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KHWARA MANGANESE (PTY) LTD

Groundwater study for the proposed Khwara Manganese Mine

Groundwater Numerical Model

SLR Project No.: 710.20008.00036

Revision No.1

August 2017

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GROUNDWATER STUDY FOR THE PROPOSED DEVELOPMENT OF THE KHWARA MANGANESE MINE

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ACRONYMS AND ABBREVIATIONS

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

Acronyms / Abbreviations	Definition
DENC	Department of Environment and Nature Conservation
DMR	Department of Mineral Resources
EAP	Environmental Assessment Practitioner
EIA	Environmental impact assessment
EMP	Environmental management programme
IAPs	Interested and/or affected parties
JMLM	Joe Morolong Local Municipality
JTGDM	John Taolo Gaetsewe District Municipality
Khwara	Khwara Manganese (Pty) Ltd
m	Meter
MAP	Mean annual precipitation
mamsl	Meters above mean sea level
MPRDA	Mineral and Petroleum Resources Development Act No. 28 of 2002
N/A	Not applicable
NEMA	National Environmental Management Act No.107 of 1998
NRMSE	Normalised Residual Mean Squared Error
ROM	Run-of-mine
RMSE	Residual Mean Squared Error
SA	South Africa
SACNSP	South African Council for Natural Scientific Professions
SANS	South African National Standards
SAS/STS	Scientific Aquatic Services/ Scientific Terrestrial Services
SLR	SLR Consulting (South Africa) (Pty) Ltd

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

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

Item	NEMA Regulations (2014): Appendix 6	Relevant Section in Report
1(a)(i)	Details of the specialist who prepared the report	Section 2
1(a)(ii)	The expertise of that person to compile a specialist report including a curriculum vitae	Appendix A
1(b	A declaration that the person is independent in a form as may be specified by the competent authority	Section 3
1(c)	An indication of the scope of, and the purpose for which, the report was prepared	Sections 1 and 5
1(d)	The date and season of the site investigation and the relevance of the season to the outcome of the assessment	Section 6
1(e)	A description of the methodology adopted in preparing the report or carrying out the specialised process	Section 6
1(f)	The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	No specific sensitive areas identified
1(g)	An identification of any areas to be avoided, including buffers	None identified
1(h)	A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	No specific sensitive areas identified
1(i)	A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 14
1(j)	A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Section 10
1(k)	Any mitigation measures for inclusion in the EMPr	Section 12
1(l)	Any conditions for inclusion in the environmental authorisation	None
1(m)	Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 11
1(n)(i)	A reasoned opinion as to whether the proposed activity or portions thereof should be authorised and	Section 16
1(n)(ii)	If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Section 16
1(o)	A description of any consultation process that was undertaken during the course of carrying out the study	Section 15
1(p)	A summary and copies of any comments that were received during any consultation process	Section 15
1(q)	Any other information requested by the competent authority.	No other information

GROUNDWATER STUDY FOR THE PROPOSED DEVELOPMENT OF THE KHWARA MANGANESE MINE

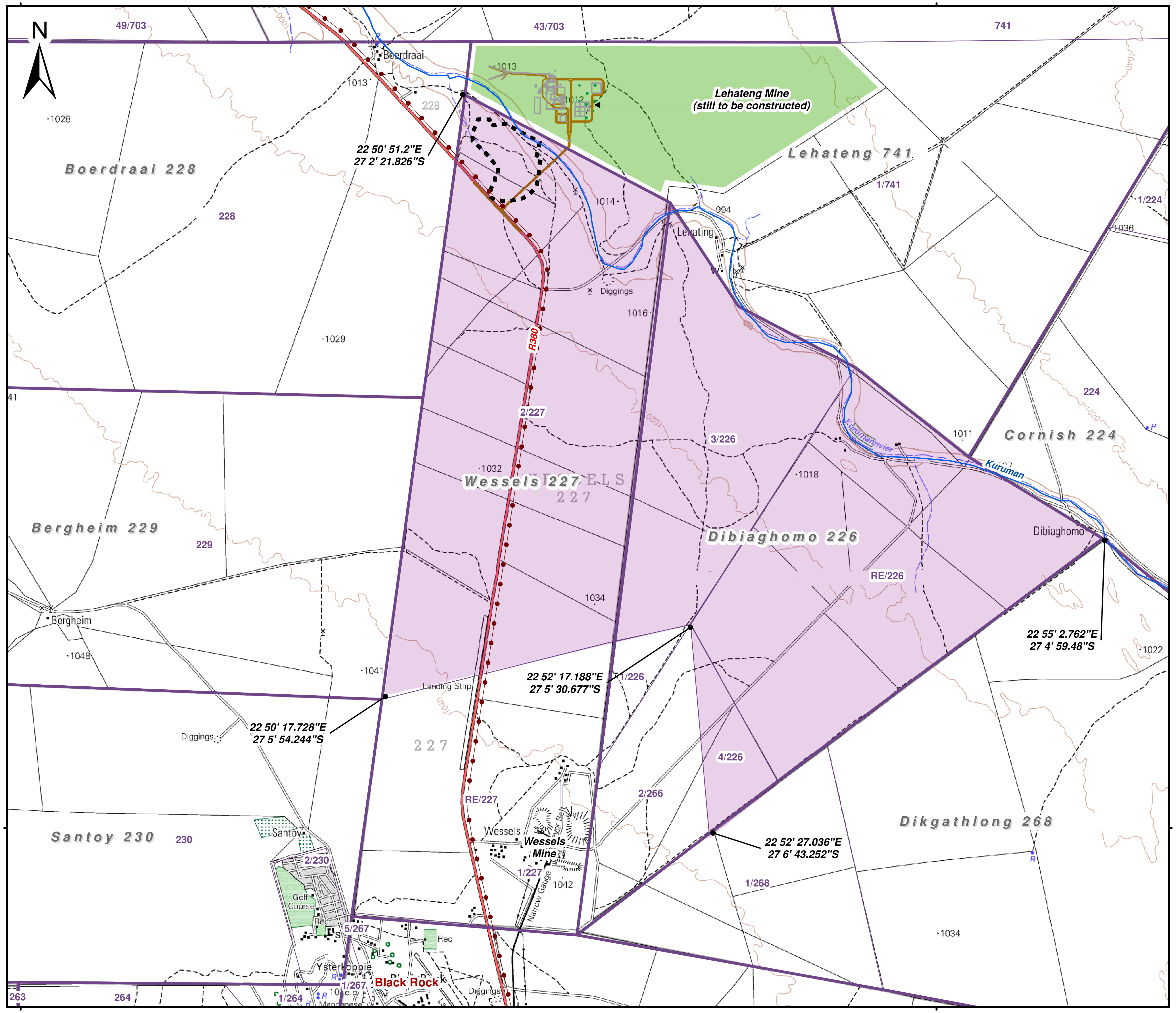
1 INTRODUCTION

Khwara Manganese (Pty) Ltd (Khwara) holds a prospecting right for manganese on portion 2 of the farm Wessels 227 and the remaining extent and portion 3 and 4 of the farm Dibiaghomo 226, north of Black Rock in the Northern Cape Province. On the adjacent farm (Portion 1 of Lehating 741), Lehating Mining (Pty) Ltd (Lehating) holds the mining right and have an approved environmental management programme (EMP) from the Department of Mineral Resources (DMR) for manganese and iron (approved October 2013). Lehating also holds an environmental authorisation (EA), issued by the Department of Environment and Nature Conservation (DENC) in September 2014 in terms of the National Environmental Management Act, 107 of 1998 (NEMA). It is important to note that the construction of the Lehating Mine is still to commence.

Khwara has applied to the DMR for a mining right over the above portions of the farms Wessels 227 and Dibiaghomo 226, referred to as the Khwara Mine project. The resource will be accessed and mined from the Lehating mine (underground). Approved surface infrastructure at the Lehating Mine will be used to support the mining of the underground resource on the farms Wessels 227 and Dibiaghomo 226 and as such no surface infrastructure will be established as part of the proposed project.

SLR Consulting (South Africa) (Pty) Limited (SLR) was appointed by Khwara to conducted a hydrogeological study to support the Environmental Impact Assessment (EIA) and Environmental Management Programme (EMP) for the Project.

The proposed mining area is located approximately 15 km northwest of Hotazel in the Northern Cape. The site location is presented in Figure 1.



Legend

- Approved Lehating Mining Right Area
- Proposed Mining Right Area
- Khwara UG Mine Area
- Main Roads
- Secondary Roads
- Power Line
- Rivers and Streams
- 20m Contour Lines
- Farm Boundaries
- Farm Portions

0 1 2 Kilometers

Scale: 1 : 41 000 @ A3

Projection: Transverse Mercator
Datum: Hartebeeshoek, Lo23

Khwara Manganese (Pty) Ltd

Figure 1

Locality Map

SLR

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2 DETAILS OF SPECIALIST

Geohydrologist Mihai Muresan prepared this groundwater report, with assistance from Linda Munro, an environmental assessment practitioner. The details of the report authors are provided in Table 1 below.

TABLE 1: DETAILS OF REPORT AUTHORS

Details	Project manager, author and reviewer	Co-author
Name	Mihai Muresan	Linda Munro
Tel No.:	011 467 0945	011 467 0945
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Key qualifications	M.Sc. in Hydrogeology and Engineering Geology	M.Sc. in Environmental Science
Experience	Over 25 years	Over 15 years
Professional registration	South African Council for Natural Scientific Professions: registration number	South African Council for Natural Scientific Professions: registration number

3 DECLARATION

I, Mihai Muresan hereby declare that I am an independent consultant, who has no interest or personal gains in this proposed project whatsoever, except receiving fair payment for rendering an independent professional service.

I am a hydrogeologist with over 25 years' experience conducting hydrogeological assessments for the mining industry. I am a registered professional scientist with the South African Council for Natural Scientific Professions.

My curriculum Vitae is provided in Appendix A.

4 GEOGRAPHICAL SETTING

4.1 TOPOGRAPHY AND DRAINAGE

The proposed project area is located in a relatively flat area with gentle slopes to the North East. The elevation on site varies from 990 m to 1107 m above mean sea level (mamsl). The Kuruman River is located on the north-eastern boundary of the proposed project site (Figure 2). The Kuruman River is ephemeral in nature and as such will only flow during heavy rain events and can be associated with a perched water table.

The general area surrounding the proposed project area is characterised with relatively flat with gentle slopes with the Koranna Berg mountain range located to the south west of the proposed project area respectively (Figure 1).

4.2 CLIMATE

Regional climate

The proposed project area falls within the Northern Steppe Climatic Zone, as defined by the South African Weather Bureau. This is a semi-arid region characterised by seasonal rainfall, hot temperatures in summer, and colder temperatures in winter.

Rainfall

The mean annual precipitation (MAP) for the site is more than 300 mm/year. The mean annual rainfall measured at the nearby Winton (40 km away) and Milner (17 km away) weather stations ranges between 330 mm and 362 mm respectively. Rainfall is typically in the form of thunderstorms during the summer months of October to March. The peak rainy period occurs between the months of January to March. Rainfall is erratic and may vary significantly from year to year. Monthly average rainfall for each month is presented in Table 2 below (SLR, September 2013).

TABLE 2: SUMMARY OF MONTHLY RAINFALL FOR THE PROPOSED PROJECT SITE (SLR, FEBRUARY 2013)

Month	Rainfall (mm)	
	Winton - 392148 w	Milner - 393083 w
January	62.1	66.1
February	61.2	61.4
March	58.0	66.4
April	31.8	35.5
May	13.9	16.1
June	4.2	6.0
July	2.5	1.9
August	4.9	4.2
September	6.2	6.2
October	16.2	19.0
November	25.7	32.0
December	43.3	46.8
Annual	330.1	361.6

Evaporation

The WR2005 (2009) shows a range in annual evaporation for the site of greater than 2118 mm (A-Pan estimate). A correction factor of approximately 0.65 (based upon the annual average for monthly correction factors) allows for the translation of the A-Pan estimate to the evaporation estimate for a very shallow body of water (Lake), equivalent to 1375 mm. A summary of the adopted evaporation data for the proposed project area is provided in Table 3 below which indicates that the proposed project area is characterised by high evaporation rates (SLR, September 2013).

TABLE 3: SUMMARY OF EVAPORATION DATA (SLR, FEBRUARY 2013)

Months	Mean monthly a-pan evaporation (mm)	Mean monthly lake evaporation (mm)
January	259.0	169.7
February	208.4	144.9
March	161.3	112.1
April	122.3	83.9
May	113.2	76.8
June	82.5	56.1
July	99.1	63.3
August	131.2	81.8
September	188.5	109.9
October	236.3	135.9
November	243.6	157.8
December	272.7	183.3
Total	**2118.1**	**1375.7**

5 SCOPE OF WORK

The objective of the study was to construct and run a numerical groundwater model to simulate the proposed Khwara mine and to determine the extent and magnitude of a possible cone of drawdown developed during and post-mining. The study was required to cumulatively assess the dewatering impacts from the Lehating and Khwara mining operations.

6 METHODOLOGY

6.1 DESK STUDY

A desk study was undertaken to collate all pertinent data:

- Geological
- Hydrogeological
- Mining

The available information examined which was applicable to the groundwater study is listed in Table 4.

TABLE 4: SOURCES OF DATA

Project	Document Title	Author and Reference	Document Date
Ntsimbintle Groundwater Assessment	Groundwater investigation for Ntsimbintle mine	Water Geosciences Consulting Ntsimbintle 27/02/09	February 2009
Groundwater Report –	Groundwater Report – Lehating 741	Metago Water Geosciences	April 2011

Project	Document Title	Author and Reference	Document Date
Lehating 741			
Numerical Modelling	Lehating Contaminant Transport Model Report	SLR Consulting	August 2013
Khwara Monitoring	Khwara Manganese Hydrocensus	SLR Consulting (Africa) (Pty) Ltd	September 2016

The reports and documents pertinent to the hydrogeological study are briefly overviewed below:

- A regional groundwater flow model was developed based on the available and determined (i.e. site specific) aquifer parameters to evaluate the potential impacts of mining activities on groundwater flow and quality. The numerical model is used to predict the development of the cone of drawdown as underground mining is progressing.
- The mining information was transmitted by the Khwara Mine and consisted of future underground mining plans, for both Khwara and Lehating mines.

6.2 HYDROCENSUS

A hydrocensus was undertaken in September 2016. The objective of the hydrocensus was to re-visit groundwater boreholes identified during the 2013 hydrocensus conducted for the Lehating EIA, identify new groundwater boreholes, and measure and sample all possible groundwater point within a 7 km radius from the mine.

During the course of the hydrocensus, thirty (30) boreholes were identified and inspected. Details of the boreholes inspected are presented in Table 5 and Figure 2 illustrates the locations of identified boreholes in relation to the Project Area. An additional borehole is located on the farm Boerdraai and is used for domestic purposes. This borehole was equipped and could not be sampled.

