UMK HYDROGEOLOGICAL STUDY

UMK Mine

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SPECIALIST DECLARATION OF INDEPENDENCE

I, MIHAI MURESAN, declare that –

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

Signature of Specialist

EXECUTIVE SUMMARY

SLR Consulting was appointed by UMK to update the Hydrogeological Study done in 2020 by UMK Mine, with the focus on full backfilling of the UML open pit and changes in Surface Infrastructure, as shown in the figure below – Infrastructure and model stresses.

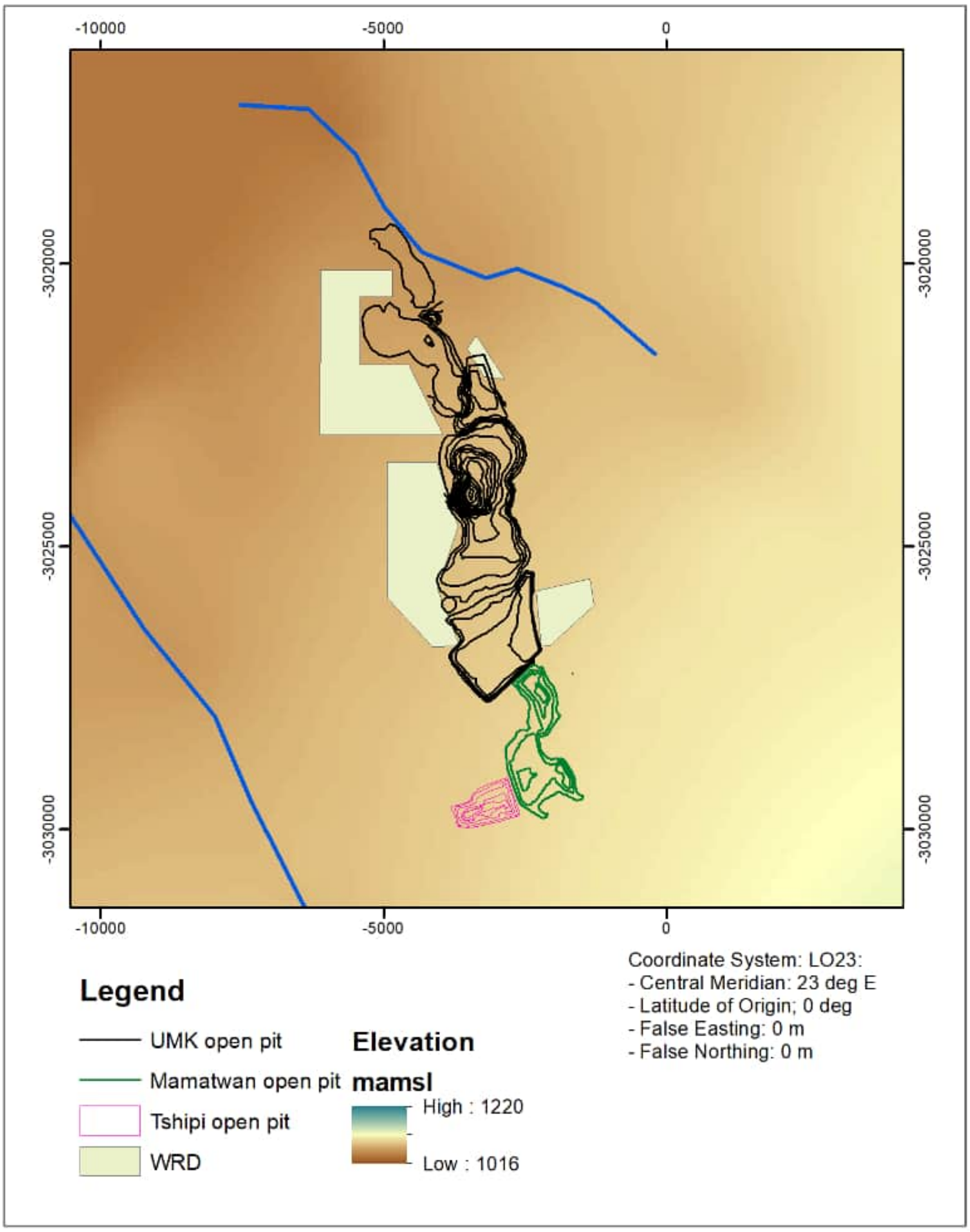

Figure 1: UMK Infrastructure and model stresses.

The numerical model was calibrated to 25 water level measurements in the monitoring boreholes/hydrocensus, achieving a Normalized Residual Mean Square Error (NRMSE) of 7.5%.

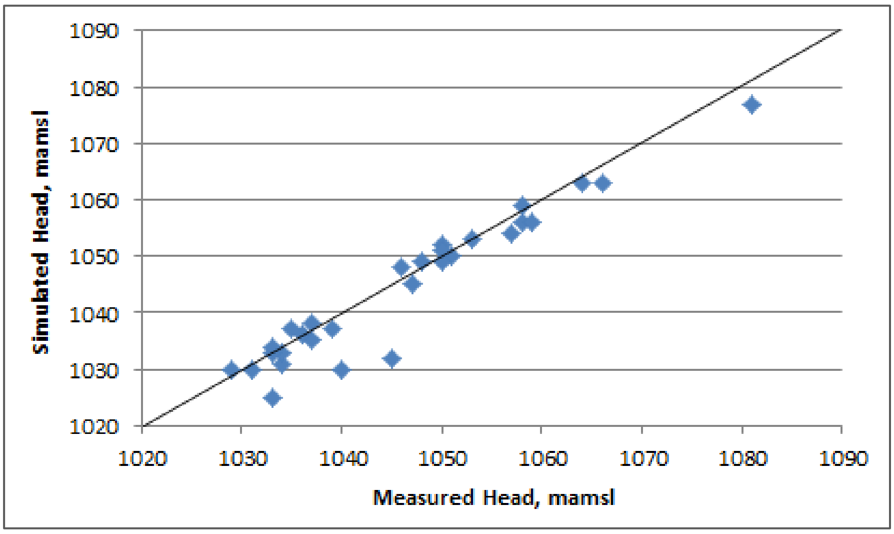

Figure 2: UMK calibration: Hydraulic heads – measured vs. simulated

Open pit mining was simulated as follows:

