably groundwater users;
- To collect all relevant information from the I&APs (i.e. name, telephone number, address, etc.);
- Accurately log boreholes and other water features/sources on the I&APs properties; and
- To collect all available information regarding the logged boreholes (i.e. yield, drill date, depth, water level, water quality etc.) but especially the use of groundwater from the borehole.

A total of 33 boreholes or other groundwater localities were located during the survey and their positions are indicated in **Figure 5**. Borehole information and uses are summarized in **Table 1**. The hydrocensus boreholes extended for a radius of about 3.5 km around the Gruisfontein farm. All equipped private user boreholes were found to be used for domestic and/or livestock watering or a combination of the two.

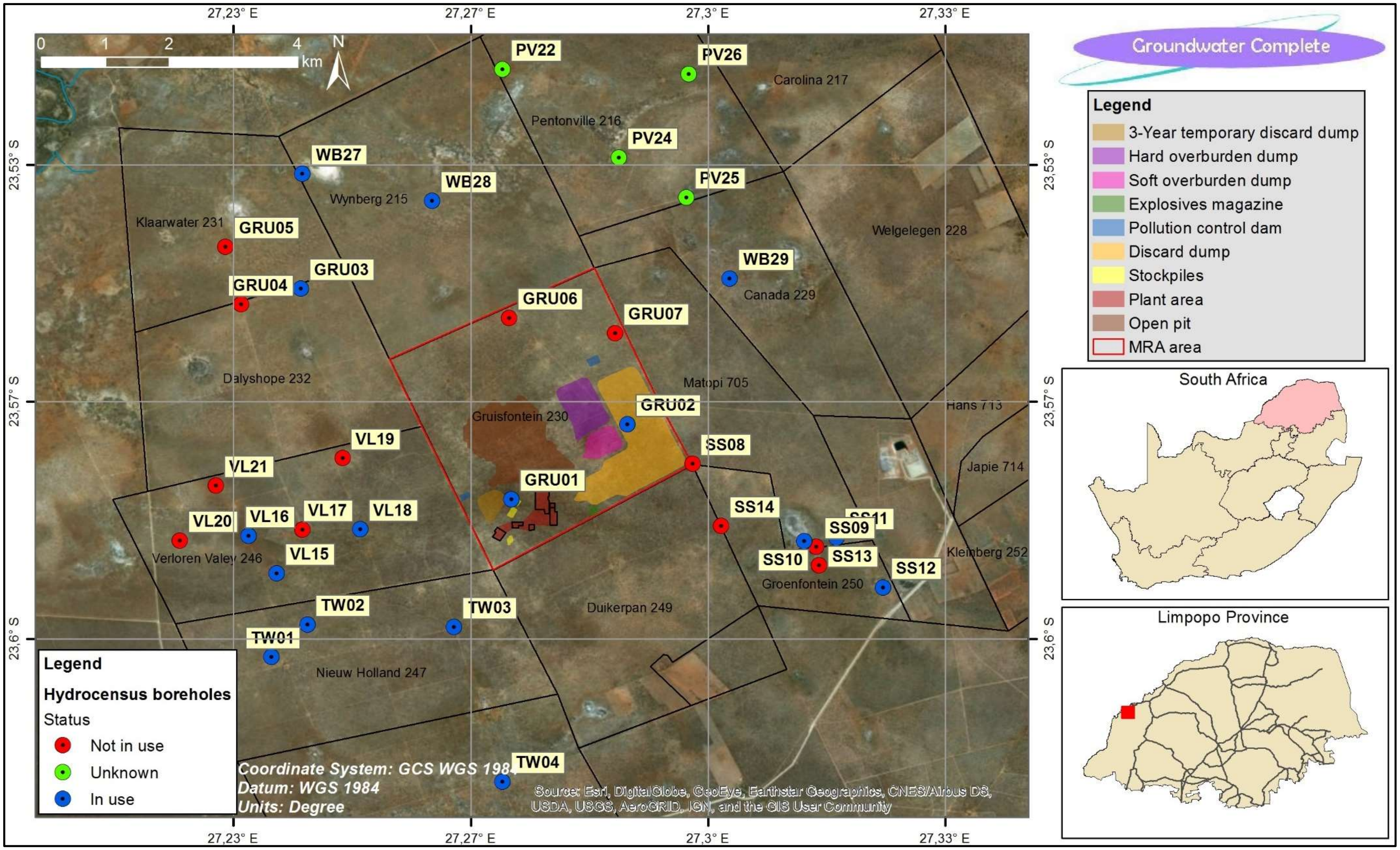

Figure 5: Positions of boreholes located during the hydrocensus/user survey

Table 1: Basic information gathered during the hydrocensus/user survey

Locality	Farmer / Owner	Farm	Locality Type	Date	Time	Coordinates		Static WL	Depth	Sampled	Analysed	Use
						X-Coordinate	Y-Coordinate					
PV22	Bekker Pelser	Pentonville	Borehole	2018/10/30	15:07	27.271189	-23.519958		145	YES	X	Domestic use
PV24	Bekker Pelser	Pentonville	Borehole	2018/10/30	14:33	27.287544	-23.532396	29.61		YES	X	Livestock - Game
PV25	Bekker Pelser	Pentonville	Borehole	2018/10/30	14:44	27.296967	-23.53797	19.31		NO		Not in Use
PV26	Bekker Pelser	Pentonville	Borehole	2018/10/30	14:55	27.29735	-23.520596	18.56	35	YES	X	Livestock Watering
SS06	Bertie Botha	Groenfontein	Borehole	2018/10/30	09:48	27.31808	-23.575512	23.5		YES		Not In Use
SS07	Bertie Botha	Groenfontein	Borehole	2018/10/30	09:59	27.313263	-23.568542	22.96		YES		Not In Use
SS08	Bertie Botha	Groenfontein	Borehole	2018/10/30	10:14	27.297834	-23.575415	22.92		YES	X	Not In Use
SS09	Bertie Botha	Groenfontein	Borehole	2018/10/30	10:31	27.315218	-23.58713	17.7		YES		Not In Use
SS10	Bertie Botha	Groenfontein	Borehole	2018/10/30	10:42	27.313528	-23.856292	19.57		YES	X	Livestock - Game
SS11	Bertie Botha	Groenfontein	Borehole	2018/10/30	10:50	27.318047	-23.585808	22.62		YES	X	Livestock - Game
SS12	Bertie Botha	Groenfontein	Borehole	2018/10/30	11:04	27.32459	-23.592823	13.85		YES	X	Domestic and Livestock
SS13	Bertie Botha	Groenfontein	Borehole	2018/10/30	11:15	27.315626	-23.589668	15.39		YES		Not In Use
SS14	Bertie Botha	Groenfontein	Borehole	2018/10/30	11:25	27.301891	-23.58419	22.23		YES		Not In Use
Sasol	Bertie Botha	Groenfontein	Pit	2018/10/30	12:56	27.326	-23.57288			YES	X	Not in Use
TW01	Hardus Steenkamp	Nieuw Holland	Borehole	2018/10/31	09:45	27.238737	-23.602589			YES	X	Livestock
TW02	Hardus Steenkamp	Nieuw Holland	Borehole	2018/10/31	10:02	27.243774	-23.598022	19.44	100	YES	X	Livestock
TW03	Hardus Steenkamp	Nieuw Holland	Borehole	2018/10/31	10:23	27.264364	-23.598372	30.83	100	YES	X	Livestock
TW04	Hardus Steenkamp	Nieuw Holland	Borehole	2018/10/31	10:36	27.271137	-23.620127			NO		Livestock
VL15	Herman Louw	Verloren Valey	Borehole	2018/10/30	12:32	27.239454	-23.59081	22.95		YES	X	Domestic Use
VL16	Herman Louw	Verloren Valey	Borehole	2018/10/30	12:44	27.235535	-23.585562	21.03		YES	X	Domestic and Livestock
VL17	Herman Louw	Verloren Valey	Borehole	2018/10/30	12:53	27.243042	-23.584679	19.61		YES		Not in Use
VL18	Herman Louw	Verloren Valey	Borehole	2018/10/30	13:01	27.251179	-23.584644			YES	X	Domestic and Livestock
VL19	Herman Louw	Verloren Valey	Borehole	2018/10/30	13:08	27.24871	-23.57464	20.51		YES	X	Not in Use
VL20	Herman Louw	Verloren Valey	Borehole	2018/10/30	13:25	27.225878	-23.586216	19.27		YES		Not in Use

Locality	Farmer / Owner	Farm	Locality Type	Date	Time	Coordinates		Static WL	Depth	Sampled	Analysed	Use
						X-Coordinate	Y-Coordinate					
VL21	Herman Louw	Verloren Valey	Borehole	2018/10/30	13:38	27.23094	-23.578493	18.98		YES		Not in Use
WB27	Tharina Pelser	Wynberg	Borehole	2018/10/31	11:51	27.243088	-23.534657	30.63		YES	X	Domestic and Livestock
WB28	Tharina Pelser	Wynberg	Borehole	2018/10/31	12:04	27.261295	-23.538456	8.98	20	YES	X	Livestock
WB29	Tharina Pelser	Cananda	Borehole	2018/10/31	12:21	27.303062	-23.549377	13.55	45	YES		Livestock - Game
GRU01	Piet Nel	Gruisfontein	Borehole	2018/10/29	14:00	27.27242	-23.58039	19.55	37.1	YES	X	Domestic and Livestock
GRU02	Piet Nel	Gruisfontein	Borehole	2018/10/29	15:45	27.28869	-23.56987	17.27	42.8	YES	X	Domestic and Livestock
GRU03	Piet Nel	Dalyshope	Borehole	2018/10/29	15:00	27.24285	-23.55079	14.64	76	YES	X	Domestic and Livestock
GRU04	Piet Nel	Dalyshope	Borehole	2018/10/29	16:00	27.23445	-23.55302			NO		Not in Use
GRU05	Piet Nel	Klaarwater	Borehole	2018/10/29	17:00	27.23228	-23.54492	10.2		NO		Not in Use
GRU06	Piet Nel	Gruisfontein	Borehole	2018/11/26	16:25	27.27213	-23.55492	17.61	32.35	YES	X	Not in Use
GRU07	Piet Nel	Gruisfontein	Borehole	2018/11/27	10.15	27.28609	-23.55706	18.01	87	YES	X	Not in Use

4.3 GEOPHYSICAL SURVEY AND RESULTS

A pilot geophysical test survey was conducted on Gruisfontein to determine if the faults and dykes in the area can be picked up by magnetic methods. Three traverses were surveyed and the positions are indicated in **Figure 6**. The interpreted faults are indicated in the abovementioned figure as yellow dotted lines. The resulting magnetic responses were however low and it was concluded that the magnetic method is not useful in mapping or delineating the geological structures. The reason is probably the thick sandy soil and mudstone cover over most of the hard rock geology where faulting has occurred. Graphs of the magnetic responses are included in **Appendix A**.

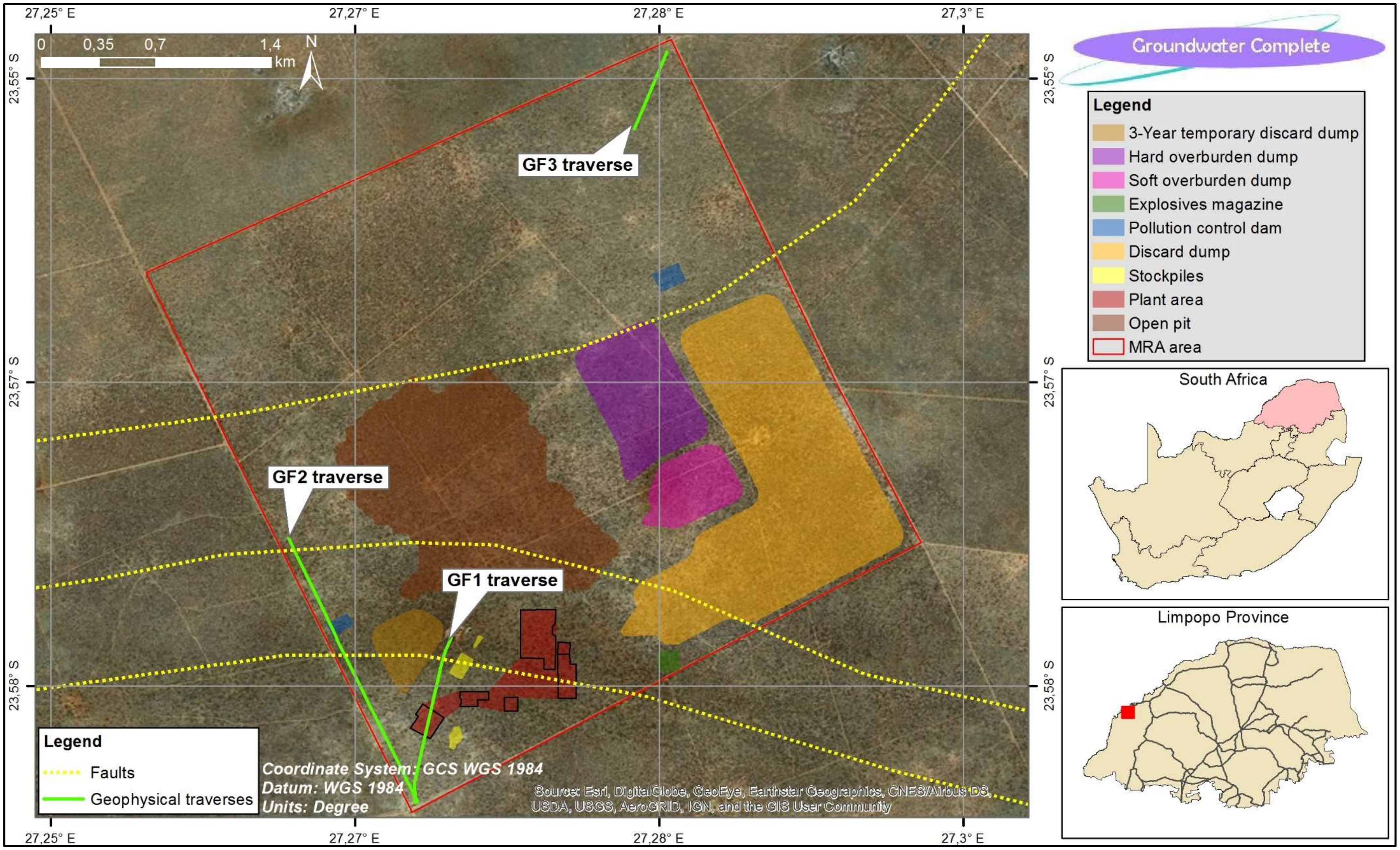

Figure 6: Positions of geophysical lines and identified geological anomalies

4.4 SITING AND DRILLING OF BOREHOLES

No boreholes were drilled for sampling or testing at Gruisfontein. The four user boreholes located in the Gruisfontein MRA area were used for aquifer testing and their positions are indicated on **Figure 7**.

Some 23 boreholes were drilled on Gruisfontein for geological exploration and resource estimation. The geological information from these boreholes was used to assist in the formulation of a conceptual model for the area. The positions of these boreholes are also indicated on the abovementioned figure.

Note that dedicated source monitoring boreholes are strongly recommended before any mining operation commences and are discussed in more detail in **Section 9.3**.

4.5 AQUIFER TESTING

An aquifer test (also referred to as a pump or slug test) is performed to determine aquifer parameters, especially transmissivity or hydraulic conductivity. Aquifer parameters play an important role in the conceptualisation of the project area (i.e. conceptual model), which ultimately forms the foundation of the numerical groundwater flow and contaminant transport models.

The test basically involves the abstraction of groundwater from a borehole by means of a pump (submersible- or mono pump) at a known rate. Measurements of the decreasing water level within the borehole are taken at predetermined intervals, which are generally short at the start of the test and increase as the test progresses. After the test has been completed and the pump has been shut down, measurements are again taken of the water level as it starts to recover/rise in the borehole (i.e. recovery test).

All four user boreholes on Gruisfontein were tested and their positions are indicated in **Figure 7**. The pump test data was analyzed with FC Method analytical software package, which offers a wide range of mathematical equations/solutions for the calculation of aquifer parameters. The Cooper-Jacob approximation method was used to obtain comparative straight-line fits for transmissivity estimates.

The time-water level data collected during the constant rate pump test is plotted on a log-linear graph. A straight line (for the Cooper-Jacob method) can then be fitted to the different flow stages on the graph (process known as curve matching) and the aquifer transmissivity and storativity are calculated in accordance with the preselected analytical equation.

It is important to note that the abovementioned equation for pump test analysis was designed for pump test interpretation in a primary porosity aquifer environment with the following assumptions:

- The aquifer is a homogeneous medium;

- Of infinite extent;
- No recharge is considered; and
- An observation borehole is used for water level recording at a distance from the pumped borehole.

Although few of these assumptions apply to the project area, the methods/equations could still be used as long as the assumptions and 'shortcomings' are recognized and taken into account by the user. The results of the pump tests are discussed in detail in **Section 5.3.3**.

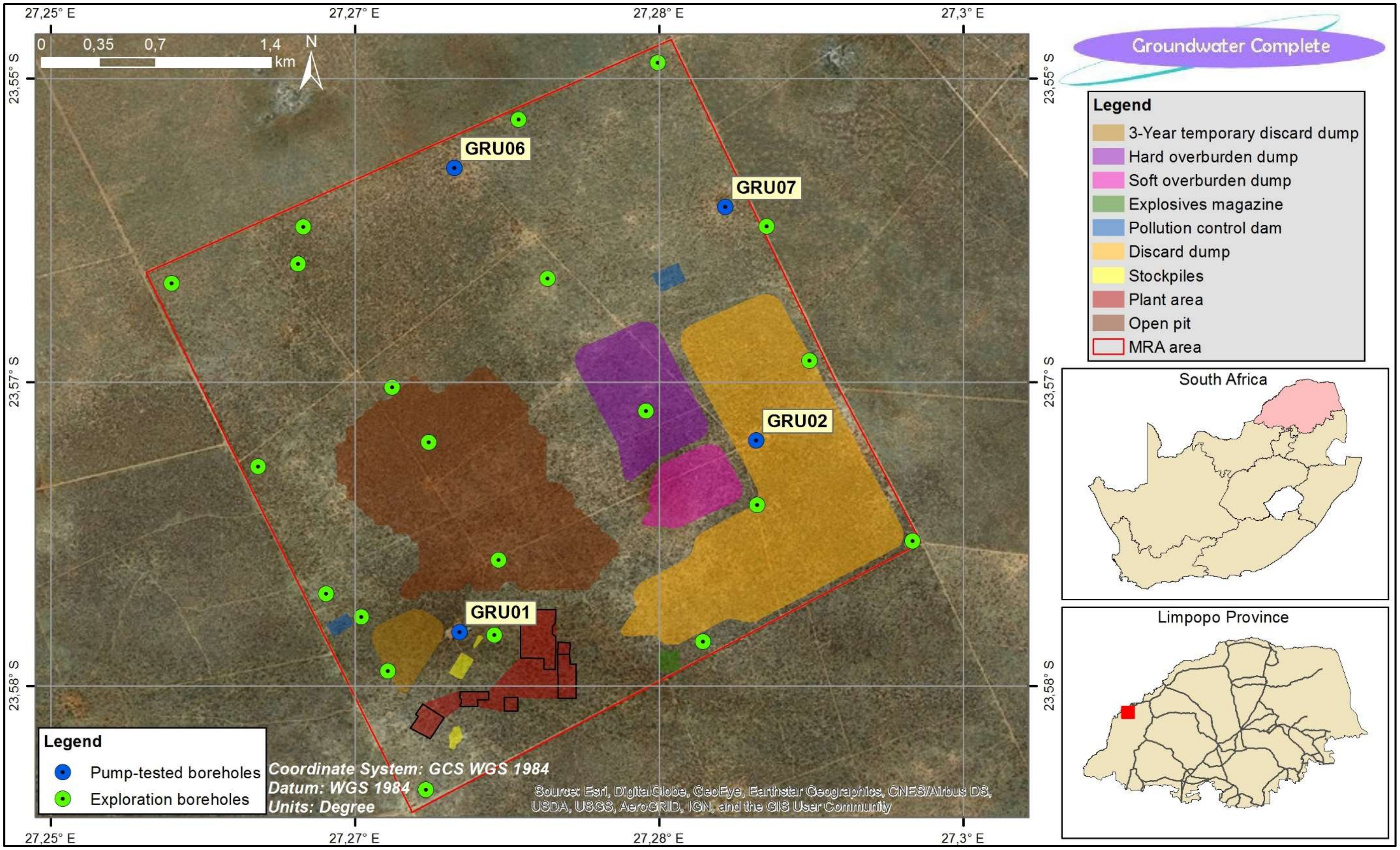

Figure 7: Boreholes on Gruisfontein used for sampling and aquifer testing

4.6 GROUNDWATER SAMPLING AND CHEMICAL ANALYSIS

Groundwater sampling was conducted by *Aquatico Scientific* and was done so based on the protocols and specifications, and code of practice contained in the SABS ISO 5667-1-15. These international standards address all aspects from the program design, sampling methods as well as sample preservation and many other aspects.

Sampling procedures are based on SABS standards namely:

- ISO 5667-1:1980 Part 1: Guidance on the design of sampling programs;
- ISO 5667-2: 1991 Part 2: Guidance on sampling techniques;
- ISO 5667-11: 1993 Part 11: Guidance on sampling of groundwater; and
- ISO 5667-3: 1994 Part 3: Guidance on preservation and handling of samples.

Aquatico maintains a state of the art (and SANAS Accredited) water laboratory in Pretoria *(Aquatico Laboratory)*. This analytical laboratory has been operational since July 2006 and takes part in the SABS Inter-laboratory Testing Scheme. Further, *Aquatico* is a SANAS Accredited Testing Laboratory, No T0685.

Groundwater samples were collected from a total of 20 hydrocensus/user boreholes. The samples were analysed for a wide range of chemical and physical indicator parameters and the results are discussed in detail in **Section 5.8**.

4.7 GROUNDWATER RECHARGE CALCULATIONS

According to Vegter's groundwater recharge map of South Africa provided in **Figure 8**, the mean annual effective recharge to the aquifer underlying the project area should be in the order of 6 mm, which based on an average rainfall of approximately 408 mm/a **(Figure 3)** calculates to a recharge percentage of approximately 1.5%.

Based on other methods (such as the chloride method), recharge to the aquifer was estimated to be less than 2% of MAP. Refer to **Table 2** with general estimates based on rock types and soil cover.

The **chloride method** uses the ratio of chloride concentration in ambient groundwater and the chloride concentration in rainwater together with the mean annual rainfall to estimate effective recharge. For three of the Gruisfontein boreholes the chloride content of groundwater is around 80 mg/l. If the chloride method is applied this translates to a recharge of about **1.3%** of rainfall. The fourth borehole located on Gruisfontein has a groundwater chloride content of 180 mg/l, while some of the surrounding/outside user boreholes displayed even higher concentrations of up to 650 mg/l. Groundwater recharge values of less than 0.65% of MAP were calculated for these higher chloride concentrations. An average of around 1.5% was used in the water balance calculations for the Gruisfontein MRA area.

Table 2: Typical recharge to different aquifer host rocks *(Van Tonder & Xu, 2000)*

Geology	% Recharge (soil cover <5m)	% Recharge (soil cover >5 m)
Sandstone, mudstone, siltstone	5	2
Hard Rock (granite, gneiss etc.)	7	4
Dolomite	12	8
Calcrete	9	5
Alluvial sand	20	15
Coastal sand	30	20
Alluvium	12	8

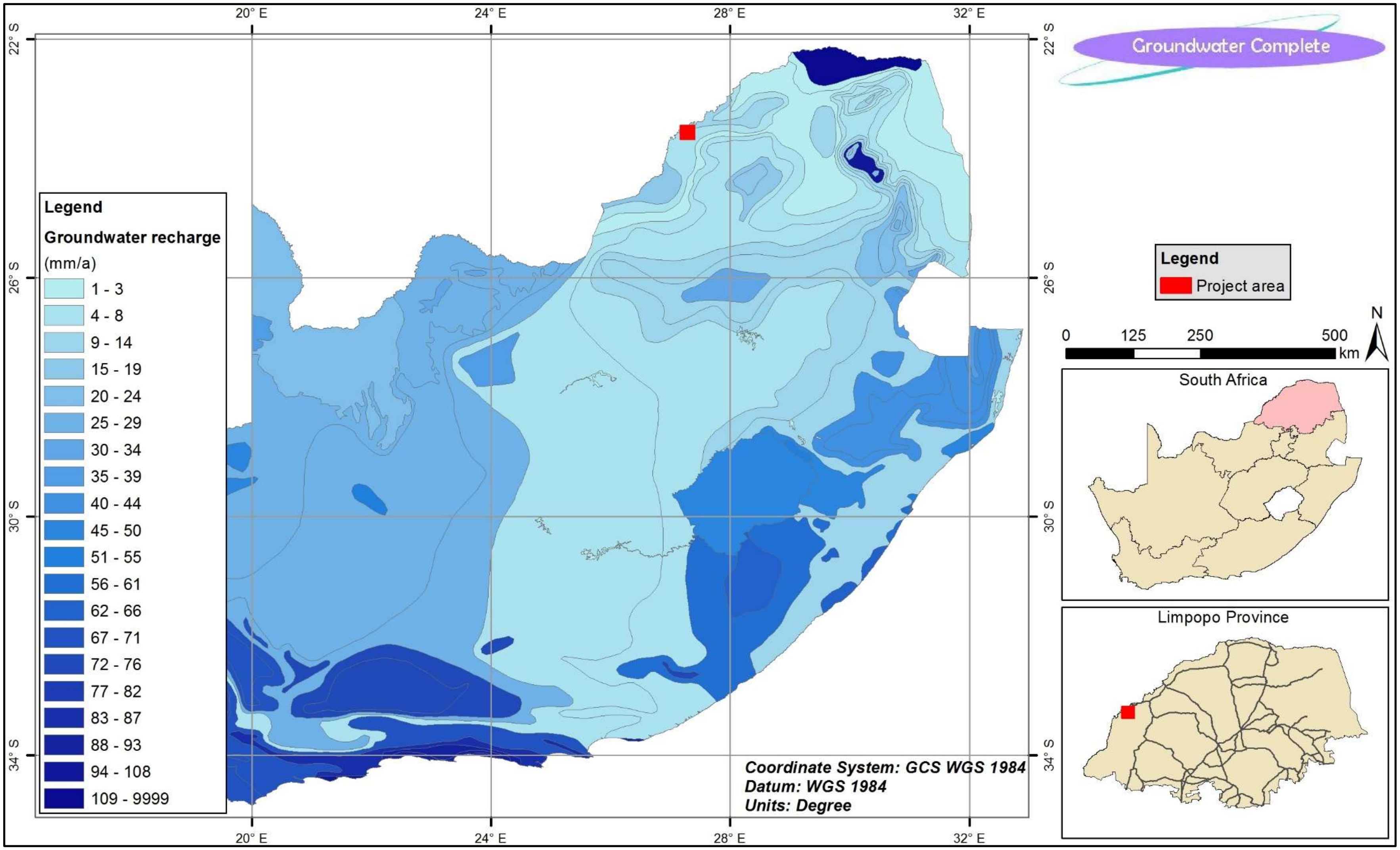

Figure 8: Mean annual aquifer recharge for South Africa *(Vegter, 1995)*

4.8 GROUNDWATER MODELLING

Numerical groundwater flow and contaminant transport models were constructed to simulate the potential groundwater quantity and quality related impacts associated with the proposed new opencast mining and related activities. The conceptual model (as summarised in **Section 7.7**) formed the basis or foundation of the numerical models.

Model calibration was aided largely by actual groundwater elevations that were measured in the field during the hydrocensus/user survey of November 2018. Detailed discussions on the choice of modelling software, model setup, boundary conditions, etc. are provided in **Section 7** of this report.

5 PREVAILING GROUNDWATER CONDITIONS

5.1 GEOLOGY

Geological information provided in this report was interpreted from the 1:250 000 scale geological map of the project area **(Figure 9)** and descriptions were obtained from the Nozala Concept Study and Progress report.

5.1.1 DESCRIPTION OF REGIONAL GEOLOGY

In a general sense the project area is underlain by sedimentary rocks of the Karoo Supergroup, more specifically shale and sandstone of the Vryheid Formation (Ecca Group) and mudstones of the Beaufort Group.

Several prominent geological structures (i.e. faults and dykes) are indicated in **Figure 9**. The faults have displacements of up to a few hundred meters and these displacements are directly responsible for the economical accessibility of the major coal reserves in some areas while it is too deep in other areas to be economically mineable – at least via opencast methods. The major faults in the larger Waterberg Coal Field generally trend north-east by south-west. Faulting occurred in other directions as well, causing upliftment of down-shifting of the geological succession.

The Waterberg Coal Field reportedly accounts for over 45% of South Africa's un-mined coal resources. It is considered a strategic coalfield in light of South Africa's (and Southern Africa's) current energy crisis, with Eskom as well as mining and exploration companies presently investing heavily in this coal field. A high-level (1:250 000 scale) geological map of the Waterberg Coal Field around Gruisfontein is provided in **Figure 9**.

The major coal bearing horizons of the Ecca Group of the Karoo Supergroup in the Waterberg are:

- The Volksrust (Grootegeluk) Formation, which consists of 55 m of intercalated mudstones and coal; and

- The Vryheid (Goedgedacht) Formation, which incorporates four major discrete seams of approximately 1.5 m, 3 m, 9 m and 4 m in thickness, respectively.

Coal measures occur over a stratigraphic interval of between 90 m to 110 m thick, characterized by 11 discrete coal zones, with the upper zones (Zone 6 – Zone 11) comprising of the highest commercial value including semi-soft coking coals. The upper zones are overlain by the barren Eendragtpan Formation of the Beaufort Group. The lower Zones are underlain by the barren Wellington Formation of the Ecca Group.

5.1.2 DESCRIPTION OF LOCAL SITE GEOLOGY

At Gruisfontein, all seams/coal zones are covered by some 30 m to 100 m of non-coal bearing superficial deposits ("overburden") with no coal outcrops. The project area has an uplifted block in the south-west where weathering has removed Zone 9 to Zone 11, whilst the rest of the area contains all 11 zones.