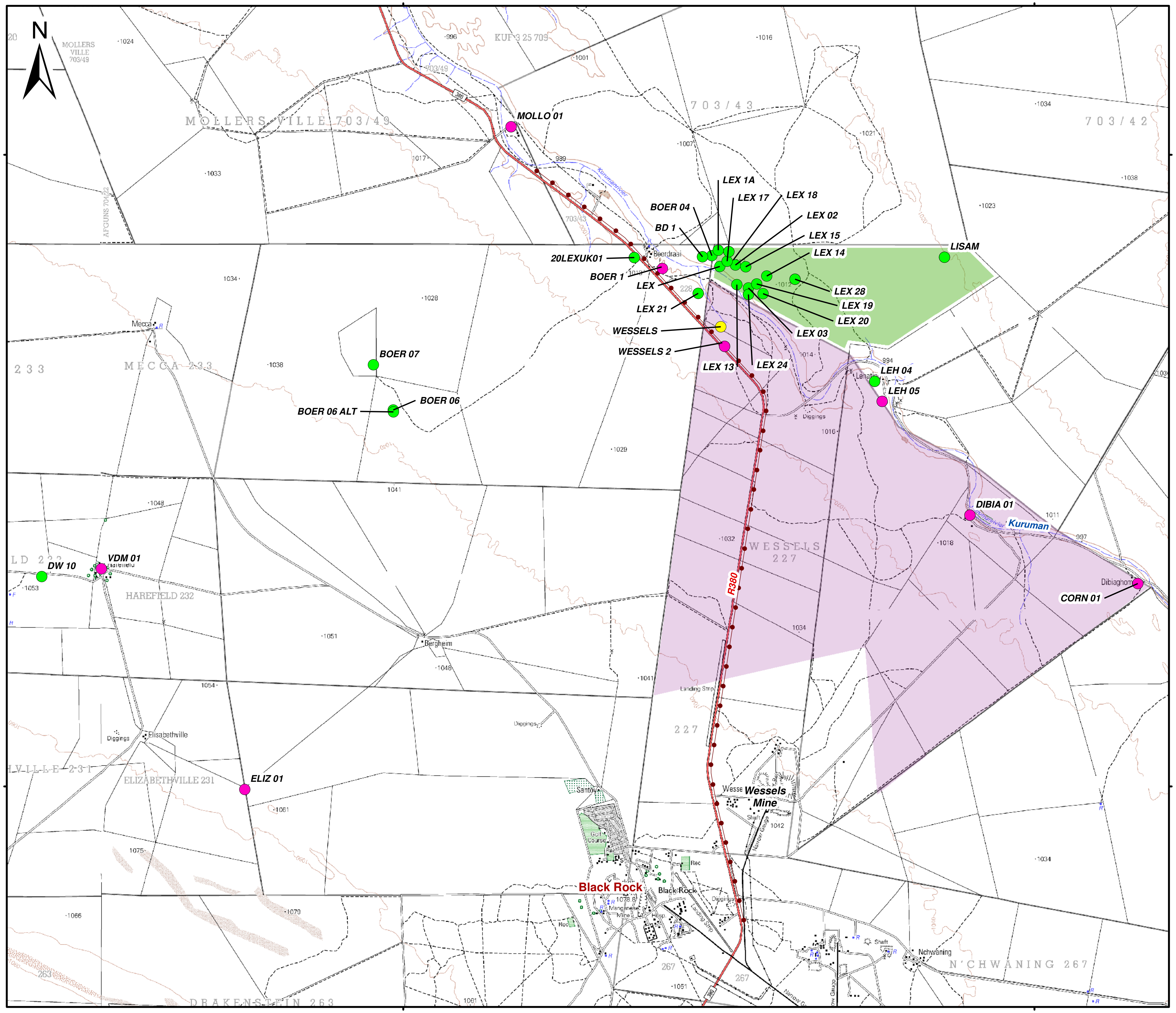
For each borehole identified, parameters including the location, groundwater level, water quality, and groundwater usage including extraction volumes and application observations were recorded. In addition, groundwater sampling was conducted at selected sites in order to gather water quality information for the area.

The hydrocensus shows that the majority of boreholes identified are not used and are prospecting boreholes, however some boreholes were identified that are utilised for domestic purposes or livestock watering.

TABLE 5: SUMMARY OF HYDROCENSUS BOREHOLES

Sample ID	Farm	Owner	Coordinates			Sampled	Water Use	Equipment	Condition
			Lat	Long	Z				
BD 1	Boerdraai 228	Gert Stander	-27.03589	22.8462	1011	Yes	Not in use	Not Equipped	Good
BOER 04	Boerdraai 228	Gert Stander	-27.03573	22.8477	1009	Yes	Not in use	Not Equipped	Good
BOER 06	Boerdraai 228	Gert Stander	-27.05772	22.7968	1038	Yes	Not in use	Not Equipped	Good
BOER 06 ALT	Boerdraai 228	Gert Stander	-27.05798	22.79683	1029	No			
BOER 07	Boerdraai 228	Gert Stander	-27.05126	22.79364	1030	No	Not in use	Not Equipped	Good
CORN 01	Cornish 224	Joseph Van Der Walt	-27.08263	22.91569	1011	Yes	Livestock watering	Windpump	Good
DIBIA 01	Dibiakgomo 226	Joseph Van Der Walt	-27.07283	22.88887	998	Yes	Livestock watering	Windpump	Good
DW 10	Dibiakgomo 226	Joseph Van Der Walt	-27.08142	22.74059	1057	Yes	Not in use	Not Equipped	Good
ELIZ 01	Dibiakgomo 226	Joseph Van Der Walt	-27.11189	22.77296	1056	Yes	Livestock and Domestic	Mono Pump	Good
VDM 01	Dibiakgomo 226	Joseph Van Der Walt	-27.08033	22.75013	1054	Yes	Domestic - All purposes	Submersible	Good
20LEXUK01	Lehating 741	ER Van Schalkwyke	-27.03599	22.835329	1008	No	Not in use	Not Equipped	Good
LEH 04	Lehating 741	ER Van Schalkwyke	-27.0537	22.87367	1005	Yes	Not in use	Not Equipped	Bad
LEH 05	Lehating 741	ER Van Schalkwyke	-27.05658	22.87487	1003	Yes	Domestic - All purposes	Submersible	Good
LEX	Lehating 741	ER Van Schalkwyke	-27.03728	22.84897	1010	Yes	Not in use	Not Equipped	Good
LEX 02	Lehating 741	ER Van Schalkwyke	-27.03708	22.85147	1012	Yes	Not in use	Not Equipped	Good
LEX 03	Lehating 741	ER Van Schalkwyke	-27.04034	22.85353	1005	Yes	Not in use	Not Equipped	Good
LEX 13	Lehating 741	ER Van Schalkwyke	-27.03986	22.85169	1009	No	No in use	Not Equipped	Good
LEX 14	Lehating 741	ER Van Schalkwyke	-27.03865	22.85645	1007	Yes	Not in use	Not Equipped	Good
LEX 15	Lehating 741	ER Van Schalkwyke	-27.03733	22.85312	1008	Yes	Not in use	Not Equipped	Good
LEX 17	Lehating 741	ER Van Schalkwyke	-27.03652	22.85015	1013	Yes	Not in use	Not Equipped	Good
LEX 18	Lehating 741	ER Van Schalkwyke	-27.03515	22.85042	1012	No	No in use	Not Equipped	Good
LEX 19	Lehating 741	ER Van Schalkwyke	-27.03978	22.85486	1006	Yes	Not in use	Not Equipped	Good
LEX 1A	Lehating 741	ER Van Schalkwyke	-27.03495	22.84873	1012	No	Not in use	Not Equipped	Good
LEX 20	Lehating 741	ER Van Schalkwyke	-27.04116	22.85587	1008	No	Not in use	Not Equipped	
LEX 21	Lehating 741	ER Van Schalkwyke	-27.0411	22.84551	1110	Yes	Not in use	Not Equipped	Good
LEX 24	Lehating 741	ER Van Schalkwyke	-27.04127	22.85354	1000	No	No in use	Not Equipped	Good
LEX 28	Lehating 741	ER Van Schalkwyke	-27.0391	22.86098	1005	Yes	Not in use	Not Equipped	Good

Sample ID	Farm	Owner	Coordinates			Sampled	Water Use	Equipment	Condition
LISAM	Lehating 741	ER Van Schalkwyke	-27.03598	22.88484	1014	No	No in use	Not Equipped	Good
MOLLO 01	Moller Ville 703	Johan Mollert	-27.01727	22.81568	991	Yes	Domestic - All purposes	Submersible	Good
WESSELS	Wessel Portion 2	Mine	-27.04588	22.84911	1007	No	Not in use	Not Equipped	Good
WESSELS 2	Wessel Portion 2	Mine	-27.04787	22.84975	1009	Yes	Domestic - All purposes	Submersible	Good



Legend

- Proposed Mining Right Area
- Approved Lehateng Mining Right Area
- Main Roads
- Secondary Roads
- Power Line
- Rivers and Streams
- 20m Contour Lines

Hydrocensus Boreholes

- Not In Use
- Prospecting
- Third Party

0 0.5 1 2 Kilometers

Scale: 1 : 59 500 @ A3

Projection: Transverse Mercator
Datum: Hartebeeshoek, Lo23

Khwara Manganese (Pty) Ltd

Figure 2

Hydrocensus Points

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Where possible, the depth to groundwater and the depth to the base of each well were measured, using a Solinst dip meter. Depths were measured against the top of casing and ground level (Table 6).

TABLE 6: KHWARA HYDROCENSUS - WATER LEVELS AND FIELD PARAMETERS

Type	Sample ID	Water level					Field Parameters		
		mbcl	mbgl	mamsl	Casing Height (m)	Water Level Status	pH	EC	TEMP
Prospecting	BD 1	35.47	35.4	975.6	0.07	Static	8.24	283.00	22.40
Prospecting	BOER 04	37.1	37.05	971.95	0.1	Static	7.95	574.00	23.10
Prospecting	BOER 06	68.87	68.83	969.17	0.04	Static	7.64	402.00	22.40
Prospecting	BOER 06 ALT	-	-	1029					
Prospecting	BOER 07	84.24	83.84	946.16	0.4	Static			
Farm Borehole	CORN 01	-	-	-			8.30	319.00	26.90
Farm Borehole	DIBIA 01	-	-	-			7.85	304.00	26.10
Prospecting	DW 10	74.26	74.26	982.74	0	Static	7.82	362.00	24.80
Farm Borehole	ELIZ 01	62.34	62.06	993.94	0.28	Static	7.98	191.00	21.20
Farm Borehole	VDM 01	70.56	70.22	983.78	0.34	Pumping	7.67	392.00	24.20
Prospecting	20LEXUK01	-	-	-					
Prospecting	LEH 04	20.94	20.56	984.44	0.38	Static	9.06	599.00	24.50
Farm Borehole	LEH 05	-	-	-			7.53	917.00	22.40
Prospecting	LEX	59.34	59.26	950.74	0.08	Static	8.81	1073.00	26.50
Prospecting	LEX 02	57.6	57.57	954.43	0.03	Static	9.63	353.00	28.10
Prospecting	LEX 03	28.9	28.56	976.44	0.34	Static	7.68	303.00	25.10
Prospecting	LEX 13	34.77	34.57	974.43	0.2	Static			
Prospecting	LEX 14	64.81	64.73	942.27	0.08	Static	8.69	503.00	336.00
Prospecting	LEX 15	62.69	62.55	945.45	0.14	Static	8.34	781.00	27.50
Prospecting	LEX 17	57.98	57.82	955.18	0.16	Static	7.84	396.00	23.40
Prospecting	LEX 18	31.16	30.97	981.03	0.19	Static			
Prospecting	LEX 19	46.62	46.52	959.48	0.1	Static	6.82	431.00	22.60
Prospecting	LEX 1A	53.41	53.27	958.73	0.14	Static			
Prospecting	LEX 20	-	-	-					
Prospecting	LEX 21	45.16	45.03	1064.97	0.13	Static	7.67	386.00	28.30
Prospecting	LEX 24	20.83	20.63	979.37	0.2	Static			
Prospecting	LEX 28	40.25	40.14	964.86	0.11	Static	8.79	345.00	25.70
Prospecting	LISAM	54.63	54.63	959.37	0	Static			
Farm Borehole	MOLLO 01	46.06	44.49	946.51	1.57	Static	8.11	459.00	20.20
Farm Borehole	WESSELS	54.98	54.8	952.2	0.18	Static			
Farm Borehole	WESSELS 2	58.58	58.28	950.72	0.3	Recovering	6.98	291.00	22.40

6.2.1 GROUNDWATER QUALITY

6.2.1.1 Sample Locations and Methodology

Groundwater samples were collected at twenty-three (23) of the boreholes visited by SLR. Sampled boreholes were selected based on location, in order to gather a spread of data across the area, and also based on operational status. Boreholes with installed and frequently operational pumps were selected as preferred sampling points to ensure water within the boreholes was representative of the intersected aquifer.

A number of samples were collected directly from the boreholes using disposable bailers and with a few groundwater samples collected from storage dams in which the borehole pumped to. Field parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS) and temperature (°C) were measured using a calibrated multi-meter.

Groundwater quality results are presented in Table 7 and show elevated concentrations of electrical conductivity, total dissolved solids, chloride, fluoride, nitrate, manganese and selenium when compared to the South African National Standards 241 of 2015.

TABLE 7: KHWARA - GROUNDWATER QUALITY RESULTS

Determinant	pH – Value at 25°C*	Electrical Conductivity in mS/m at 25°C*	Total Dissolved Solids at 180°C	Total Alkalinity as $CaCO_3$	Chloride as Cl	Sulphate as SO_4		Fluoride as F	Nitrate as N	Calcium as Ca
Unit	pH units	mS/m	mg/L	mg/l	mg/l	mg/l		mg/l	mg/l	mg/l
SANS 241 (2015) DWS	5 - 9.7	<170	<1200		<300	<250	<500	<1.5	<11	
Risk	Operational	Aesthetic	Aesthetic		Aesthetic	Aesthetics	Acute	Chronic health	Chronic health	
Lex 04	8.3	65.5	340	172	137	2		0.3	0.2	3
Lex 02	8.7	57.1	308	100	109	42		0.2	0.1	11
Lex 05	7.8	111	648	424	114	61		0.2	6.8	70
Alex 03 ALT	7.8	53.8	258	120	115	2		0.2	0.2	33
Alex 19	7.8	43.5	208	185	159	2		0.2	0.2	19
Mollo 01	7.4	158	940	324	264	155		0.7	3.5	63
Lex 28	7.9	79.6	376	148	192	2		0.2	0.4	11
Lex 21	8.3	66.6	378	240	87	17		0.02	0.6	7
VDW 01	7.9	103	662	296	108	48		2	24	83
Lex 14	7.9	73.1	364	100	192	2		0.3	0.2	14
Wessels 2	7.8	193	1204	444	338	146		0.4	2.5	97
Corn 01	8.1	106	614	304	150	84		0.2	9.9	35
Boer 01	8	85.2	478	372	97	8		0.2	0.2	20
Boer 04	7.7	176	478	816	111	2		0.2	0.2	7
Lex 24	7.8	95.7	534	436	104	18		2	0.4	40
Elize 01	7.9	83.4	550	288	66	38		0.2	15	70
Lex 17	8.7	55.6	294	188	88	2		0.2	0.2	6
Lex 15	8.6	59.8	278	48	170	2		0.4	0.2	8
Lea 4	8.1	143	712	112	403	2		0.3	0.3	21
Boer 04 Alt	8.1	77.4	400	296	98	2		0.2	0.5	33
DW 10	7.8	90.4	528	408	76	12		0.3	0.5	74
Bib 19 01	7.7	128	770	424	166	95		0.2	8.2	76
Lex 13	8.4	53.7	238	140	106	2		2	0.2	9

Determinant	Magnesium as Mg	Potassium as K	Sodium as Na	Zinc as Zn	Aluminium as Al	Antimony as Sb	Arsenic as As	Cadmium as Cd	Total Chromium as Cr	Cobalt as Co
Unit	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
SANS 241 (2015) DWS			<200	<5	<0.3	<0.02	<0.01	<0.003	<0.05	
Risk			Aesthetic	Aesthetic	Operational	Chronic health	Chronic health	Chronic health	Chronic health	
Lex 04	36	5.1	68	0.02	0.1	0.01	0.01	0.01	0.01	0.01
Lex 02	14	6.9	78	0.035	0.1	0.01	0.01	0.01	0.01	0.01
Lex 05	78	3.6	41	0.118	0.1	0.01	0.01	0.01	0.01	0.01
Alex 03 ALT	25	2.3	23	0.026	0.1	0.01	0.01	0.01	0.01	0.01
Alex 19	16	3.6	40	0.034	0.1	0.01	0.01	0.01	0.01	0.01
Mollo 01	55	6.7	184	0.22	0.1	0.01	0.01	0.01	0.01	0.01
Lex 28	52	6.3	53	0.028	0.1	0.01	0.01	0.01	0.01	0.01
Lex 21	49	5.1	46	0.063	0.1	0.01	0.01	0.01	0.01	0.01
VDW 01	40	10.2	58	0.049	0.1	0.01	0.01	0.01	0.004	0.01
Lex 14	21	6.1	89	0.031	0.1	0.01	0.01	0.01	0	0.01
Wessels 2	92	10.2	157	0.231	0.1	0.01	0.01	0.01	0	0.01
Corn 01	79	3.5	47	0.042	0.1	0.01	0.01	0.01	0.002	0.01
Boer 01	71	4.5	41	0.018	0.1	0.01	0.01	0.01	0	0.01
Boer 04	63	17.5	52	0.037	0.1	0.01	0.01	0.01	0	0.01
Lex 24	64	3.7	58	0.021	0.1	0.01	0.01	0.01	0	0.01
Elize 01	27	8	48	0.16	0.1	0.01	0.01	0.01	0	0.01
Lex 17	36	3.6	52	0.038	0.1	0.01	0.01	0.01	0	0.01
Lex 15	3	3.9	92	0.03	0.1	0.01	0.01	0.01	0	0.01
Lea 4	41	7.5	183	0.028	0.1	0.01	0.01	0.01	0	0.01
Boer 04 Alt	41	16	46	0.026	0.1	0.01	0.01	0.01	0	0.01
DW 10	39	9.3	44	0.032	0.1	0.01	0.01	0.01	0	0.01
Bib 19 01	81	3.4	66	2.079	0.1	0.01	0.01	0.01	0	0.01
Lex 13	25	3.9	42	0.034	0.1	0.01	0.01	0.01	0	0.01