- Existing open pits, Mamatwan and Tshipi, were simulated as permanent inactive elements (permanent excavations) with drain (seepage) nodes on the pit faces; the seepage face nodes will only allow negative flow; negative flow constraint is translated by groundwater entering the open pits and pumped out of the system.
- Existing UMK open pits and future UMK open pits were simulated as transient inactive elements with seepage face nodes.
- The transient nature of active/inactive elements will allow activation of the element for backfilling; the inactive elements become active as pit backfilling takes place.
- The seepage face nodes will remain active on the pits faces for as long as open pit mining take place; these are switched-of as backfilling takes place, allowing groundwater to flow into the backfill volumes, at respective times.
- The Waste Rock dumps have been updated as per latest transmitted footprints (2021)
- The backfill has been simulated as full pit backfill.

In transient mode, the recharge was assigned as cyclic monthly time series, considering that recharge to groundwater is 2 % of monthly rainfall averages.

The Source Term has been simulated in transient mode on the two main contaminant sources, as follows:

- Updated Waste Rock Dumps: permanent Sulphate Concentration Boundary Condition for the whole duration of the simulation; this can be adjusted if UMK decides to remove the existing Waste Rock Dumps
- Open pit backfill: the Concentration Boundary Condition is turned-on at the end of mining when full backfilling (to ground level) occurs in the open pit; the concentration is maintained after that, until the end of the simulation.

Sulphate was identified by the Source Term Study (SLR, 2017) as the critical parameter with the highest concentration. The mass transport simulation was run in non-reactive mode.

The UMK 3-dimensional groundwater numerical model has been run in transient mode for a period of 100 years. This will cover 20 years of mining and 80 years post-mining.

The model results were extracted at the following relevant time-steps/milestones:

- Year 32 (2053) – End of mining.
- Year 100 (2121) – End of simulation: 68 years post-mining.

Model Results

The cone of drawdown developed as a consequence of mining the UMK open pit will fully recover at the end of the numerical simulation. A residual drawdown noted n Figure 3 is attributed to the Tshipi and Mamatwan open pit sinks.