The faults on Gruisfontein itself generally trend east-west with mostly sub-vertical displacement. These geological structures have the potential to act as preferred pathways along which groundwater and potential contamination may flow at increased rates and are therefore of significant importance to the conceptual understanding of the geohydrological environment.

Low transmissivity structures such as dykes may act as barriers for the flow of groundwater, consequently forming groundwater compartments with the potential of harbouring uniquely different types of groundwater – contributing to the heterogeneous nature of the fractured rock aquifer system. The hydraulic properties of the local geological structures need to be assessed (geophysics, drilling, aquifer testing) before mining commences.

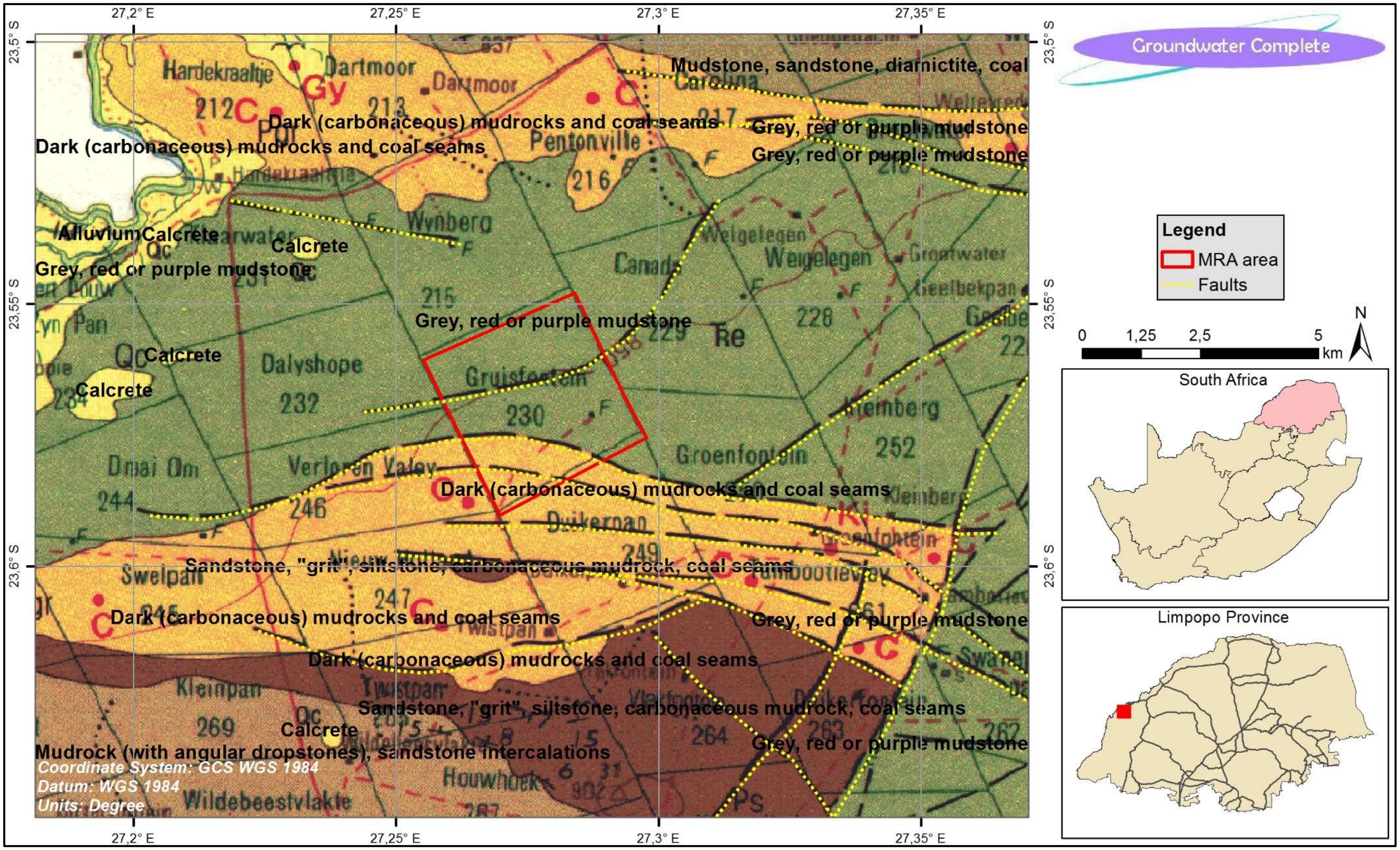

Figure 9: Regional geology around Gruisfontein

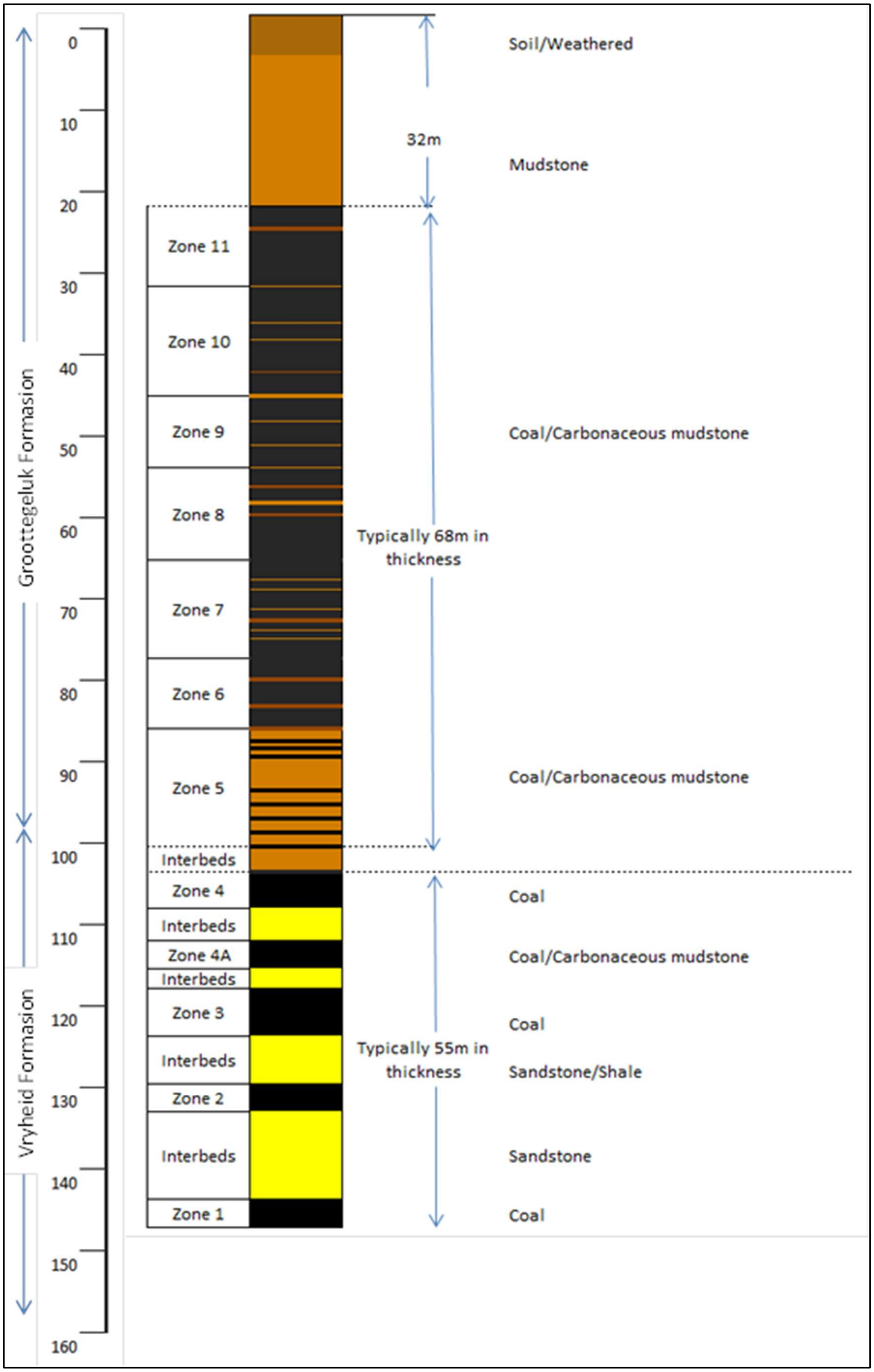

Figure 10: General stratigraphic column in the Waterberg Coal Field

5.2 ACID GENERATING POTENTIAL

No dedicated geochemical tests were conducted on Gruisfontein for the purpose of this geohydrological investigation. Geochemical investigations were however conducted for the nearby active Grootegeluk Colliery (±25 km south-east), the Temo Coal Project (±5 km east) and the proposed Sekoko Coal Smitspan Colliery (±15 km south-east), which are all located within the same geochemical environment. The results of both these two investigations are summarised in the following paragraphs and provide a high-level indication of the acid generating potential of the Karoo rocks underling the MRA area.

Acid Base Accounting (ABA) is a static test commonly conducted to determine the total amount of sulphur (sulphide sulphur + sulphate sulphur) present in a sample. The higher the sulphur content, the higher the potential to generate acid – more specifically sulphuric acid. This information is then used to determine the Neutralisation Potential (NP), Acid Potential (AP), Net Neutralisation Potential (NNP) and Neutralising Potential Ratio (NPR).

Note that an NNP value smaller than 20 suggests that the material may potentially generate acid, while the opposite holds true for values larger than 20 *(Usher et al., 2003)*. Furthermore, material composed of 0.3% sulphide sulphur or more is expected to continually generate acid over a long period of time.

Summary of Grootegeluk investigation:
The Grootegeluk geochemical tests were conducted as part of an investigation for a masters degree in 2014, titled '*Evaluation of Acid Rock Drainage Potential in the Waterberg Coalfield*".

A total of 34 samples were collected from three exploration boreholes at depths varying between 1 and 50 meters below surface. Acid base accounting tests were conducted, which found that approximately 85% of all samples have a low acid generating potential. The remaining 15% were classified as having a medium acid generating potential.

Summary of Temo investigation:
The Temo tests formed part of an environmental investigation that was conducted by Digby Wells Environmental in 2011, titled *"Environmental Impact Assessment & Environmental Management Programme Report, Temo Coal Project'*.

A total of 13 samples were collected of the overburden and inter-burden at depths of between 35 and 164 meters below surface. Acid base accounting tests were conducted and the results are provided in **Table 5**.

The following criteria were used to assess the samples' potential to generate acid:

- The difference between the neutralisation potential and acid potential is known as the net-neutralisation potential (NNP = NP – AP). Therefore, whenever the NNP is a negative value the acid potential exceeds the neutralisation potential, suggesting that water leaching through this material may potentially turn acidic **(Table 3)**; and

- The ratio of NP:AP is termed the Neutralising Potential Ratio (NPR). The classification based on NPR and sulphur content is provided in **Table 4**.

Table 3: Classification of samples according to net neutralisation potential (Usher et al., 2003)

NNP < 20	Potentially acid generating
NNP > 20	Non-acid generating

Table 4: Classification of samples according to the neutralising potential ratio (NPR) and sulphur content ***(Soregaroli & Lawrence, 1998; Usher et al., 2003)***

Type 1	Potentially acid generating	Sulphide sulphur > 0.3% with NPR ratio of < 1:1
Type 2	Intermediate or inconclusive	NPR ratio of 3:1 – 1:1
Type 3	Non-acid generating	Sulphide sulphur < 0.3% with NPR ratio of > 4:1

The average neutralisation potential (NP) exceeds the acid potential (AP), resulting in a positive net neutralisation potential value of 4 **(Table 5)**. According to the **net neutralisation potential classification (Table 3)**, the composite sample is potentially acid generating.

The average sulphide content was calculated to be in the region of 0.54% **(Table 5)**, meaning that enough oxidisable sulphur is available to sustain long term acid generation. According to the **neutralising potential ratio (NPR) classification** explained in **Table 4**, the composite sample is potentially acid generating.

Note that the net neutralising potential decreases considerably from an average of approximately 50 kg/t $CaCO_3$ at shallow depths of between 35 and 40 meters below surface to nearly -10 kg/t $CaCO_3$ at deeper depths exceeding 100 mbs. The shallow samples seem to have enough calcium carbonate to buffer against acidification, however they do contain significant sulphide (up to 0.58%) that may over the long-term cause conditions to turn acidic – especially if the calcium carbonate is consumed faster than the rate of sulphide oxidation. All samples are therefore considered to be potentially acid generating over the long term.

Summary of Sekoko Smitspan investigation:
Geochemical tests were also conducted for the Sekoko Waterberg Project located between the operational Grootegeluk Colliery and Gruisfontein MRA area. The tests formed part of a groundwater baseline study that was conducted by Future Flow in 2009, titled *"Sekoko Waterberg Project Coal Mine, Groundwater Baseline Study"*.

Acid Base Accounting tests were conducted on five samples, i.e. two of the hanging wall, two coal samples and one representing the foot wall. The tests concluded that only the coal has a high acid generating potential, while the hanging wall and foot wall samples contain enough neutralising minerals (specifically calcium carbonate) to adequately buffer against acidification.

These test results are considered to be preliminary, however do highlight the heterogeneous nature of the Waterberg geochemical environment as the Temo investigation found all material to be potentially acid generating over the long term.

In conclusion, site specific geochemical testing at Gruisfontein is strongly recommended for confirmation of the acid generating potential of the underlying Karoo rocks.

Table 5: Results of ABA tests conducted for the Temo Coal Project *(Digby Wells Environmental, 2011)*

ID	Depth	Comments	Total sulphide (%S)	Paste pH	NP	AP	NNP (kg/t $CaCo_3$)	NPR
					(kg/t $CaCo_3$)			
20A	35m - 40m	Coal altering with mudstone	0.09	7.90	64.90	2.81	62.09	23.00
23A			0.52	8.60	56.40	16.30	40.10	3.50
26A			0.58	7.80	53.00	15.30	37.70	3.50
20B1	103m - 115m	Predominantly sandy mudstone, interspersed with bands of pyrite bearing coaly shale	1.92	5.60	5.00	60.00	-55.00	0.10
20B2			0.46	6.30	5.30	14.10	-8.80	4.40
23B			0.39	7.50	19.90	12.20	7.70	1.60
26B			0.06	8.10	15.00	14.50	0.50	7.70
23C	116m - 123m	Predominantly sandy mudstone, interspersed with bands of pyrite bearing coaly shale	0.34	7.10	4.50	10.60	-6.10	0.40
26C	126m - 132m	Predominantly sandstone	<0.01	7.80	8.20	0.31	7.89	26.00
20D1	150m - 154m	Predominantly a sandstone region, possibly overlapping with coal seams	1.16	7.50	14.00	36.30	-22.30	0.40
20D2			0.03	7.10	7.50	0.94	6.56	8.00
23D			0.11	7.80	2.80	3.40	-0.60	0.80
26D	160m - 164m	Predominantly sandstone	0.78	6.50	3.20	23.80	-20.60	0.10
Average:			**0.54**	**7.30**	**20.00**	**16.00**	**4.00**	**6.10**

5.3 HYDROGEOLOGY

5.3.1 UNSATURATED ZONE

The unsaturated zone refers to the portion of the geological/soil profile that is located above the static groundwater elevation or water table. Based on the exploration drilling results and widespread water level measurements, the unsaturated zone is predominantly composed of sandy soil followed by mudstone and shale.

The unsaturated zone affects both the quality and quantity of the underlying groundwater. The type of material forming the unsaturated zone as well as the permeability and texture thereof will significantly influence aquifer recharge as well as the transport of surface contamination to the underlying aquifer/s. Factors like ion exchange, retardation, biodegradation and dispersion all play a role in the unsaturated zone. The unsaturated zone at Gruisfontein consists of deep (3 - 10 m), sandy soils and alluvium which can be correlated with Kalahari sediments. The sand is underlain by mudstone at the top of the Grootegeluk formation.

The thickness of the unsaturated zone is obtained by subtracting the static water level elevation in the project area from the surface elevation, or simply by measuring the depth of the groundwater level below surface. The average thickness of the unsaturated zone (where no impacts from groundwater abstraction occur) at Gruisfontein is in the region of 18 to 20 meters.

5.3.2 SATURATED ZONE

The saturated zone, as the name suggests, is the portion of the geological/soil profile that is located below the static groundwater elevation or water table and is therefore saturated with water. The saturated zone in the study area is therefore from around 18 mbs to an infinite depth.

The saturated zone is important as it forms the groundwater zone or system on which groundwater users rely for their domestic/other water supply. The focus of this investigation is also on the saturated zone, more specifically its properties and characteristics and potential impact of the proposed activities thereon.

5.3.3 HYDRAULIC CONDUCTIVITY

Constant rate pumping tests were performed on four user boreholes located within the Gruisfontein MRA area and their positions are indicated on **Figure 7**. The main aim or purpose was to calculate representative aquifer parameters such as transmissivity and hydraulic conductivity. The idea was to conduct similar tests on some of the exploration boreholes on the property as well, but all of these were sealed and rehabilitated according to legal requirements and for the sake of safety.

Because aquifer hydraulic parameters (like most geological parameters) usually display a log-normal distribution, it is an accepted approach to calculate the harmonic mean in preference to the arithmetic mean.

The transmissivities and storativities calculated from the pumping tests are provided in **Table 6**. The mean matrix transmissivity of 1.0 m^2/d calculates to an average hydraulic conductivity of approximately 0.033 m/d.

Table 6: Aquifer parameters calculated for the four Gruisfontein boreholes from pump tests

Borehole	Test type	T-fracture	T-matrix	S-fracture	S-matrix
GRU01	Pump	11	**2.1**	0.00005	**0.01**
	Recovery	13	**3.6**	NA	**NA**
GRU02	Pump	4.4	**0.4**	0.004	**0.01**
	Recovery	12	**2.1**	NA	**NA**
GRU06	Pump	2.8	**0.5**	0.005	**0.007**
	Recovery	4	**0.6**	NA	**NA**
GRU07	Pump	75	**8**	1.00E-08	**0.02**
	Recovery	110	**5.4**	NA	**NA**
Harmonic Mean		**7.2**	**1.0**	**4E-08**	**0.01**

Key:

Abbreviation	***Description***
T-fracture	*Transmissivity of the fracture-dominated flow stage*
T-matrix	*Transmissivity of the matrix-dominated flow stage once fractures have been dewatered*
S-fracture	*Storativity of the fracture-dominated flow stage*
S-matrix	*Storativity of the matrix-dominated flow stage once fractures have been dewatered*

5.4 GROUNDWATER LEVEL DEPTHS AND ELEVATIONS

Groundwater level measurements were taken at 26 user boreholes during the hydrocensus/user survey of November 2018, providing a good distribution of water levels over the project area. Only 19 boreholes were equipped and in use at the time of the survey, which means that some of the water levels are bound to have been affected to various extents by abstraction.

The groundwater level depths vary between approximately 9 and 31 meters below surface. Deeper water levels were generally measured to the south of Gruisfontein in the slightly higher surface topographies. The shallower water levels were measured north and north-west of Gruisfontein in the downgradient groundwater flow direction and lower surface topographies. On Gruisfontein itself the rest water levels vary between 17 and 22 mbs. A thematic map of groundwater depths is provided in **Figure 12**, while groundwater elevations are indicated in **Figure 13**.

Clear anomalies were recorded as well, which is expected to be mostly caused by groundwater abstraction. The deeper levels thus do not represent static water levels and were discarded during interpolation of static (steady state) groundwater level contours.

Gravity dictates that groundwater will always flow from high to low hydraulic heads (groundwater elevations). Under natural/unaffected conditions, a strong correlation generally exists between the surface topography and groundwater elevations, meaning that groundwater elevations tend to follow the surface topography.

A graph of groundwater level elevation versus surface elevation using the hydrocensus boreholes is provided in **Figure 11**. If the water levels of boreholes clearly affected by abstraction are ignored, there exists a very good correlation. This aspect will also be used during the impact assessment for the project to aid in numerical groundwater model construction and calibration.

Despite some localized impacts on groundwater levels, groundwater still follows the trend of the surface topography, i.e. from south/south-east to north/north-west.

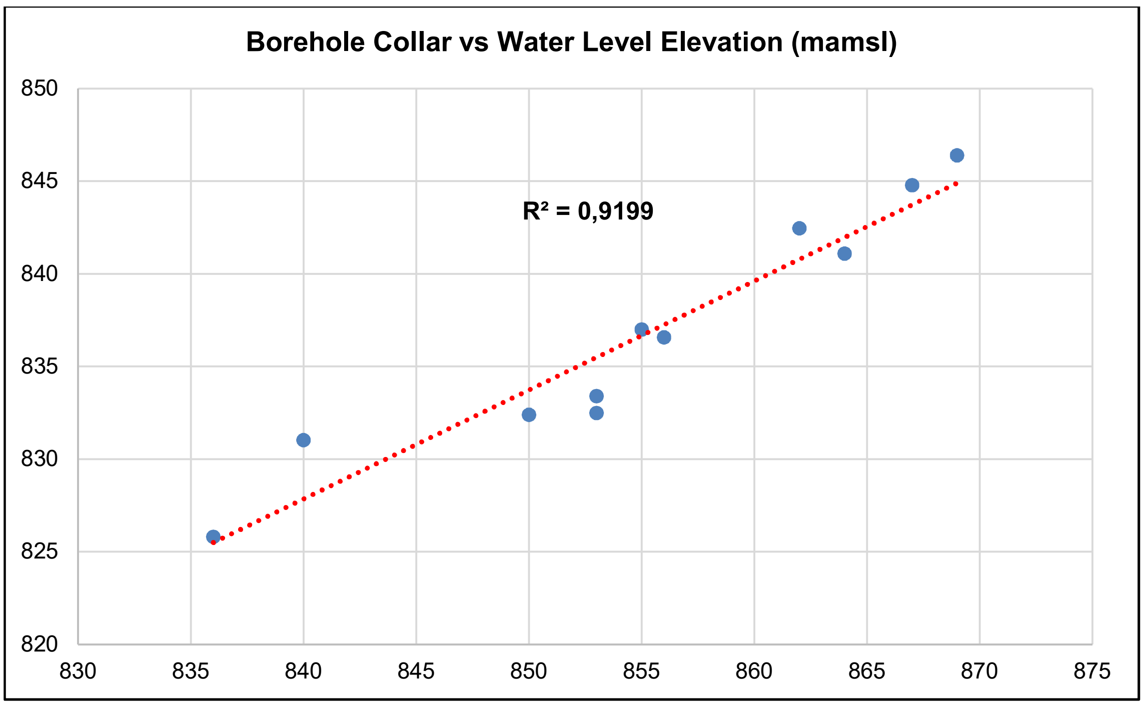

Figure 11: Relationship between groundwater level elevation and surface elevation in the Gruisfontein area

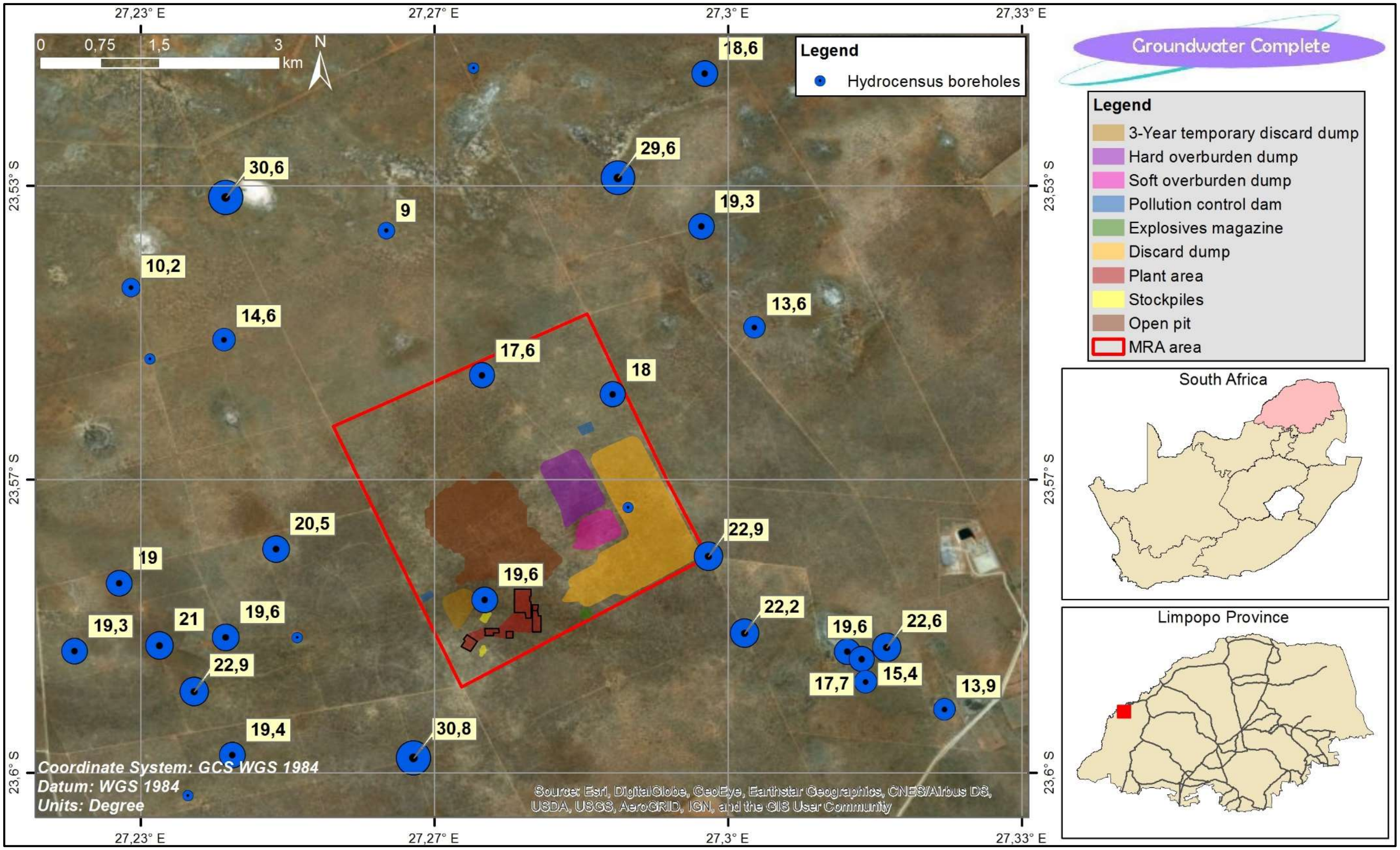

Figure 12: Thematic map of groundwater level depths (mbs)

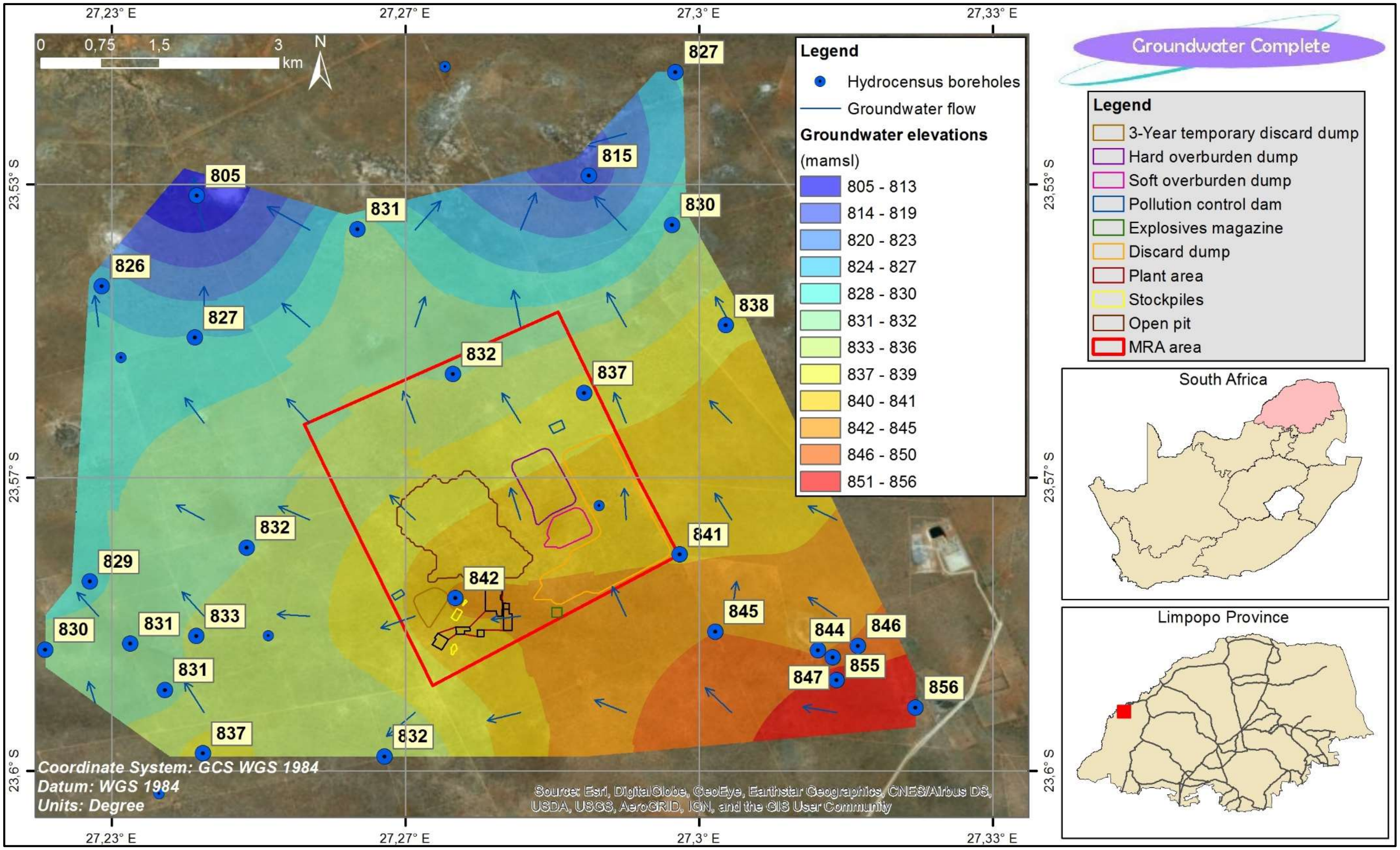

Figure 13: Contour map of groundwater level elevations (mamsl)

5.5 POTENTIAL SOURCE OF GROUNDWATER CONTAMINATION

A groundwater source area is defined as an area in which groundwater contamination is generated or released from as seepage or leachate. Source areas are subdivided into two main groups:

- Point sources
  The contamination can easily be traced back to the source.
- Diffuse sources
  Diffuse sources of groundwater contamination are typically associated with poor quality leachate formation through numerous surface sources.