Determinant	Copper as Cu	Iron as Fe		Lead as Pb	Manganese as Mn		Nickel as Ni	Selenium as Se	Vanadium as V
Unit	mg/l	mg/l		mg/l	mg/l		mg/l	mg/l	mg/l
SANS 241 (2015) DWS	<2	<0.3	<2	<0.01	<0.1	<0.4	<0.07	<0.04	
Risk	Chronic health	Aesthetics	Chronic health	Chronic health	Aesthetics	Chronic health	Chronic health	Chronic health	
Lex 04	0.01	0.025		0.01	0.025		0.01	0.016	0.01
Lex 02	0.01	0.025		0.01	0.215		0.01	0.024	0.01
Lex 05	0.01	0.025		0.01	0.025		0.01	0.02	0.01
Alex 03 ALT	0.01	0.025		0.01	**0.57**		0.01	0.039	0.01
Alex 19	0.01	0.025		0.01	0.033		0.01	0.017	0.01
Mollo 01	0.01	0.025		0.01	0.025		0.01	0.049	0.01
Lex 28	0.01	0.025		0.01	0.033		0.01	0.029	0.01
Lex 21	0.01	0.025		0.01	0.034		0.01	0.019	0.01
VDW 01	0.003	0.025		0.01	0.025		0.01	0.025	0.014
Lex 14	0.001	0.025		0.01	0.115		0.01	0.032	0.01
Wessels 2	0.002	0.025		0.01	0.184		0.01	0.075	0.01
Corn 01	0.002	0.025		0.01	0.025		0.01	0.043	0.01
Boer 01	0.001	0.025		0.01	0.055		0.01	0.032	0.01
Boer 04	0	0.192		0.01	0.074		0.01	0.03	0.01
Lex 24	0	0.025		0.01	0.052		0.01	0.022	0.01
Elize 01	0.001	0.025		0.01	0.025		0.01	0.013	0.01
Lex 17	0	0.025		0.01	0.025		0.01	0.024	0.01
Lex 15	0	0.025		0.01	0.025		0.01	0.028	0.01
Lea 4	0.001	0.025		0.01	**0.468**		0.01	0.075	0.01
Boer 04 Alt	0.001	0.025		0.01	0.025		0.01	0.027	0.01
DW 10	0.001	0.025		0.01	0.025		0.01	0.012	0.01
Bib 19 01	0.001	0.025		0.01	0.253		0.01	0.051	0.01
Lex 13	0.001	0.025		0.01	0.025		0.01	0.026	0.01

6.3 GROUNDWATER MODELLING

A three dimensional groundwater numerical model was constructed using FEFLOW (finite elements) to simulate flow during and post mining. The results of the numerical model have been used for groundwater impact assessment.

7 PREVAILING GROUNDWATER CONDITIONS

7.1 GEOLOGY

7.1.1 REGIONAL GEOLOGY

The proposed project is located on the south western outer rim of the **Kalahari Manganese Field (KMF).** The general stratigraphic column of the Kalahari Manganese Field is presented in Table 8.

TABLE 8: GENERAL STRATIGRAPHIC COLUMN FOR THE KALAHARI MANGANESE FIELD

<table>
<tr><th colspan="4">Supergroup / Group / Subgroup / Formation</th><th>Geological Description</th></tr>
<tr><td colspan="4">Kalahari Group</td><td>Kalahari sands, calcrete, clays & gravel beds</td></tr>
<tr><td colspan="5">Kalahari unconformity</td></tr>
<tr><td colspan="4">Karoo Supergroup</td><td>Dwyka tillite</td></tr>
<tr><td colspan="5">Dwyka unconformity</td></tr>
<tr><td colspan="3" rowspan="2">Olifantshoek Supergroup</td><td>Lucknow Formation</td><td>White ortho-quartzite</td></tr>
<tr><td>Mapedi Formation</td><td>Green, maroon and black shales and quartzites</td></tr>
<tr><td colspan="5">Olifantshoek unconformity</td></tr>
<tr><td rowspan="9">Transvaal Supergroup</td><td rowspan="9">Postmansburg Group</td><td rowspan="8">Voelwater Subgroup</td><td>Mooidraai Formation</td><td>Dolomite, chert</td></tr>
<tr><td rowspan="7">Hotazel Formation</td><td>Banded ironstone (upper)</td></tr>
<tr><td>Upper Mn Ore Body</td></tr>
<tr><td>Banded ironstone (middle)</td></tr>
<tr><td>Middle manganese body</td></tr>
<tr><td>Banded ironstone (middle)</td></tr>
<tr><td>Lower manganese body</td></tr>
<tr><td>Banded ironstone (lower)</td></tr>
<tr><td colspan="2">Ongeluk Formation</td><td>Andesitic Lava</td></tr>
</table>

Three beds of manganese ore are interbedded with the Banded Iron Formation (BIF) of the Hotazel Formation (Transvaal Supergroup).

The BIF of the **Hotazel Formation** typically consists of repeated thin layers of black iron oxides (magnetite or hematite) alternating with bands of iron-poor shales and cherts.

7.1.2 LOCAL GEOLOGY

The Khwara Mine is located on the south western outer rim of the Kalahari Manganese Field (KMF). Khwara plans to exploiting the manganese from the Hotazel Formation. The general stratigraphic column for the KMF is shown in Figure 3.

The **Hotazel Formation** is underlain by basaltic lava of the **Ongeluk Formation** (Transvaal Supergroup) and directly overlain by dolomite of the **Mooidraai Formation** (Transvaal Supergroup). The Transvaal Supergroup is overlain unconformably by the **Olifantshoek Supergroup** which consists of arenaceous sediments, typically interbedded shale, quartzite and lavas overlain by coarser quartzite and shale. The different formations present in the project area include the Mapedi and Lucknow units. The whole Supergroup has been deformed into a succession with an east-verging dip (SLR, 2014).

The Olifantshoek Supergroup is overlain by **Dwyka Formation** which forms the basal part of the Karoo Supergroup. At the mine this consists of tillite (diamictite) which is covered by sands, claystone and calcrete of the **Kalahari Group** (SLR, 2014)

The **Hotazel Formation** consists of Banded Iron Formation (BIF) and is made up of three manganese rich zones:

- Upper Manganese Ore Body (UMO)
- Middle Manganese Ore Body (MMO)
- Lower Manganese Ore Body (LMO).

The UMO is 10 cm to 15 cm thick and comprises moderate deposits of manganese. The poorly mineralised MMO is approximately 1 m thick and not economically efficient. The LMO is a highly mineralised unit consisting of six important mineralised zones (X, Y, Z, M. C and N).

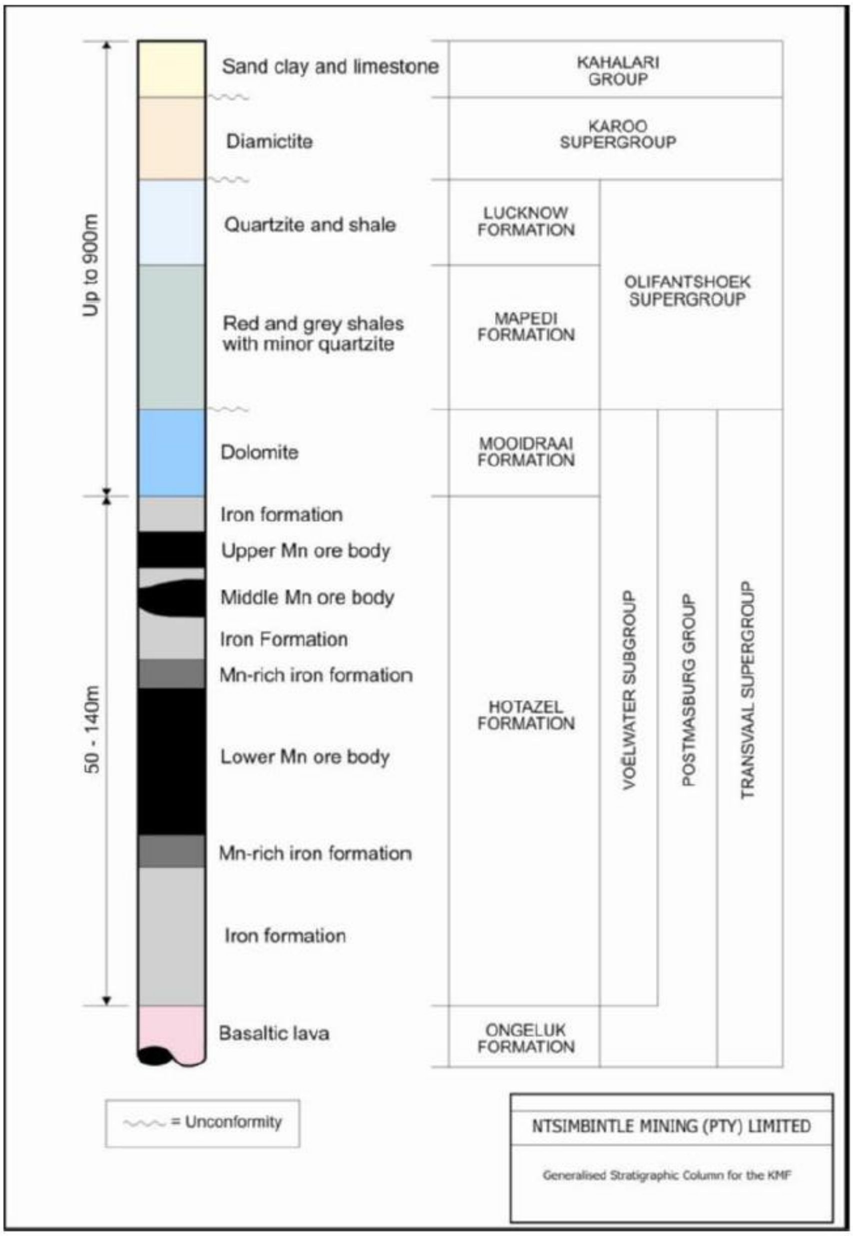

FIGURE 3: GENERALISED STRATIGRAPHIC COLUMN FOR THE KMF

7.2 ACID GENERATION CAPACITY

Geochemical analysis was conducted for the Lehating Project, and this information is relevant to Khwara because the geology is the same.

Laboratory tests to determine the potential of samples to produce Acid Rock Drainage (ARD) are generally grouped into two categories; static and kinetic tests. Static tests are relatively simple and undertaken as a preliminary assessment whereas kinetic tests are typically carried out if the results of the static tests are not conclusive or the samples are flagged as potentially acid generating

Static tests include Acid Base Accounting, sulphur speciation, inorganic carbon content, Net Acid Generation Tests and Synthetic Precipitation Leaching Procedure leach tests.

Acid Base Accounting (ABA) is an internationally accepted analytical procedure that screens the acid-producing and acid-neutralizing potential of a sample. The ABA tests assumes conservatively that all sulphur in the sample will react to form sulphuric acid, while some of the sulphur may also be present in non-acid producing sulphates, organic or elemental sulphur. An assessment of sulphur speciation is therefore undertaken to allow a better characterisation of the acid generating potential, which is related to the type of sulphur minerals present. Acid generation of samples with sulphide sulphur content below 0.3 % is considered short term.

The acid neutralising potential of a rock sample, predominantly from carbonates and exchangeable alkali and alkali earth cations is further characterised by the inorganic carbon content (as an estimate of carbonate contents in the tailing material) of the sample.

Net Acid Generation (NAG) tests directly determine the acid generating potential of sulphur minerals in a rock sample by oxidation with hydrogen peroxide (H_2O_2). The final NAG pH after complete oxidation of the sample is used as a screening criterion for the acid generation potential.

Four samples of various materials likely to be mined at Lehating Mine were collected by a project geologist during exploratory drilling in December 2011 and sent to an accredited laboratory in Pretoria for static geochemical analysis. The sample consisted of the Kalahari Sands, Dwyka Formation and Ongeluk Lava which are considered to be representative of waste rock material.

The results of the ABA analysis are provided in Table 9 (SLR, Feb 2012).

TABLE 9: SUMMARY OF ABA AND SULPHUR SPECIATION RESULTS FOR THE LEHATING MINE SAMPLES (SLR, FEB 2012)

Parameter	Kalahari Formation	Dwyka	Ongeluk Lava	Manganese Ore
NAG pH	6.72	6.8	4.18	6.45
NAG (kg H2So4/t)	<0.01	<0.01	1.176	<0.01
Paste pH	7.2	7.7	8	6.9
Total sulphur (%)	<0.01	Repeat Analysis	<0.01	0.05
Sulphate (SO_4^{2-}) Sulphur (%)	<0.01	Repeat Analysis	<0.01	0.04
Sulphate (S^{2-}) Sulphur (%)	0.01	Repeat Analysis	<0.01	<0.01
Acid potential (AP) (kg $CaCO_3$/t)	0.31	8.46	0.31	1.44
Total Carbon (%)	1.94	1.55	0.03	0.12
Organic Carbon	0.05	0.46	0.01	<0.01

Parameter	Kalahari Formation	Dwyka	Ongeluk Lava	Manganese Ore
(%)				
Inorganic Carbon (%)	1.89	1.09	0.02	0.11
Neutralising Potential (NP) (kg $CaCO_3$/t)	85.82	39.2	5.59	23.5
Net Neutralising Potential (NNP = NP + NA) - open	85.51	30.73	5.28	22.06
Net Neutralising Potential Ratio (NPR = NP/AP)	274.62	4.63	17.88	16.32
Assessment	Non-Acid Forming	Non-Acid Forming	Non-Acid Forming	Non-Acid Forming

The results suggest that all four samples are non-acid forming due to the limited sulphide sulphur content which is the primary source of acid. The total sulphur content of the manganese ore sample predominantly occurs as sulphate sulphur. This along with the paste pH of near neutral (6.9) suggests that the majority of sulphide minerals have been oxidised and the possibility of generating acid is low. The Kalahari sample demonstrates significant neutralising potential.

No residue material will however be disposed of on surface as part of the Khwara Project.

7.3 HYDROGEOLOGY

7.3.1 UNSATURATED ZONE

From the groundwater risk assessment conducted by SLR (2013) it was established that the depth of the unsaturated zone is approximately 45 m. The unsaturated zone falls within the Kalahari Formation and consists of sand, clay and limestone.

7.3.2 SATURATED ZONE

A groundwater assessment was carried out by SLR in September 2013 for the Lehating Mine. From the investigations conducted two aquifers were distinguished to lie below the unsaturated zone within the Khwara project area:

- Aquifer I: Shallow aquifer made of the Kalahari Beds, sand and calcrete
- Aquifer II: Deep fractured aquifer made of the Dwyka clay and the Mooidraai dolomite Formation.

The Kalahari sand and the sediment beds with its associated underlying calcrete layer overlie the low permeability Dwyka clay bed. The deeper fractured bedrock aquifer is formed from the Mooidraai dolomite Formation and Dwyka clay contact which acts as a confining layer (WGC, 2009).

7.3.3 HYDRAULIC CONDUCTIVITY

A groundwater model was constructed in *MODFLOW* by SLR in 2013 to establish the groundwater regime with groundwater inflows into Lehating Mine as well as to evaluate the potential future impacts on the groundwater flow regime with mine dewatering and possible contamination.

The summary of the initial hydraulic parameters, derived from the previous work is detailed in Table 10.

TABLE 10: HORIZONTAL AND VERTICAL K OF GEOLOGICAL UNITS USED IN PREVIOUS MODELLING ASSESSMENTS IN METERS PER DAY

Aquifer	Hydraulic conductivity [m/d] Model Setup
Kalahari Deposits	0.975
Dwyka/Diamictites	0.03 – 0.975
Olifantshoek/Granite	0.006 – 0.178
Hotazel/BIF	0.01 – 0.975
Ongeluk/Basalt	0.013 – 0.23

7.4 GROUNDWATER LEVELS

Hydrocensus results and groundwater levels on site indicated that shallow groundwater levels correlated with surface topography. However, a similar correlation for deeper groundwater levels is not applicable. The groundwater level depths are provided in Table 6.