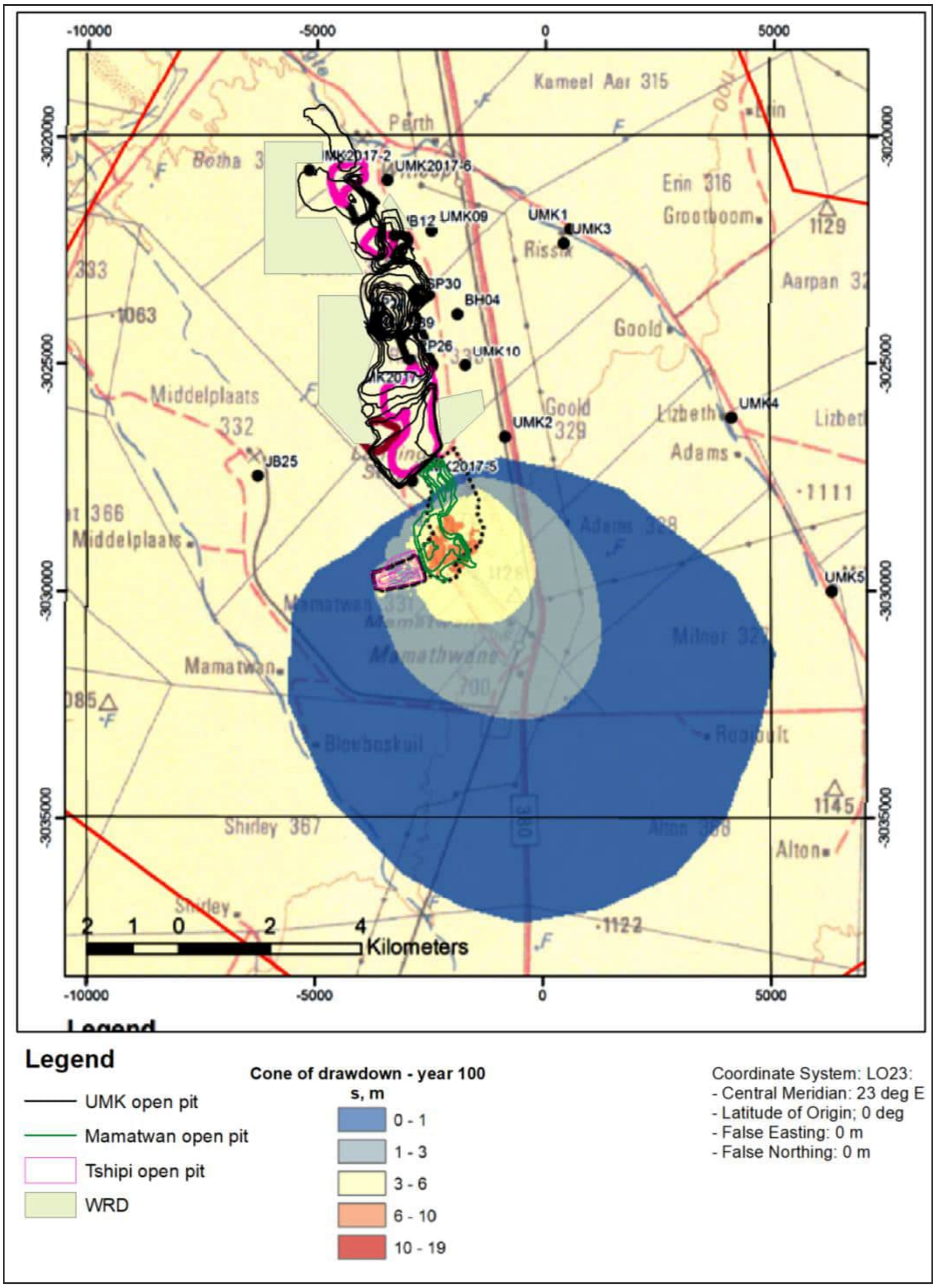

Figure 3: Cone of drawdown at the end of the numerical simulation

The predicted passive groundwater inflow into the UMK pit is shown in Figure 4.

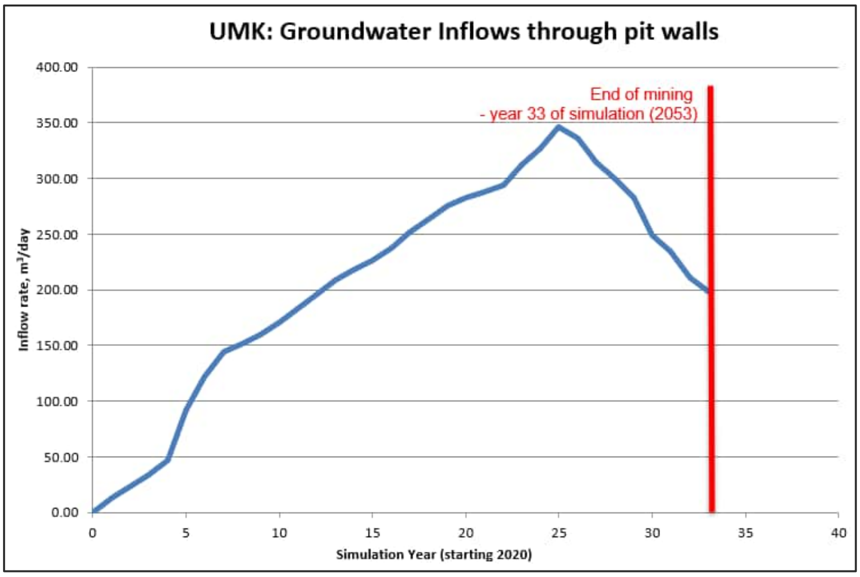

Figure 4 – UMK predicted residual passive groundwater inflow

The peak inflow occurs in year 33 of simulation (2047) of 350 m^3/day.

The SO4 contaminant plume simulated is shown in Figure 5.