The proposed coal mining operation will include the following sources or activities with the potential to produce poor quality leachate or seepage that may adversely affect groundwater quality:

- The opencast pit;
- Overburden and discard dumps, product stockpiles and run-of-mine stockpiles;
- Pollution control dams, return water dams and storm water control dams;
- Sewage treatment and waste disposal facilities; and
- Workshops, wash bays and fuel storage areas.

The contaminants of concern will be typical of a coal mining operation where pyrite in the coal and carbonaceous shale material causes a group of reactions collectively referred to as acid rock drainage (ARD). The contaminants of concern are usually sulphate, total dissolved solids in general and acidity, which in turn causes mobilisation of heavy metals.

5.6 POTENTIAL PATHWAYS FOR CONTAMINATION

In order for contamination to reach and eventually affect a receptor/s, it needs to travel along a preferred pathway. The effectiveness of a pathway to conduit contamination is determined by three main factors, namely:

- Hydraulic conductivity of pathway;
- Groundwater hydraulic gradient; and
- Area through which flow occurs.

All three abovementioned factors have a linear relationship with the flow of contamination through a preferred pathway, meaning an increase in any one of the three will lead to an increase in flow. This concept is explained by means of the Darcy flow equation below:

$$Q = KIA$$

Where Q = Flow (m^3/d)
K = Hydraulic conductivity (m/d)
I = Hydraulic gradient
A = Area through which flow occurs (m^2)

The saturated weathered zone aquifer and geological structures were identified as potential pathways in the project area and are briefly discussed below.

The weathered zone aquifer is mostly composed of sandy soil and weathered bedrock. With a relatively deep (17 - 22 mbs) water table at Gruisfontein the weathered zone will not play a major role as pathway since weathering is nearly exclusively above the water table. Borehole logs indicate the weathering at Gruisfontein to extend down to between 17 and 39 mbs.

With the weathered zone generally not extending far below the water table, the majority of flow through the groundwater pathway will be through transmissive fractures, fissures and joints in the solid bedrock. Such structures are mostly caused by faulting or other tectonic deformation processes.

Geological structures such as dykes and faults have the potential to serve as sufficient pathways for contamination. The crystalline nature of an igneous dyke is characteristic of an aquiclude, however rapid cooling during intrusion caused highly transmissive fracture zones to form along the contact between the intrusive and surrounding rock.

Several prominent faults occur in the Gruisfontein area. These faults are however mostly perpendicular to the general groundwater flow gradient and will rather act as barriers for groundwater flow and contaminant transport than preferred pathways on a regional scale.

The seepage rate (Darcy flux) of groundwater and potential contamination through the aquifer can be estimated with the following equation *(after Fetter, 1994)*:

$$v = \frac{KI}{\phi}$$

Where: *v = flow velocity (m/day)*
K = hydraulic conductivity (m/day)
I = average hydraulic gradient
ϕ = probable average porosity

Based on aquifer parameters estimated for the area the groundwater/contaminant flux in the Gruisfontein aquifer is estimated to be less than 2 m/y, which is considered to be relatively slow.

5.7 POTENTIAL RECEPTORS OF CONTAMINATION

A receptor of groundwater contamination usually occurs in the form of a groundwater user that relies on groundwater for domestic, irrigation or livestock watering purposes. Surface water features (stream, river, dam, etc.) that rely on groundwater base flow for the sustainment of the aquatic environment are the other type of important receptor.

Groundwater from some 20 of the actively used boreholes located during the user survey was sampled and the positions relative to the proposed activities have been indicated in several figures above. The nearest groundwater user outside Gruisfontein is located approximately 3.5 km downgradient from the proposed mining and waste activities – well beyond the model simulated/predicted groundwater quality and water level impacts **(Section 7.9)**.

The Limpopo River is the only potential receptor of groundwater base flow and is situated about 8 km from the proposed mine in the downgradient direction.

5.8 GROUNDWATER QUALITY

Groundwater quality data was analyzed for 20 user boreholes that were located and sampled during the hydrocensus/user survey. The positions of these boreholes are indicated on **Figure 15**, while the results of the analyses are provided in **Table 8**. A water sample was also collected at the Sasol minipit (SSPit) located nearly 3 kilometers to the east of the Gruisfontein MRA area. The samples were analyzed at a SANAS accredited laboratory *(Aquatico Laboratories)* for a wide range of chemical and physical indicator parameters.

The data was evaluated with the aid of diagnostic chemical diagrams and by comparing the inorganic concentrations with the South African National Standards for drinking water **(Table 7)**.

The four main factors usually influencing groundwater quality are:

- **Annual recharge** to the groundwater system;
- **Type of bedrock** where ion exchange may impact on the hydrogeochemistry;
- **Flow dynamics** within the aquifer(s), determining the water age; and
- **Source(s) of pollution** with their associated leachates or contaminant streams.

Where no specific source of groundwater pollution is present up gradient from the borehole, only the other three factors play a role.

One of the most appropriate ways to interpret the type of water at a sampling point is to assess the plot position of the water quality on different analytical diagrams like a Piper, Expanded Durov and Stiff diagrams. Of these three types, the Expanded Durov diagram probably gives the most holistic water quality signature. The layout of the fields of the Expanded Durov diagram (EDD) is shown in **Figure 16**.

Although never clear-cut, the general characteristics of the different fields of the diagram could be summarized as follows:

Field 1:

Fresh, very clean recently recharged groundwater with HCO_3 and CO_3 dominated ions.

Field 2:

Field 2 represents fresh, clean, relatively young groundwater that has started to undergo mineralization with especially Mg ion exchange.

Field 3:

This field indicates fresh, clean, relatively young groundwater that has undergone Na ion exchange (sometimes in Na - enriched granites or felsic rocks) or because of contamination effects from a source rich in Na.

Field 4:

Fresh, recently recharged groundwater with HCO_3 and CO_3 dominated ions that has been in contact with a source of SO_4 contamination or that has moved through SO_4 enriched bedrock.

Field 5:

Groundwater that is usually a mix of different types – either clean water from fields 1 and 2 that has undergone SO_4 and NaCl mixing / contamination or old stagnant NaCl dominated water that has mixed with clean water.

Field 6:

Groundwater from field 5 that has been in contact with a source rich in Na or old stagnant NaCl dominated water that resides in Na rich host rock/material.

Field 7:

Water rarely plots in this field that indicates NO_3 or Cl enrichment or dissolution.

Field 8:

Groundwater that is usually a mix of different types – either clean water from fields 1 and 2 that has undergone SO_4, but especially Cl mixing/contamination or old stagnant NaCl dominated water that has mixed with water richer in Mg.

Field 9:

Old or stagnant water that has reached the end of the geohydrological cycle (deserts, salty pans etc.) or water that has moved a long time and / or distance through the aquifer or on surface and has undergone significant ion exchange because of the long distance or residence time in the aquifer.

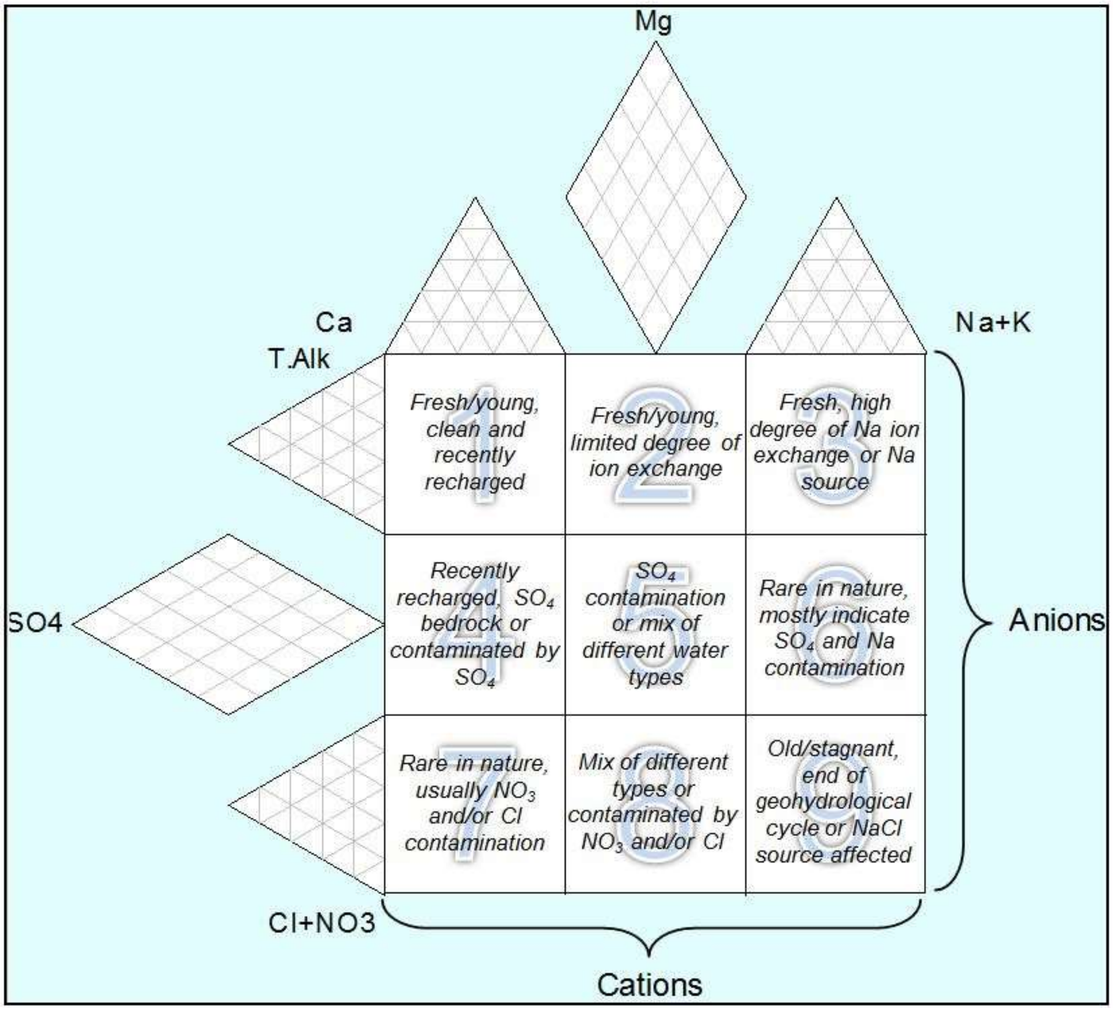

Figure 14: Layout of fields of the Expanded Durov diagram

Another way of presenting the signature or water type distribution in an area is by means of Stiff diagrams. These diagrams plot the equivalent concentrations of the major cations and anions on a horizontal scale on opposite sides of a vertical axis. The plot point on each parameter is linked to the adjacent one resulting in a polygon around the cation and anion axes. The result is a small figure/diagram of which the geometry typifies the groundwater composition at the point. Groundwater with similar major ion ratios will show the same geometry. Ambient groundwater qualities in the same aquifer type and water polluted by the same source will for example display similar geometries.

Table 7: South African National Standards for drinking water *(SANS 241:2015)*

Determinant	Risk	Unit	Standard limits
Physical and aesthetic determinants			
Free chlorine	Chronic health	mg/l	≤ 5
Monochloramine	Chronic health	mg/l	≤ 3
Conductivity at 25 °C	Aesthetic	mS/m	≤ 170
Total dissolved solids	Aesthetic	mg/l	≤ 1 200
Turbidity	Operational	NTU	≤ 1
	Aesthetic	NTU	≤ 5
pH at 25 °C	Operational	pH units	≥ 5 to ≤ 9.7
Chemical determinants - macro-determinants			
Nitrate as N	Acute health – 1	mg/l	≤ 11
Nitrite as N	Acute health – 1	mg/l	≤ 0.9
Sulfate as SO_4^{2-}	Acute health – 1	mg/l	≤ 500
	Aesthetic	mg/l	≤ 250
Fluoride as F^-	Chronic health	mg/l	≤ 1.5
Ammonia as N	Aesthetic	mg/l	≤ 1.5
Chloride as Cl^-	Aesthetic	mg/l	≤ 300
Sodium as Na	Aesthetic	mg/l	≤ 200
Zinc as Zn	Aesthetic	mg/l	≤ 5
Chemical determinants - micro-determinants			
Aluminium as Al	Operational	µg/l	≤ 300
Antimony as Sb	Chronic health	µg/l	≤ 20
Arsenic as As	Chronic health	µg/l	≤ 10
Barium Ba	Chronic health	µg/l	≤ 700
Boron B	Chronic health	µg/l	≤ 2 400
Cadmium as Cd	Chronic health	µg/l	≤ 3
Total chromium as Cr	Chronic health	µg/l	≤ 50
Cobalt as Co	Chronic health	µg/l	≤ 500
Copper as Cu	Chronic health	µg/l	≤ 2 000
Cyanide (recoverable) as CN^-	Acute health – 1	µg/l	≤ 70
Iron as Fe	Chronic health	µg/l	≤ 2 000
	Aesthetic	µg/l	≤ 300
Lead as Pb	Chronic health	µg/l	≤ 10
Manganese as Mn	Chronic health	µg/l	≤ 400
	Aesthetic	µg/l	≤ 100
Mercury as Hg	Chronic health	µg/l	≤ 6
Nickel as Ni	Chronic health	µg/l	≤ 70
Selenium as Se	Chronic health	µg/l	≤ 40
Uranium as U	Chronic health	µg/l	≤ 15
Vanadium as V	Chronic health	µg/l	≤ 200
Organic determinants			
Total organic carbon	Acute health – 1	mg/l	≤ 10

Total dissolved solids (TDS) is a good indicator of the overall quality of groundwater, as it provides a measure of the total amount/weight of salts that are present in solution. An increase in TDS will therefore indicate an increase in the total inorganic ion content of the groundwater. Groundwater from user boreholes around Gruisfontein display a relatively wide range of groundwater TDS concentrations of between 380 mg/l and 2130 mg/l. The lower end indicates good groundwater quality with water in only three boreholes exceeding the SANS guideline concentration of 1 200 mg/l. Water from the Sasol minipit to the east of Gruisfontein is also below the guideline concentration at 1 088 mg/l.

Groundwater TDS concentrations in the four boreholes on the Gruisfontein farm vary between 480 mg/l and 580 mg/l, which is in the lower part of the hydrocensus population **(Table 8)**.

Groundwater **pH** under natural conditions is affected by the chemical composition and redox status of the aquifer host rock/s. At very low pH levels dissolved toxic metal ions are present, which can lead to severe health problems if consumed. At low pH levels (less than ± 4.5) the water will have a sourly taste. At high pH levels there is a health hazard due to the de-protonated species and water will have a soapy taste. Groundwater pH values on and around Gruisfontein vary between 7 to 8.9, which are well within recommended SANS ranges for drinking water purposes.

Groundwater **nitrate** contamination in a rural environment may potentially originate from nitrate-based fertilisers, sewage treatment facilities, pit latrines and animal feedlots or kraals. In the Gruisfontein area only the last two activities are generally present. The groundwater nitrate content of uncontaminated groundwater is usually less than 2 mg/l. Groundwater nitrate concentrations around Gruisfontein generally vary between 0.4 mg/l and 10 mg/l, which are below the maximum permissible SANS value of 11 mg/l. User borehole WB28 is however the exception and displayed a very high groundwater nitrate concentration of 162 mg/l, far exceeding the maximum content of 11 mg/l allowed in drinking water *(SANS 241:2015)*. **This borehole is used for livestock watering, but it poses a health risk even to livestock**. Concentrations of between ±7 mg/l and 10 mg/l were measured in boreholes GRU02, 03, 06, 07 and SS12. These concentrations are considered to be high for the project area given that the average ambient/unaffected groundwater nitrate content is expected to be just under 1 mg/l. With the exception of GRU03 all abovementioned boreholes are situated within or close to kraals.

Magnesium is an alkaline metal that occurs naturally in groundwater. Except for diarrhoea when consumed at very high concentrations (>200 mg/l), no significant health risks are associated with the intake of magnesium. No guideline concentration is therefore specified for magnesium in the South African National Standards *(SANS 241:2015)* for drinking water purposes. Groundwater magnesium concentrations are relatively low and vary between ± 17 mg/l and 55 mg/l **(Table 8)**.

Chloride usually has no health effects when consumed at concentrations generally found in fresh groundwater. Sensitive groundwater users may experience nausea and vomiting at chloride concentrations in excess of ± 1 200 mg/l. The maximum permissible SANS value for chloride is 300 mg/l. Groundwater from user boreholes around Gruisfontein display chloride concentrations of between ±150 mg/l and 660 mg/l. Chloride concentrations measured in the four boreholes to the north of Gruisfontein exceed the guideline concentration.

Sodium is the dominating cation in the majority of boreholes and varies between 90 mg/l and 290 mg/l.

On Gruisfontein the groundwater chloride content varies between 78 mg/l and 180 mg/l. The chloride content provides an indication of the effective recharge percentage to the aquifer (refer to the Chloride Method estimation results in **Section 4.7**). Based on the general trend of groundwater chloride content the effective recharge will be slightly higher in the central Gruisfontein area and lower towards the north.

The **manganese** concentrations are generally below 0.1 mg/l or below the detection limit (0.005 mg/l) in Gruisfontein boreholes and those further north. In the southern user boreholes manganese content varies between 0.1 mg/l and 0.25 mg/l. All concentrations are below the SANS guidelines of 0.4 mg/l and 1.5 mg/l respectively **(Table 8)**. The slightly higher manganese content in the southern boreholes may be a result of the geology of the aquifer host rocks.

According to the Expanded Durov diagram **(Figure 18)** groundwater around Gruisfontein is dominated by sodium on the anion side (plot in fields 3, 6 and 9). The exception is WB28, which plots in field 8 due to its very high nitrate content. On the cation side the split is about even between those dominated by bicarbonate alkalinity (field 3) and chloride (field 9). Borehole GRU03 plots in field 6 not because sulphate dominates, but because the anion content is divided nearly equally between bicarbonate alkalinity and chloride.

On Gruisfontein itself the four analysed samples plot in field 3 of the Expanded Durov diagram **(Figure 17)**, indicating relatively fresh groundwater where sodium has exchanged calcium and dominates the cation content, while bicarbonate alkalinity dominates the anion content.

The Stiff diagrams for the boreholes surrounding Gruisfontein show the same picture as the Expanded Durov diagram with two main geometries dominating. The geometry of WB28 is markedly different with calcium and chloride dominating the macro element content.

The Stiff diagrams of the four boreholes on Gruisfontein have very similar geometries due to similar water qualities.

Summary:

- According to the South African National Standards for drinking water *(SANS 241:2015)*, groundwater from most of the user boreholes is suitable for human consumption and domestic use.
- Exceptions do however occur with some elevated inorganic salinities (TDS, chloride, sodium) exceeding the maximum concentrations allowed in drinking water.
- **The highest risk borehole in terms of drinking water for humans and even livestock is WB28.** This borehole displayed a nitrate concentration of 168 mg/l, which

far exceeds the maximum content of 11 mg/l allowed in drinking water. It is strongly recommended that this borehole not be used since it poses a health risk to livestock.

- The most apparent reason for the high nitrate content in WB28 and five other user boreholes is their proximity to kraals where livestock urine and waste are believed to be responsible for the nitrate contamination.
- Groundwater within the Gruisfontein MRA area is generally of good quality, suitable for human consumption and dominated by sodium cations, while bicarbonate alkalinity dominates the anion content.

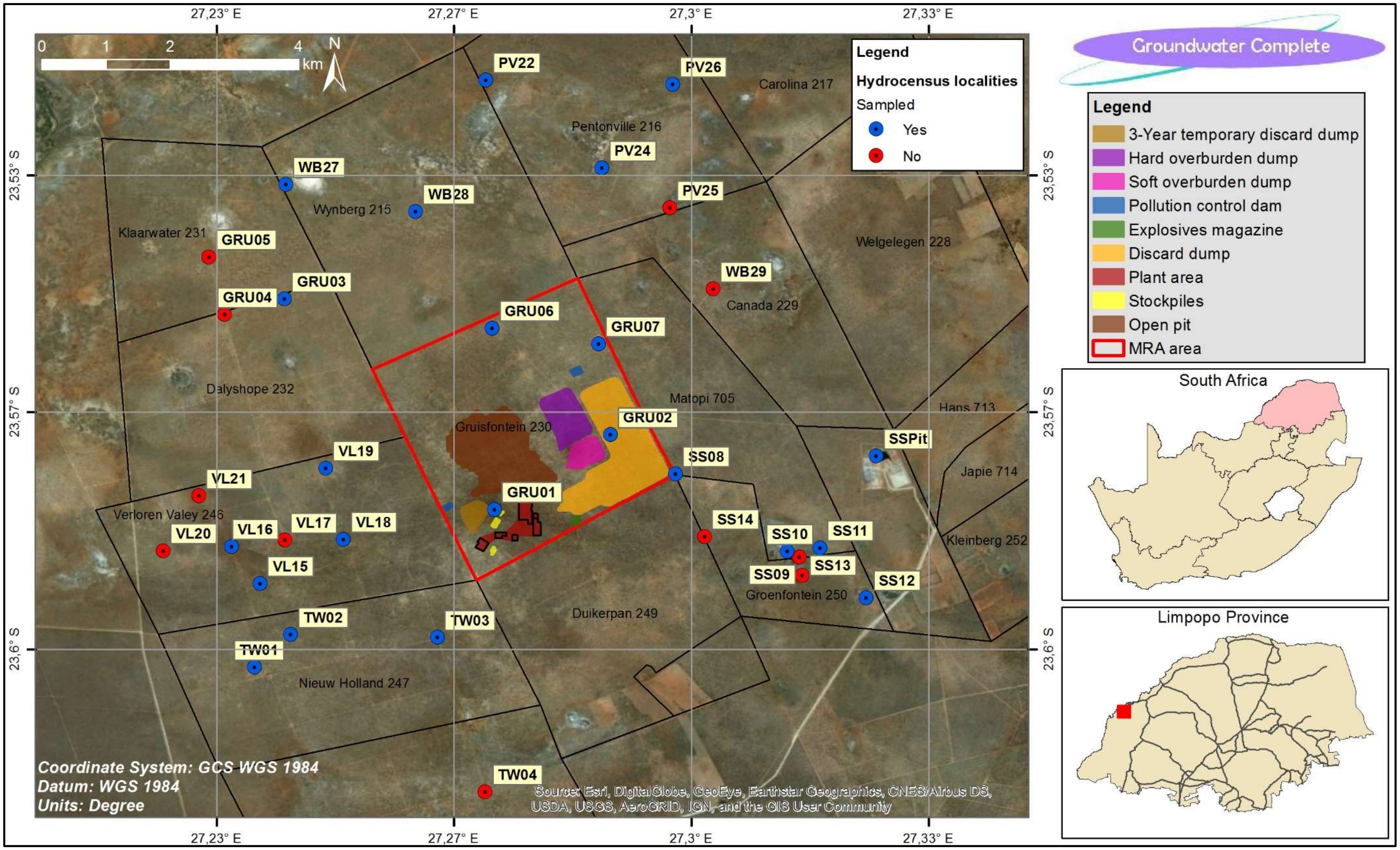

Figure 15: Distribution of groundwater quality data points

Table 8: Concentrations of chemical and physical indicator parameters

BH ID	pH	EC mS/m	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO_4 mg/l	NO_3 mg/l	F mg/l	Al mg/l	Fe mg/l	Mn mg/l	NH_4 mg/l	PO_4 mg/l	Total Hard. mg/l	Total Alk. mg/l
TW01	8.07	119	823	65.9	39.4	180	13	289	64.5	0.569	0.56	<0.002	<0.004	<0.001	0.015	<0.005	327	274
SS10	6.53	70.4	469	22.8	17.9	117	12.3	173	30.1	0.439	<0.263	<0.002	<0.004	0.228	0.879	<0.005	131	152
SS11	7.42	101	692	43.1	24.7	171	12.2	276	38.5	1.05	<0.263	<0.002	<0.004	0.223	0.024	<0.005	209	199
SS12	7.26	82	559	36.1	28.4	130	6.33	164	15.4	9.68	0.773	<0.002	<0.004	0.254	0.019	<0.005	207	221
VL15	7.04	96.8	692	54.7	29.7	154	11	174	31.3	0.47	0.646	<0.002	<0.004	0.087	0.16	<0.005	259	383
VL16	7.3	111	813	50.7	37.9	191	5.64	213	56.5	1.96	1.01	<0.002	<0.004	<0.001	0.016	<0.005	283	406
VL18	7.27	81	544	32.1	24.4	143	3.46	147	18.1	4.05	0.611	<0.002	<0.004	<0.001	0.013	<0.005	181	258
VL19	7.78	108	666	35.8	42.3	147	11	402	<0.141	0.422	1.24	<0.002	<0.004	0.109	0.152	<0.005	264	39.8
TW02	7.42	117	810	66.5	36.5	174	15	291	51.6	0.486	0.546	<0.002	<0.004	0.257	0.159	<0.005	316	284
PV24	7.73	178	1243	114	54.4	239	23.8	560	68.9	1.67	1.02	0.01	<0.004	0.004	0.113	<0.005	508	286
PV26	7.65	205	1432	131	54.8	290	24.8	659	94.3	0.971	1.3	<0.002	<0.004	0.036	0.659	<0.005	552	282
WB27	7.94	133	922	83	39.5	188	20.6	359	47	0.555	1.05	<0.002	<0.004	<0.001	1.12	<0.005	370	296
WB28	7.75	256	2126	277	118	195	24	549	71.1	162	1.05	<0.002	<0.004	<0.001	0.022	<0.005	1179	284
TW03	7.26	111	769	30.8	21.9	217	13.1	256	52.2	1.02	0.532	<0.002	<0.004	<0.001	0.013	<0.005	167	285
SS08	8.34	56.6	381	19.6	31.1	89.3	4.55	84.9	<0.141	0.598	<0.263	<0.002	<0.004	<0.001	0.043	<0.005	177	244
GRU03	8.21	75.7	532	45.5	24.2	113	6.11	141	23.9	8.77	0.711	<0.002	<0.004	<0.001	0.011	0.011	213	228
SS Pit	8.89	155	1088	26.5	37.5	305	17.5	372	101	3.67	1.61	<0.002	<0.004	<0.001	0.026	<0.005	220	344
GRU01	7.37	84.8	577	33.7	24.1	153	5.49	180	9.35	0.597	0.673	<0.002	<0.004	0.038	0.498	<0.005	183	275
GRU02	7.96	73.2	514	37.4	16.7	133	6.41	82.8	33.4	8	0.717	<0.002	<0.004	<0.001	0.026	<0.005	162	275
GRU06	7.71	69.2	510	46.6	19.2	120	6.17	84.7	39.3	8.55	0.642	0.003	<0.004	<0.001	0.482	0.022	196	254
GRU07	7.75	72.9	479	39.7	16.6	114	6.01	78	35.1	7	0.686	0.009	<0.004	<0.001	0.032	<0.005	168	259

Notes: ***Red*** – *Parameter value exceeds maximum concentration allowed in drinking water for health effects (SANS 241:2015);*
Blue – *Parameter value exceeds maximum concentration allowed in water for domestic use for aesthetic effects (SANS 241:2015);*
Shaded – *Four boreholes on Gruisfontein farm.*

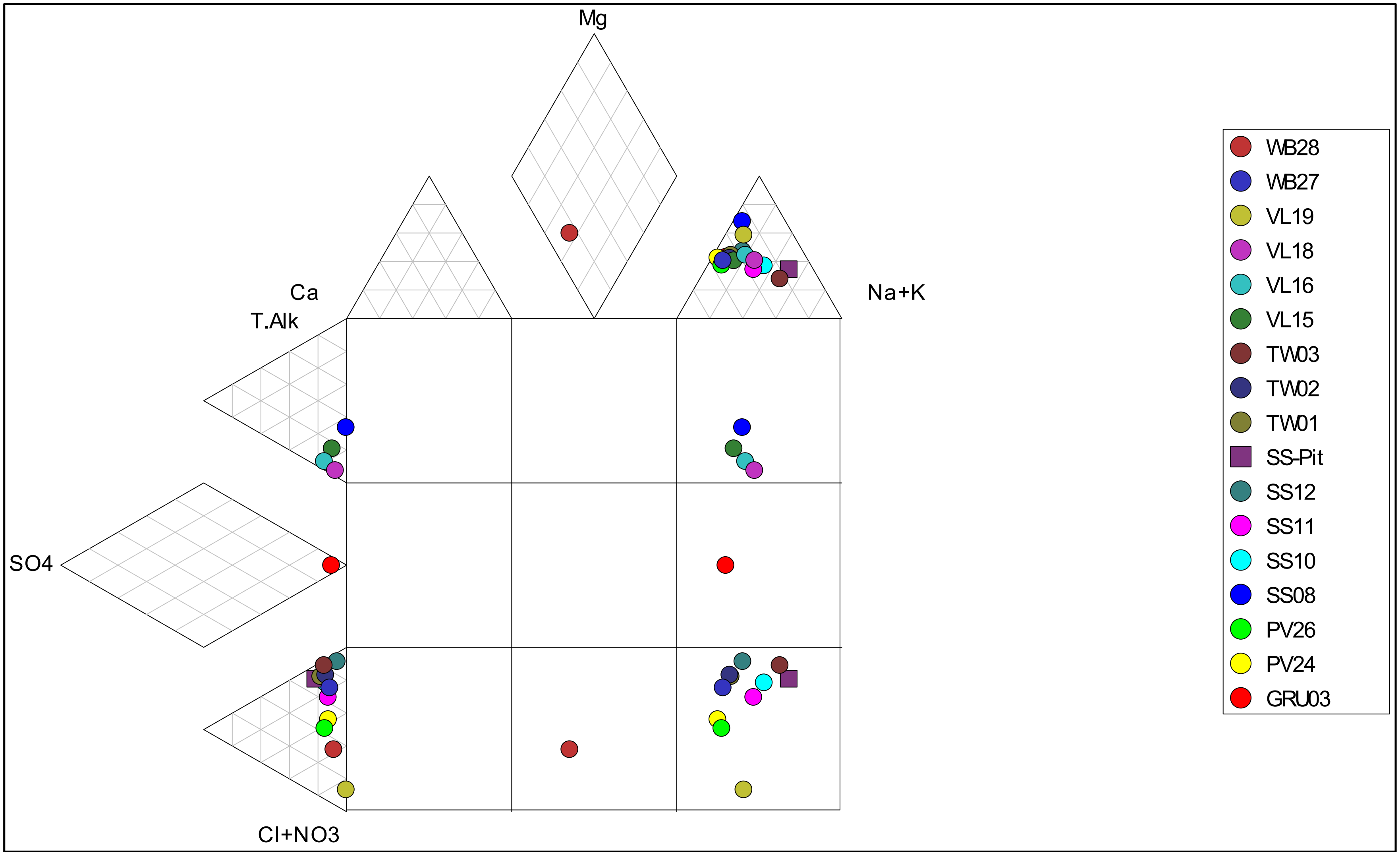

Figure 16: Expanded Durov diagram of groundwater chemistries on farms around Gruisfontein