Of major importance for regional groundwater flow in the Lehating Mine area is the continuous presence of an impermeable or semi-permeable interface between the upper, unconfined Kalahari aquifer and the deeper, confined Dwyka aquifer. This interface (i.e. a permeability contrast) prevents rapid vertical drainage of the Kalahari aquifer on a regional scale, thus permitting lateral groundwater flow in the Kalahari aquifer driven by topographic gradients. Vertical infiltration across this interface is controlled by the existence of major permeable zones such as regional fault systems, etc. Furthermore, there is no evidence of hydraulic connectivity between the river and groundwater.

7.5 GROUNDWATER QUALITY

Groundwater quality is discussed in section 6.2.1.

8 AQUIFER CHARACTERISATION

8.1 GROUNDWATER VULNERABILITY

The Aquifer Vulnerability Map of South Africa (Conrad et al. 1999c) indicates the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer. Based on the map, the project area is classified as least to moderately vulnerable which implies the following:

- Least vulnerable: only vulnerable to conservative pollutants in the long term when continuously discharged or leached; and
- Moderately vulnerable: vulnerable to some pollutants, but only when continuously discharged or leached.

8.2 AQUIFER CLASSIFICATION

The classification scheme outlined in Table 11, (WRC Parsons, 1995) was created for strategic purposes as it allows the grouping of aquifer areas into types according to their associated supply potential, water quality and local importance as a resource.

TABLE 11: AQUIFER CLASSIFICATION (RSA)

Aquifer System	Defined by Parsons (1995)	Defined by DWAF Min Requirements (1998)
Sole Source Aquifer	An aquifer which is used to supply 50 % or more of domestic water for a given area, and for which there are no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.	An aquifer, which is used to supply 50% or more of urban domestic water for a given area for which there are no reasonably available alternative sources should this aquifer be impacted upon or depleted.
Major Aquifer	High permeable formations 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 (<150 mS/m).	High yielding aquifer (5-20 L/s) of acceptable water quality.
Minor Aquifer	These can be fractured or potentially fractured rocks, which do not have a high primary permeability or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and in supplying baseflow for rivers.	Moderately yielding aquifer (1-5 L/s) of acceptable quality or high yielding aquifer (5-20 L/s) of poor quality water.
Non-Aquifer	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 as unusable. However, groundwater flow through such rocks, although imperceptible, does take place, and need to be considered when assessing the risk associated with persistent pollutants.	Insignificantly yielding aquifer (< 1 L/s) of good quality water or moderately yielding aquifer (1-5 L/s) of poor quality or aquifer which will never be utilised for water supply and which will not contaminate other aquifers.
Special Aquifer	An aquifer designated as such by the Minister of Water Affairs, after due process.	An aquifer designated as such by the Minister of Water Affairs, after due process.

Based on the aquifer classification map (Parsons and Conrad, 1998) the majority of study area is regarded a "poor aquifer" while the aquifer adjacent (west) to the proposed Lehating portion is regarded as "minor" (Figure). A summary of the classification scheme is provided in Table 11. In this classification system, it is important to note that the concepts of Minor and Poor Aquifers are relative and that yield is not quantified. Within any specific area, all classes of aquifers should therefore, in theory, be present.

Therefore, Based on the 1:500 000 hydrogeological map sheet, Lehating is located on an aquifer classed as a poor aquifer with potential groundwater yields between 0.1L/s and 2L/s.

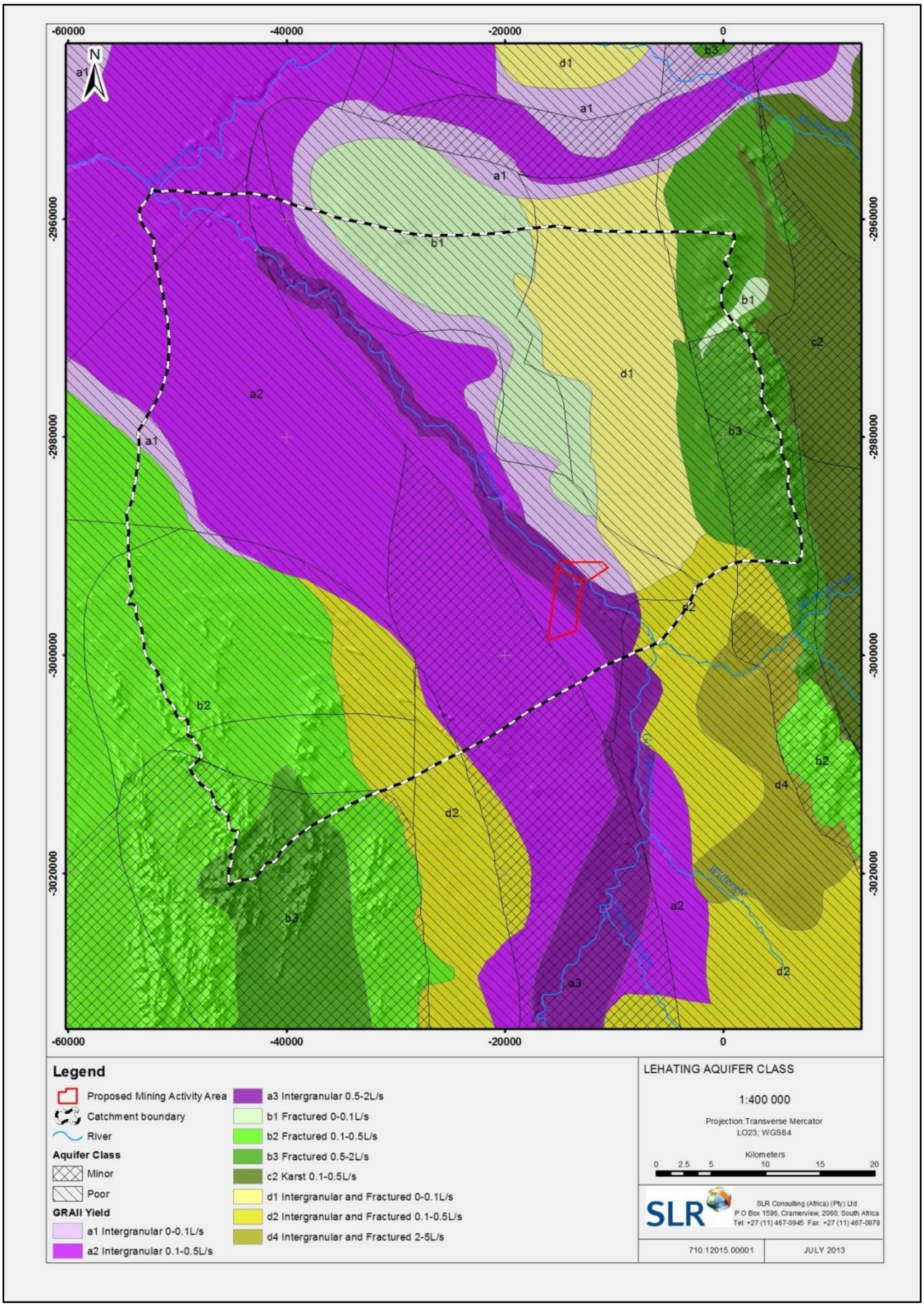

FIGURE 4: AQUIFER CLASSIFICATION MAP

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9 GROUNDWATER MODELLING

9.1 SOFTWARE MODEL CHOICE

For successful assessment of the mining and mining related activities impacts on the groundwater environment, *FEFLOW* (DHI-WASY) was selected to simulate groundwater flow and contaminant transport. *FEFLOW* is a finite elements groundwater flow and contaminant transport code appropriate for mining simulations.

9.2 MODEL SET-UP AND BOUNDARIES

The groundwater model domain for Khwara Mine is shown in Figure 5. The model domain was selected based mainly on topography and the sub-catchments identified on the topographic data (RSA topography 50.000 series).

The northern model boundary and partially the southern boundary were selected as Specified head boundary, where groundwater flow in- and out- the model domain is allowed during predictive simulations.

The remaining boundaries are declared “no-flow” boundaries and generally represent watershed lines along the higher elevation in the area. The North-Eastern boundary was also included as a “no-flow” boundary as it delineates two sub-catchments, to the north and south, where the mine is situated.

From a groundwater flow point of view, all boundaries are sufficiently far from Khwara mine, in such a way that they do not influence groundwater flow in the mine area.

It should be noted that the Khwara underground mining area (on the Wessels farm) is referred to as the Wessels mining area in this report and is shown adjacent to the Lehating Mine in all report figures.

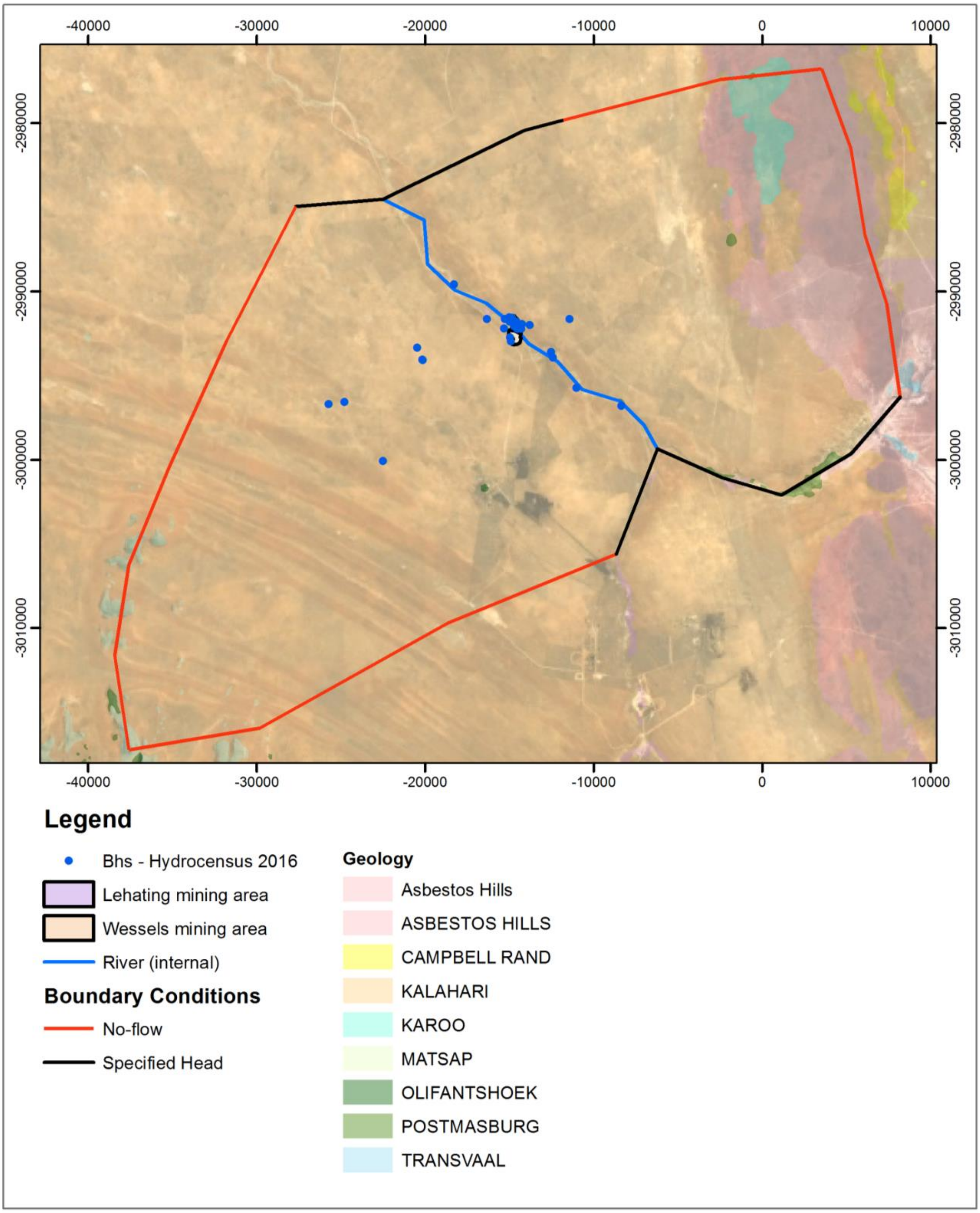


FIGURE 5: KHWARA MODEL DOMAIN

9.3 GROUNDWATER ELEVATION AND GRADIENT

The groundwater elevation over the whole model domain was interpolated from the existing boreholes groundwater measurements, and compared with groundwater elevations from previous work (SLR, 2013). The initial (pre-mining) groundwater elevations computed for the model domain is shown in Figure 6.

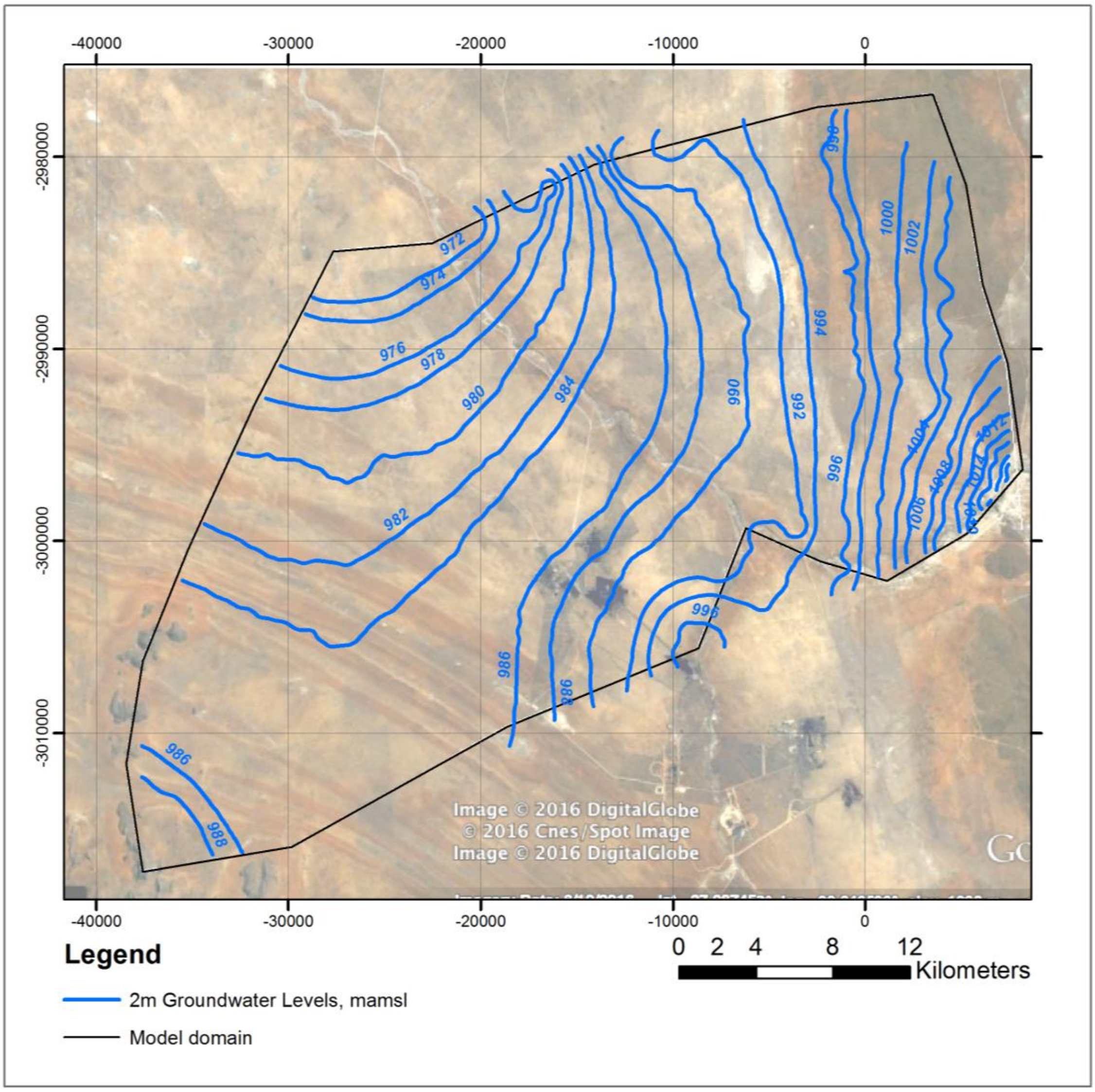


FIGURE 6: PRE-MINING WATER LEVELS

The groundwater flow is from East-South-East towards North-West with a calculated gradient of 0.001 towards North-West.