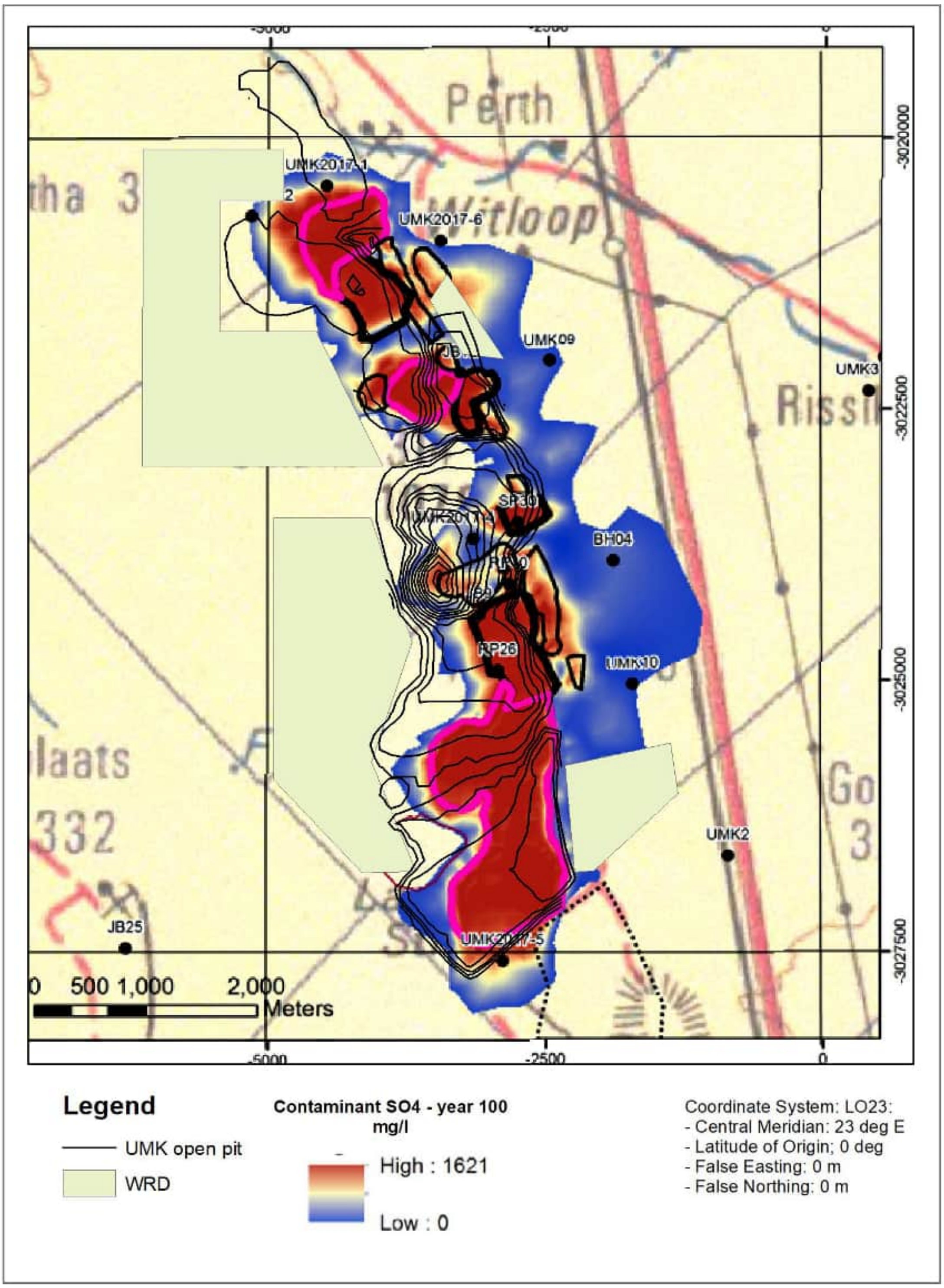

Figure 5: Maximum extent of SO4 plume at the end of the simulation (2121)

The simulations show that the maximum sulphate plumes developed from the sources extend up to 1.7 km in an eastern direction from the UMK Mine, at the end of the simulation at year 100. Please note that this is SO4 concentration resulting from the WRD/backfill load/deposition, which is added to the general water chemistry. The predicted contamination plume at this maximum extent could impact on boreholes JB9 and 12, RP26, 21 and

40 as well as SP30, with sulphate concentrations of up to 1 631 mg/ℓ. These are however all UMK prospecting and monitoring boreholes. The predicted contamination plume is therefore not expected to impact on third party water users. When considered incrementally this has a low severity in the unmitigated and mitigated scenarios.

Year	Max extent of plume, m
Year 32	893
Year 100	1,700

Based on the findings of the hydrogeological study, no fatal flaws have been identified that may limit the proposed activities. It is the opinion of the specialist that the proposed project may proceed on condition that all mitigation measures as outlined and discussed in this report be adhered to.

Update of monitoring network

It must be noted that 7 (seven) monitoring boreholes will be mined out or covered by the proposed WRD.

In order to replace the monitoring boreholes which will be decommissioned and to augment the monitoring network with sufficient coverage permit early detection and monitoring outside the proposed WRD, SLR recommends drilling of 7 (seven) new monitoring boreholes – at locations as shown in Figure 6.