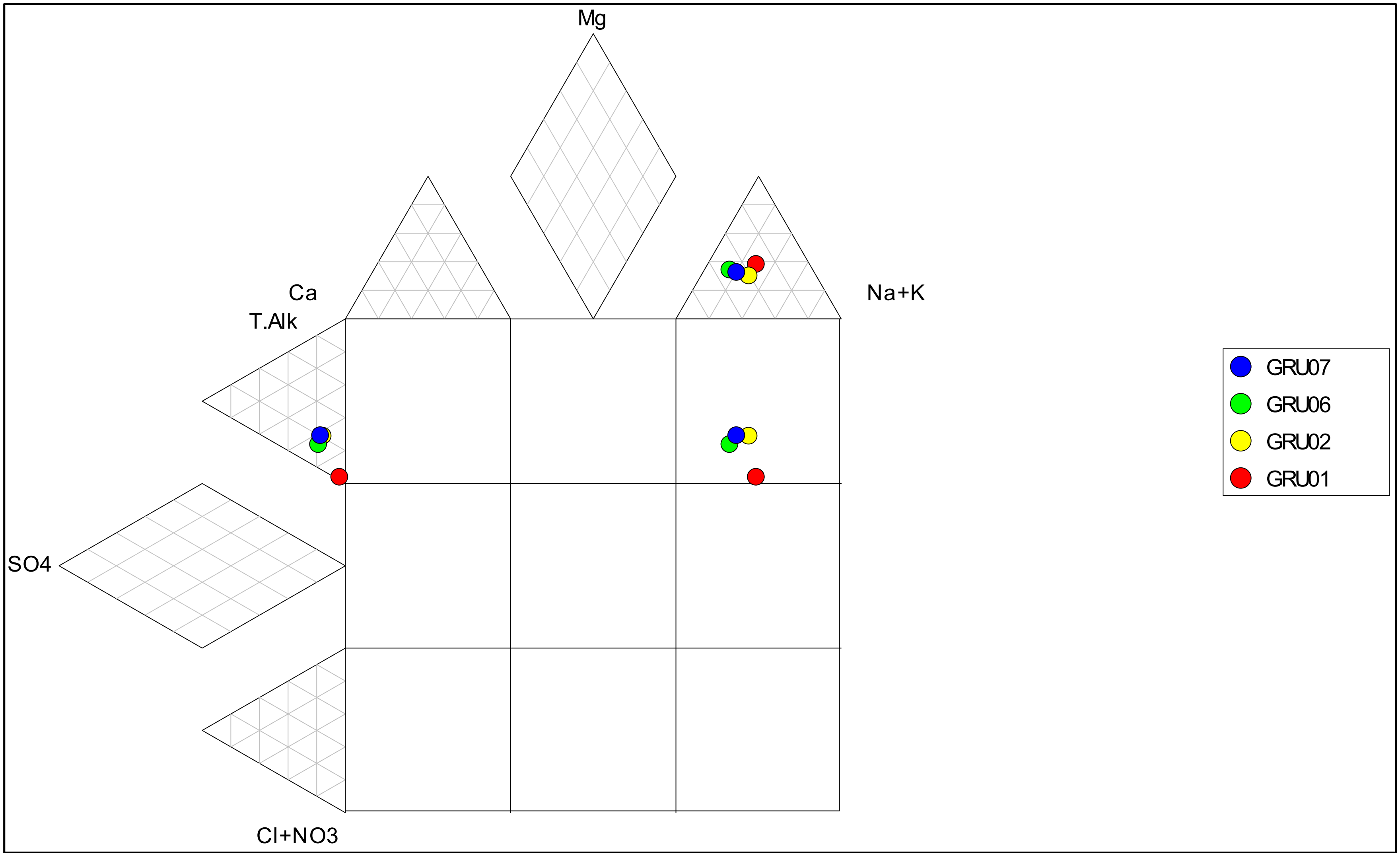

Figure 17: Expanded Durov diagram of groundwater chemistries on the farm Gruisfontein

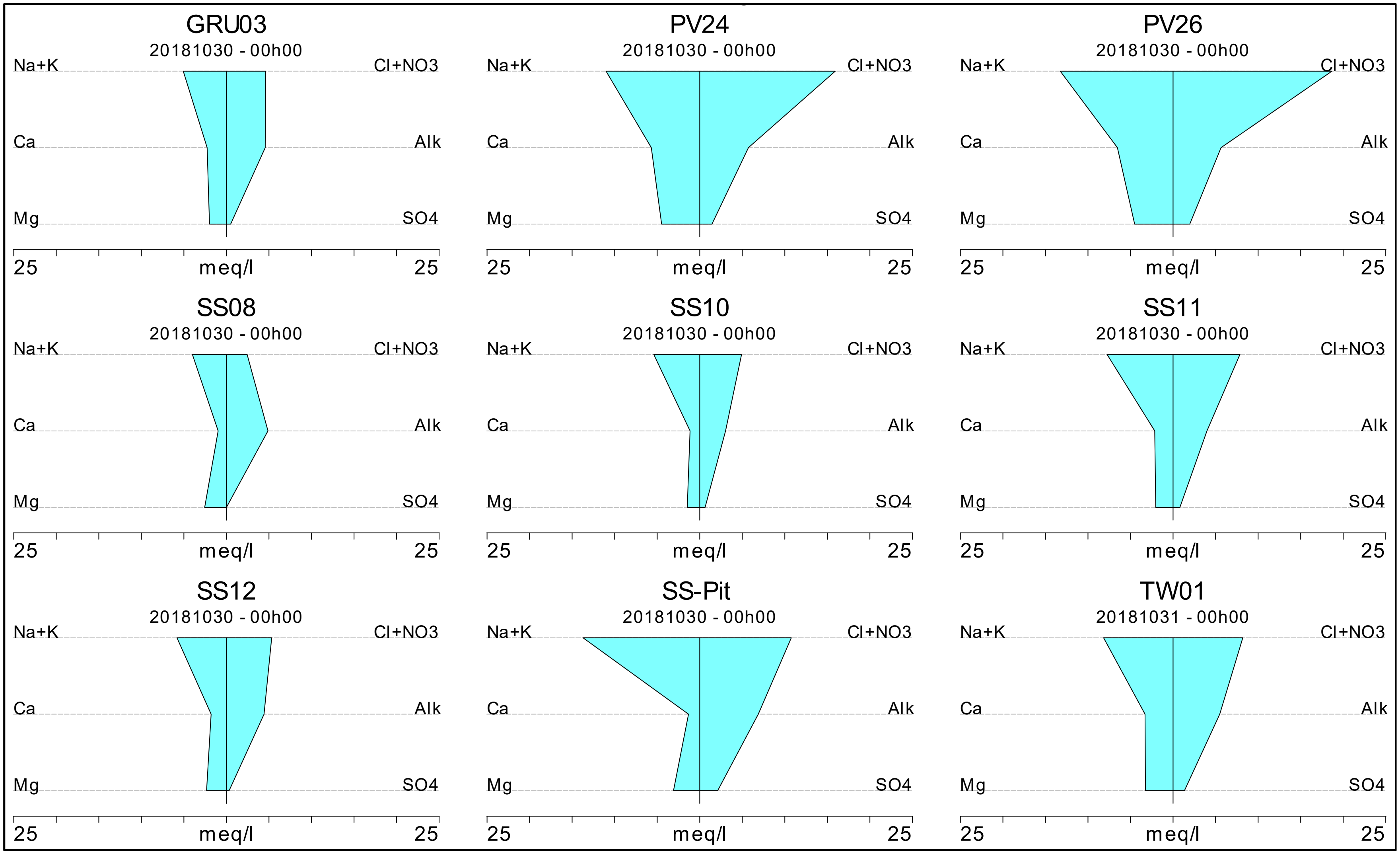

Figure 18: Stiff diagrams of surrounding farms groundwater quality

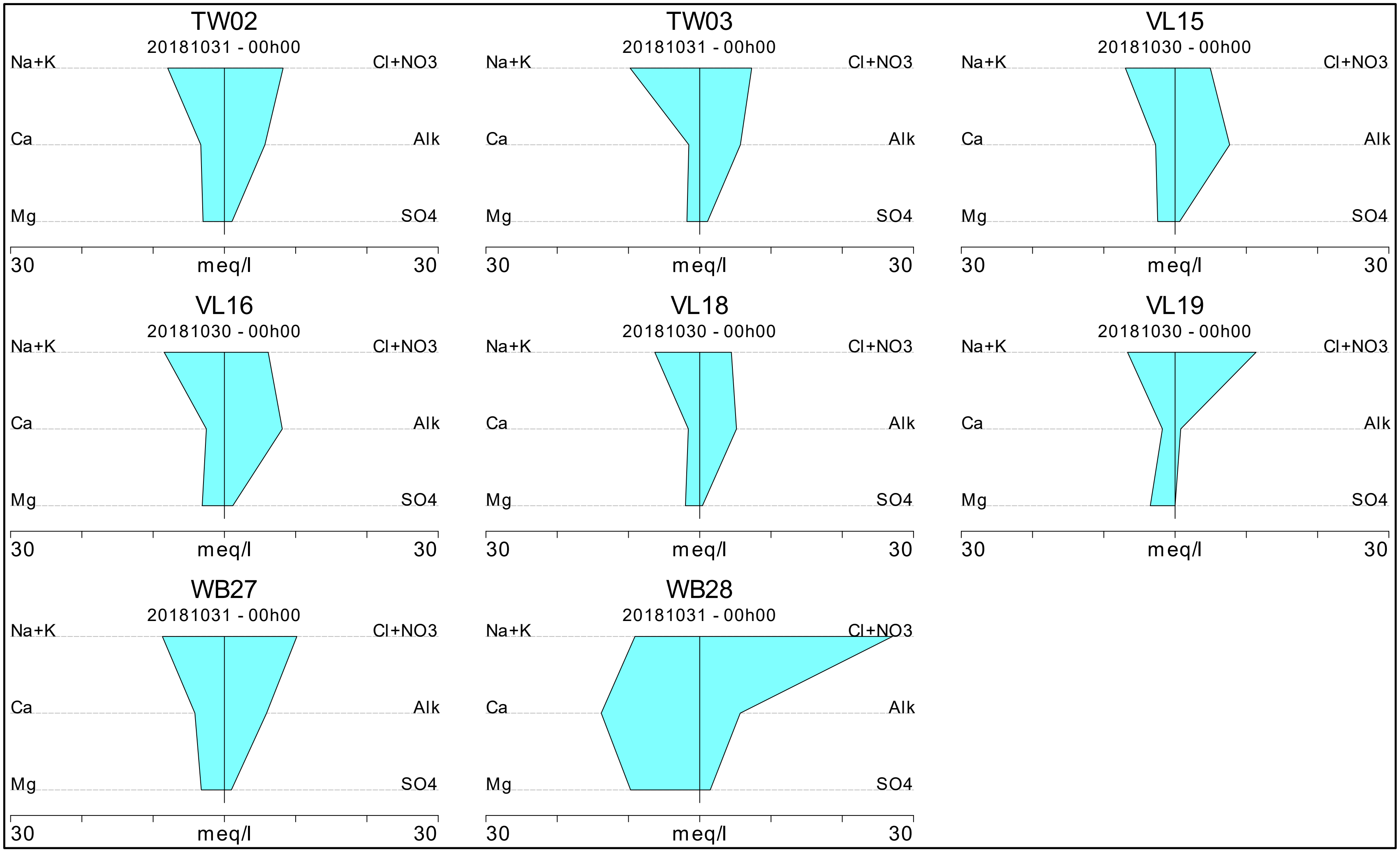

Figure 18: Stiff diagrams of surrounding farms groundwater quality (continue)

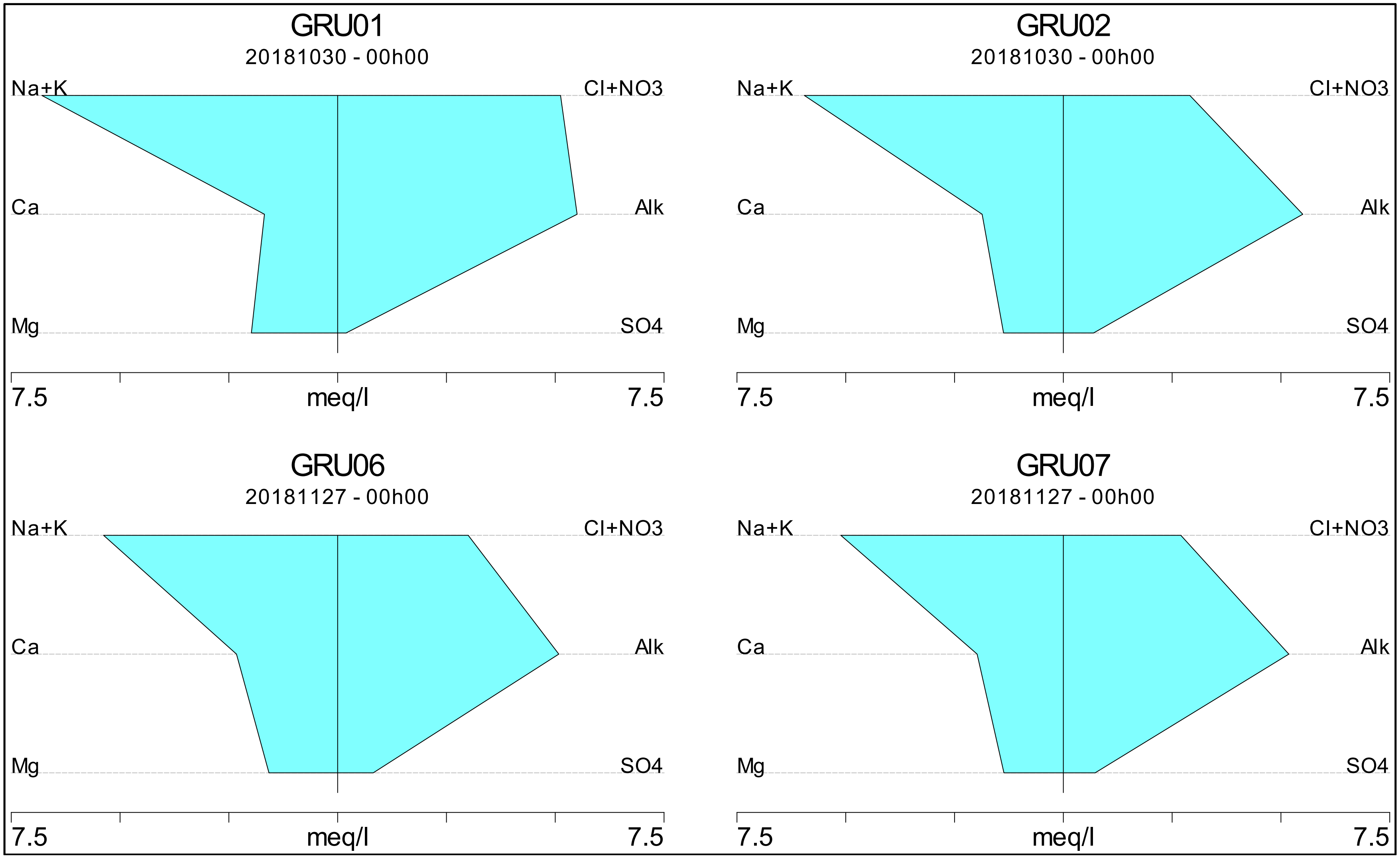

Figure 19: Stiff diagrams of Gruisfontein groundwater quality

6 AQUIFER CHARACTERISATION

6.1 GROUNDWATER VULNERABILITY

The *Groundwater Vulnerability Classification System* used in this investigation was developed as a first order assessment tool to aid in the determination of an aquifer's vulnerability/susceptibility to groundwater contamination. This system incorporates the well-known and widely used *Parson's Aquifer Classification System* as well as drinking water quality guidelines as stated by the *Department of Water and Sanitation*. This system is especially useful in situations where limited groundwater related information is available and is explained in **Table 9** and **Table 10**. The project area achieved a score of 8 **(Table 11)** and the underlying aquifer can therefore be regarded as having a medium vulnerability.

Table 9: Groundwater vulnerability rating for project area

	Rating
Depth to groundwater level	1
Groundwater quality	3
Aquifer type	4
Total score:	**8**

Table 10: Groundwater vulnerability classification system

Rating	***4***	***3***	***2***	***1***
Depth to groundwater level	0 – 3 m	3 – 6 m	6 – 10 m	>10 m
Groundwater quality *(Domestic WQG*)*	Excellent (TDS < 450 mg/l)	Good (TDS > 450 < 1 000 mg/l)	Marginal (TDS > 1 000 < 2 400 mg/l)	Poor (TDS > 2 400 mg/l)
Aquifer type *(Parsons Aquifer Classification)*	Sole aquifer system	Major aquifer system	Minor aquifer system	Non-aquifer system

** WQG = Water Quality Guideline.*

Table 11: Groundwater vulnerability rating

Vulnerability	**Rating**
Low vulnerability	≤ 4
Medium vulnerability	> 4 ≤ 8
High vulnerability	≥ 9

6.2 AQUIFER CLASSIFICATION

Information collected during the hydrocensus, aquifer testing and assessment of numerous exploration borehole logs and geological maps as well as experience from numerous studies conducted in similar geohydrological environments suggest that two possible aquifer types may be present in the project area. For the purpose of this study an aquifer is defined as a geological formation or group of formations that can yield groundwater in economically useable quantities. Aquifer classification according to the Parson's Classification system is summarised in **Table 12**.

The **first aquifer** is a shallow, semi-confined or unconfined aquifer that occurs in the transitional soil and weathered bedrock zone or sub-outcrop horizon and often displays characteristics of a **primary porosity aquifer** (i.e. **weathered zone aquifer**). Yields in this aquifer are generally low (less than 0.5 l/s) and the aquifer is usually not fit for supplying groundwater on a sustainable basis. Consideration of the shallow aquifer system becomes important during seepage estimations from pollution sources to receiving groundwater and surface water systems because the lateral seepage component in this aquifer often dominates the flow. **According to the Parsons Classification system, this aquifer is usually regarded as a minor- and in some cases a non-aquifer system.**

The **second aquifer** system is the deeper **double porosity aquifer** that is hosted within the sedimentary rocks of the Karoo Supergroup (i.e. **fractured rock aquifer**). Groundwater yields, although more heterogeneous, can be higher. This aquifer system usually displays semi-confined or confined characteristics with piezometric heads often significantly higher than the water-bearing fracture position. Fractures may occur in any of the co-existing host rocks due to different tectonic, structural and genetic processes. **According to the Parsons Classification system, the aquifer could be regarded as a minor aquifer system, but also a sole aquifer system since groundwater is the only source of water in the project area.**

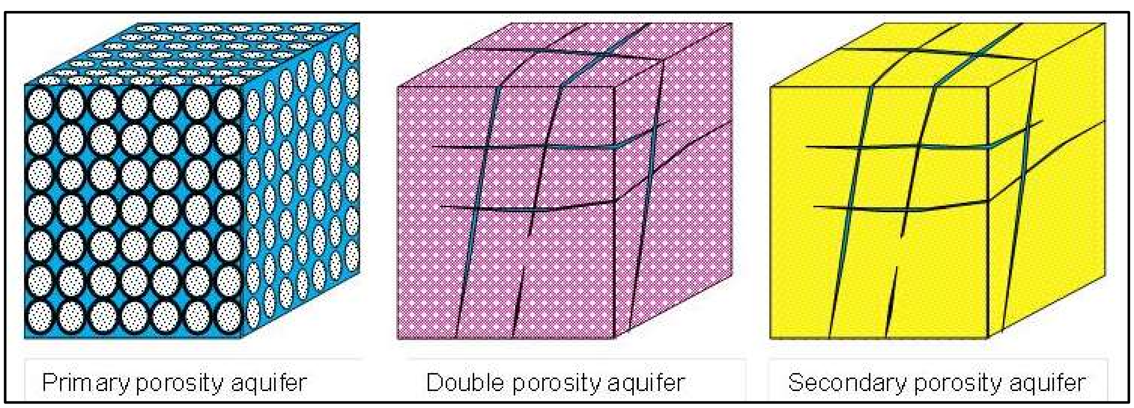

Figure 20: Types of aquifers based on porosity

Table 12: Parsons Aquifer Classification *(Parsons, 1995)*

Sole Aquifer System	An aquifer that is used to supply 50% or more of domestic water for a given area, and for which there is no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
Major Aquifer System	Highly permeable formation, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (less than 150 mS/m).
Minor Aquifer System	These can be fractured or potentially fractured rocks that do not have a primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large volumes of water, they are important both for local suppliers and in supplying base flow for rivers.
Non-Aquifer System	These are formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks, although impermeable, does take place, and needs to be considered when assessing the risk associated with persistent pollutants.
Special Aquifer System	An aquifer designated as such by the Minister of Water Affairs, after due process.

6.3 AQUIFER PROTECTION CLASSIFICATION

In 1995 Roger Parsons prepared a report for the Water Research Commission and the Department of Water Affairs titled, "*A South African Aquifer System Management Classification*". Amongst other things, he described how the need or importance to protect groundwater led to the development of a Groundwater Quality Management classification system, or GQM. The level of protection depends on the aquifer vulnerability **(Section 6.1)**, and aquifer classification **(Section 6.2)**. The GQM (or level of protection) is calculated by multiplying aquifer vulnerability with aquifer classification and the results can be interpreted as follows:

Aquifer vulnerability		**Aquifer classification**		**GQM**		**Rating**
Class	**Points**	**Class**	**Points**	**Index**	**Level of protection**	
High	3	Sole aquifer	6	<1	Limited	**12**
		Major aquifer	4	1 - 3	Low	
Medium	2	Minor aquifer	2	3 – 6	Medium	
Low		Non-aquifer	0	6 – 10	High	
	1	Special aquifer	0 - 6	>10	Strictly non-degradation	

The GQM for Gruisfontein calculates to 12, which indicates a very high-level of protection where strictly no groundwater degradation is allowed. The high score is a direct result of the aquifer's classification as a sole source since groundwater users do occur within the project area that rely on groundwater as the only source of water for their livelihood **(Section 4.2)**. It is therefore crucial that a comprehensive groundwater monitoring program **(Section 9)** be implemented and followed with diligence should the project go ahead.

6.4 AQUIFER DELINEATION

Because the main aquifer is a fractured rock type and fractures could assume any geometry and orientation, the physical boundary or 'end' of the aquifer is very difficult to specify or quantify. Aquifer boundary conditions that are generally considered during the delineation process are described below:

- No-flow boundaries are groundwater divides (topographic high or low areas/lines) across which no groundwater flow is possible;
- Dolerite dykes or faults with major displacement may also act as barriers for horizontal groundwater flow and thus cause local 'boundaries' for the aquifer; and
- Constant head boundaries are positions or areas where the groundwater level is fixed at a certain elevation and does not change (perennial rivers/streams or dams/pans).

Topographic highs and lows were used to roughly delineate the aquifer system underlying the project area **(Figure 21)** in combination with major faults and dyke structures. Based on this delineation the aquifer as it relates to the proposed project covers an area of approximately 252 km^2.

Please note that more geological structures may occur within the project area that have not yet been identified, neither have the hydraulic properties of the known structures been determined during this investigation. The aquifer boundaries as indicated in **Figure 21** are therefore considered to be conceptual and should be confirmed through field testing.

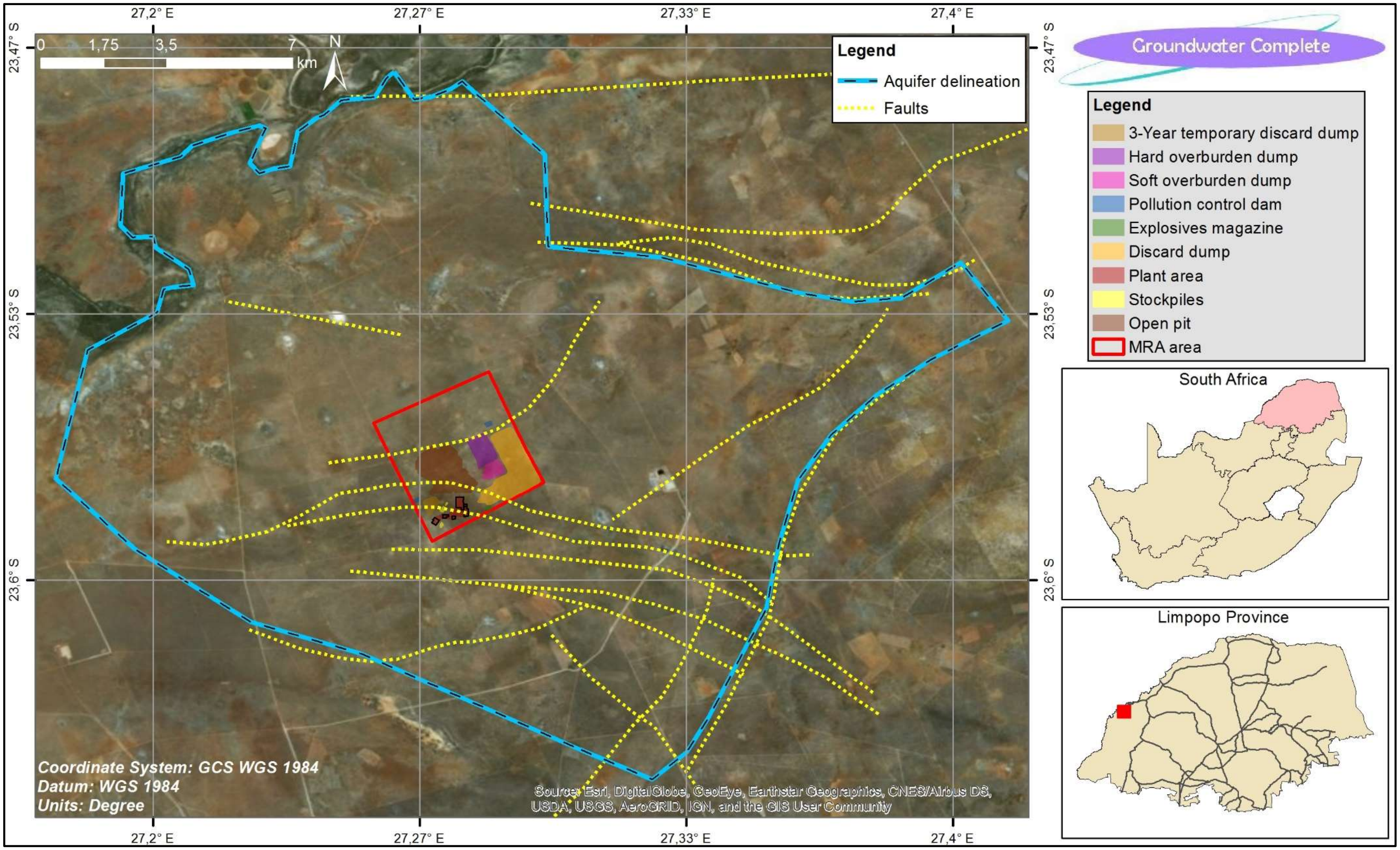

Figure 21: Aquifer delineation for Gruisfontein project area

7 NUMERICAL GROUNDWATER MODELLING

7.1 MODEL RESTRICTIONS AND LIMITATIONS

The numerical groundwater model, despite all efforts and advances in software and algorithms, remains a very simplified representation of the very complex and heterogeneous interacting aquifer systems underlying the project area. The integrity of a numerical model depends strongly on the formulation of a sound conceptual model and the quality and quantity (distribution, length of records etc.) of input data.

Nonetheless, a numerical model can still be used quite successfully to assess the effectiveness of various management and remediation options/techniques, especially if the shortcomings in information and assumptions made in the construction and calibration of the model are clearly listed and considered by the modeller during modelling.

The main purpose is thus not to try and predict what the exact groundwater level or quality would be at a certain position at a specific moment in the future. The heterogeneity of the natural groundwater system is simply too great to accurately incorporate and simulate accurately in the model. **The purpose is therefore to rather evaluate what the relative magnitude or contribution of certain impacts would be on the larger groundwater regime.**

7.2 MODEL SOFTWARE

The Processing Modflow 8 modelling package was used for the model simulations, which is a finite difference type model capable of performing multi-layered (3-dimensional) flow and contaminant transport simulations. It uses the MODFLOW algorithm for the flow modelling, while the MT3DMS algorithm was used for contaminant transport simulations.

7.3 MODEL SET-UP AND BOUNDARIES

Model dimensions and aquifer parameters used in the construction and calibration of the flow model are provided in **Table 13**.