9.4 GROUNDWATER SOURCES AND SINKS

Groundwater sources for the Khwara numerical model are represented mainly by rainfall recharge to the model. The annual recharge considered initially for the numerical model calibration is 2 x 10^{-4} m/d, calculated at 2% of M.A.P. The groundwater sinks are represented by the Lehating and Wessels underground mine voids (Figure 7).

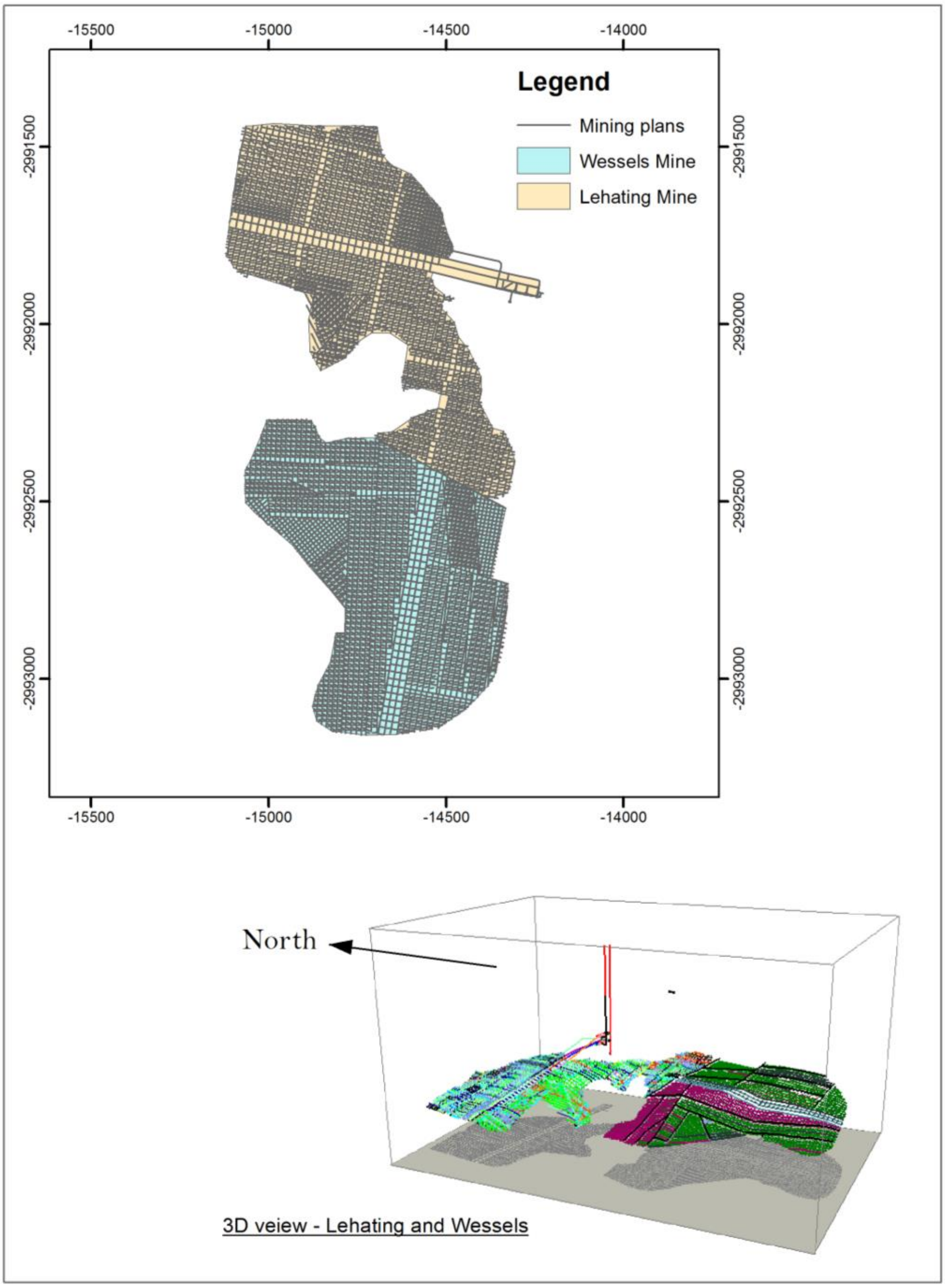


FIGURE 7: KHWARA - LEHATING AND WESSELS UNDERGROUND MINES

9.5 CONCEPTUAL MODEL

Figure 8 illustrates the hydrogeological conceptual model which forms the basis of the groundwater numerical model. The conceptual model is simplification of the real world conditions, but in the same time captures the main elements to be simulated in the numerical model.

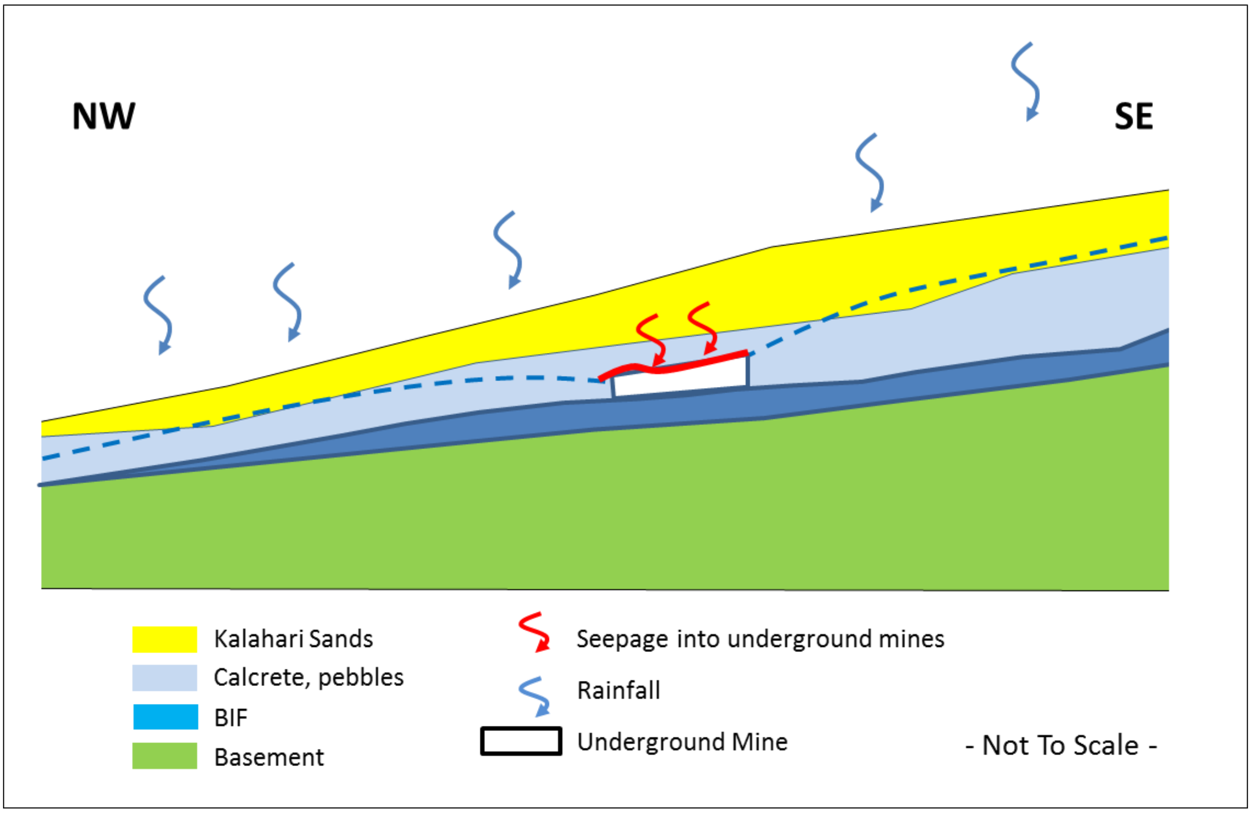


FIGURE 8: KHWARA - HYDROGEOLOGICAL CONCEPTUAL MODEL

The Kalahari layer is included across the full extent of the groundwater model as the deposits are surficial and aeolian. The Kalahari overlies the calcrete layer, which is a minor aquifer in this area. The deeper aquifer is represented by the banded ironstone formation (Hotazel). To avoid numerical non-convergence during the model run, the model is extended to a depth elevation of 300 mamsl, represented by the Basement formations.

9.6 MODEL DISCRETIZATION

The horizontal discretization of the model domain takes into consideration the geology and both underground mines, Wessels and Lehating. The resulting horizontal finite elements mesh is showed in Figure 9. The initial vertical discretization was based on the simplified geology described in the area (Table 12). This was further refined considering the mining levels (existing and future).

TABLE 12: VERTICAL LAYERS (AGES, 2007)

No	Zone	Hydraulic conductivity (K)	Thick (m)	Trans-missivity (m^2/d)	Head gradient (1)	Darcy flux (m/d)	Recharge (mm/y)	Recharge (m/d)	Seep Vel (m/y)
1	Sand	6.00	5	30	0.005	0.030	344	9.42E-04	110
2	Calcrete	1.50	20	30	0.005	0.008	344	9.42E-04	27
3	BIF	1.00	30	30	0.005	0.005	344	9.42E-04	18
4	Faults	2.40	25	60	0.005	0.012	344	9.42E-04	44

The final vertical layering of Khwara groundwater model is shown in Table 13.

TABLE 13: KHWARA GROUNDWATER MODEL - VERTICAL DISCRETIZATION

Layer	Description	Top slice description
1	Kalahari	topo
2	Dwyka	top Dwyka
3	BIF1	top BIF
4	BIF2	Mining layer
5	Lava	top Lava
6	Lava	interm

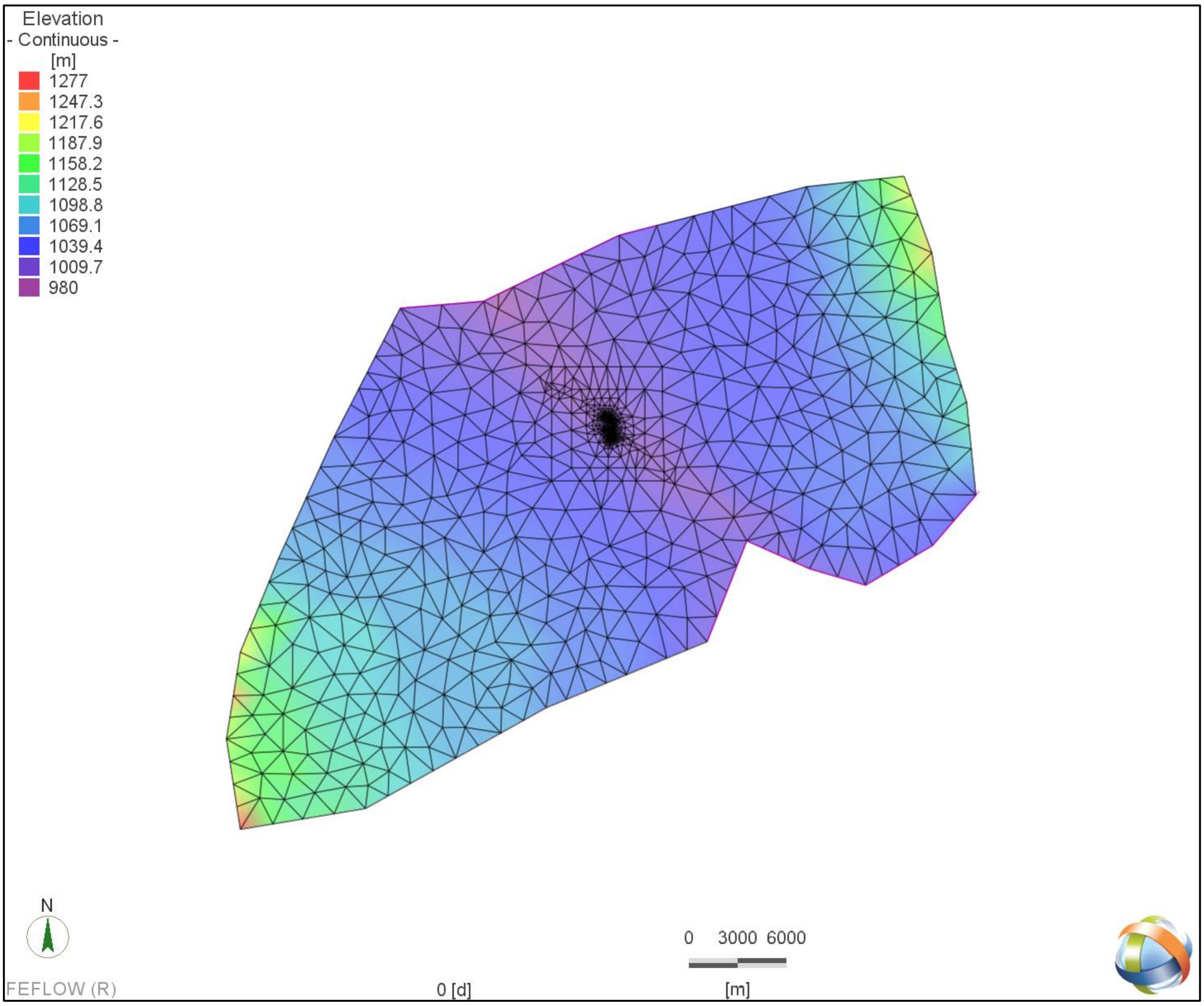


FIGURE 9: KHWARA GROUNDWATER MODEL - HORIZONTAL MESH

The resulting 3-dimensional numerical model is illustrated in Figure 10, and can be summarized as follows:

- Model area: 600 km^2
- Model bottom elevation: 500 mamsl
- Numbers of elements: 222,075
- Number of nodes: 119,488

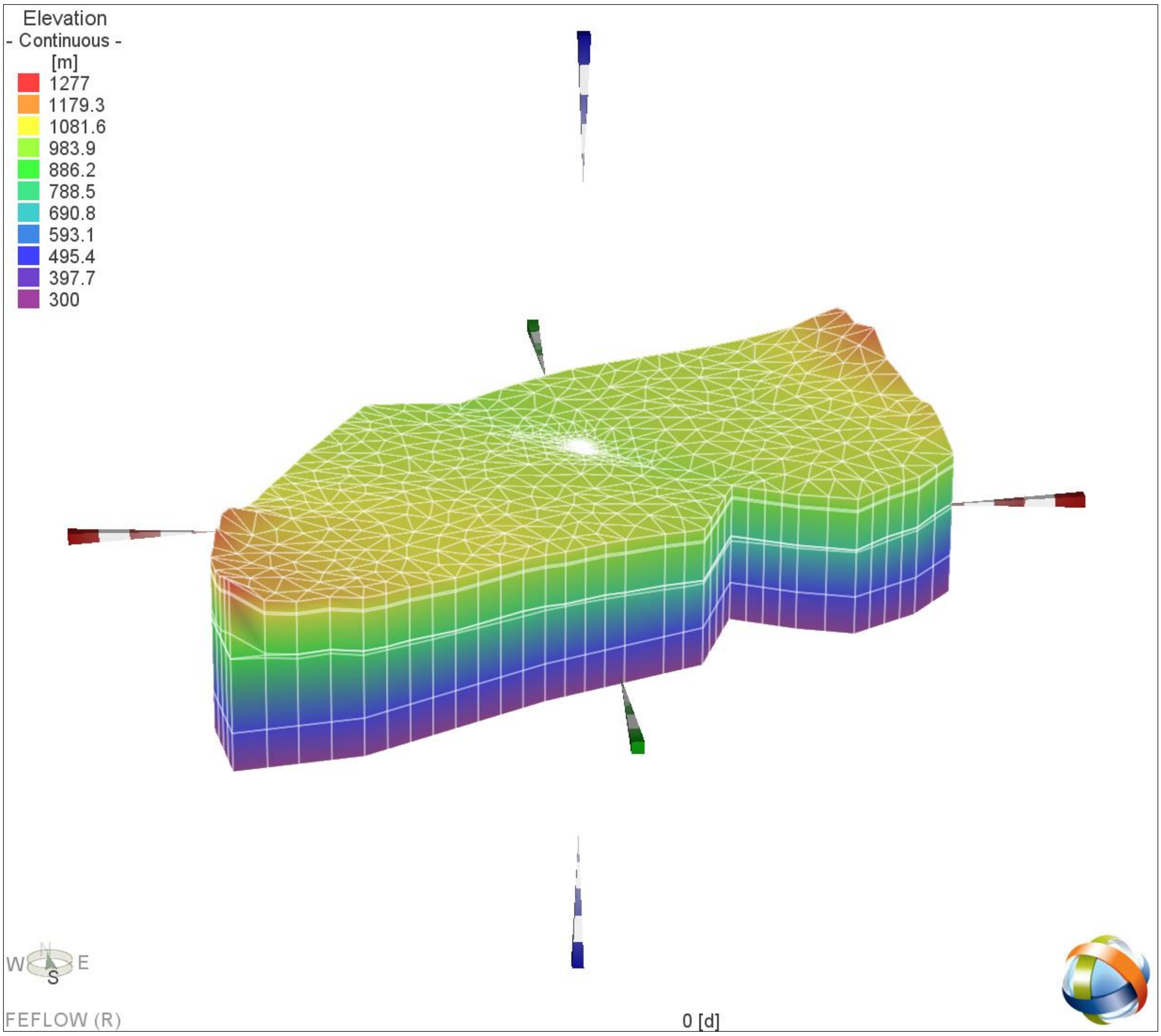


FIGURE 10: KHWARA - 3D NUMERICAL MODEL

9.7 NUMERICAL MODEL

9.7.1 MODEL INITIALS

Once the 3-D numerical model is constructed, hydraulic properties are assigned to the model elements. The table below details the hydraulic properties assigned to the formations represented in the model.