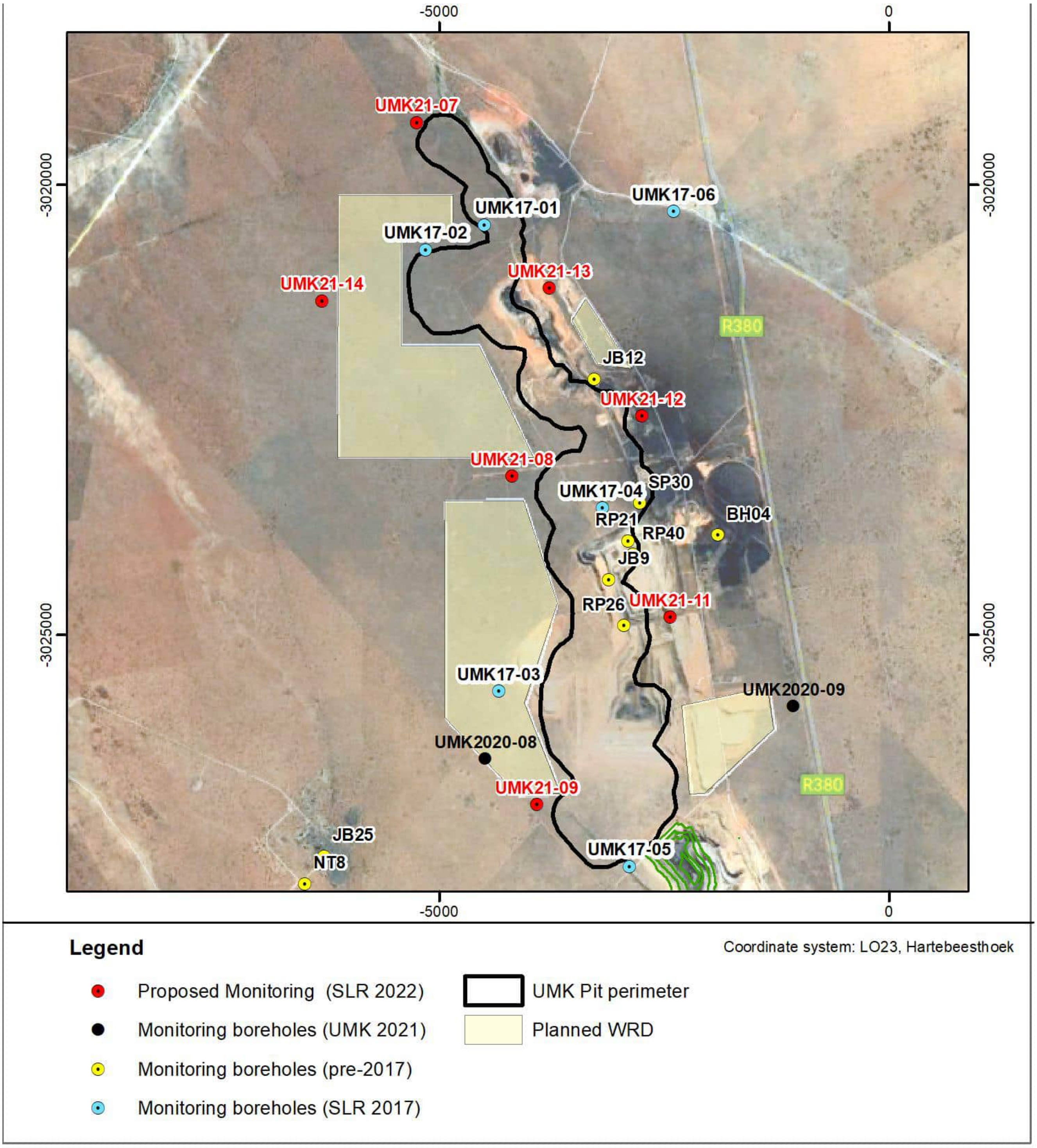

Figure 6: Existing and proposed new monitoring boreholes.

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ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
BIF	Banded Iron Formation
DLL	Dynamic Link Library
GWL	Groundwater Level
K	Hydraulic conductivity, m/d
KMF	Kalahari Manganese Fields
Mamsl	Metres above mean sea level
MAP	Mean annual precipitation
NEMA	National Environment Management Act
NAG	Net Acid Generating
PMP	Probable Maximum Precipitation
m^3/d	Cubic meters per day

1. INTRODUCTION

SLR Consulting was appointed by UMK to update the Hydrogeological Study done in 2020 by UMK Mine, with the focus on full backfilling of the UML open pit and changes in Surface Infrastructure.

The technical report has been prepared to examine the possible impact on the hydrogeological environment by predicting the long-term water chemistry and water levels for the changes of Surface Infrastructure. This has included probabilistic hydrogeological (FEFLOW) to predict the possible development of a contaminant plume. This specialist report has been prepared with due reference to the requirements held in Appendix 6 of National Environment Management Act (NEMA, December 2014) (Table 1).

Table 1. Specialist Report Requirements.

Requirement from Appendix 6 of GN 326 EIA Regulation 2017	Chapter
(a) Details of - (i) the specialist who prepared the report; and (ii) the expertise of that specialist to compile a specialist report including a curriculum vitae	Section 1.1 and Appendix A
(b) Declaration that the specialist is independent in a form as may be specified by the competent authority	Page iii
(c) Indication of the scope of, and the purpose for which, the report was prepared	Section 2
(cA)an indication of the quality and age of base data used for the specialist report	Section 3.4
(cB) a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	Section 6
(d) Duration, Date and season of the site investigation and the relevance of the season to the outcome of the assessment	Section 3.5
(e) Description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used	Section 2 & Section 5
(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 site plan identifying site alternatives;	Section 6
(g) Identification of any areas to be avoided, including buffers	Section 6
(h) Map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers	Section 6
(I) Description of any assumptions made and any uncertainties or gaps in knowledge	Section 5
(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 or activities;	Section 6
(k) Mitigation measures for inclusion in the EMPr	Section 6.2
(I) Conditions for inclusion in the environmental authorisation	Section 6
(m) Monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 6.3
(n) Reasoned opinion - (i) as to whether the proposed activity, activities or portions thereof should be authorised; (iA) regarding the acceptability of the proposed activity or activities; and	Section 6.4

Requirement from Appendix 6 of GN 326 EIA Regulation 2017	Chapter
(ii) 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	
(o) Description of any consultation process that was undertaken during the course of preparing the specialist report	N/A
(p) A summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	N/A
(q) Any other information requested by the competent authority	N/A

1.1 SPECIALIAST DETAILS

Mihai Muresan is a Team Leader (Water) within SLR South Africa and is responsible for SLR's Hydrology and Hydrogeology in South Africa. Mihai has over 25 years of experience within Hydrogeology, Mining, Oil and Gas Exploration and Unconventional Gas. Mihai has managed a wide range of major projects which include Mine Dewatering (open pit and underground systems) and Environmental Impact Assessment projects (Groundwater Specialist Studies including ground water contaminant flow modelling) for major minerals developments throughout Africa for many of the major mining operators.

2. SCOPE OF WORK

The Scope of Work for the current project is to determine development and extent of the contaminant plume due to changes in Surface Infrastructure.

During the study, no investigative hydrogeological drilling and testing was performed.

3. SITE SETTING

The UMK Mine is located in the Kalahari Manganese Fields (KMF) of the Northern Cape Province of South Africa, approximately 12 km south of the town of Hotazel. The mine is approximately 1080 metres above mean sea level (mamsl), with a generally flat topography that gently slopes towards the north. Local topography at the mine falls gently to the west towards the Vaal Gamagara drainage line. The mine falls within an arid climatic region of South Africa with an average annual precipitation of 367 mm, where evaporation rates far exceed annual rainfall. The region experiences predominantly astral summer rainfall (October to April) that occurs as intensive sub-tropical trough thunderstorms. This environment is likely to cause a passive pit closure lake to function as a terminal hydraulic sink with water levels in the pits remaining below surrounding groundwater levels and which will develop evapo-concentrated water quality over time. There are no perennial surface water flows in the area and the annual runoff volume is concentrated in the form of ephemeral and storm water surface water flows during the wet periods; even the natural drainage lines surrounding the mining area are not well defined.

Figure 1 shows the locality of UML Mine together with the updated footprint of the UMK Waste Rock Dumps.