The following model boundaries were used to define the model area and are also indicated on **Figure 22**:

- **No-flow boundaries** in the form of local topographic highs. These boundaries, as in nature, are groundwater divides (topographic high or low areas/lines) across which no groundwater flow is possible.

- **General head boundaries** are boundaries through which groundwater movement is possible. The rate at which the groundwater moves through the boundary depends on the groundwater gradients as well as the hydraulic conductivities on opposite sides of the boundary position.
- **Constant head boundaries** are positions or areas where the groundwater level is fixed at a certain elevation and does not change, i.e. perennial rivers/streams or dams/pans. The perennial Limpopo River forms the north-western model boundary, however it was simulated using general river nodes instead of constant head nodes.

All model boundaries were set at a distance that would ensure they do not interfere with the flow and contaminant transport model simulations. The conceptual model as summarised in **Section 7.7** formed the basis for the numerical groundwater model.

Table 13: Model dimensions and aquifer parameters

Grid size	Easting = 13 980 m Northing = 18 000 m
Rows and Columns	Rows = 600, Columns = 466
Cell size	30 m by 30 m
Layers	Layer 1: Confined/Unconfined
	Layer 2: Confined
Transmissivity	Layer 1: 1.2 m^2/day
	Layer 2: 0.25 m^2/day
Specific yield	Layer 1: 0.15
Storage coefficient	Layer 2: 0.006
Recharge	1% of MAP

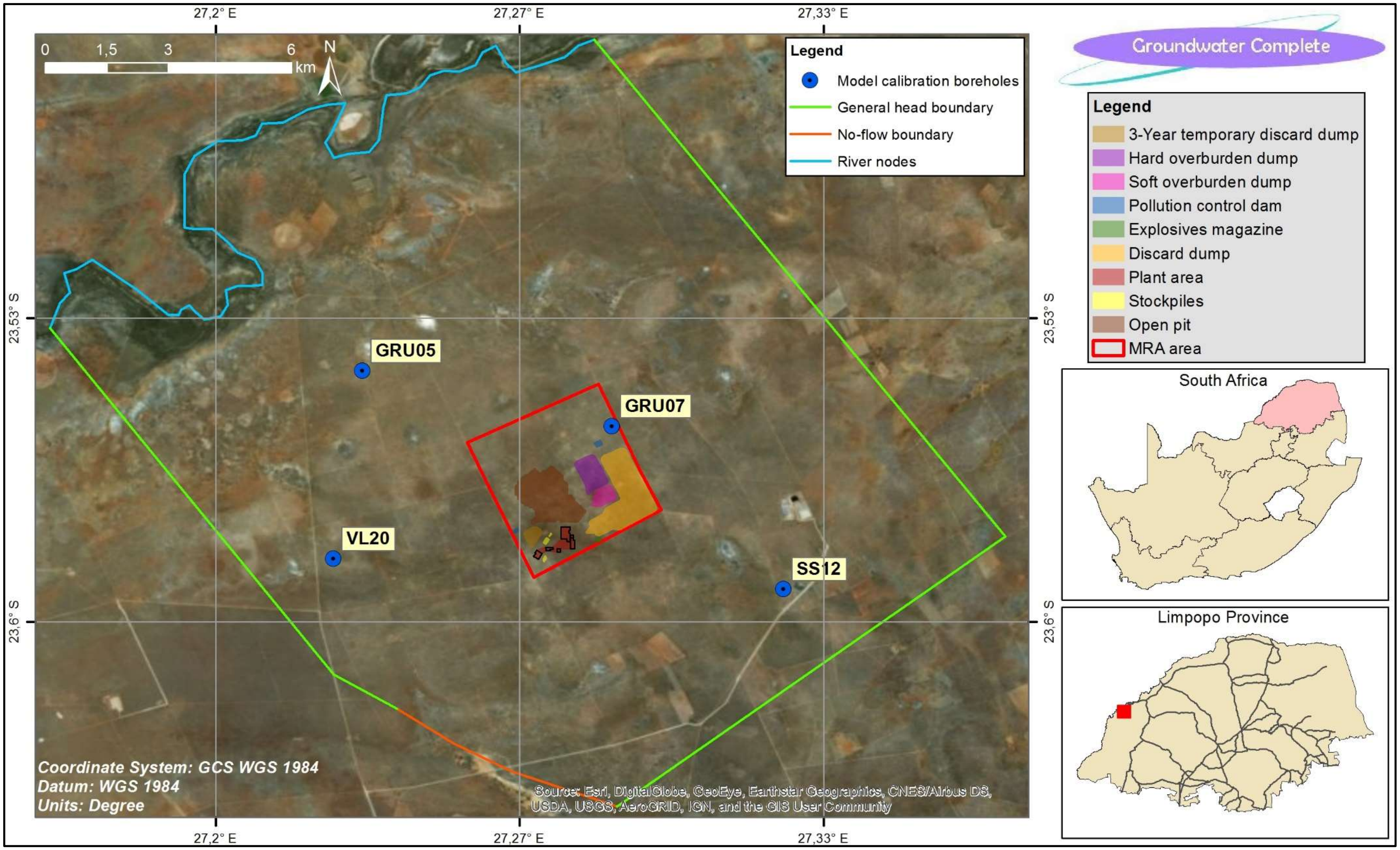

Figure 22: Numerical groundwater model domain

7.4 GROUNDWATER ELEVATION AND GRADIENT

During the steady state calibration of a flow model, changes are made to mainly the hydraulic properties (transmissivity) of the aquifer host rock and effective recharge **(Table 13)** until an acceptable correlation is achieved between the measured/observed groundwater elevations and those simulated by the model. These model simulated groundwater elevations are then specified as initial groundwater levels and form the basis for the transient state model simulations to follow.

Groundwater level information collected during the hydrocensus/user survey of November 2018 **(Section 5.4)** was used in the calibration of the flow model. A very good correlation (i.e. root mean square error or RMSE of ±0.9) was achieved with the calibration of the flow model and the results are provided in **Figure 23**. The good correlation suggests that the simulated water levels in the simplified model simulation closely resemble the actual water levels. Model predictions in reasonable time frames should therefore provide results to an acceptable level of confidence. However, it should be noted that areas do exist where very little or even no water level information is available, which combined with the heterogeneous nature of the underlying aquifer are bound to result in over- and/or underestimations of the groundwater elevations.

The calibrated groundwater elevations were exported from the flow model and used to construct a contour map of the steady state groundwater elevations **(Figure 24)**. Groundwater flow from the MRA area is towards the north-west in the direction of the perennial Limpopo River. The average groundwater gradient in this direction was simulated to be in the region of 0.4%.

Steady state simulation – model runs until groundwater levels reach a state of equilibrium, i.e. total groundwater inflow from natural sources is equal to the total volume of groundwater outflow through natural sinks. Transient state simulation – model runtime is predetermined according to desired scenario and groundwater levels are now affected by sinks and sources other than natural.

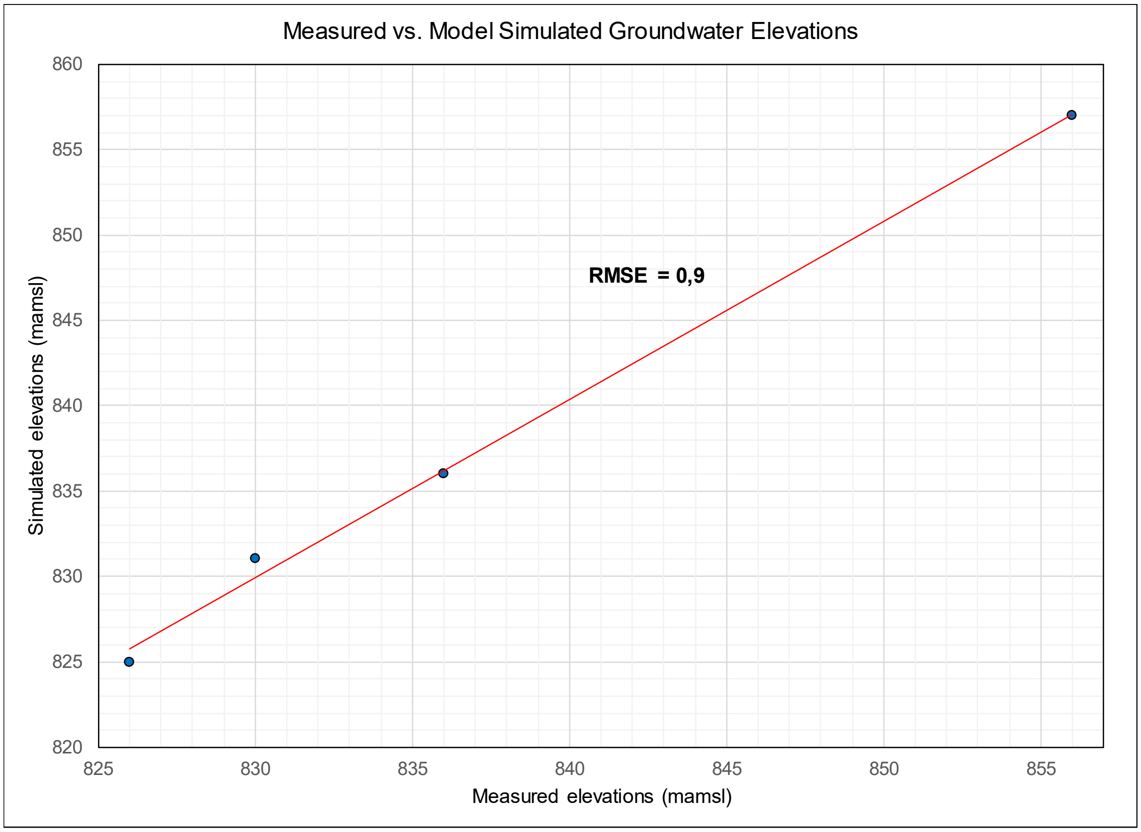

Figure 23: Numerical flow model calibration results

Notes: *Root mean square error (RMSE) – statistical method widely used to determine the difference or error between measured and predicted/simulated data sets.*

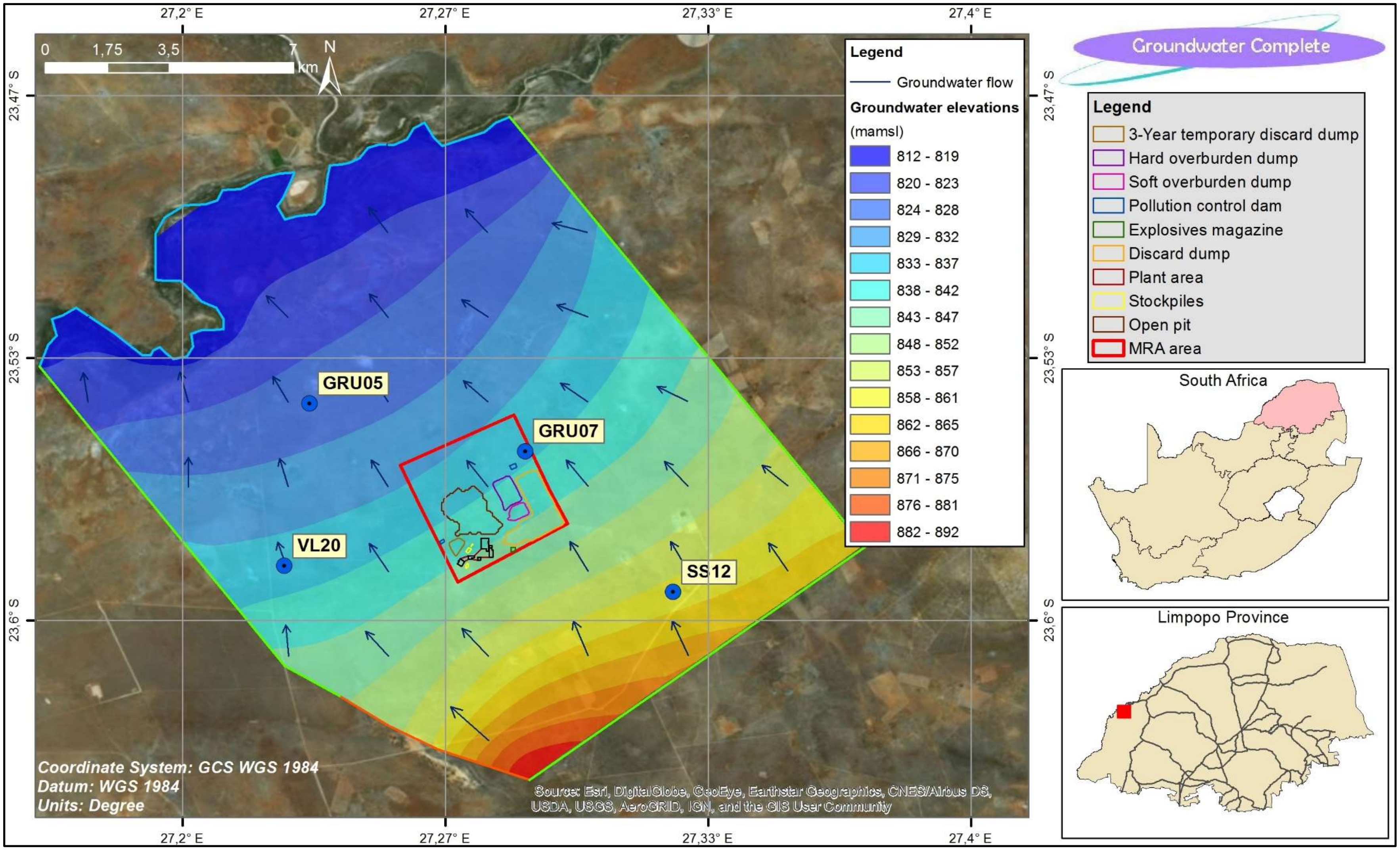

Figure 24: Model simulated steady state (ambient/unaffected) groundwater elevations (mamsl)

7.5 GEOMETRIC STRUCTURE OF THE MODEL

The model boundaries that were used in the delineation of the model area are indicated on **Figure 22**. A three-dimensional model (i.e. two layers) was constructed in which layer one (confined/unconfined) represents the weathered zone aquifer, while the deeper fractured rock aquifer is represented by layer two (confined).

The model grid is composed of 600 rows and 466 columns, consequently dividing the model area into a total of 279 600 cells that are 30 meters long by 30 meters wide.

7.6 GROUNDWATER SOURCES AND SINKS

Groundwater sources and sinks in modelling terms refer to features that either add or remove water from the model domain. River nodes were used to simulate the perennial Limpopo River that cuts through the model domain, which could either act as sinks or sources depending on the immediate groundwater level elevations. Much in the same manner, the general head boundaries used in the model **(Figure 22)** will also add or remove water depending on the groundwater gradients and hydraulic conductivities on opposite sides of the boundary position.

The proposed opencast pit will intersect the groundwater level and will progress even further below the water level before mining eventually ceases. Groundwater is therefore expected to flow into the pit and will need to be abstracted to ensure safe and dry mining conditions. The pit was consequently included in the groundwater flow model as a sink using drain nodes that were inserted at the floor of the lowest mined coal seam.

A recharge of approximately 1.0% of MAP was applied to the model grid, adding ±1 910 m^3/d of rainwater.

7.7 CONCEPTUAL MODEL

A conceptual model is really our holistic understanding of the workings and nature of the aquifer regime underlying the MRA area. A good understanding of the geohydrological environment is central to the accurate assessment of potential future groundwater related impacts associated with the proposed opencast mining and related activities.

A vertical cross section through the MRA area from south to north is provided in **Figure 25**. Please note that this section is not drawn to scale and serves only as a simplified visual representation of the geohydrological conceptual model. Based on our assessment of all groundwater related aspects, we conceptualize the underlying geohydrological system as follows:

- There is no documented surface drainage feature in the immediate vicinity of Gruisfontein. The flat topography and deep sandy soils result in a very low run-off component in the area. The dominant surface drainage feature is the perennial

Limpopo River, which flows from south-west to north-east and passes about 6.5 km to the north-west of Gruisfontein.

- The MRA area receives on average approximately 408 mm of rainfall annually.
- A hydrocensus/groundwater user survey was conducted on and around Gruisfontein by Aquatico Scientific in November 2018 during which a total of 33 boreholes or other groundwater localities were located. The equipped private user boreholes were found to be used for domestic and/or livestock watering, or a combination of the two.
- Recharge to the fractured rock aquifer underlying the MRA area was estimated to be in the region of 1.5% of the mean annual rainfall.
- The MRA area is generally underlain by sedimentary rocks of the Karoo Supergroup, more specifically shale and sandstone of the Vryheid Formation (Ecca Group) and mudstones of the Beaufort Group. All seams/coal zones are covered by some 30 m to 100 m of non-coal bearing superficial deposits referred to as overburden.
- Geological structures in the form of faults are known to cut through the Gruisfontein MRA area, which generally trend east-west with mostly sub-vertical displacement. Fractures and discontinuities have the potential to store and transmit significant volumes of groundwater and are therefore of significant geohydrological importance.
- Based on the findings of geochemical tests that were conducted for the nearby Temo Coal Project, all material (overburden, inter burden and discard) is potentially acid generating over the long term.
- Based on the exploration drilling results and widespread water level measurements, the unsaturated zone is predominantly composed of sandy soil followed by mudstone and shale. The average thickness of the unsaturated zone (where no impacts from groundwater abstraction occur) is in the order of 18 to 20 meters.
- Constant rate pumping tests were performed on all four user boreholes located within the Gruisfontein MRA area. A mean matrix transmissivity of 1.0 m^2/d was calculated and an average hydraulic conductivity of approximately 0.033 m/d.
- Groundwater level depths vary between approximately 9 and 31 meters below surface (mbs), while elevations of between 805 and 856 meters above mean sea level (mamsl) were observed. Groundwater flow from the MRA area is towards the west/north-west in the direction of the perennial Limpopo River.
- Groundwater from most user boreholes is suitable for human consumption and domestic use according to the South African National Standards *(SANS 241:2015)*. Exceptions do however occur with some elevated inorganic salinities (TDS, chloride, sodium) exceeding the maximum concentrations allowed in drinking water. The highest risk borehole in terms of drinking water for humans and even livestock is WB28 with a nitrate content of 162 mg/l.
- The aquifer underlying the MRA area scored a groundwater vulnerability rating of 8 and is therefore regarded as having a medium vulnerability.
- Two aquifer systems are present, namely a shallow aquifer (minor/non-aquifer) composed of soil and weathered bedrock, and a deeper fractured rock aquifer (minor/sole-aquifer) hosted within the sedimentary rocks of the Karoo Supergroup.
- The GQM rating for Gruisfontein calculates to 12, which indicates a very high level of protection where strictly no groundwater degradation. The high score is a direct result of the aquifer's classification as a sole-source aquifer.

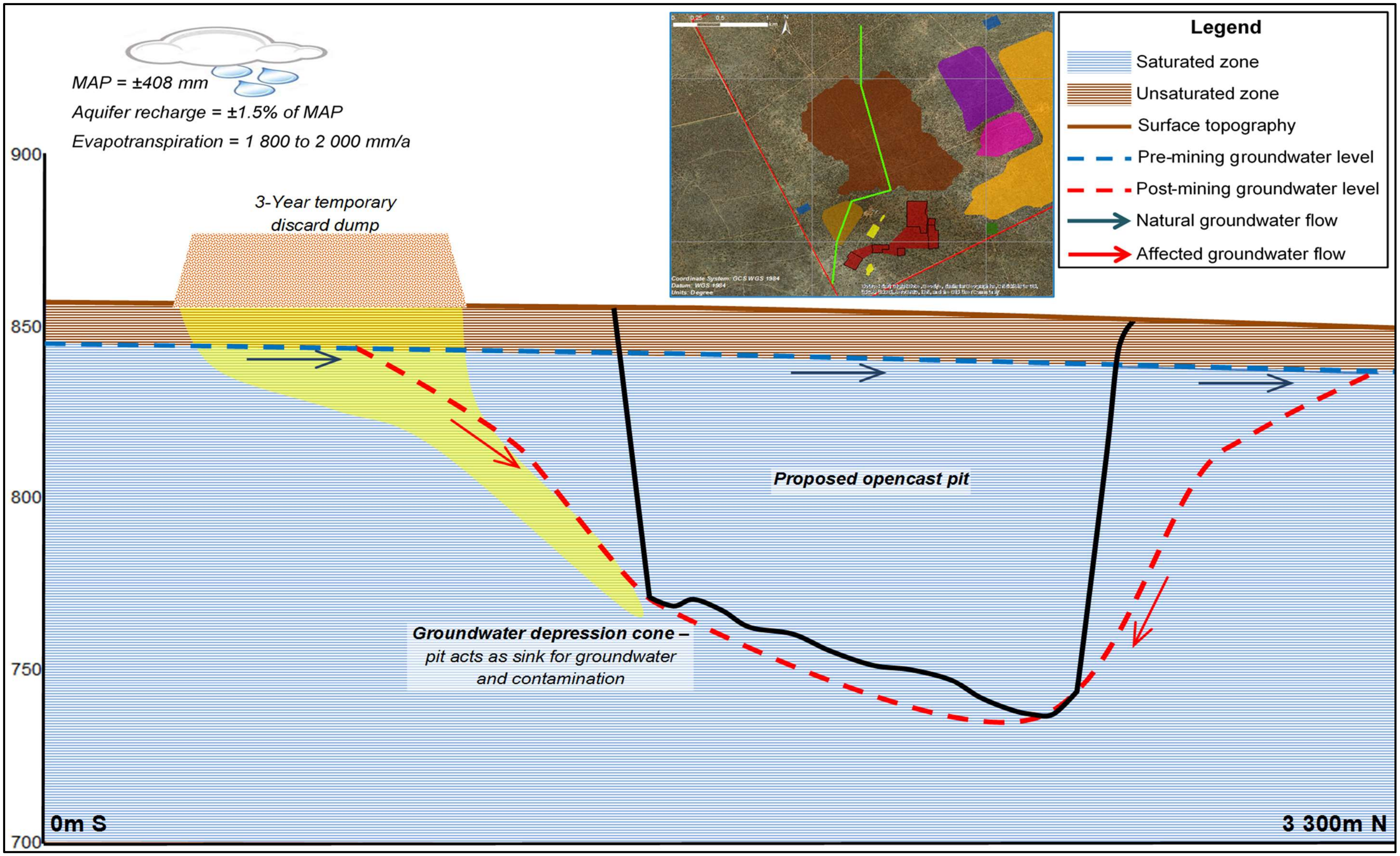

Figure 25: Vertical cross section from south to north through the proposed opencast pit

7.8 NUMERICAL GROUNDWATER MODEL

7.8.1 FLOW MODEL

The main aim with the calibrated flow model was to assess the potential groundwater level impacts resulting from the dewatering of the proposed opencast pit, i.e. to simulate or to predict the formation of a groundwater depression cone. The model was also used to predict groundwater flow volumes into the mine void during the operational phase.

The conceptual model as summarised in **Section 7.7** formed the basis for the numerical groundwater model.

A stress period in the model is a period where groundwater flow conditions are constant. All time dependent parameters in the model (i.e. sinks and sources) remain constant during the course of a stress period. The total model simulation runtime of 66 years was subdivided into 19 individual stress periods:

Stress period	Time (year)	Comment
1 - 16	16	Simulate active opencast mining and lowering of local groundwater levels.
17	10	Simulate water level recovery and contaminant migration in the weathered zone aquifer – 10 years after closure.
18	15	Simulate water level recovery and contaminant migration in the weathered zone aquifer – 25 years after closure.
19	25	Simulate water level recovery and contaminant migration in the weathered zone aquifer – 50 years after closure.

The calibrated flow model governs not only the rate and direction of groundwater flow in the model simulated aquifer, but also that of mass or contamination and therefore formed the basis for the contaminant transport model.

7.8.2 CONTAMINANT TRANSPORT MODEL

The contaminant transport model was constructed to simulate the migration of contamination in the underlying aquifer system. The contamination was simulated by applying contaminated recharge to the entire surface area of the proposed new opencast pit, overburden and discard dumps, product stockpiles and run-of-mine stockpiles, pollution control dams and plant area. **Source areas were assigned a theoretical concentration of 100%**, therefore the results of the model simulations should be regarded as being qualitative rather than quantitative and are discussed in detail in **Section 7.9**.

7.9 MODEL RESULTS

7.9.1 FLOW MODEL

The pit floor was simulated to intersect the water table from year one through to year 16 and the resulting groundwater inflow volumes for each year were determined/predicted with the numerical flow model. Volumes were also calculated with the Darcy equation and the averages calculated from these two methods or data sets are provided in **Table 14**. The findings of the flow model simulations are summarised in **Table 15**.

In order to better indicate the model simulated water level impacts resulting from the opencast mining, initial/unaffected groundwater elevations were subtracted from the affected groundwater elevations. The difference between these two data sets represents the groundwater level drawdown simulated for the particular stress period. This data was used to construct contour maps of the model simulated groundwater depression cone for stress period/year four **(Figure 26)**, eight **(Figure 27)**, twelve **(Figure 28)** and sixteen **(Figure 29)**. The positions of nearby hydrocensus/user boreholes are also indicated on the abovementioned figures.

The affected area (i.e. groundwater depression cone) was simulated to increase throughout the life of mine from approximately 0.27 km^2 during year 1 to ±3.43 km^2 at the end of the 16^{th} and final year of mining. Impacts were simulated to extend further towards the east along a fault that acts as a preferred pathway for groundwater. The maximum drawdown increased from more or less 39 meters to a maximum of ±90 meters at mine closure. **Note that the water level impacts were simulated to remain within the MRA area. The water levels of outside user boreholes are consequently expected to remain unaffected by the proposed opencast mining at Gruisfontein.**

Groundwater inflow was simulated to increase from approximately 3.4 l/s during the first year to ±7.8 l/s at the end of the 16^{th} and final year of mining. The proposed pit was simulated to intersect a high transmissivity geological structure and its position is indicated on all four abovementioned figures. Approximately 13% of the groundwater inflow simulated for year 1 came from this structure, however its contribution gradually decreased over the following years due to the dewatering of the aquifer.

A time-series graph of the model simulated groundwater level elevations for the pit area is provided in **Figure 30**, which shows that water levels have still not fully recovered from the impacts of pit dewatering after a post closure simulation time of 50 years. The backfilled pit is consequently expected to remain a groundwater sink long after mine closure.