TABLE 14: KHWARA GROUNDWATER MODEL – HYDRAULIC PROPERTIES

Aquifer	Kh	Kv
Kalahari Deposits	0.7	0.01
Dwyka/Diamictites	0.01	0.001
Olifantshoek/Granite	0.01	0.001
Hotazel/BIF	0.01	0.001
Ongeluk/Basalt	0.001	0.0001

The initial recharge assigned as in-out flow from top/bottom is 2 x 10^{-4} m/d, representing 2 % of M.A.P.

9.7.2 Model Calibration

The steady state calibration is performed to determine the suitability of hydraulic properties which allow groundwater flow and to compare the simulated hydraulic heads with the measure hydraulic heads in the observation points.

The calibration of the Khwara groundwater model was run using the initial hydraulic properties assigned together with the hydraulic head values and average annual groundwater recharge computed from the average rainfall data throughout the model domain. Table 10 shows the plot of measured hydraulic heads vs. simulated hydraulic heads.

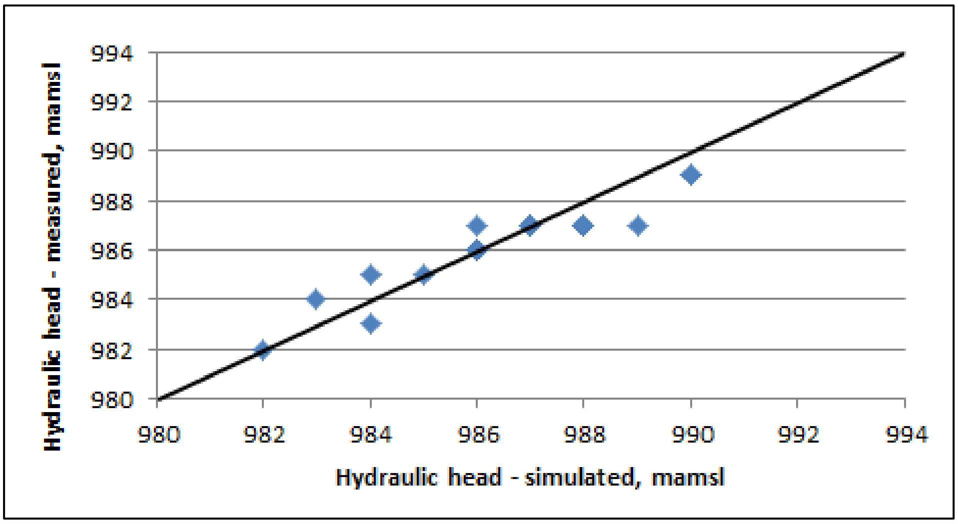


FIGURE 11: HYDRAULIC HEAD – MEASURED VS. SIMULATED

The differences between the measured hydraulic head and computed hydraulic head are very small, and the calibration was considered satisfactory. The RMSE and NRMSE, which represent the quantitative measure of the model calibration are within the prescribed groundwater model calibration guidelines (ASTM Guidelines) – Table 15.

TABLE 15: KHWARA GROUNDWATER MODEL CALIBRATION

Name	computed	measured	head_diff	Head diff^2
LEX19	987	987	0	0
LEX14	989	987	2	4
BH01	987	987	0	0
BH02	988	987	1	1
BOER06	983	984	-1	1
BH03	986	986	0	0

Name	computed	measured	head_diff	Head diff^2
BOER07	984	983	1	1
BH04	986	986	0	0
LEX15	987	987	0	0
LEX02	988	987	1	1
LEX17	986	986	0	0
LEH04	990	989	1	1
BH05	986	986	0	0
BH06	986	986	0	0
BH07	987	987	0	0
BH08	986	986	0	0
LEX03	987	987	0	0
MOLL01	982	982	0	0
ELIZ01	988	987	1	1
BH09	984	985	-1	1
DW10	985	985	0	0
BH10	988	987	1	1
BH11	986	986	0	0
LEX24	986	987	-1	1
BH12	990	989	1	1
			RMSE	**0.72**
			NRMSE	**9%**

A Normalised Residual Mean Square Error (NRMSE) value below 10 % is considered as an acceptable calibration.

9.7.3 SIMULATION OF MINING – TRANSIENT MODE

Underground mining was simulated for both Lehating and Wessels in a transient mode, as shown in Figure 12.

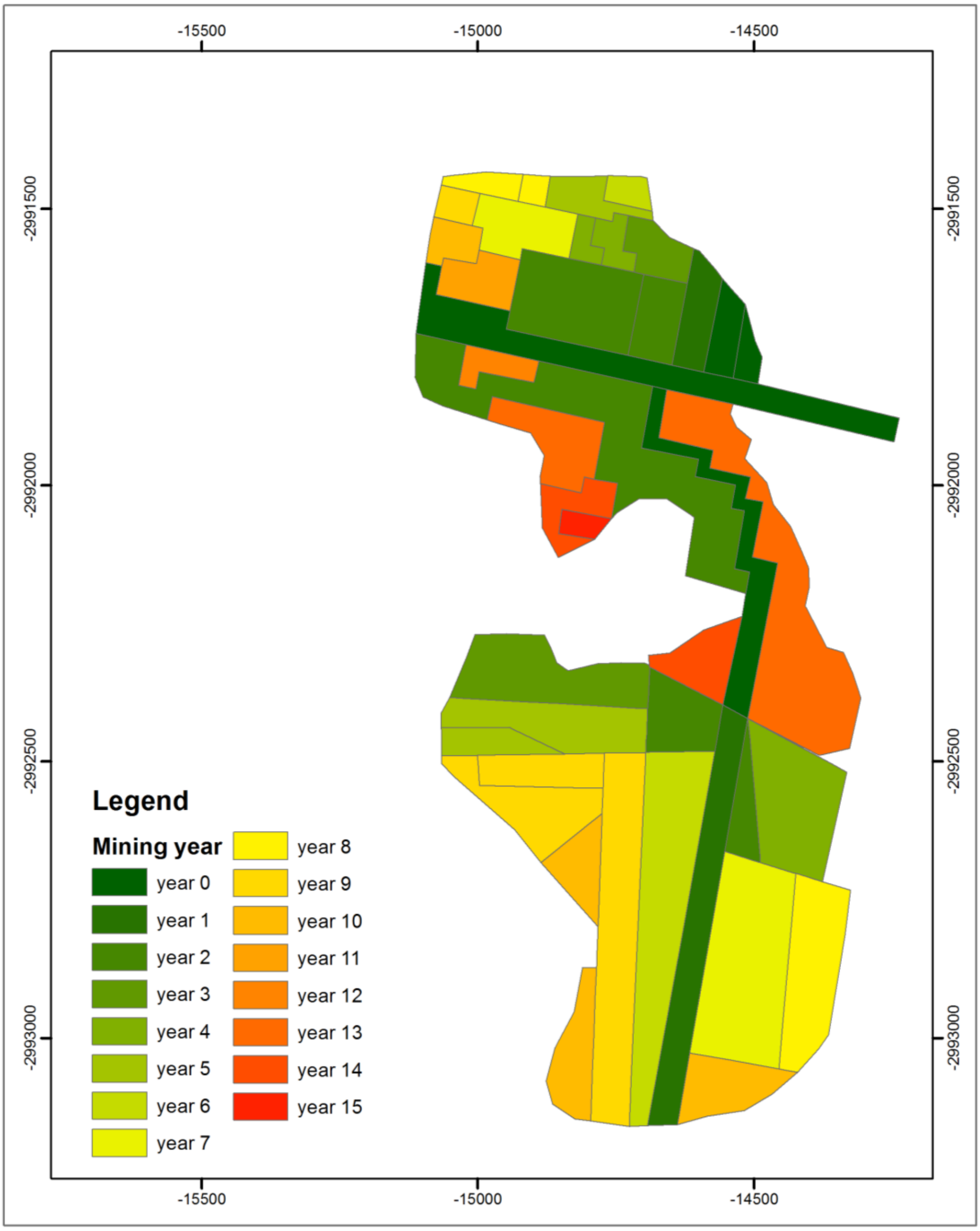


FIGURE 12: ANNUAL MINING SCHEDULE

9.7.4 SIMULATION OF RECHARGE – TRANSIENT MODE

In transient mode, the recharge was assigned as cyclic monthly time series, as shown in Figure 13, considering 2% on monthly rainfall averages.

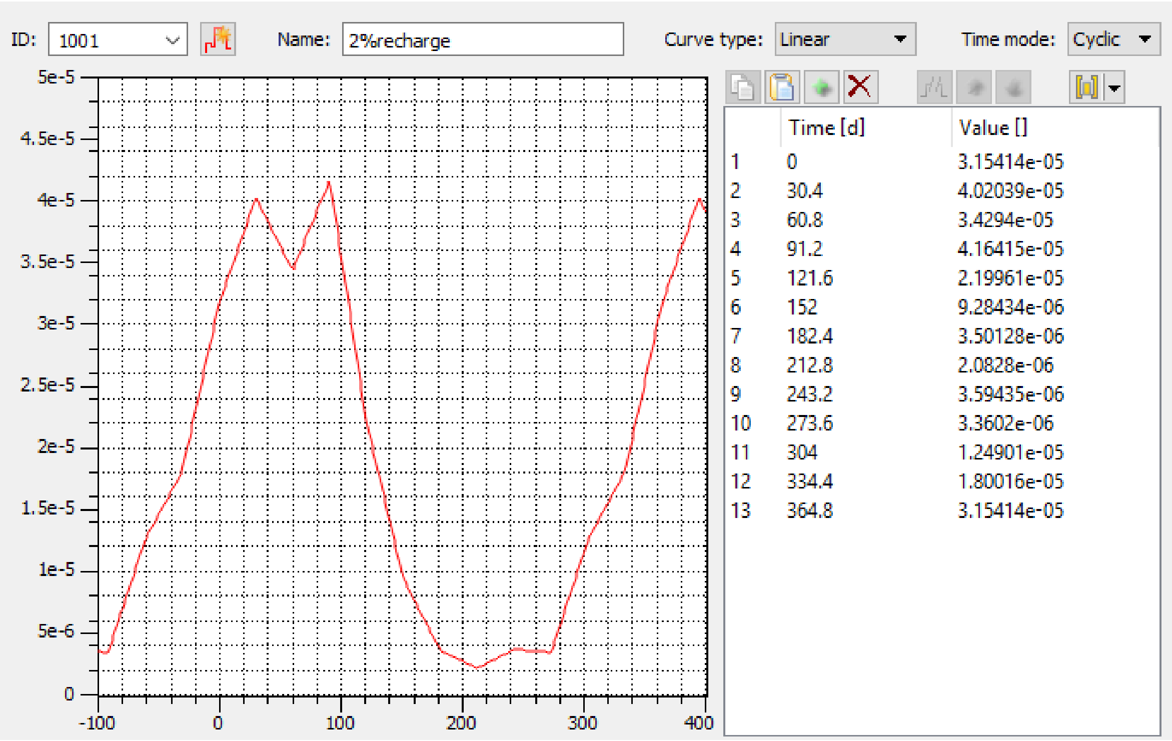


FIGURE 13: KHWARA GROUNDWATER MODEL - TRANSIENT RECHARGE

9.8 RESULTS OF THE MODEL

The Khwara 3D groundwater numerical model was run in transient mode for a period of 100 years. This will cover 12 years of mining and 88 years post-mining. The model results were extracted at the following time-steps:

- Year 5
- Year 10 – End of mining (Wessels Khwara resource)
- Year 12 – End of mining (Lehating resource)
- Year 50
- Year 100 – End of simulation.

9.8.1 DEVELOPMENT OF CONE OF DRAWDOWN

As mining is progressing it is expected that a cone of drawdown will develop as a result of groundwater passive inflows (ingress) into the underground excavation. The following figures show the development of the cone of drawdown during simulations:

- Year 5 - Figure 14
- Year 10 - Figure 15
- Year 12 - Figure 16
- Year 50 - Figure 17

- Year 100 - Figure 18.