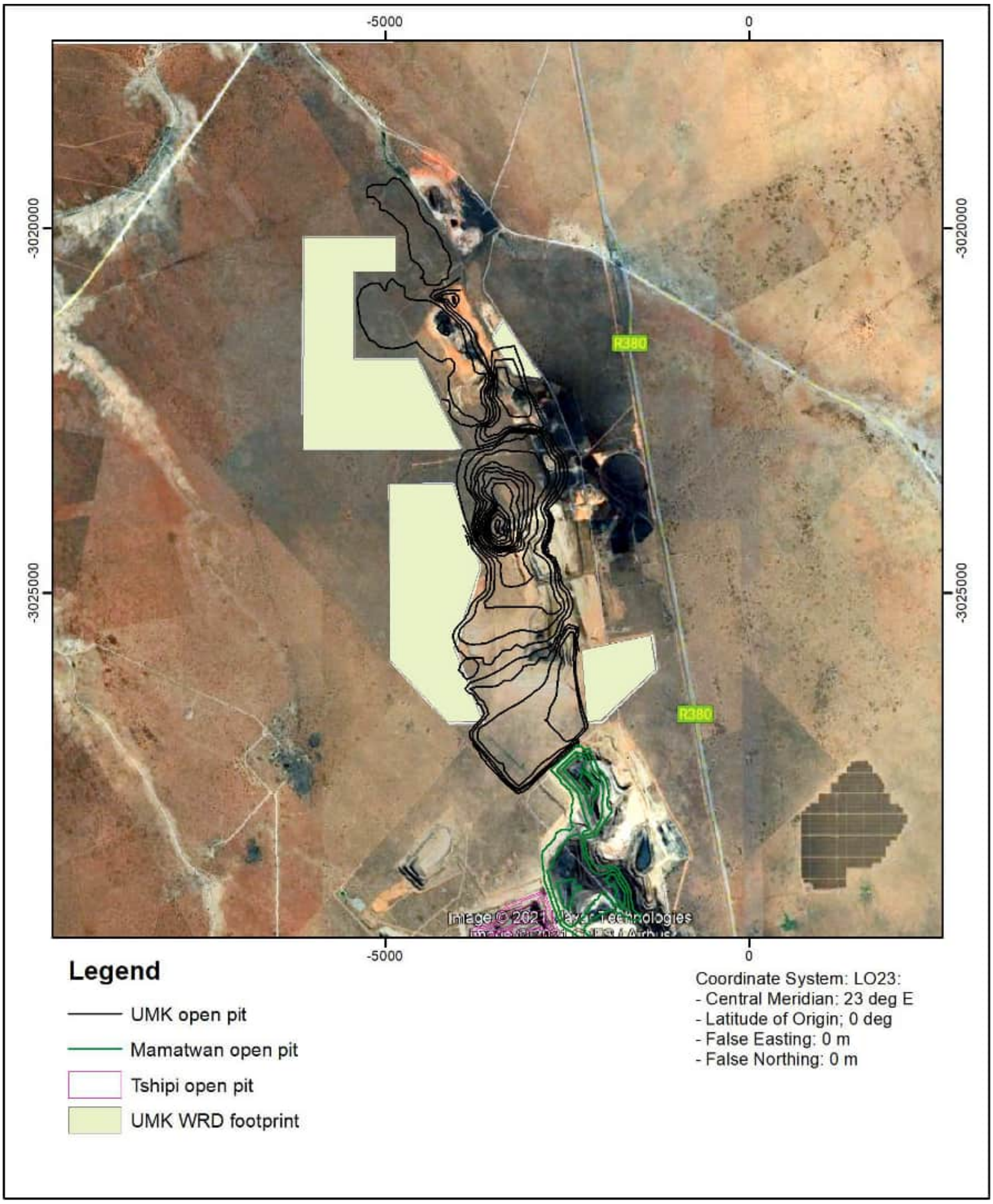

Figure 1: UMK Locality plan

3.1 GEOLOGICAL SETTING

The UMK Mine is located on the south western outer rim of the KMF. Three beds of manganese ore are interbedded with the Banded Iron Formation (BIF) of the Hotazel Formation (Transvaal Supergroup). According to Tsikos and Moore (1997)[1], this formation was deposited between 2,200 and 2,300 million years ago and

[1] Tsikos, H., Moore, J. M., 1997. Petrography and Geochemistry of the Paleoproterozoic Hotazel Iron-Formation, Kalahari Manganese Field, South Africa: Implications for Precambrian Manganese Metallogenes. Economic Geology, 92, 87-97.

structurally confined within the Dimoten Syncline, a north-westerly plunging basin containing more than 80% of global land-based manganese reserves within an area of approximately 525 km^2. It is this basin that defines the extent of the KMF. Figure 2 presents cross sections the through the Kalahari manganese fields.