Table 14: Estimated groundwater inflow volumes

Stress period/Year	Volume (m^3/d)	Volume (l/s)
1	290	3.4
2	450	5.2
3	480	5.6
4	570	6.6
5	520	6.0
6	520	6.0
7	560	6.5
8	600	6.9
9	620	7.2
10	640	7.4
11	600	6.9
12	660	7.6
13	610	7.1
14	660	7.6
15	620	7.2
16	670	7.8

Table 15: Summary of flow model simulations

Stress period/Year	Total affected area (km^2)	Maximum drawdown (m)
1	0.27	39
2	0.45	72
3	0.70	72
4	0.92	81
5	1.10	81
6	1.31	81
7	1.55	81
8	1.73	89
9	1.94	89
10	2.14	89
11	2.32	89
12	2.47	90
13	2.72	90
14	2.98	90
15	3.21	90
16	3.43	90

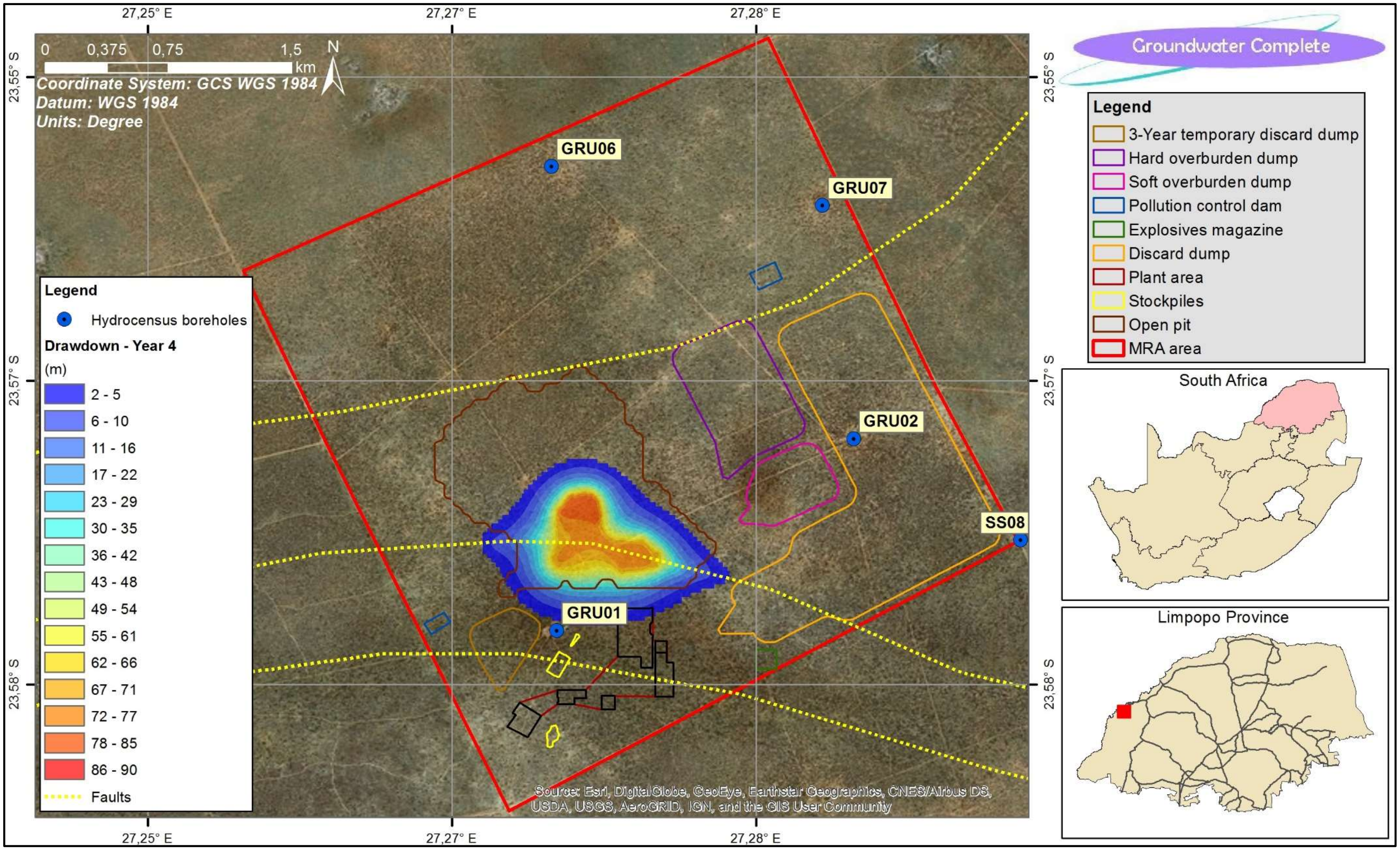

Figure 26: Model simulated groundwater depression cone – Year 4

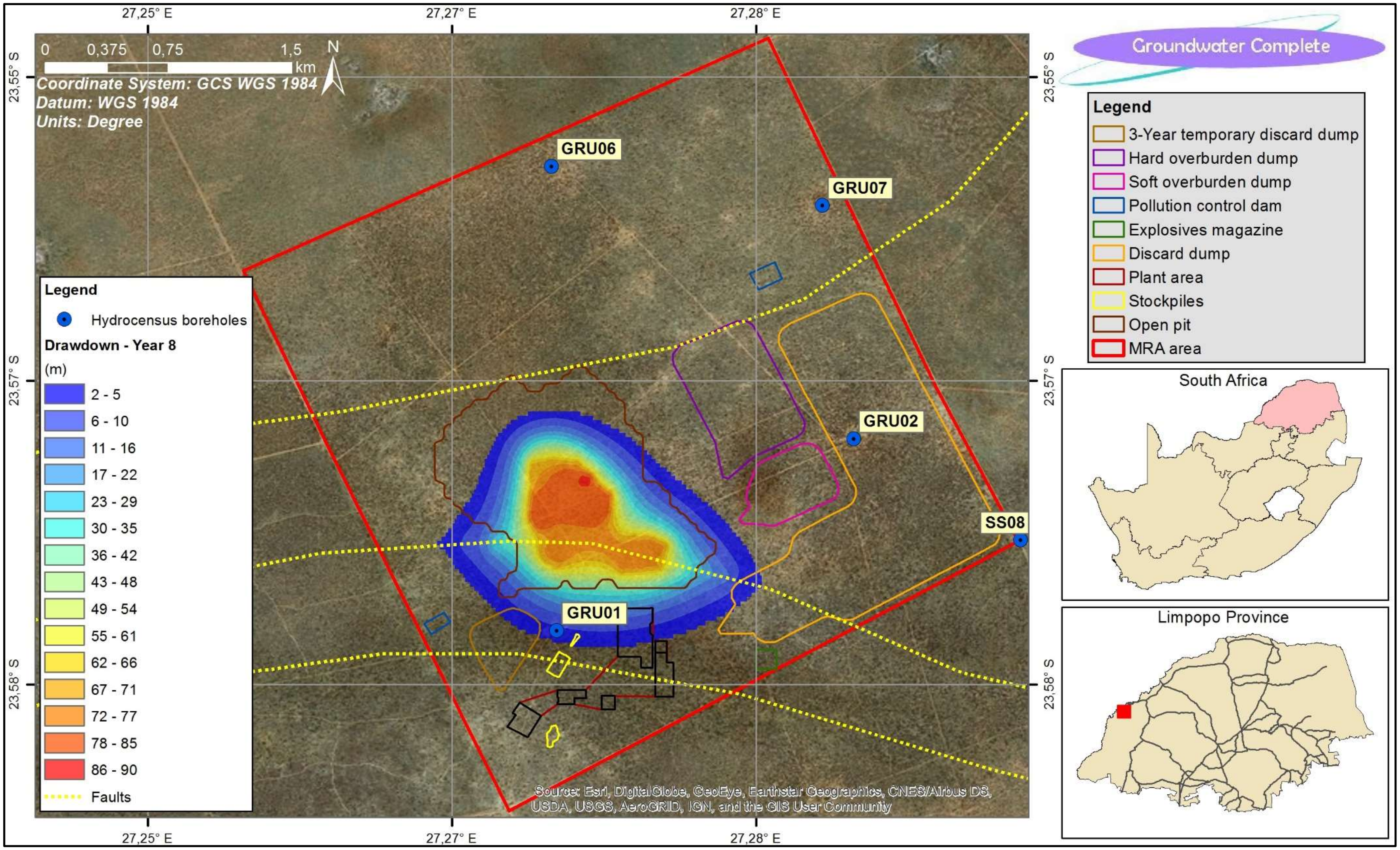

Figure 27: Model simulated groundwater depression cone – Year 8

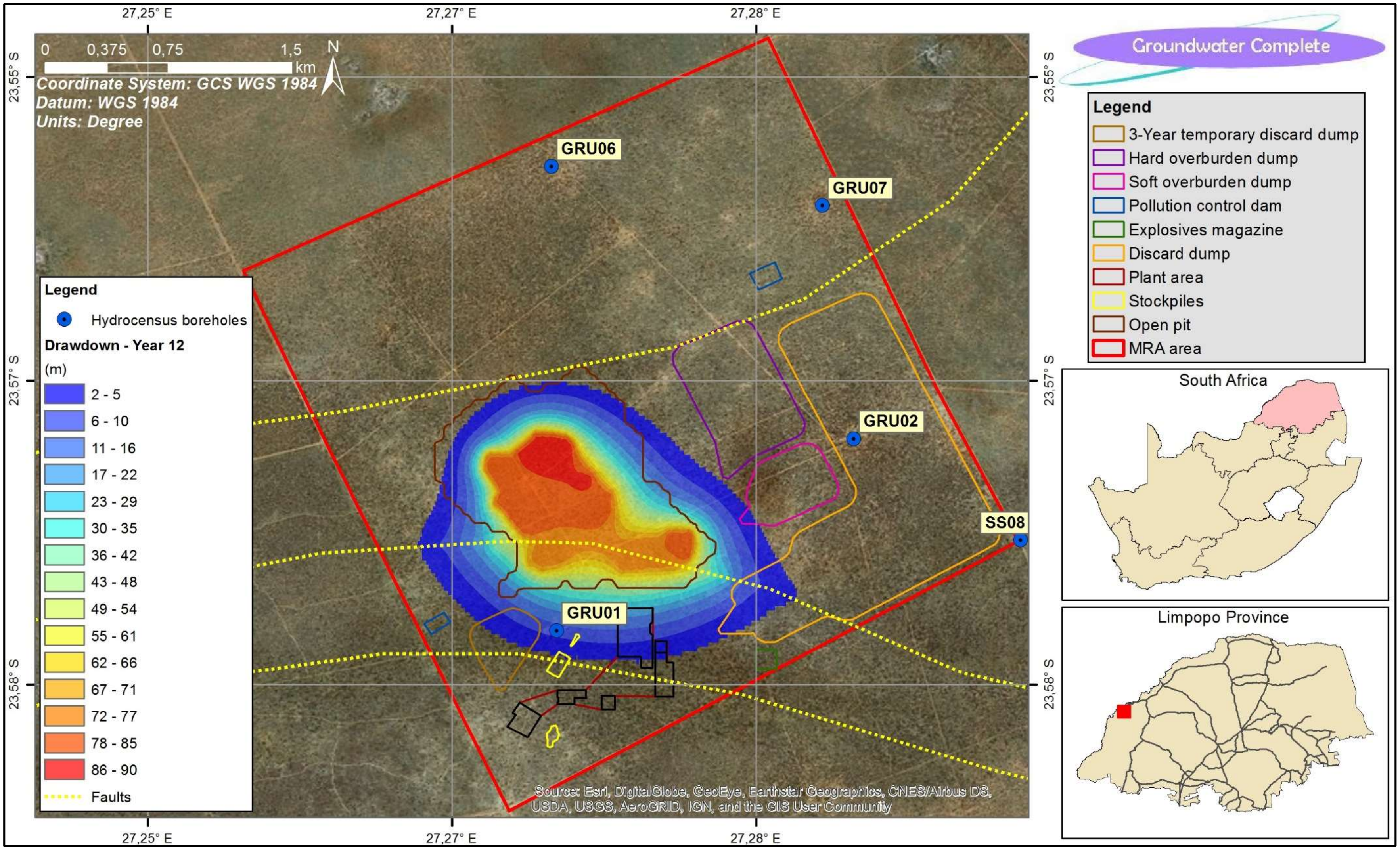

Figure 28: Model simulated groundwater depression cone – Year 12

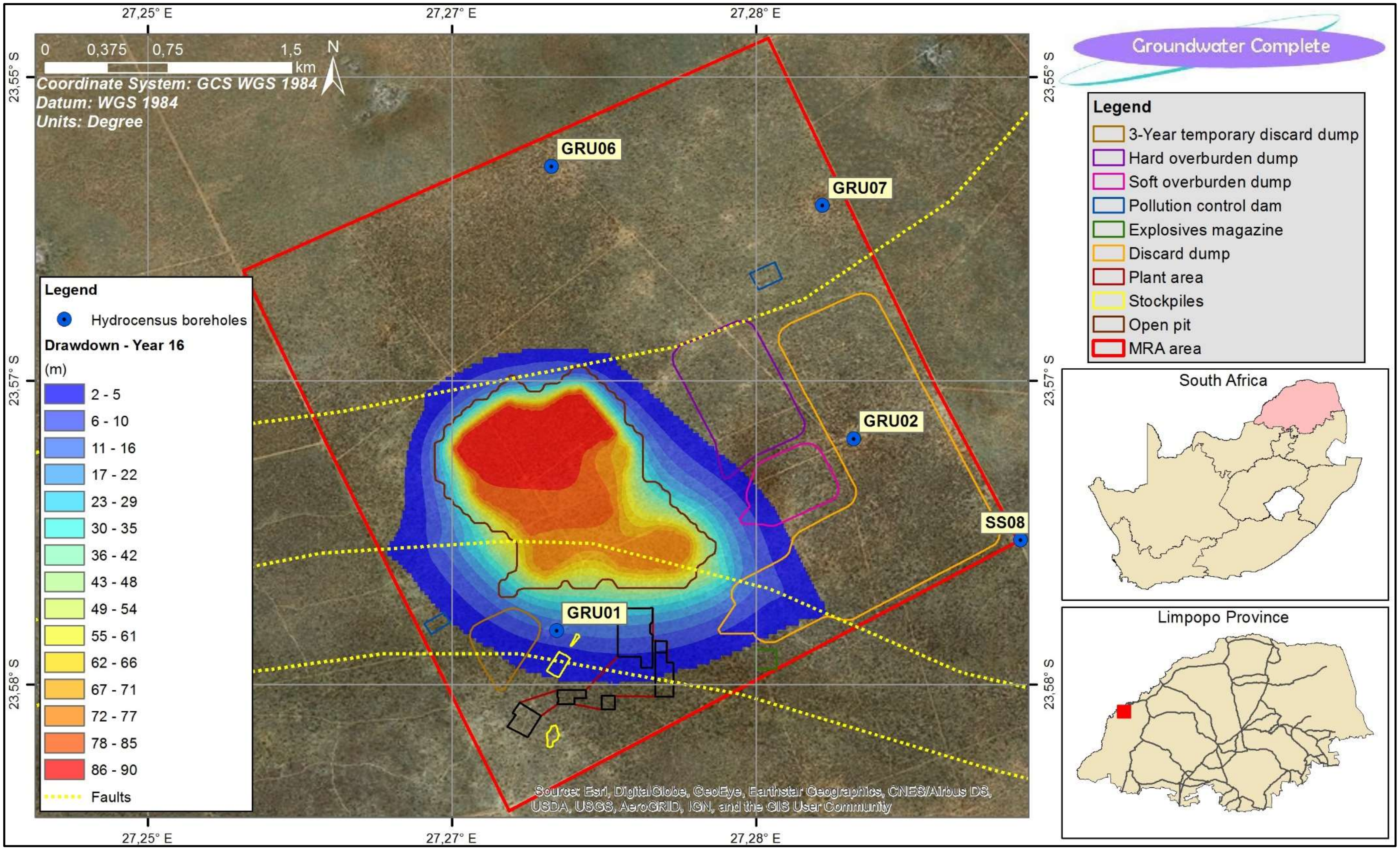

Figure 29: Model simulated groundwater depression cone – Year 16

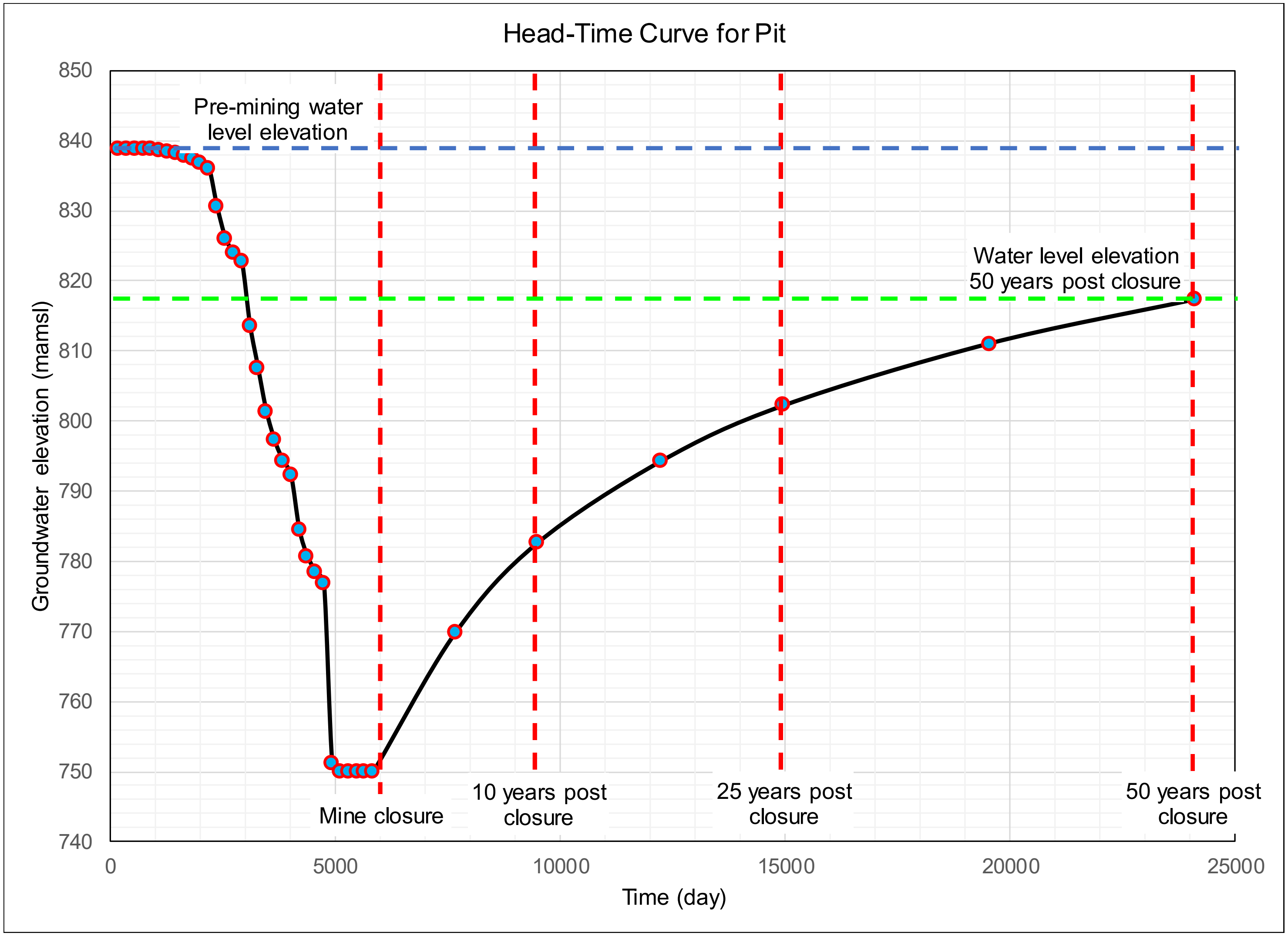

Figure 30: Model simulated groundwater level elevation for the pit area

7.9.2 CONTAMINANT TRANSPORT MODEL

In order to better indicate the model simulated groundwater quality impacts, contamination contours for stress periods 16 (mine closure), 17 (10 years after closure), 18 (25 years after closure) and 19 (50 years after closure) were exported from the contaminant transport model and used to construct the contour maps provided in **Figure 31** to **Figure 34**. The positions of all user boreholes located during the hydrocensus of November 2018 are also indicated on the abovementioned figures.

Stress period 16 simulation – mine closure:
A groundwater depression cone will alter hydraulic gradients and force groundwater and any potential contamination (within the affected area) to migrate towards its center. Groundwater levels therefore firstly need to recover from the impacts of pit dewatering before contamination can leave the pit area and migrate in the pre-mining/ambient downgradient direction. On the other hand, contamination emanating from the surface source areas was simulated to migrate towards the pit that will continue to act as a sink long after mine closure **(Figure 31)**.

Stress period 17 simulation – 10 years after closure:
All surface source areas were removed from the post closure model simulations, leaving the backfilled opencast pit as the only remaining source. Residual contamination from the former source areas was however simulated to continue on a path towards the pit **(Figure 32)**.

The maximum plume concentration was simulated to be just over 30% of the source concentration, or 900 mg/l if the source had a theoretical sulphate concentration of 3 000 mg/l.

The average plume migration rate was simulated to be in the region of 7 m/y, which is significantly higher than the ambient/unaffected groundwater flow rate estimated to be just under 1 m/y. This increase is the result of aquifer dewatering and subsequent lowering of groundwater levels, ultimately leading to an increase in groundwater gradients and flow towards the pit.

Stress period 18 simulation – 25 years after closure:
Contamination plumes were simulated to continue in a direction towards the backfilled opencast pit **(Figure 33)**. Most plumes were simulated to have reached the position of the pit and cannot migrate further since the pit will still be a groundwater sink at this stage.

Processes such as dispersion and dilution with fresh recharge will cause a natural decrease in residual plume concentrations over time. On the other hand, concentrations in the backfilled pit are expected to initially increase over time as metal sulphides such as pyrite are exposed to oxygen and water to generate poor quality leachate. Please refer to **Section 5.2** for a high-level discussion on the acid generating potential of the Karoo rocks underlying the MRA area.

Simulated concentrations in the backfilled pit increased to approximately 40%, or 1 200 mg/l assuming a theoretical source concentration of 3 000 mg/l.

Stress period 19 simulation – 50 years after closure:
Water levels have still not fully recovered from the impacts of pit dewatering, and plumes were consequently simulated to continue in a direction towards the backfilled opencast pit **(Figure 34)**.

Residual contamination, albeit at lower concentrations, was still simulated for most of the rehabilitated surface source areas. The maximum concentration in the backfilled opencast pit was simulated to be nearly 60%, or 1 800 mg/l if the source had a theoretical sulphate concentration of 3 000 mg/l.

Note that the groundwater quality impacts (i.e. contamination plumes) were simulated to remain within the MRA area and more specifically concentrated at the pit position. The water quality of outside user boreholes is consequently expected to remain unaffected by the proposed opencast mining and related activities.

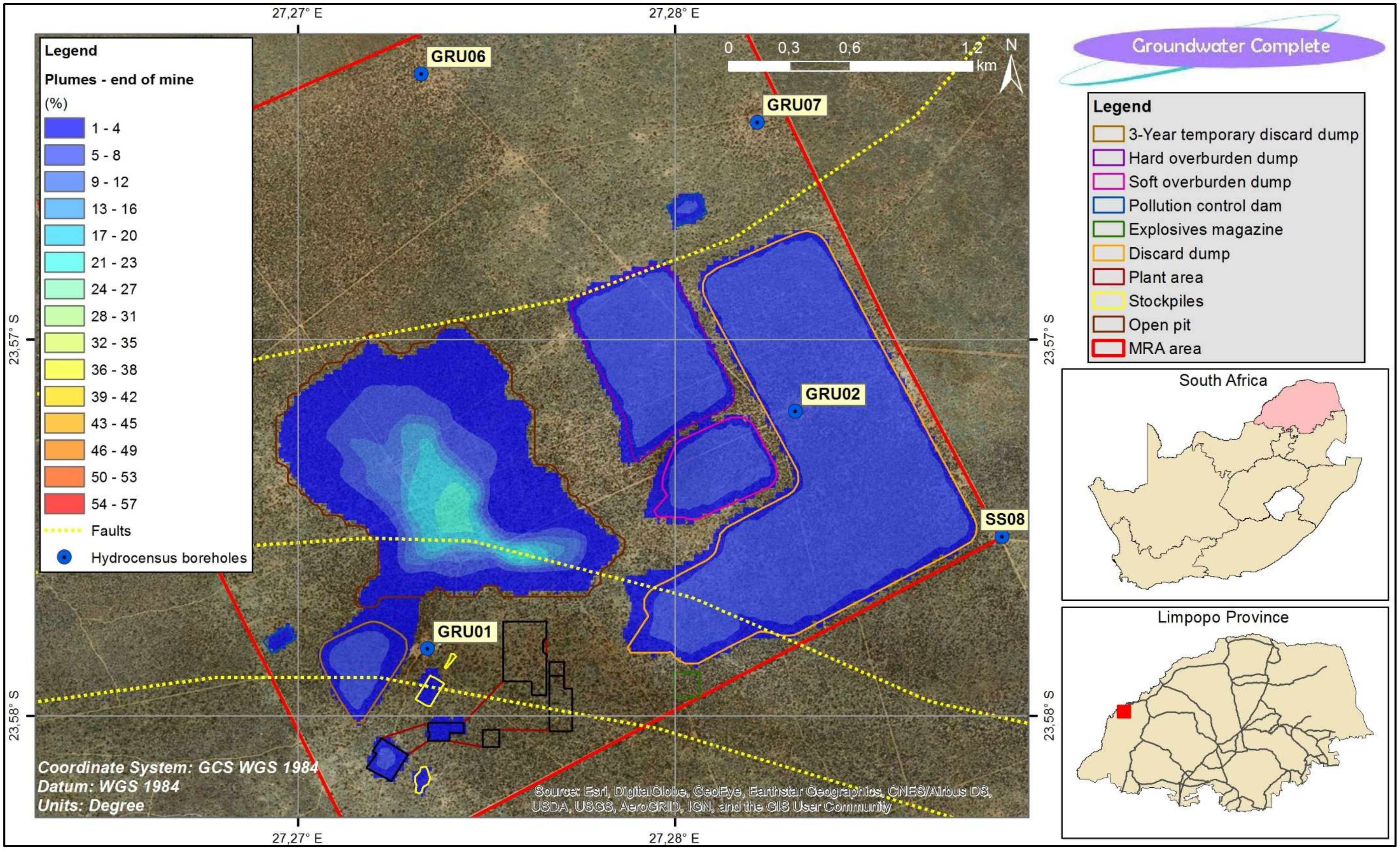

Figure 31: Model simulated groundwater contamination plume – mine closure

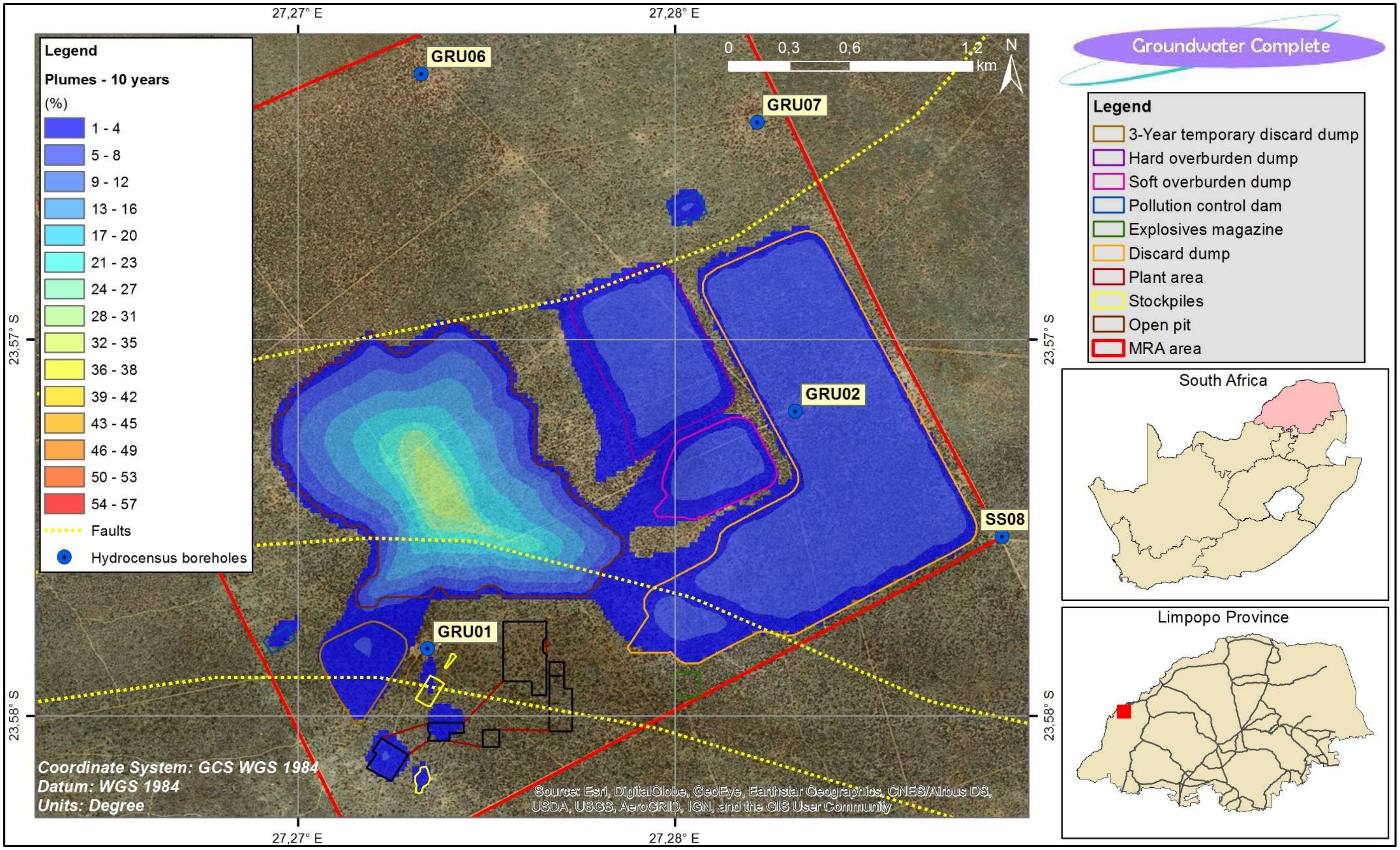

Figure 32: Model simulated groundwater contamination plume – 10 years after closure

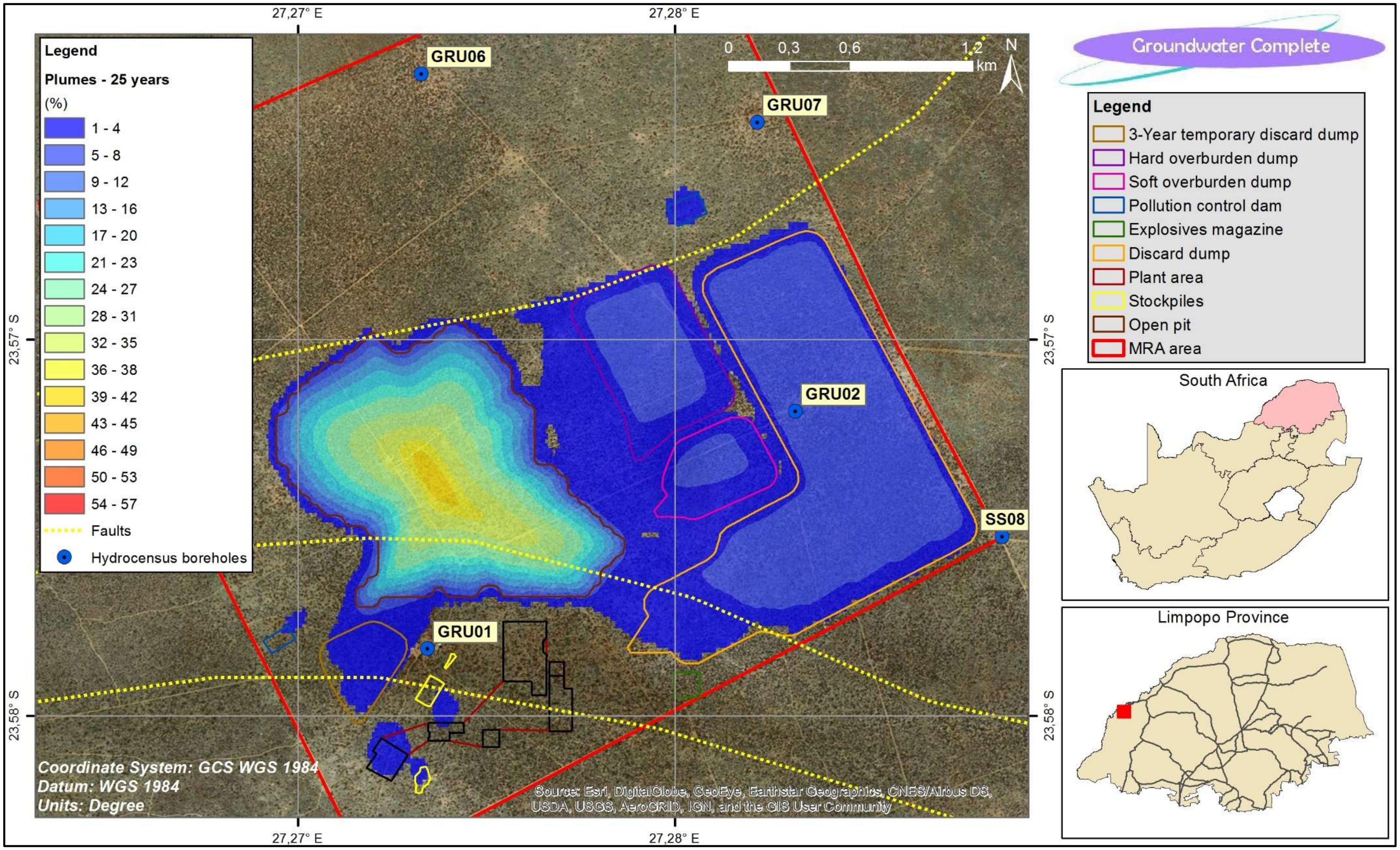

Figure 33: Model simulated groundwater contamination plume – 25 years after closure