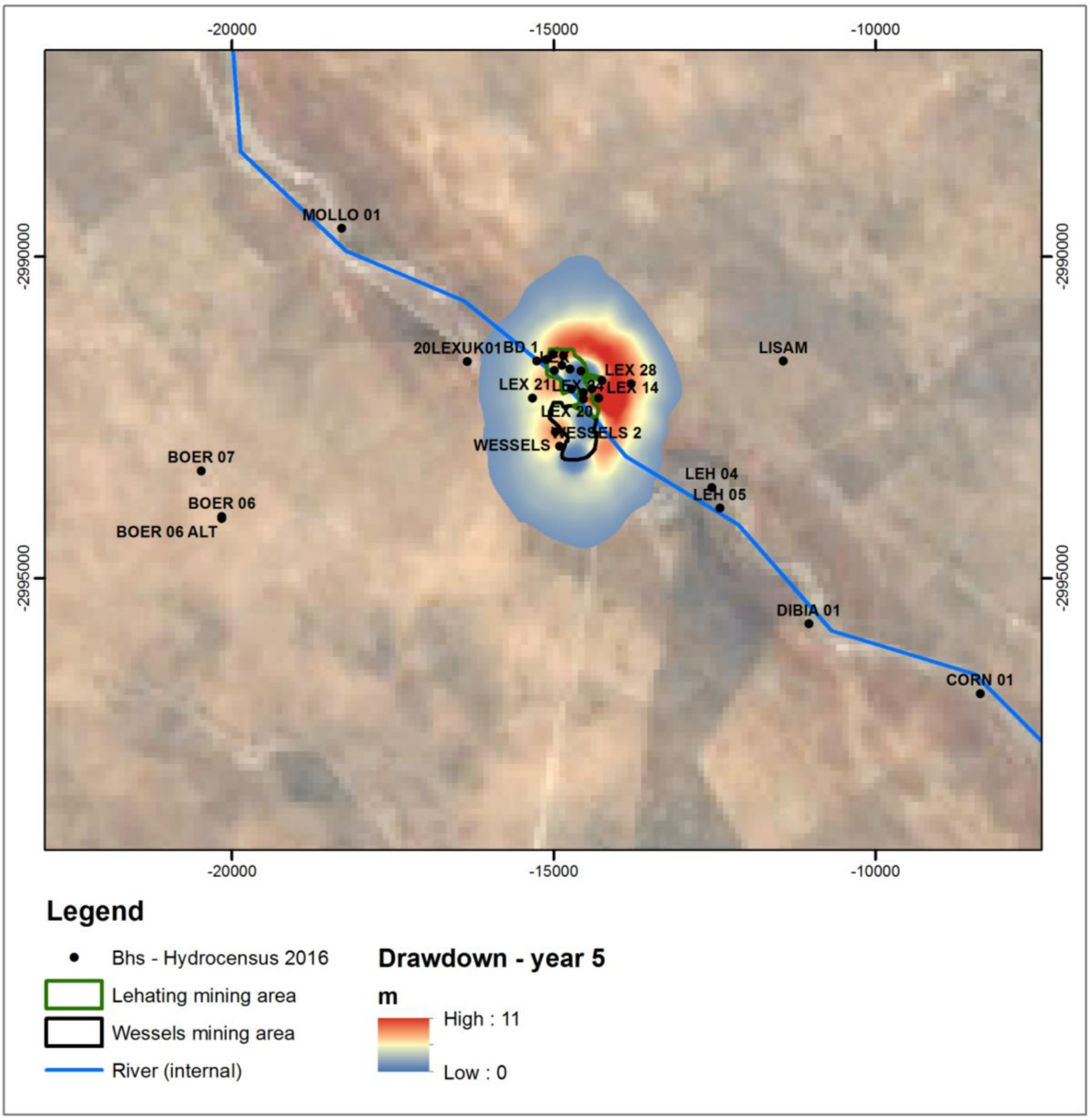


FIGURE 14: CONE OF DRAWDOWN - YEAR 5

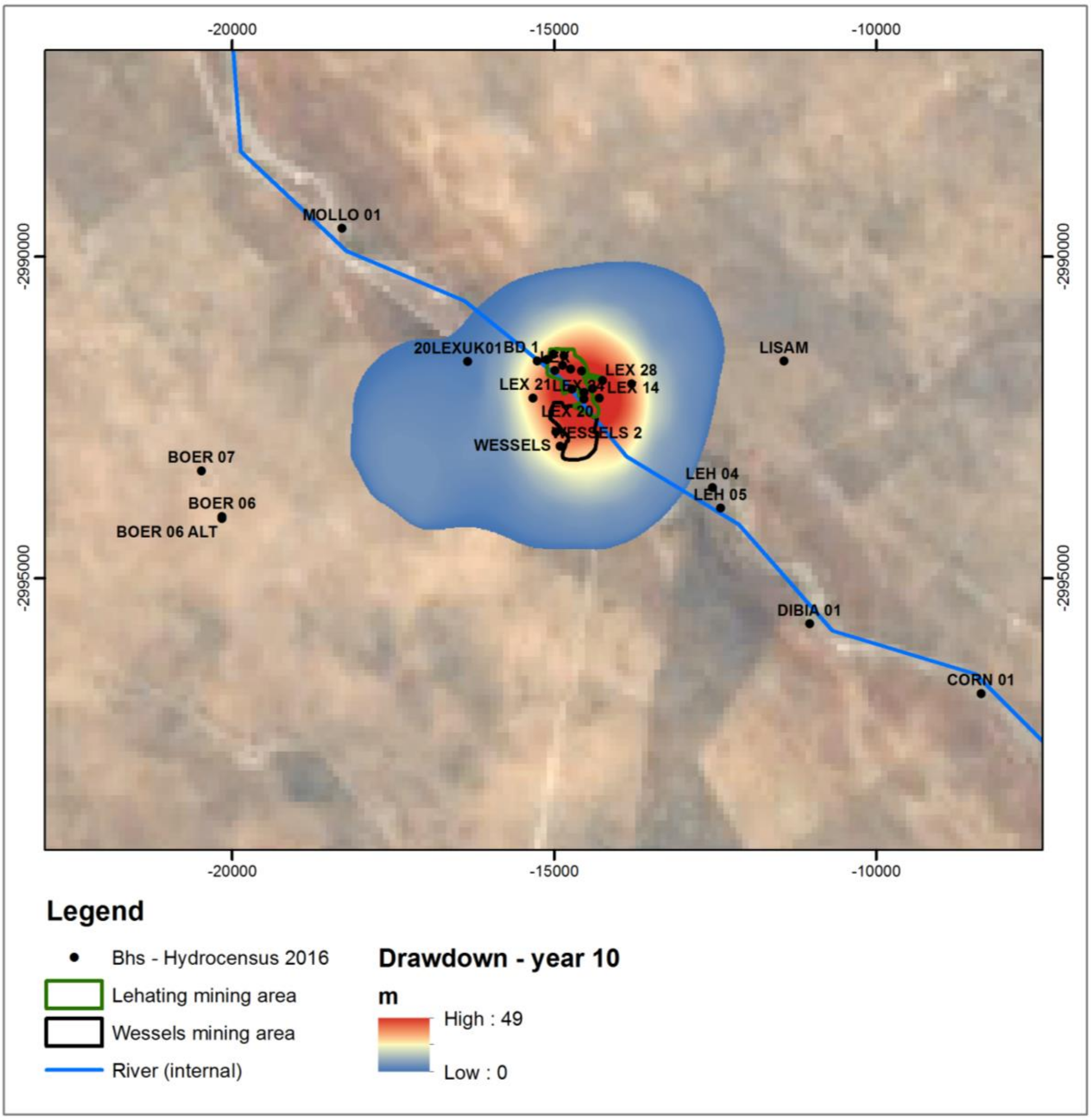


FIGURE 15: CONE OF DRAWDOWN - YEAR 10

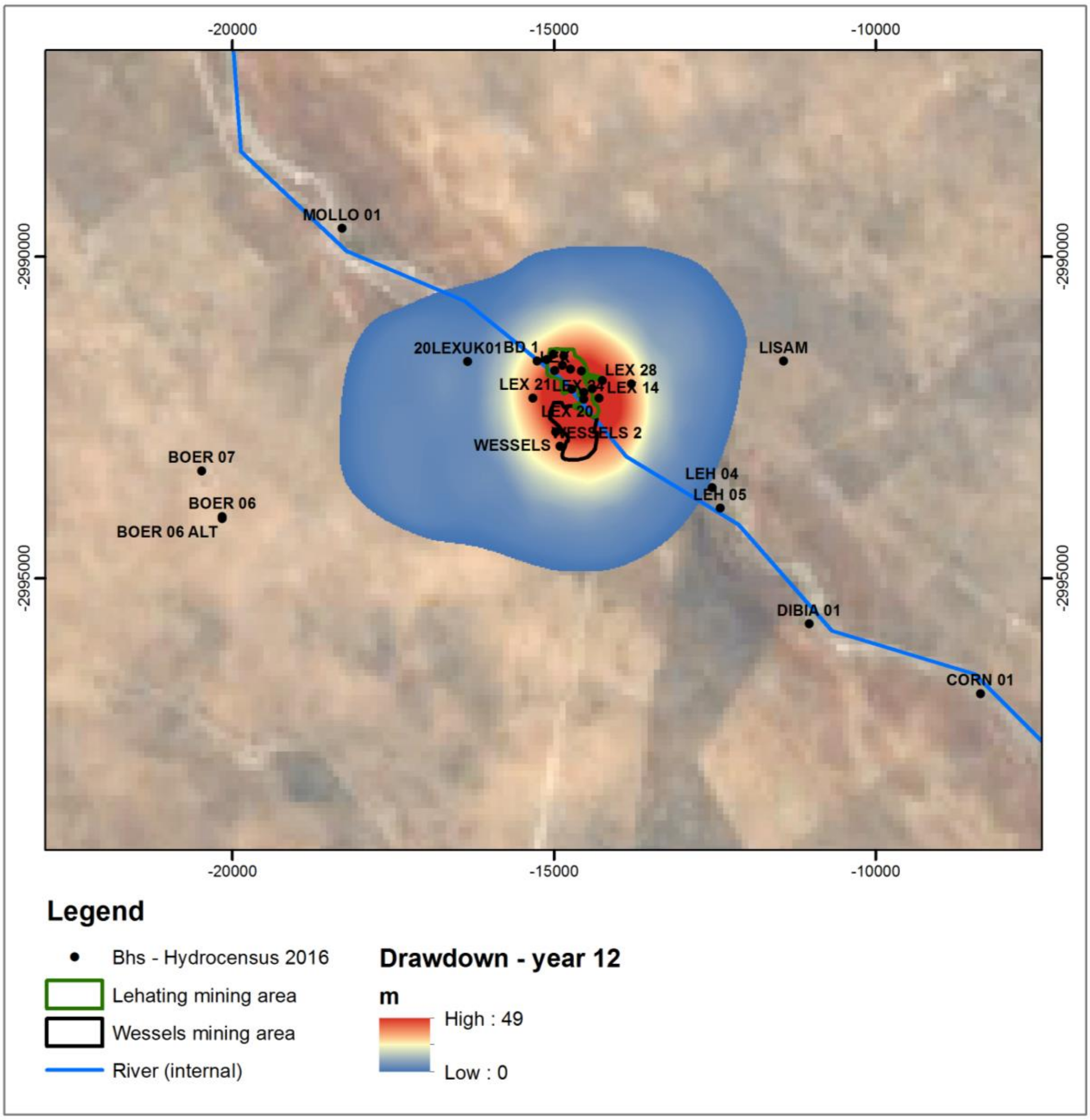


FIGURE 16: CONE OF DRAWDOWN - YEAR 12

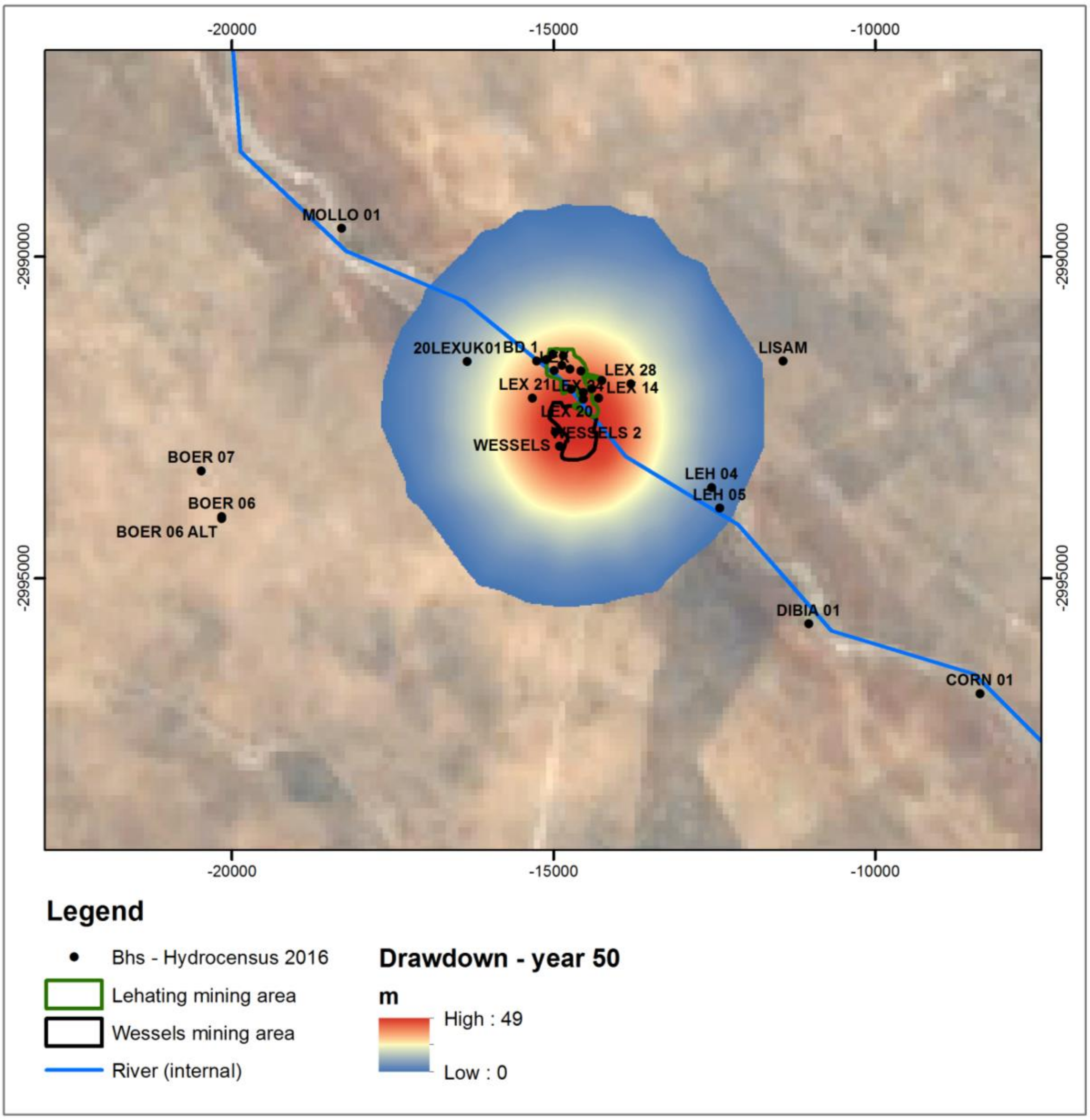


FIGURE 17: CONE OF DRAWDOWN - YEAR 50

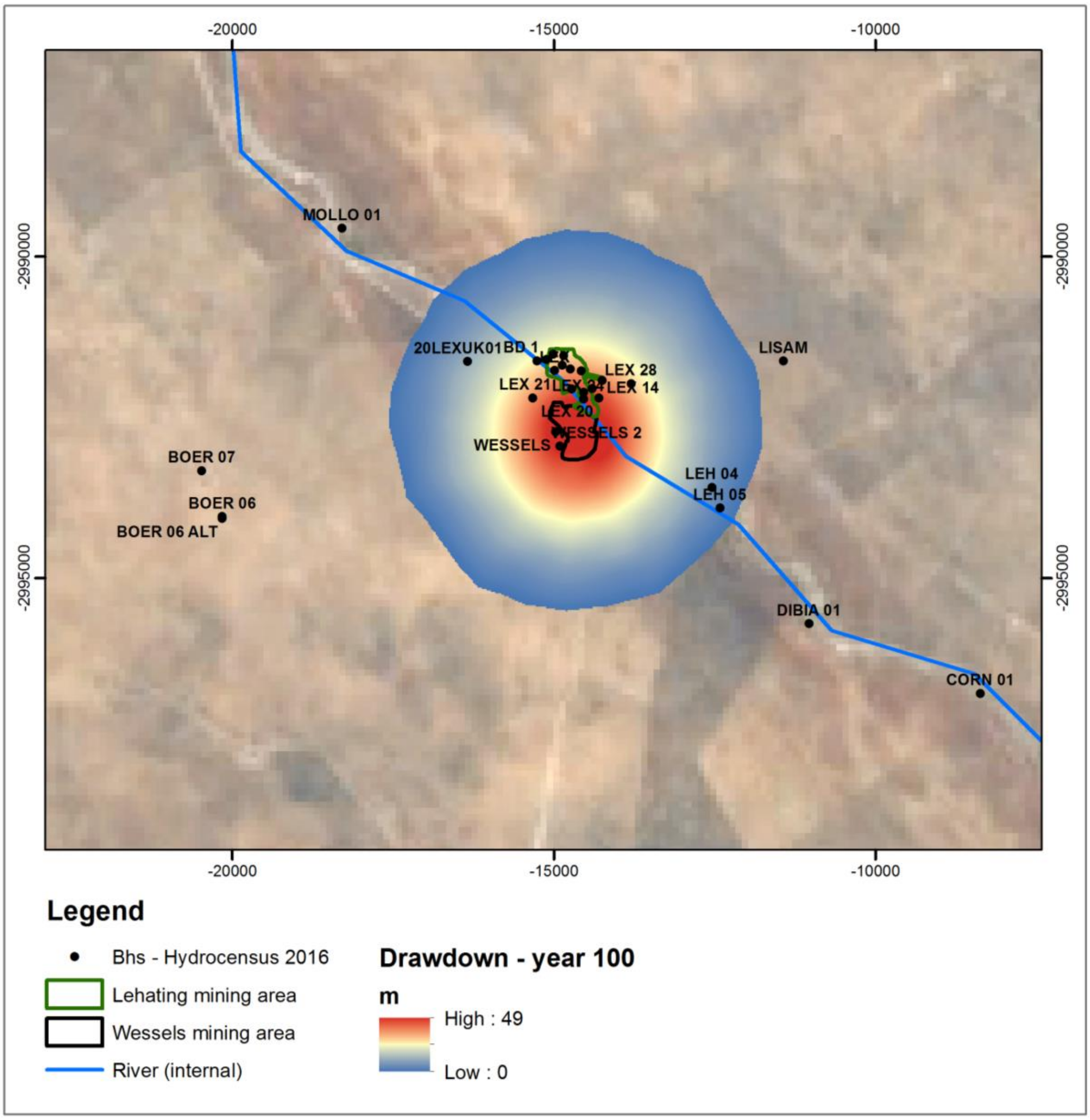


FIGURE 18: CONE OF DRAWDOWN - YEAR 100

9.8.2 CONCLUSIONS

Mining will create a cone of drawdown which extends during the mining period. Maximum depth of the cone of drawdown is 49 m. The cone of drawdown shows a slight recovery trend post-mining.