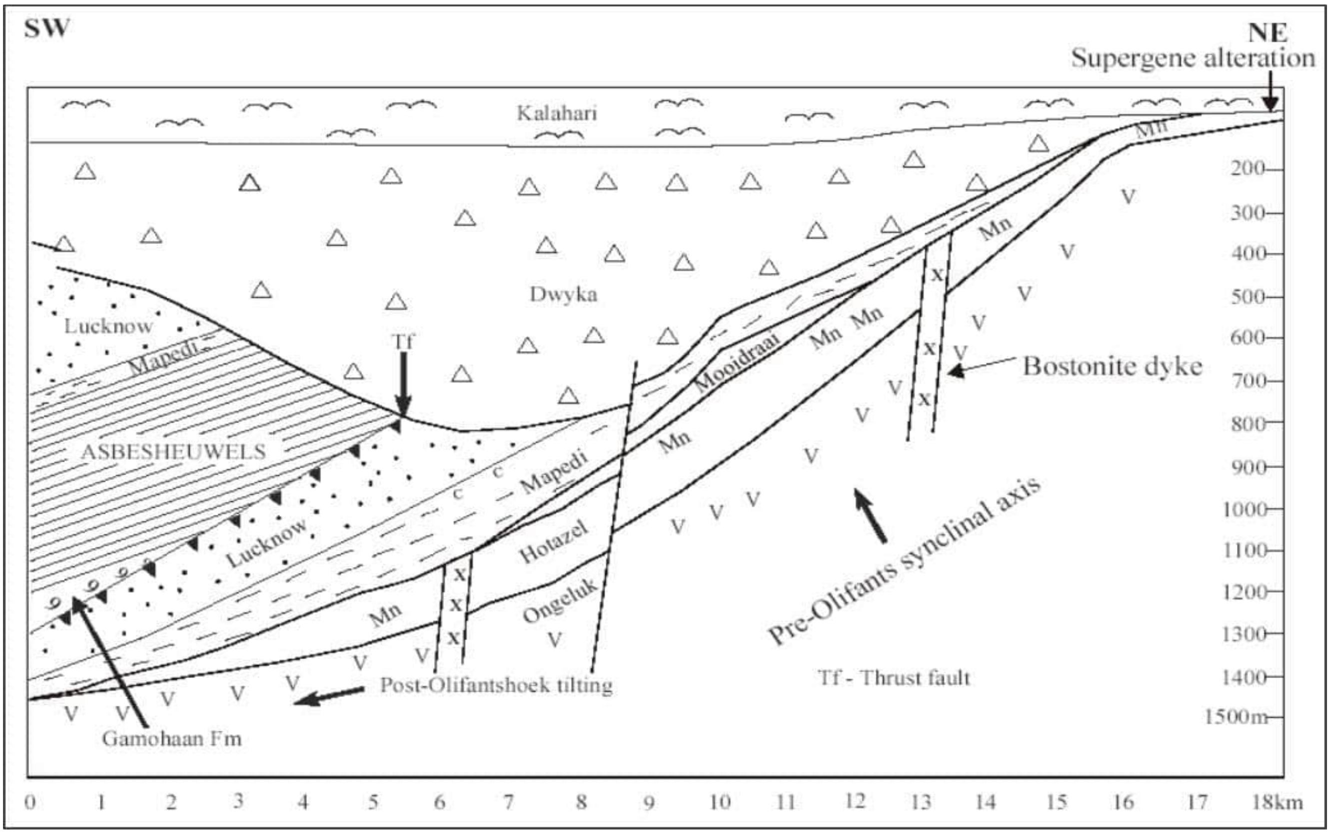

Figure 2: Cross section through the Kalahari Manganese Fields (Du Plooy, 2002[2])

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. 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 that consists of arenaceous sediments, typically interbedded shale, quartzite and lavas overlain by coarser quartzite and shale. The Olifantshoek Supergroup is overlain by Dwyka Formation, which forms the basal part of the Karoo Supergroup and in turn is typically covered by sands, claystone and calcrete of the Kalahari Group.

The manganese resource is hosted by the Hotazel Formation and consists of three ore bodies (Lower, Middle and Upper) that are intercalated with BIF and rhythmites. The Lower manganese orebody varies in thickness from 5 to 40 m and contains the highest manganese grades. It is the main ore horizon that is mined.

The Middle orebody has a maximum of 2 m thickness, is poorly mineralised and is considered uneconomic. The Upper orebody is moderately mineralised and is stockpiled at the mine for possible future use. The dominant ore minerals are braunite and hausmanite. The ore is carbonate rich and sulphide minerals are rare.

The overburden consists of the 0-84 m thick dolomites of the Mooidraai Formation, which overlies the Hotazel Formation. Above the dolomites is the Dwyka Group, which consists of glacial diamitites/tillites that vary in thickness from 0 m to 90 m. These are covered by 30-100 m thick gravels, clays, calcretes and aeolian sands of

[2] Du Plooy, A.P., 2002. Geochemistry and mineralogy of supergene altered manganese ore below the Kalahari unconformity in the Kalahari manganese field, Northern Cape Province, South Africa.

the Kalahari Group. The Mooidraai Formation and upper parts of the Hotazel Formation have been eroded in the southern portion of the mine area.