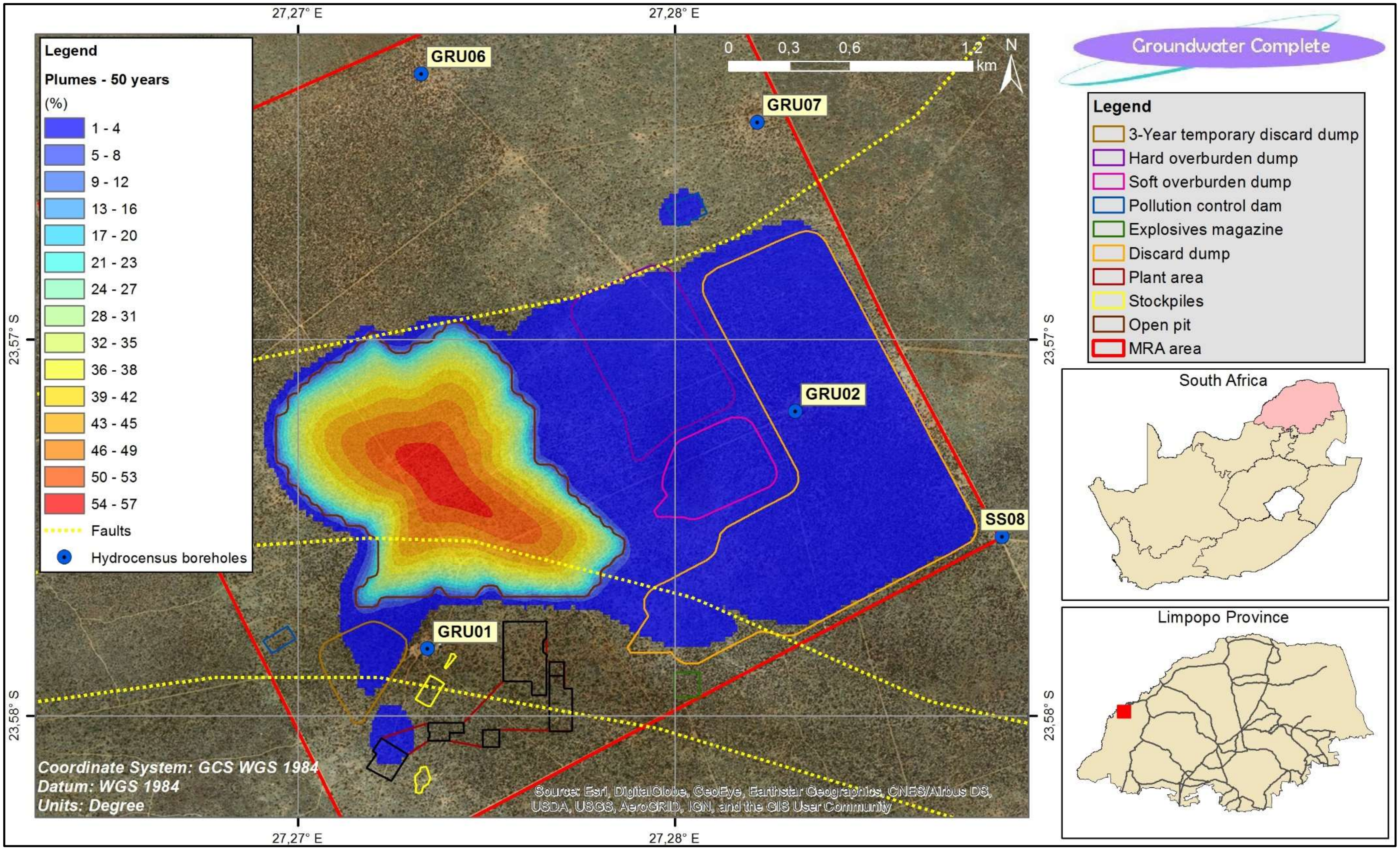

Figure 34: Model simulated groundwater contamination plume – 50 years after closure

8 GEOHYDROLOGICAL IMPACT ASSESSMENT

The potential groundwater quality and water level impacts associated with the proposed new opencast mining and related activities were simulated/predicted with a numerical groundwater flow and contaminant transport model and the results are provided and discussed in detail in **Section 7.9**. This part of the report focuses on the actual rating of the impacts as well as possible management and mitigation measures.

According to the Information Series 5: Impact Significance of the Integrated Environmental Management Information Series *(Department of Environmental Affairs and Tourism, 2002)*: *'The concept of significance is at the core of impact identification, prediction, evaluation and decision-making. Deciding whether a project is likely to cause significant environmental effects is central to the practice of EIA.'*

Impact assessment is therefore based on the description of an impact, the significance of this impact, and how the impact can be managed and/or mitigated. It must be noted that many of the potential negative consequences can be mitigated successfully. It is however necessary to make a thorough assessment of all possible impacts in order to ensure that environmental considerations are taken into account in a balanced way, thus supporting the aim of minimising any adverse impacts on the environment.

8.1 METHODOLOGY

8.1.1 IMPACT SIGNIFICANCE

Nature and Status

The 'nature' of the impact describes what is being affected and how. The 'status' is based on whether the impact is positive, negative or neutral.

Spatial Extent

'Spatial Extent' defines the spatial or geographical scale of the impact.

Category	Rate	Descriptor
Site	1	Site of the proposed development
Local	2	Limited to site and/or immediate surrounds (500m zone of influence)
District	3	Local Municipal Areas
Region	4	District Municipal Areas
Provincial	5	Mpumalanga Province
National	6	South Africa
International	7	Beyond South African borders

Duration

'Duration' gives the temporal scale of the impact.

Category	Rate	Descriptor
Temporary	1	0 – 1 years
Short term	2	1 – 5 years
Medium term	3	5 – 15 years
Long term	4	Where the impact will cease after the operational life of the activity either because of natural process or by human intervention
Permanent	5	Where mitigation either by natural processes or by human intervention will not occur in such a way or in such a time span that the impact can be considered as transient

Probability

The 'probability' describes the likelihood of the impact actually occurring.

Category	Rate	Descriptor
Rare	1	Where the impact may occur in exceptional circumstances only
Improbable	2	Where the possibility of the impact materialising is very low either because of design or historic experience
Probable	3	Where there is a distinct possibility that the impact will occur
Highly probable	4	Where it is most likely that the impact will occur
Definite	5	Where the impact will occur regardless of any prevention measures

Intensity

'Intensity' defines whether the impact is destructive or benign, in other words the level of impact on the environment.

Category	Rate	Descriptor
Insignificant	1	Where the impact affects the environment is such a way that natural, cultural and social functions and processes are not affected. Localised impact and a small percentage of the population is affected
Low	2	Where the impact affects the environment is such a way that natural, cultural and social functions and processes are affected to a limited extent
Medium	3	Where the affected environment is altered in terms of natural, cultural and social functions and processes continue albeit in a modified way

Category	Rate	Descriptor
High	4	Where natural, cultural or social functions or processes are altered to the extent that they will temporarily or permanently cease
Very High	5	Where natural, cultural or social functions or processes are altered to the extent that they will permanently cease and it is not possible to mitigate or remedy the impact

Ranking, Weighting and Scaling

The weight of significance define the level or limit at which point an impact changes from low to medium significance, or medium to high significance. The purpose of assigning such weights serves to highlight those aspects that are considered the most critical to the various stakeholders and ensure that the element of bias is taken into account. These weights are often determined by current societal values or alternatively by scientific evidence (norms, etc.) that define what would be acceptable or unacceptable to society and may be expressed in the form of legislated standards, guidelines or objectives.

The weighting factor provides a means whereby the impact assessor can successfully deal with the complexities that exist between the different impacts and associated aspect criteria.

Spatial Extent	Duration	Intensity / Severity	Probability	Weighting factor	Significance Rating (SR - WOM) Pre-mitigation	Mitigation Efficiency (ME)	Significance Rating (SR-WM) Post Mitigation
Site (1)	Short term (1)	Insignificant (1)	Rare (1)	Low (1)	Low (0 – 19)	High (0.2)	Low (0 – 19)
Local (2) District (3)	Short to Medium term (2)	Minor (2)	Unlikely (2)	Low to Medium (2)	Low to Medium (20 – 39)	Medium to High (0.4)	Low to Medium (20 – 39)
Regional (4)	Medium term (3)	Medium (3)	Possible (3)	Medium (3)	Medium (40 – 59)	Medium (0.6)	Medium (40 – 59)
Provincial (5) National (6)	Long term (4)	High (4)	Likely (4)	Medium to High (4)	Medium to High (60 – 79)	Low to Medium (0.8)	Medium to High (60 – 79)
International (7)	Permanent (5)	Very high (5)	Almost certain (5)	High (5)	High (80 – 110)	Low (1.0)	High (80 – 110)

Impact significance without mitigation (WOM)

Following the assignment of the necessary weights to the respective aspects, criteria are summed and multiplied by their assigned weightings, resulting in a value for each impact (prior to the implementation of mitigation measures).

Equation 1:

Significance Rating (WOM) = (Extent + Intensity + Duration + Probability) x Weighting Factor

Effect of significance on decision-making

Significance is determined through a synthesis of impact characteristics as described in the above paragraphs. It provides an indication of the importance of the impact in terms of both tangible and intangible characteristics. The significance of the impact "without mitigation" is the prime determinant of the nature and degree of mitigation required.

Rating	Rate	Descriptor
Negligible	0	The impact is non-existent or insignificant, is of no or little importance to decision making.
Low	1 – 19	The impact is limited in extent, even if the intensity is major; the probability of occurrence is low and the impact will not have a significant influence on decision making and is unlikely to require management intervention bearing significant costs.
Low to Medium	20 – 39	The impact is of importance, however, through the implementation of the correct mitigation measures such potential impacts can be reduced to acceptable levels. The impact and proposed mitigation measures can be considered in the decision-making process
Medium	40 – 59	The impact is significant to one or more affected stakeholder, and its intensity will be medium or high; but can be avoided or mitigated and therefore reduced to acceptable levels. The impact and mitigation proposed should have an influence on the decision.
Medium to High	60 – 79	The impact is of major importance but through the implementation of the correct mitigation measures, the negative impacts will be reduced to acceptable levels.
High	80 – 110	The impact could render development options controversial or the entire project unacceptable if it cannot be reduced to acceptable levels; and/or the cost of management intervention will be a significant factor and must influence decision-making.

8.1.2 MITIGATION

"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 land use. 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:

- 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 (reduce) impact: can be done through utilisation of alternatives that will ensure that impacts on biodiversity and eco-services provision are reduced. Impact minimisation is considered an essential part of any development project.
- Rehabilitate (restore) 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, for example arable land. Rehabilitation can however not be considered as the primary mitigation toll 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 subject property 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.

According to the DMR (2013) "Closure" refers to the process for ensuring that mining operations are closed in an environmentally responsible manner, usually with the dual objectives of ensuring sustainable post-mining land uses and remedying negative impacts on biodiversity and ecosystem services.

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.

Impact significance with mitigation measures (WM)
In order to gain a comprehensive understanding of the overall significance of the impact, after implementation of the mitigation measures, it is necessary to re-evaluate the impact.

Mitigation Efficiency (ME)
The most effective means of deriving a quantitative value of mitigated impacts is to assign each significance rating value (WOM) a mitigation effectiveness (ME) rating. The allocation of such a rating is a measure of the efficiency and effectiveness, as identified through professional experience and empirical evidence of how effectively the proposed mitigation measures will manage the impact. Thus, the lower the assigned value the greater the effectiveness of the proposed mitigation measures and subsequently, the lower the impacts with mitigation.

Equation 2:
Significance Rating (WM) = Significance Rating (WOM) x Mitigation Efficiency (ME)

Mitigation Efficiency is rated out of 1 as follows:

Category	Rate	Descriptor
Not Efficient (Low)	1	Mitigation cannot make a difference to the impact
Low to Medium	0.8	Mitigation will minimize impact slightly
Medium	0.6	Mitigation will minimize impact to such an extent that it becomes within acceptable standards
Medium to High	0.4	Mitigation will minimize impact to such an extent that it is below acceptable standards
High	0.2	Mitigation will minimize impact to such an extent that it becomes insignificant

Significance Following Mitigation (SFM)
The significance of the impact after the mitigation measures are taken into consideration. The efficiency of the mitigation measure determines the significance of the impact. The level of impact is therefore seen in its entirety with all considerations taken into account.

8.1 IMPACT RATING FOR CONSTRUCTION PHASE

The following construction phase activities have the potential to affect the underlying groundwater:

- Land clearance; and
- Handling of waste material and/or hydrocarbons.

The impact rating for the construction phase is provided in **Table 17**.

8.1.1 IMPACTS ON GROUNDWATER LEVEL/QUANTITY

Clearing of topsoil from footprint areas can increase infiltration rates of water (recharge) to the underlying aquifer, ultimately leading to an increase in groundwater elevations. This potential impact is not necessarily a negative one.

8.1.2 IMPACTS ON GROUNDWATER QUALITY

Handling of waste and the transport of building material can cause various types of spills (especially hydrocarbons) that may potentially infiltrate and contaminate the underlying groundwater.

8.1.3 GROUNDWATER MANAGEMENT AND MITIGATION

Waste should be discarded at a dedicated waste disposal site, bunded and lined to prevent the infiltration and spread of contamination, or removed by credible contractors. Spills should be cleaned up immediately and the relevant authorities notified.

8.2 IMPACT RATING FOR OPERATIONAL PHASE

The following operational phase activities have the potential to adversely affect the underlying groundwater:

- Removal of hard and soft overburden and disposal thereof at dedicated dump sites;
- Opencast mining of coal;
- Operation of coal handling and preparation plant, i.e. crushing, screening and washing of coal;
- Disposal of discard material at dedicated dump sites;
- Stockpiling of coal at dedicated site;

- Retainment of potentially poor quality water in purpose-built pollution control dams; and
- Operation of workshops and wash bay.

8.2.1 IMPACTS ON GROUNDWATER LEVEL/QUANTITY

Opencast mining, when occurring below the water table, results in an influx of groundwater. Pit dewatering is consequently required to ensure dry and safe mining conditions, which ultimately leads to the dewatering of the local aquifer and lowering of groundwater levels.

The pit floor was simulated with the numerical groundwater flow model to intersect the water table throughout the entire life of mine, affecting the surrounding groundwater levels from year one through to the 16^{th} and final year. The model simulated groundwater depression cone (i.e. affected area) is indicated for stress period/year four **(Figure 26)**, eight **(Figure 27)**, twelve **(Figure 28)** and sixteen **(Figure 29)**, and the impact rating is provided in **Table 18**.

8.2.2 IMPACTS ON GROUNDWATER QUALITY

Based on the findings of geochemical tests that were conducted for the nearby Temo Coal Project **(Section 5.2)**, all material (overburden, inter burden and discard) is potentially acid generating over the long term. The model simulated contamination plumes are indicated on **Figure 31** to **Figure 34**, and the impact rating is provided in **Table 18**.

The planned soft and hard overburden dumps, discard dumps and ROM and product stockpiles are consequently potential sources of poor quality, acid rock drainage affected seepage. Surface water run-off originating from these source areas, toe-seeps and seepage through the base may potentially have a high TDS and especially sulphate content. Some localised low pH seepage may also occur, resulting in elevated metals such as iron.

Impacts associated with the plant, workshops and wash bay are expected to occur through leachate formation from dirty/contaminated surface areas. Impacts thus only occur as a result of rainfall recharge or when water is introduced where leachate can form that seeps to the underlying groundwater. Organic contaminants are usually the main pollutants of concern around workshops and wash bays (e.g. oil, grease, diesel, petrol, hydraulic fluid, solvents, etc.).
Dirty water retaining facilities such as the planned pollution control dams are developed and constructed for the sole purpose of containing dirty/contaminated water and therefore minimising the risk of it contaminating the groundwater. Mismanagement of these facilities may however lead to spills and/or leakages that have the potential to contaminate the underlying groundwater.

Note that the opencast pit will act as a sink for both groundwater and contamination during the operational phase and long after mine closure. Contamination from the numerous potential source areas as discussed in the preceding paragraphs will consequently remain largely restricted to the MRA area and more specifically the pit.

8.2.3 GROUNDWATER MANAGEMENT AND MITIGATION

No mitigation measures are available for when mining occurs below the local water table. Only by remaining above it can the impact/s on groundwater levels be avoided.

Potential dirty surface areas should be covered with concrete to prevent poor quality seepage from reaching the aquifer and contaminating the underlying groundwater. Surface areas should also be bunded to prevent clean surface water runoff from being contaminated by dirty surface areas. In other words, contact between clean and dirty water or coal bearing material should be prevented, while clean runoff water should be diverted away from dirty areas.

Spills should be cleaned up immediately and the relevant authorities notified. Stockpiles and dirty footprint areas should be kept as small as practically possible.

Dedicated source monitoring boreholes should be drilled to monitor the groundwater quality conditions. More detailed information relating to the proposed groundwater monitoring program for Gruisfontein is provided in **Section 9**.

8.3 IMPACT RATING FOR POST CLOSURE PHASE

The impact rating for the post closure phase is provided in **Table 19**.

8.3.1 IMPACTS ON GROUNDWATER LEVEL/QUANTITY

No adverse impacts are envisaged as groundwater levels are left to recover from the impacts of pit dewatering.

8.3.2 IMPACTS ON GROUNDWATER QUALITY

After rehabilitation of the mining area, the backfilled opencast pit will be the only remaining source. Groundwater quality impacts were simulated with a numerical contaminant transport model and the results are discussed in detail in **Section 7.9.2** of this report. The most significant impacts resulting from coal mining usually occur post closure, because:

- Sulphide bearing minerals such as pyrite have had some time to oxidise in the presence of water to create poor quality, acidic leachate (i.e. acid mine/rock drainage);
- Contamination will at some point begin to migrate in the downgradient direction as water levels slowly recover from the impacts of pit dewatering and return to pre-mining levels; and
- The backfilled pit will at some point begin to decant as a result of an increase in recharge. Please note that a detailed discussion on the potential decanting of the proposed pit is provided in **Section 8.3.4** of this report.

Long-term pollution effects depend on the acid generating potential of the overburden and discard material used in the backfilling of the pit, and the availability of oxygen and water for chemical reaction. Geochemical testing that was conducted for the nearby Temo Coal Project concluded that all material, over the long term, have the potential to generate acid.

With AMD reactions becoming active, the pH and bicarbonate alkalinity values of the water can be expected to decrease. The majority of metals have very low solubility in water at the normal (pH 6 to 8) pH range, but will go into solution as a result of the lower pH environment.

As the AMD affected water leaves the backfilled pit, it will mix with better quality water and the pH and bicarbonate values will be buffered back to more acceptable levels. Metals should also precipitate, and the sulphate and TDS concentrations should decrease through dilution.

Water collecting in the backfilled pit is expected to display a stratified quality distribution with the better quality water on top and the more saline (and with slightly higher specific gravity) water at the bottom of the pit. Furthermore, contaminant migration is expected to be retarded by the transmissivity and porosity of the host rocks. Other reactions like sorption, dispersivity and tortuosity in the aquifer also contain contamination spread and these aspects are generally referred to as the aquifer retardation properties.

8.3.3 GROUNDWATER MANAGEMENT AND MITIGATION

Dedicated plume monitoring boreholes should be drilled in the down gradient groundwater flow direction and sampled at quarterly intervals to monitor plume migration. Should the monitoring program indicate significant plume migration, interception trenches and/or rehabilitation boreholes may be considered as a form of mitigation.

8.3.4 PIT WATER DECANT

Decanting of a backfilled pit generally occurs because of an excess volume of water that cannot be “absorbed” by the aquifer system. This excess water is the result of an increase in recharge over the disturbed backfilled opencast pit.

Decanting can however be prevented by simply controlling the water level. This is done by drilling a borehole into the deepest part of the backfilled pit, and when necessary, abstracting water from it to lower the water level and thus keeping it below the decant elevation. Another method involves leaving a void open at the decant position, which will allow evaporation to keep the water level below the decant elevation.

During decommissioning, and for a certain time after closure, the geohydrological environment will dynamically attain a new equilibrium after the dewatering effects of the opencast workings. Decant predictions in an opencast mining environment is affected by the following:

- The mean annual precipitation (MAP);
- Recharge to the mine void, expressed as a percentage of the MAP. Recharge on the other hand is affected by:
    - The size of the surface area disturbed by mining activities,
    - The permeability of the backfill material,
    - Surface water runoff,

- The overall porosity of the backfilled pit; and
- The groundwater contribution to pit water, which is determined by the hydraulic properties of the surrounding aquifer host rock/s.

The groundwater gradient within a backfilled opencast pit is generally very close to being zero because of the high permeability of the backfill material. Decanting of an opencast pit is therefore most likely to occur wherever the pit intersects the lowest surface elevation. The expected time it will take the backfilled Gruisfontein pit to fill with water was calculated with the use of volume/recharge calculations to be in the region of 160 years post closure **(Table 16)**. The most probable decant position is also indicated on **Figure 35**.

Should decanting of the rehabilitated pit occur, it will happen at a surface elevation of ±856 meters above mean sea level (mamsl). The average rate of recharge once the rehabilitated pit void has filled to (near) surface will be approximately 150 m^3/d, or 1.7 l/s. Given the topography, geological profile and climate of the area it is our opinion that this water is not expected to daylight as actual decant due to the following reasons:

- The topography is relatively flat and the decant 'point' will in practice cover an area of several hectares were the surface topography differs less than a meter or so;
- The deep, sandy nature of the surface material (soil) will allow for lateral movement in the soil rather than outflow on surface; and
- The significant rate of evapotranspiration in the area will easily get rid of the potential decant once it reaches near-surface levels before actual daylighting of the water occurs.

The water recovering in the rehabilitated pit is expected to be of poor quality due to the high potential of the backfill material to generate sulphuric acid over the long term **(Section 5.2)**. Without any disturbance in the pit, the effect of salinity stratification is bound to result in significantly better quality water occurring near surface where recharge occurs at high rate and with very good quality water.

Table 16: Time-to-fill calculations

General information		
	Units	**Gruisfontein Pit**
Surface area	m^2	1 347 340
Decant elevation	mamsl	856
Total void volume	m^3	113 790 980
Mean annual rainfall	m/a	0.408
Backfilled void volume		
20% Porosity	m^3	22 758 196
25% Porosity	m^3	28 447 745
30% Porosity	m^3	34 137 294
Recharge/Rainfall contribution		
8% Recharge	m^3/y	43 977
10% Recharge	m^3/y	54 971
12% Recharge	m^3/y	65 966
Groundwater contribution		
Average	m^3/y	120 450
Time to fill		
Most probable scenario (25% Ø and 10% RCH)	**Years**	**162**

Notes: *Ø = Porosity;*
RCH = Recharge.

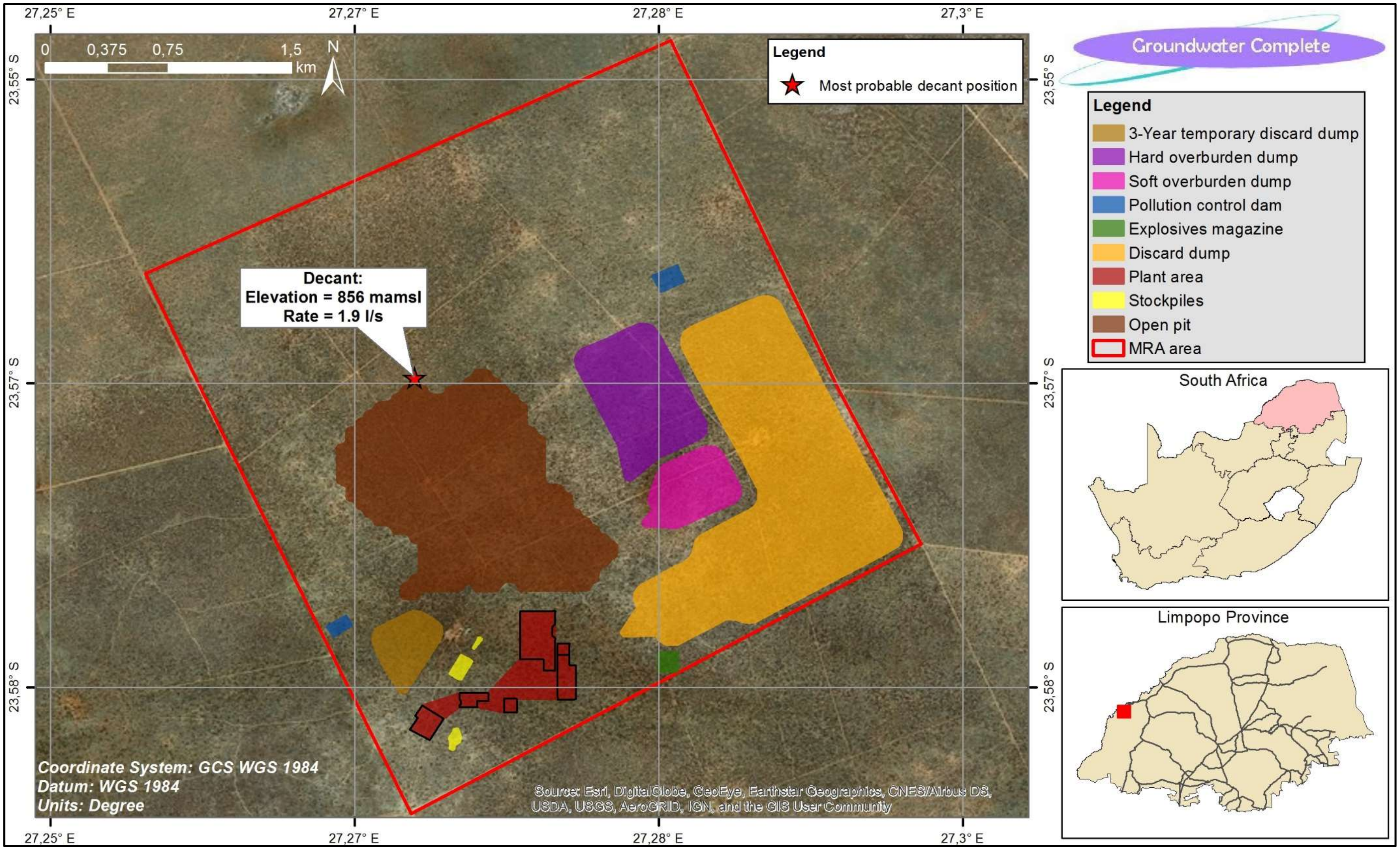

Figure 35: Most probable decant position and estimated discharge volume

Table 17: Groundwater impact rating for construction phase

Impact	Nature of impact	Duration	Extent	Probability	Intensity	Weighting factor	Pre-mitigation impact significance	Mitigation efficiency	Post-mitigation impact significance
Groundwater Level/Quantity									
Increase in aquifer recharge due to clearing of topsoil from footprint areas	Positive	Temporary (1)	Site (1)	Highly probable (4)	Insignificant (1)	Low (1)	Low	Not efficient	Low
Groundwater Quality									
Contamination of groundwater due to spills	Negative	Short term (2)	Site (1)	Highly probable (4)	Low (2)	Low (1)	Low	Medium to high	Low

Table 18: Groundwater impact rating for operational phase

Impact	Nature of impact	Duration	Extent	Probability	Intensity	Weighting factor	Pre-mitigation impact significance	Mitigation efficiency	Post-mitigation impact significance
Groundwater Level/Quantity									
Lowering of groundwater levels due to pit dewatering	Negative	Permanent (5)	Local (2)	Definite (5)	Medium (3)	Medium (3)	Medium	Not efficient	Medium
Groundwater Quality									
Contamination of groundwater due to acid mine/rock drainage	Negative	Long term (4)	Site (1)	Highly probable (4)	Low (2)	Low to medium (2)	Low to medium	Medium to high	Low

Table 19: Groundwater impact rating for post closure phase

Impact	Nature of impact	Duration	Extent	Probability	Intensity	Weighting factor	Pre-mitigation impact significance	Mitigation efficiency	Post-mitigation impact significance
Groundwater Level/Quantity									
No adverse impact envisaged									
Groundwater Quality									
Contamination of groundwater due to acid mine/rock drainage	Negative	Permanent (5)	Local (2)	Definite (5)	High (4)	High (5)	High	High	Low

9 GROUNDWATER MONITORING SYSTEM

9.1 GROUNDWATER MONITORING NETWORK

9.1.1 SOURCE, PLUME, IMPACT AND BACKGROUND MONITORING (CONCENTRATIONS)

Boreholes located in close proximity to potential sources of groundwater contamination are generally referred to as **source monitoring boreholes**. The main aim or objective of such a borehole is to detect a contamination breakthrough long before it reaches a groundwater user or sensitive surface water feature (receptors).

Plume monitoring refers to the groundwater quality monitoring points that have been committed specifically for determining the extent, geometry, concentration and migration rate of a groundwater pollution plume downgradient from a source. In the event of a source monitoring borehole detecting a contamination breakthrough, additional plume monitoring boreholes should be developed to ensure that the concentration distribution and extent of the contamination plume are well understood and accurately definable.

9.1.2 SYSTEM RESPONSE MONITORING (GROUNDWATER LEVELS)

Post closure recharge to the backfilled opencast pit is expected to be more or less seven times higher (10% of MAP) than the pre-mining figure of approximately 1.5%. The aquifer's response to this increase should be monitored and a dedicated water level monitoring borehole should ideally be drilled into the backfilled pit for this purpose.

9.1.3 MONITORING FREQUENCY

Groundwater monitoring (i.e. sampling and water level measurements) should be conducted at quarterly intervals and the schedule re-assessed by a qualified geohydrologist at a later stage in terms of stability of water levels and quality. If the sampling program requires changes, it should be done so in consultation with the appropriate authorities.