10 GROUNDWATER IMPACTS

ISSUE: REDUCTION OF GROUNDWATER LEVELS AND AVAILABILITY

Introduction

It is necessary to dewater the underground mining area to create a safe working environment. With dewatering the concern is that third party groundwater users may be negatively affected. This activity will take place during operations and will cease in the decommissioning phase. Upon closure, the groundwater levels will be allowed to rebound naturally.

Activities and infrastructure - link to mine phases

Operation	Decommissioning	Closure
Dewatering	Recovery of groundwater levels	Recovery of groundwater levels

Rating of impact

<u>Severity / nature</u>

Dewatering activities will take place during the operational phase. The cone of drawdown has been simulated to reach its maximum extent in year 12 of the simulation, with a maximum drop in water levels of 49 m close to the underground mine area. The cone of drawdown shows a slight recovery trend in the post-mining simulation. Table 16 shows the development of the cone of drawdown during and post-mining. The simulation included both the mining void at Lehating and Khwara in order to assess the dewatering impacts cumulatively. Limited movement of water between the shallow and deep aquifers is expected due to the presence of a geological layer with lower permeability between these aquifers. The drawdown is therefore considered to affect the deep aquifer, with no significant impacts on the shallow aquifer expected.

TABLE 16: CONE OF DRAWDOWN EXTENT AND DROP IN WATER LEVEL (SLR, AUGUST 2017B)

Simulation year	Max. extent
5	2.2 km radius
10	3.4 km radius
12	3.6 km radius
50	3.1 km radius
100	2.8 km radius

Figure 16 shows the cone of drawdown at its maximum extent and Figure 18 shows the drawdown post closure. The following third party water users have been identified within the cone of drawdown:

- Wessels 2 is a borehole is located within Ntsimbintle Mining Company (Pty) Ltd's property, however this land is used by Mr Willem Strauss for cattle grazing and his staff resides on this property. This borehole is therefore used for domestic use and livestock watering and is located at the edge of the underground mining area. It is however understood that there is also access to Sedibeng water on this property.
- Leh05 is a borehole owned by ER Van Schalkwyke (Waltwyk CC) and is used for domestic use and livestock watering.
- Boer 1 is a borehole owned by Mr. Gert Stols and is used for domestic use.

Borehole logs for the construction of these boreholes are not available and therefore it cannot be accurately determined whether these boreholes access the shallow or the deep aquifer. Taking a precautionary approach which assumes that these boreholes access the deep aquifer, Boer 1 and Wessels 2 could experience a drop in groundwater levels ranging from 3 metres in year 5 of mining, up to 49 m towards the end of mining, and LEH05 could experience a slight drop (less than 3 m) in water levels after closure as shown in Figure 17. The predicted drop in water levels in Boer 1 and Wessels 2 would render these boreholes unusable.

The simulation showed that groundwater levels would not recover within the 100 year simulation period and shows a sustained depressed water level, therefore no decant is expected. However the persistent depressed water level will continue to negatively affect Wessels 2 and LEH05 boreholes after closure. The potential impact on third parties is rated as having a high severity, but can be reduced to low with mitigation.

<u>Duration</u>

The duration of the impacts is linked to the duration of the dewatering and the recharge time thereafter. Based on groundwater model predictions, the dewatering cone of depression will extend well after closure. It follows that in both the unmitigated and mitigated scenarios the duration is high.

<u>Spatial scale / extent</u>

The spatial scale of the predicted dewatering cone extends beyond the mining area in both the mitigated and unmitigated scenarios.

<u>Consequence</u>

The consequence is high and can be reduced to moderate with mitigation.

<u>Probability</u>

The probability of impacting on third party water users is high given that there are third party boreholes identified within the simulated impact zone. With mitigation the probability reduces to low.

Significance

The impact significance is high in the unmitigated scenario and low in the mitigated scenario.

Summary of the rated dewatering impact per phase of the project

Mitigation	Severity / nature	Duration	Spatial scale / extent	Consequence	Probability of Occurrence	Significance
All phases						
Unmitigated	H	H	M	H	H	H
Mitigated	L	H	M	M	L	L

11 GROUNDWATER MONITORING SYSTEM

11.1 GROUNDWATER MONITORING NETWORK

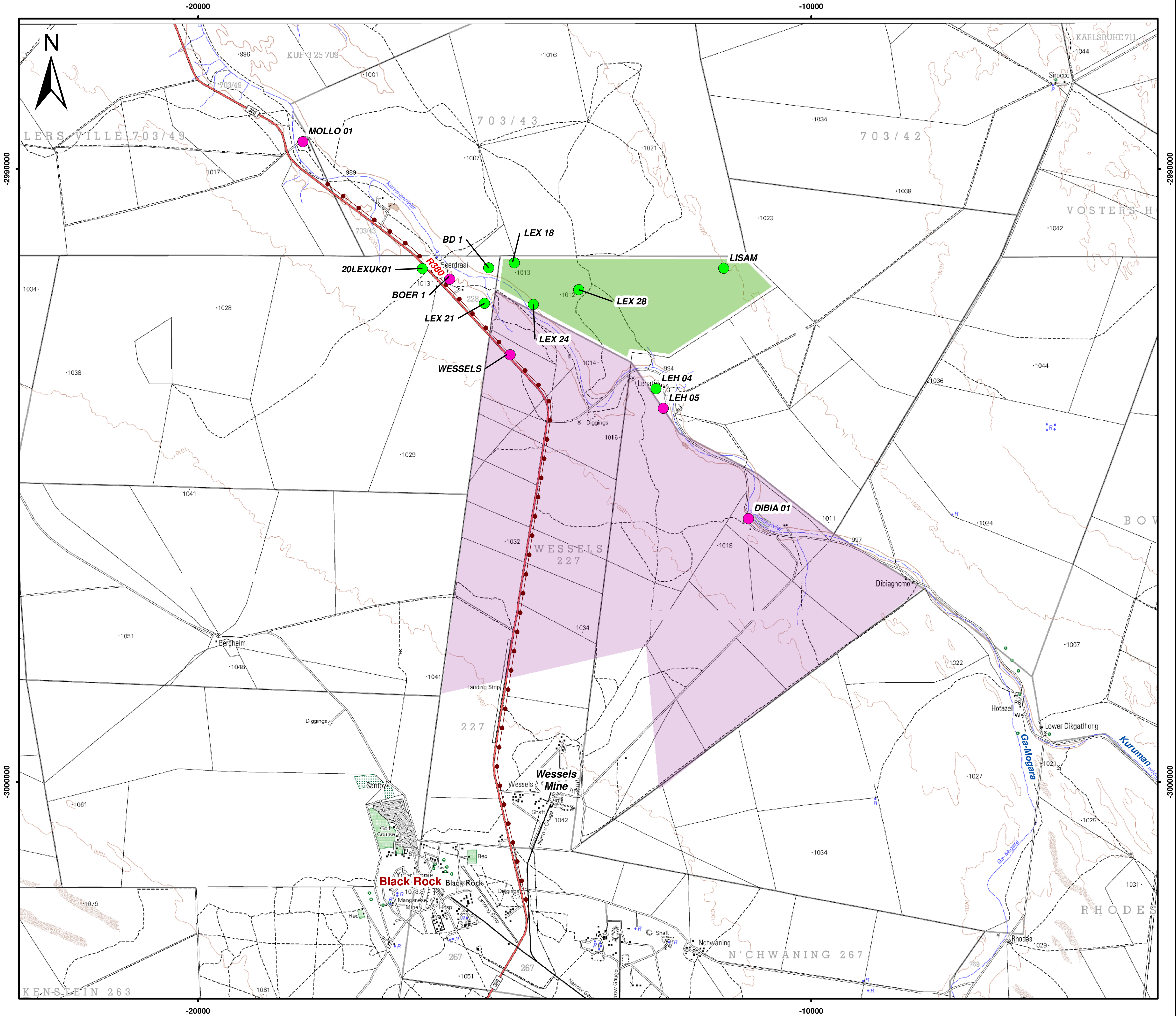
Boreholes currently used by third parties for domestic use and livestock watering have been identified within and around the simulated cone of depression to be monitored for any changes in water levels. In addition various prospecting and mine boreholes will also be monitored within the simulated cone of depression to monitor water levels. These monitoring points are shown in Figure 19.

In addition, these boreholes will be monitored for quality in a bi-annual basis as good practice. Water quality analyses results should be classified in terms of the SANS 241 (2015) Water Quality Standards and the DWAF Target Quality Range for Livestock Watering (1996) or whichever is applicable at the time. The monitoring results should be assessed by a suitably-qualified professional registered with the South African Council for Natural Scientific Professional (SACNASP). The parameters that need to be analysed include:

pH
Conductivity in mS/m at 25 ° c
Total dissolved solids (TDS) at 180 ° c
Alkalinity as $CaCO_3$
Carbonate as CO_3
Bicarbonate as HCO_3
Boron as B
Nitrate as N
Chloride as Cl
Sulphate as SO_4
Fluoride as F
Sodium as Na
Potassium as K
Calcium as Ca
Magnesium as Mg
Manganese as Mn
Full metal scan - Inter Coupled Plasma Scan (ICP) (via Mass Spectrometry (MS)

11.2 MONITORING FREQUENCY

Water levels in the identified boreholes will be monitored on a quarterly basis. Water quality monitoring will be limited to bi-annual monitoring.



Legend

- Approved Lehating Mining Right Area
- Proposed Mining Right Area
- Main Roads
- Secondary Roads
- Power Line
- Rivers and Streams
- 20m Contour Lines

Groundwater Monitoring Points

- Prospecting
- Third Party

0 0.5 1 2 Kilometers

Scale: 1 : 59 500 @ A3

Projection: Transverse Mercator
Datum: Hartebeeshoek, Lo23

Khwara Manganese (Pty) Ltd

Figure 19

Groundwater Level Monitoring Programme

SLR

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720.12015.00004

August 2017

12 GROUNDWATER ENVIRONMENTAL MANAGEMENT PROGRAMME

12.1 CURRENT GROUNDWATER CONDITIONS

The baseline groundwater conditions are described in Section 7 of this report.

12.2 PREDICTED IMPACTS OF FACILITY (MINING)

The results of the simulations are provided in Section 9.8 and the impact assessment is provided in Section 10 of this report.

12.3 MITIGATION MEASURES

12.3.1 LOWERING OF GROUNDWATER LEVELS DURING FACILITY OPERATION

The objective of the mitigation measures is to prevent water losses to third party water users.

Mitigation must include:

- Khwara will update the hydrocensus to check for any new third party water uses prior to mining
- Khwara will monitor groundwater levels in third party boreholes identified within the cone of depression on a quarterly basis during operations and for a period of 8 years after decommissioning and closure.
- Where Khwara's dewatering causes a loss of water supply to third parties, Khwara will provide compensation, which could include an alternative water supply of equivalent water quality and quantity, until such time as the dewatering impacts cease.
- With respect to the potential drop in water levels in Boer 1 and Wessels 2 boreholes, the mine will report water level measurements to the land users on request in order to closely monitor and allow for ongoing meaningful discussions with respect to managing water supply impacts.

12.3.2 RISE OF GROUNDWATER LEVELS POST- FACILITY OPERATION

The simulation shows that groundwater levels will not recover well after mine closure. Therefore the monitoring and compensation measures stated above must continue after mine closure until no further significant dewatering impacts are experienced by third parties.

13 POST CLOSURE MANAGEMENT PLAN

No surface infrastructure and waste facilities will be established on the Khwara mine site and therefore no rehabilitation costs are relevant. In addition, no latent post closure impacts have been identified. Groundwater recharge/rebound is not expected to have any impact i.e. no seepage/decant at surface requiring attention, furthermore groundwater quality is not expected to change as a result of mining activities. Therefore post closure groundwater level monitoring is considered relevant to monitor the recovery of water levels. However, post closure groundwater quality monitoring will be included as good practice.

14 ASSUMPTIONS AND LIMITATIONS

A numerical groundwater flow and transport model is a representation of some or all characteristics of a real system on an appropriate scale. It is a management tool that is typically used to understand why a system is behaving in a particular observed manner or to predict how it will behave in the future. Its precision depends on chosen simplifications (in a conceptual model) as well as on the completeness and accuracy of input parameters. In particular, data on input parameters like water levels and aquifer properties is often scare and limits the precision and confidence of numerical groundwater models. Impact predictions are based on numerical model results, the precision of which depends obviously on the chosen simplifications as well as the accuracy of input parameters like hydraulic conductivities, porosities or source concentrations.

It should be noted that no significant faults, fractures or other lineaments were observed and therefore no geological structures have been included in the model. Should such structures be encountered, further hydrogeological work will be needed and the groundwater model will need to be updated.

Aquifer characteristics and hydraulic properties was based on previous studies groundwater studies completed for the Lehating Mine EIA. No new pump tests were performed to define the site specific anisotropy of hydraulic properties. It is possible that the predicted cone of drawdown and the rate of recovery could have a different configuration to the simulation in this report. Recording of groundwater levels during the operational phase in Boreholes Boer 1, Wessels 2 and Leh05 will allow further calibration of the model.

The model only simulated cone of drawdown. No contaminant mass transport was simulated as no residue material will be placed on surface as part of the proposed project. Similarly it is considered unlikely that the mine void will generate pollution.

15 INTERESTED AND AFFECTED PARTY COMMENTS

As part of the environmental impact assessment and environmental management programme process, groundwater related concerns were raised by interested and affected parties (IAP). These concerns are summarised in the table below, along with a response.

TABLE 17: GROUNDWATER RELATED IAP CONCERNS AND RESPONSES

IAP concern	Response
If the mine’s activities results in a loss of underground water on the remaining extent, which is private property, the mine will be held responsible.	Key management measures include monitoring groundwater levels in third party boreholes identified within the simulated cone of depression and where Khwara’s dewatering causes a loss of water supply to third parties, Khwara will provide compensation, which could include an alternative

IAP concern	Response
	water supply of equivalent water quality and quantity, until such time as the dewatering impacts cease.
Has the cumulative effects of the surrounding mines been taken into account?	A hydrocensus was undertaken for the proposed project to characterise the existing groundwater quality and quantity prior to the commencement of the project. From a cumulative perspective, the hydrocensus characterises the current baseline condition taking into account the effects that existing mining operations have had towards groundwater quality and quantity. Further to this, the groundwater model takes into consideration the impacts associated with the approved Lehating Mine.

16 CONCLUSION AND RECOMMENDATIONS

A groundwater modelling exercise was conducted to determine potential dewatering impact of the proposed Khwara Project. The resource will be accessed and mined from the approved Lehating mine (underground). Approved surface infrastructure at the Lehating Mine will be used to support the mining of the underground resource on the farms Wessels 227 and Dibiaghomo 226 and as such no surface infrastructure will be established as part of the proposed project.

The main conclusions of the groundwater study include:

- Dewatering activities will take place during the operational phase. The cone of drawdown has been simulated to reach its maximum extent in year 12 of the simulation, with a maximum drop in water levels of 49 m close to the underground mine area. The drawdown is considered to affect the deep aquifer, with no significant impacts on the shallow aquifer expected.
- Third parties could experience a significant drop in water level during operations which could render the boreholes unusable. An additional third party user could experience a slight drop in water level after closure.
- The simulation showed that groundwater levels would not recover within the 100 year simulation period and shows a sustained depressed water level, therefore no decant is expected.
- The potential impact on third parties is rated as high, but can be reduced to low with mitigation.
- Key mitigation includes monitoring of water levels and compensation which could include an alternative water supply of equivalent water quality and quantity, until such time as the dewatering impacts cease.

Based on the above assessment, and assuming that the relevant mitigation measures will be effectively implemented; there are no apparent reasons why the project should not be authorised.

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(Report Author)

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(Report Reviewer)

17 REFERENCES

Matoti A, Conrad J, and Jones S., 1999: Aquifer Classification of South Africa. Map recompiled 2012. Published by CSIR and Department of Water Affairs, 22 March 1999

Metago Water Geosciences, 2011: Groundwater Report – Lehating 741

SLR Consulting, 2013: Lehating Contaminant Transport Model Report

SLR Consulting, 2016: Khwara Manganese Hydrocensus Report

Water Geosciences Consulting, 2009: Groundwater investigation for Ntsimbintle mine

APPENDIX A: CURRICULUM VITAE

RECORD OF REPORT DISTRIBUTION

SLR Reference:	710.20008.00036
Title:	Groundwater study for the proposed development of the Khwara Manganese Mine
Site name:	Khwara Manganese Mine
Report Number:	1
Client:	Khwara Manganese (Pty) Ltd

Name	Entity	No. of copes	Date issued	Issuer
J. Leader	Khwara Manganese Mine	1	September 2017	M. Muresan

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