9.2 MONITORING PARAMETERS

Groundwater samples should be analysed at a SANAS accredited laboratory for chemical and physical constituents normally associated with a coal mining environment **(Table 20)**. Laboratory results should be evaluated against the target water quality guidelines for domestic use (i.e. the South African National Standards for drinking water; *SANS 241:2015*).

Monitoring results should be entered into an electronic database as soon as results are available, and at no less than one quarterly interval, allowing:

- Data presentation in tabular format;
- Time-series graphs with comparison abilities;
- Statistical analysis (minimum, maximum, average, percentile values) in tabular format;

- Graphical presentation of statistics;
- Linear trend determination;
- Performance analysis in tabular format;
- Presentation of data, statistics and performance on diagrams and maps; and
- Comparison and compliance to the South African National Standards for drinking water *(SANS 241:2015)*.

Table 20: Groundwater constituents for routine analysis

Monitoring	Variable
Quarterly	EC, pH, TDS, total hardness, total alkalinity, calcium, magnesium, sodium, potassium, chloride, sulphate, fluoride, nitrate, iron, manganese, aluminium and turbidity.

Regular assessment and reporting on the monitoring results are recommended to investigate trends and non-compliance over the geohydrological year.

9.3 MONITORING BOREHOLES

A total of 12 source monitoring boreholes are recommended for the Gruisfontein MRA area and their positions are indicated on **Figure 36**. Note that these positions are only conceptual and ideally need to be finalised with the aid of a geophysical survey, preferably not magnetic as explained in **Section 4.3**.

Proposed monitoring borehole GRU01 is an existing user borehole that was located during the hydrocensus/user survey of November 2018 **(Section 4.2)** and its location downgradient from the ROM stockpile is appropriate for source monitoring purposes. Furthermore, user boreholes GRU06 and GRU07 should also be included in the regular groundwater monitoring program as water level and quality control points further downgradient from the proposed opencast mining and related activities. More borehole related information is provided in **Table 21**.

A borehole depth of 30 meters is usually sufficient in a coal mining environment. Steel casing should be inserted well through the loose weathered zone, and perforated PVC casing the full length/depth of the borehole. A concrete collar should be constructed around the completed borehole, which will help support the steel casing and prevent surface water runoff from flowing into the borehole.

Boreholes should be completed with a lockable cap to prevent vandalism, and clearly marked in the field with a nameplate.

Table 21: Information on proposed source/sink monitoring boreholes

BH	Coordinates *(WGS 84)*		Elevation (mamsl)	Depth (m)	Comment
	South	East			
GRU01	-23.5804	27.2724	862	37	Existing borehole downgradient from proposed stockpiles
GRU06	-23.5549	27.2721	850	32	Existing borehole further downgradient water level and quality control point
GRU07	-23.5571	27.2870	855	87	Existing borehole further downgradient water level and quality control point
MBH01	-23.5605	27.2830	856	30	Downgradient from pollution control dam
MBH02	-23.5634	27.2817	856	30	Downgradient from hard overburden dump
MBH03	-23.5634	27.2850	857	30	Downgradient from discard dump
MBH04	-23.5749	27.2855	862	30	Downgradient from discard dump
MBH05	-23.5843	27.2700	862	30	Downgradient from plant area
MBH06	-23.5801	27.2676	860	30	Downgradient from 3-year temporary discard dump
MBH07	-23.5798	27.2651	860	30	Downgradient from pollution control dam
MBH08	-23.5663	27.2700	856	30	Downgradient from potential pit decant position
MBH09	-23.5894	27.2699	862	30	Upgradient monitoring point for control/reference

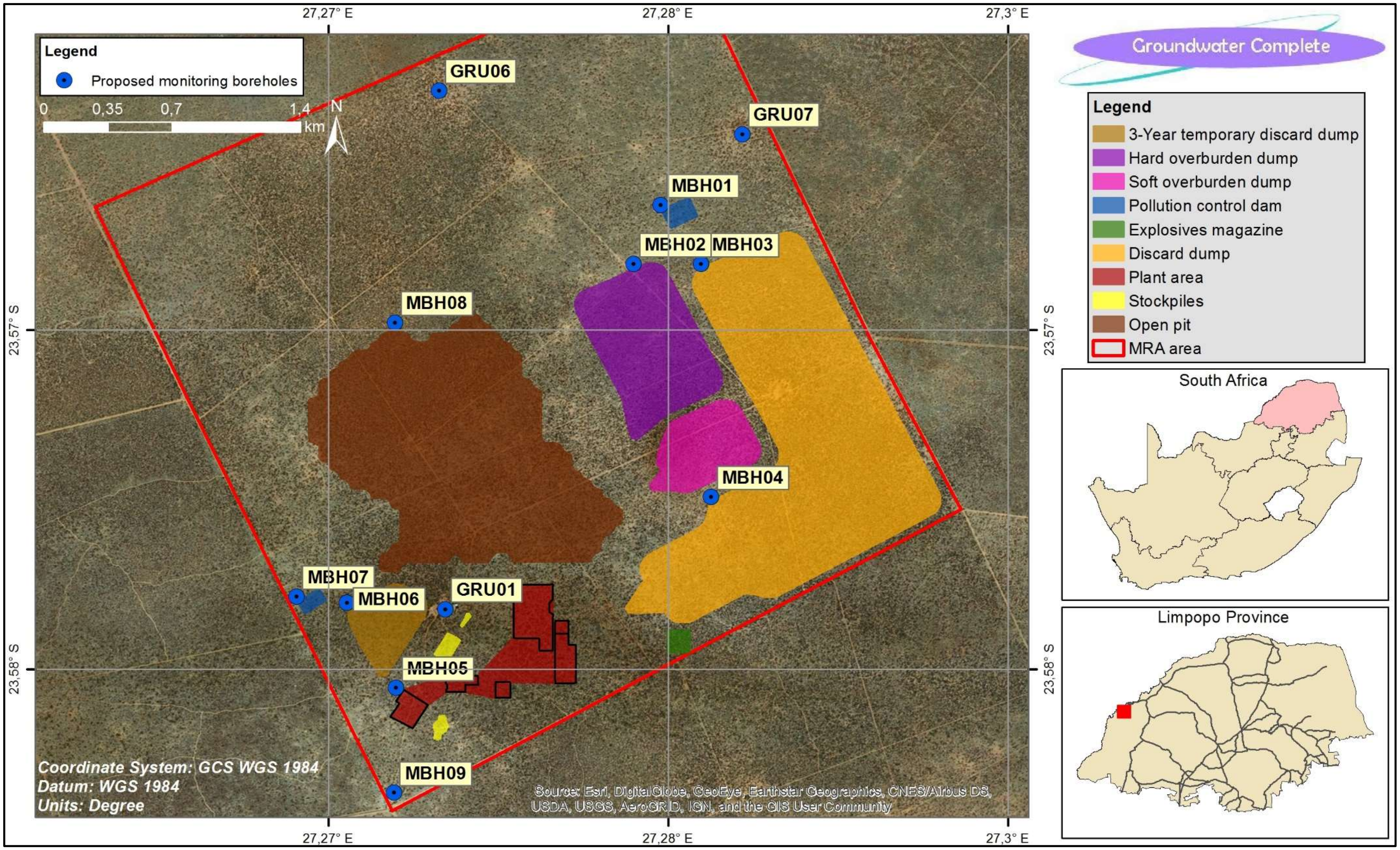

Figure 36: Conceptual positions of dedicated source monitoring boreholes

10 GROUNDWATER ENVIRONMENTAL MANAGEMENT PROGRAM

10.1 CURRENT GROUNDWATER CONDITIONS

10.1.1 GROUNDWATER LEVEL CONDITIONS

The current groundwater level depths, elevations and gradients are discussed in detail in **Section 5.4**. Groundwater level depths vary between approximately 9 and 31 meters below surface (mbs), while elevations of between 805 and 856 meters above mean sea level (mamsl) were observed.

Groundwater flow from the MRA area is towards the west/north-west in the direction of the perennial Limpopo River

10.1.2 GROUNDWATER QUALITY CONDITIONS

A detailed discussion on the current groundwater quality conditions is provided in **Section 5.8**. According to the South African National Standards for drinking water *(SANS 241:2015)*, groundwater from most of the user boreholes is suitable for human consumption and domestic use.

Exceptions do however occur with some elevated inorganic salinities (TDS, chloride, sodium) exceeding the maximum concentrations allowed in drinking water. The highest risk borehole in terms of drinking water for humans and even livestock is WB28 with a nitrate content of 162 mg/l. It is strongly recommended that this borehole not be used since it poses a health risk to livestock.

10.2 IMPACTS ON GROUNDWATER QUANTITY

The potential groundwater quality and water level impacts associated with the proposed new opencast mining and related activities were simulated/predicted with a numerical groundwater flow and contaminant transport model and the results are provided and discussed in detail in **Section 7.9** of this report. The environmental impact rating is provided in **Section 8**.

10.3 MITIGATION MEASURES

Groundwater mitigation refers to measures that are put in place to help ease or reduce adverse impacts on groundwater users and the geohydrological environment. Mitigation measures, where possible, are discussed in detail in **Section 8** of this report.

11 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are based on the findings of the groundwater investigation that was conducted for Gruisfontein.

Conclusions – Geohydrological Environment:

- There is no documented surface drainage feature in the immediate vicinity of Gruisfontein. The flat topography and deep sandy soils result in a very low run-off component in the area. The dominant surface drainage feature is the perennial Limpopo River, which flows from south-west to north-east and passes about 6.5 km to the north-west of Gruisfontein.
- The MRA area receives on average approximately 408 mm of rainfall annually.
- A hydrocensus/groundwater user survey was conducted on and around Gruisfontein by Aquatico Scientific in November 2018 during which a total of 33 boreholes or other groundwater localities were located. The equipped private user boreholes were found to be used for domestic and/or livestock watering, or a combination of the two.
- Recharge to the fractured rock aquifer underlying the MRA area was estimated to be in the region of 1.5% of the mean annual rainfall.
- The MRA area is generally underlain by sedimentary rocks of the Karoo Supergroup, more specifically shale and sandstone of the Vryheid Formation (Ecca Group) and mudstones of the Beaufort Group. All seams/coal zones are covered by some 30 m to 100 m of non-coal bearing superficial deposits referred to as overburden.
- Geological structures in the form of faults are known to cut through the Gruisfontein MRA area, which generally trend east-west with mostly sub-vertical displacement. Fractures and discontinuities have the potential to store and transmit significant volumes of groundwater and are therefore of significant geohydrological importance.
- Based on the findings of geochemical tests that were conducted for the nearby Temo Coal Project, all material (overburden, inter burden and discard) is potentially acid generating over the long term.
- Based on the exploration drilling results and widespread water level measurements, the unsaturated zone is predominantly composed of sandy soil followed by mudstone and shale. The average thickness of the unsaturated zone (where no impacts from groundwater abstraction occur) is in the order of 18 to 20 meters.
- Constant rate pumping tests were performed on all four user boreholes located within the Gruisfontein MRA area. A mean matrix transmissivity of 1.0 m^2/d was calculated and an average hydraulic conductivity of approximately 0.033 m/d.
- Groundwater level depths vary between approximately 9 and 31 meters below surface (mbs), while elevations of between 805 and 856 meters above mean sea level (mamsl) were observed. Groundwater flow from the MRA area is towards the west/north-west in the direction of the perennial Limpopo River.
- Groundwater from most user boreholes is suitable for human consumption and domestic use according to the South African National Standards *(SANS 241:2015)*. Exceptions do however occur with some elevated inorganic salinities (TDS, chloride, sodium) exceeding the maximum concentrations allowed in drinking water. The

highest risk borehole in terms of drinking water for humans and even livestock is WB28 with a nitrate content of 162 mg/l.

- The aquifer underlying the MRA area scored a groundwater vulnerability rating of 8 and is therefore regarded as having a medium vulnerability.
- Two aquifer systems are present, namely a shallow aquifer (minor/non-aquifer) composed of soil and weathered bedrock, and a deeper fractured rock aquifer (minor/sole-aquifer) hosted within the sedimentary rocks of the Karoo Supergroup.
- The GQM rating for Gruisfontein calculates to 12, which indicates a very high level of protection where strictly no groundwater degradation is allowed. The high score is a direct result of the aquifer's classification as a sole-source aquifer.

Conclusions – Numerical Groundwater Modelling:

The potential groundwater quality and water level impacts associated with the proposed new opencast mining and related activities were simulated/predicted with a numerical groundwater flow and contaminant transport model and the results are summarised below:

- The pit floor was simulated to intersect the groundwater level throughout the entire life of mine and the model simulated groundwater inflow volumes for each year are as follows:

Stress period/Year	Volume (m^3/d)	Volume (l/s)
1	290	3.4
2	450	5.2
3	480	5.6
4	570	6.6
5	520	6.0
6	520	6.0
7	560	6.5
8	600	6.9
9	620	7.2
10	640	7.4
11	600	6.9
12	660	7.6
13	610	7.1
14	660	7.6
15	620	7.2
16	670	7.8

- The affected area (i.e. groundwater depression cone) was simulated to increase throughout the life of mine from approximately 0.27 km^2 during year 1 to ±3.43 km^2 at the end of the 16th and final year of mining.
- **Note that the water level impacts were simulated to remain within the MRA area. The water levels of outside user boreholes are consequently expected to remain unaffected by the proposed opencast mining at Gruisfontein.**
- The maximum water level drawdown was simulated to increase from more or less 39 meters to a maximum of ±90 meters at mine closure.

- Water levels were simulated not to have fully recovered from the impacts of pit dewatering after a post closure simulation time of 50 years. The backfilled pit is consequently expected to remain a groundwater/contamination sink long after mine closure.
- Residual contamination from the rehabilitated surface source areas was simulated to migrate towards the pit, while contamination generated by the pit was simulated to remain restricted to its borders.
- The maximum plume concentrations were simulated to increase from approximately 20% at mine closure to ±60% at 50 years post closure, or 600 mg/l to 1 800 mg/l respectively if the source had a constant sulphate concentration of 3 000 mg/l.
- **Note that the groundwater quality impacts (i.e. contamination plumes) were simulated to remain within the MRA area and more specifically concentrated at the pit position. The water quality of outside user boreholes is consequently expected to remain unaffected by the proposed opencast mining and related activities.**

Conclusions – Decant Predictions:

- The expected time it will take the backfilled Gruisfontein pit to fill with water was calculated with the use of volume/recharge calculations to be in the region of 160 years post closure.
- Post closure decanting of the rehabilitated pit is expected to occur at a surface elevation of ±856 meters above mean sea level (mamsl) and at an estimated rate of approximately 150 m^3/d, or 1.7 l/s. Given the topography, geological profile and climate of the area it is our opinion that this water is not expected to daylight as actual decant.
- The pit water is expected to be of poor quality due to the high potential of the backfill material to generate sulphuric acid over the long term.

Recommendations:

- Post closure recharge to the backfilled opencast pit is expected to be more or less seven times higher (10% of MAP) than the pre-mining figure of approximately 1.5%. The aquifer's response to this increase should be monitored and a dedicated water level monitoring borehole should ideally be drilled into the backfilled pit for this purpose.
- Groundwater monitoring (i.e. sampling and water level measurements) should be conducted at quarterly intervals and the schedule re-assessed by a qualified geohydrologist at a later stage in terms of stability of water levels and quality. If the sampling program requires changes, it should be done so in consultation with the appropriate authorities.
- Groundwater samples should be analysed at a SANAS accredited laboratory for chemical and physical constituents normally associated with a coal mining environment.
- Site specific geochemical tests should be conducted at Gruisfontein for confirmation of the acid generating potential of the underlying Karoo rocks.
- Twelve dedicated source monitoring boreholes are deemed necessary.

- Borehole positions should be finalised with the aid of a geophysical survey, preferably not magnetic.
- A borehole depth of 30 meters is usually sufficient in a coal mining environment. Steel casing should be inserted well through the loose weathered zone, and perforated PVC casing the full length/depth of the borehole. A concrete collar should be constructed around the completed borehole, which will help support the steel casing and prevent surface water runoff from flowing into the borehole.
- Boreholes should be completed with a lockable cap to prevent vandalism, and clearly marked in the field with a nameplate.

BH	Coordinates *(WGS 84)*		Elevation (mamsl)	Depth (m)	Comment
	South	East			
GRU01	-23.5804	27.2724	862	37	Existing borehole downgradient from proposed stockpiles
GRU06	-23.5549	27.2721	850	32	Existing borehole further downgradient water level and quality control point
GRU07	-23.5571	27.2870	855	87	Existing borehole further downgradient water level and quality control point
MBH01	-23.5605	27.2830	856	30	Downgradient from pollution control dam
MBH02	-23.5634	27.2817	856	30	Downgradient from hard overburden dump
MBH03	-23.5634	27.2850	857	30	Downgradient from discard dump
MBH04	-23.5749	27.2855	862	30	Downgradient from discard dump
MBH05	-23.5843	27.2700	862	30	Downgradient from plant area
MBH06	-23.5801	27.2676	860	30	Downgradient from 3-year temporary discard dump
MBH07	-23.5798	27.2651	860	30	Downgradient from pollution control dam
MBH08	-23.5663	27.2700	856	30	Downgradient from potential pit decant position
MBH09	-23.5894	27.2699	862	30	Upgradient monitoring point for control/reference

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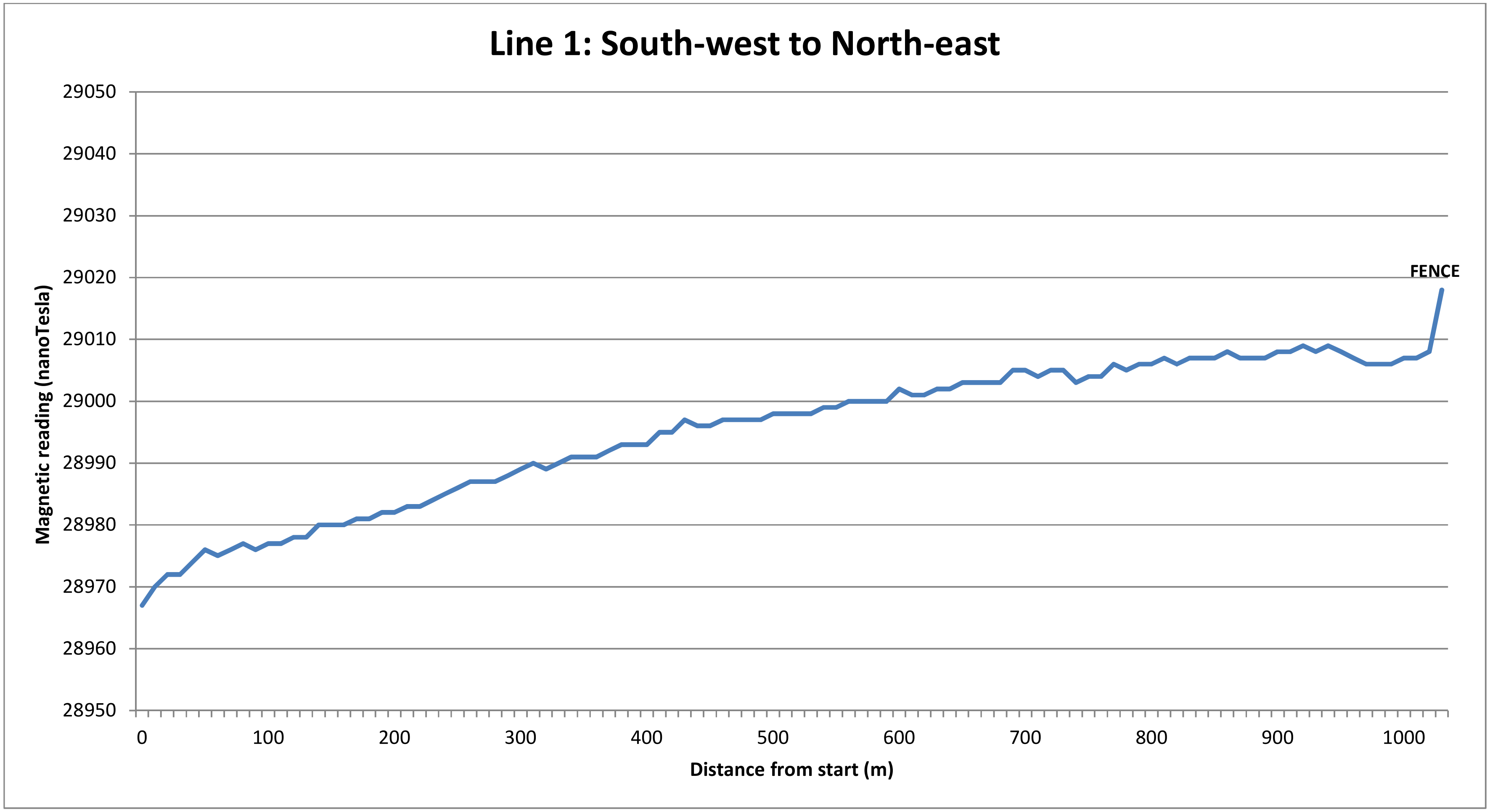
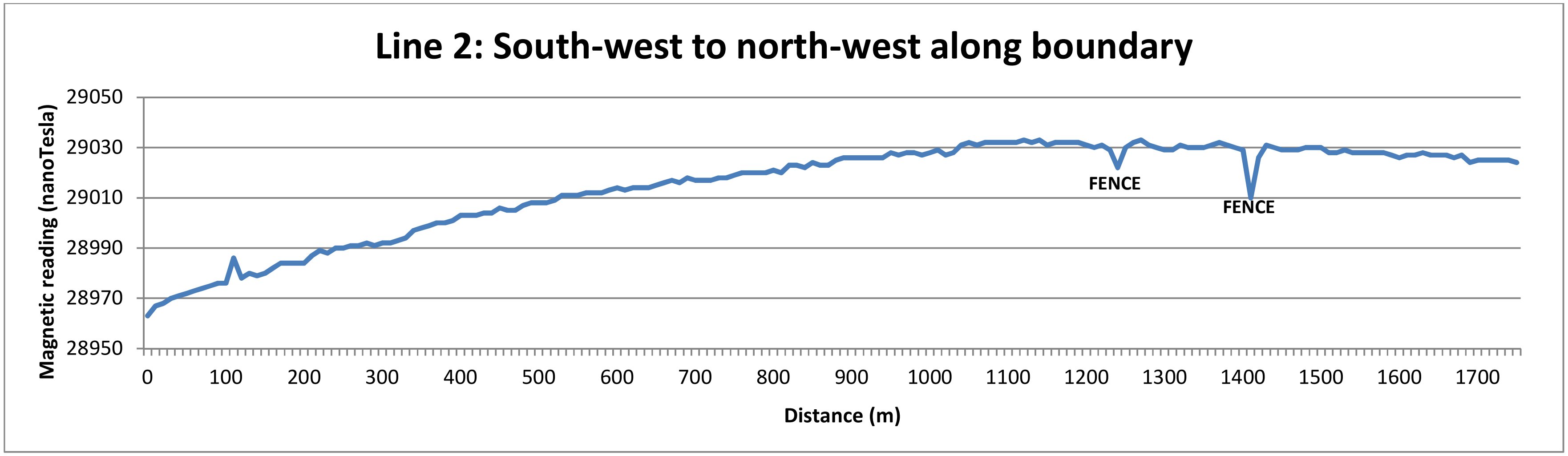
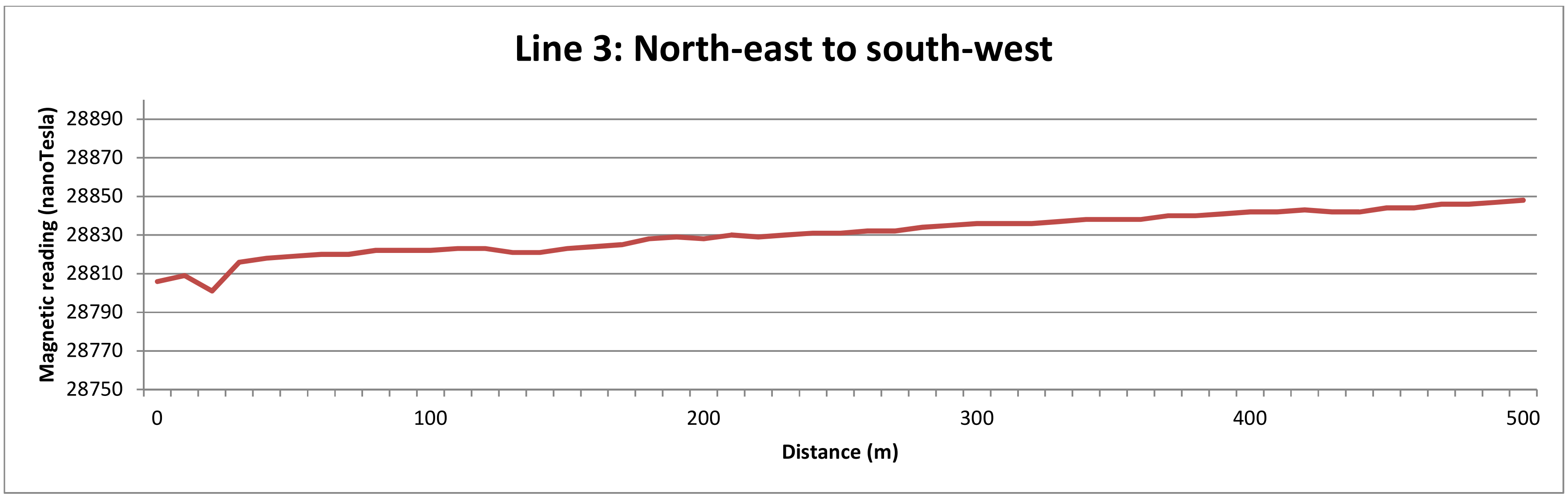
13 APPENDIX A: GEOPHYSICAL SURVEY GRAPHS




Line 2: South-west to north-west along boundary
Magnetic reading (nanoTesla)
29050
29030
29010
28990
28970
28950
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
Distance (m)
FENCE
FENCE


Line 3: North-east to south-west
Magnetic reading (nanoTesla)
28890
28870
28850
28830
28810
28790
28770
28750
0
100
200
300
400
500
Distance (m)

14 APPENDIX B: PUMP TEST RESULTS

GRU01						
SWL=	19.53			DATE:	26/11/2018	
BH DEPTH=	37.1					
PUMP TEST				RECOVERY TEST		
Time	Drawdown	WL	Q (l/s)	Time	Drawdown	WL
0.5				0.5	3.86	23.39
1	0.66	20.19		1	3.48	23.01
1.5	1.69	21.22		1.5	3.13	22.66
2	2.12	21.65	0.625	2	2.56	22.09
3	2.51	22.04		3	2.18	21.71
5	3	22.53		5	1.56	21.09
7.5	3.37	22.9		7.5	1.07	20.6
10	3.62	23.15		10	0.77	20.3
12.5	3.78	23.31		12.5	0.72	20.25
15	3.88	23.41		15	0.64	20.17
20	3.99	23.52		20	0.52	20.05
25	4.07	23.6		25	0.44	19.97
30	4.17	23.7		30	0.39	19.92
40	4.25	23.78		40	0.32	19.85
50	4.34	23.87		50	0.27	19.8
60	4.38	23.91		60	0.24	19.77

GRU02						
SWL=	17.27			DATE:	27/11/2018	
BH DEPTH=	42.8					
PUMP TEST				RECOVERY TEST		
Time	Drawdown	WL	Q (l/s)	Time	Drawdown	WL
0.5	2.13	19.4				
1	2.73	20		1	12.63	29.9
1.5	3.63	20.9		2	5.24	22.51
2	3.79	21.06		3	4.53	21.8
3	5.31	22.58	0.9	4	3.73	21
5	6.39	23.66		6	3.16	20.43
7.5	7.53	24.8		7	2.73	20
10	8.73	26		9	2.04	19.31
12.5	13.14	30.41		16	1.48	18.75

15	14.73	32		268	0.35	17.62
20	14.73	32	stop			
25	14.73	32				

GRU06

SWL= 15.22 DATE: 27/11/2018

BH

DEPTH= 32.35

PUMP TEST				RECOVERY TEST		
Time	Drawdown	WL	Q (l/s)	Time	Drawdown	WL
0.5	0.93	16.15		0.5	13.13	28.35
1	1.78	17		1	12.58	27.8
1.5	2.63	17.85	0.71	1.5	12.13	27.35
2	3.48	18.7		2	11.58	26.8
3	4.05	19.27		3	10.68	25.9
5	6.68	21.9		5	8.88	24.1
7.5	9.78	25		7.5	6.58	21.8
10	13.08	28.3		10	4.31	19.53
12.5	13.63	28.85	pump inlet	12.5	2.91	18.13
15	13.63	28.85		15	1.65	16.87
20	13.63	28.85		20	0.55	15.77
25	13.63	28.85		25	0.41	15.63
30	13.63	28.85	0.29	30	0.33	15.55
40	13.63	28.85		40	0.26	15.48

GRU07

SWL= 18 DATE: 27/11/2018

BH DEPTH= 87

PUMP TEST				RECOVERY TEST		
Time	Drawdown	WL	Q (l/s)	Time	Drawdown	WL
0.5	0.27	18.27		0.5	0.8	18.8
1	0.67	18.67	0.8333333	1	0.43	18.43
1.5	1.03	19.03		1.5	0.28	18.28
2	1.2	19.2		2	0.22	18.22
3	1.35	19.35		3	0.15	18.15
5	1.46	19.46		5	0.11	18.11
7.5	1.5	19.5		7.5	0.09	18.09
10	1.52	19.52		10	0.08	18.08
12.5	1.53	19.53		12.5	0.07	18.07

15	1.54	19.54		15	0.06	18.06
20	1.55	19.55		20	0.05	18.05
25	1.56	19.56		25	0.04	18.04
30	1.57	19.57		30	0.03	18.03
40	1.58	19.58		40	0.02	18.02
50	1.59	19.59		50	0.01	18.01
60	1.6	19.6		60	0	18