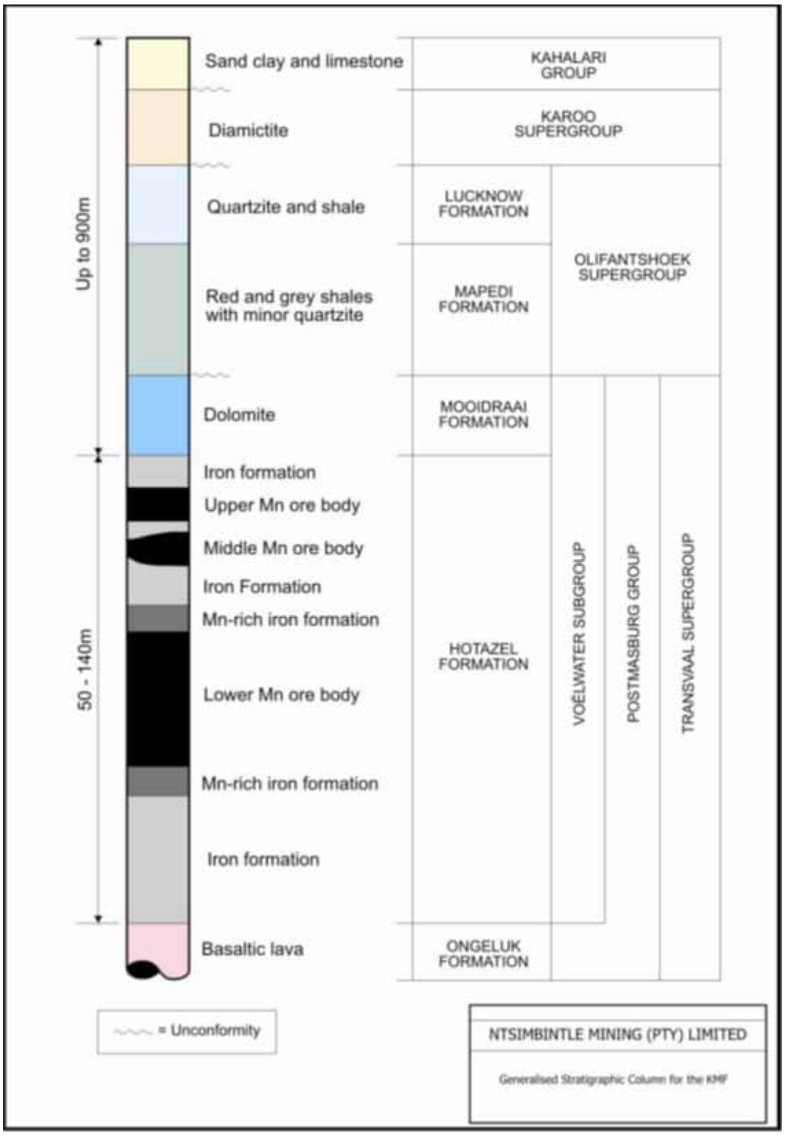

Figure 3: General Stratigraphic Column of the Kalahari Manganese Field

3.2 HYDROGEOLOGICAL AND HYDROLOGICAL SETTING

The main regional aquifer is the deep fractured aquifer, consisting of the weathered Dwyka tillite and the Mooidraai Formation dolomite. The Kalahari sand and the sediment beds that overlie the low permeability Dwyka tillite is also considered under certain circumstances as an aquifer.

The aquifers are classified as poor to minor aquifers. Borehole yields in the deeper aquifer are low; however, structural features such as faults and fractures can produce relatively high yielding boreholes.

The water management area under which this site falls is the Lower Vaal, within which the major rivers are the Harts, Malopa and Vaal. It falls into quaternary catchment D41K.

The non-perennial drainage line Gamagara River is located approximately 5 km to the west of the site, and the non-perennial drainage line Witleegte Stream is located approximately 2.5 km to the northeast of the site.

Drainage from the site is likely to flow in a westerly direction following the local topography. Currently, no water is discharged from the site into regional water resources.

Typically, there are no influence on the groundwater level by the presence of the non-perennial streams, as groundwater levels do not become shallower with the presence of the stream. This indicates that the stream is not fed by baseflow from the aquifer (AGES, 2007).

Prior to mining, regional groundwater flow at the site was from southwest to northeast towards the Gamagara River with the average water level in the area approximately 40-45 metres below ground level (mbgl).

3.3 AQUIFER SYSTEMS

According to the 1:500 000 General Hydrogeological Map Series sheet, groundwater in the vicinity of the UMK mine, which is mainly underlain by rocks of the Kalahari Formation, occurs mainly within 'intergranular' and 'fractured and intergranular' aquifers. Potential groundwater yields of between 0.1 L/s and 0.5 L/s are associated with the 'intergranular' aquifers and yields of up to 5 L/s are associated with the 'fractured and intergranular' aquifers. The primary porosity of the rocks provides the storage capacity with limited groundwater movement, while secondary features such as fractures, faults, bedding planes and dolerite intrusions enhance the groundwater flow.

Furthermore, based on the aquifer classification map (Parsons and Conrad, 1998) the aquifer underlying the UMK mine is regarded a "poor aquifer". A summary of the classification scheme is provided in Table 2. In this classification system, it is important to note that the concepts of Minor and Poor Aquifers are relative and that the yield for any particular class is not quantified. Within any specific area, all classes of aquifers should therefore, in theory, be present.

Table 2: AQUIFER CLASSIFICATION SCHEME (PARSONS, 1995; PARSONS AND CONRAD, 1998).

Sole source aquifer	An aquifer 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 region	High-yielding aquifer of acceptable quality water.
Minor aquifer region	Moderately yielding aquifer of acceptable quality or high yielding aquifer of poor quality water.
Poor aquifer region	Insignificantly yielding aquifer of good quality or moderately yielding aquifer of poor quality, or aquifer that will never be utilised for water supply and that will not contaminate other aquifers.
Special aquifer region	An aquifer designated as such by the Minister of Water

Further to the national aquifer classification systems described above, the groundwater occurrence below the UMK mine can be conceptualised in more detail as follows:

3.3.1 Unconfined Kalahari Aquifer

The unconfined, intergranular Kalahari aquifer represents the upper-most aquifer in the regional area, covering all other aquifer units, except for localized areas where rocks of the Danielskuil, Kuruman and Ghaap rock units that outcrop on the eastern boundaries of quaternary catchment (D41K). The Kalahari aquifer consists of heterogeneous sedimentary deposits, changing in porosity over short distances, influencing both the groundwater flow and borehole yields. The Kalahari aquifer thickness decreases southwards away from the Kalahari Basin that covers geographically most of Botswana and some parts of Namibia and South Africa. Borehole yields in the Kalahari Formation aquifer are relatively low - between 0.1 and 0.5 L/s. These typical borehole yields can be significantly improved by siting near faults and dolerite dykes. Groundwater is mostly associated with primary porosity of sedimentary units, but it can also accumulate along fractures and as water bodies above clay lenses.

3.3.2 Deeper Fractured Hotazel /Ongeluk Aquifer (BIF Aquifer)

The confined, fractured Hotazel and Ongeluk aquifers underlie the Kalahari Formation. The Ongeluk Formation underlies the Hotazel Formation (orebody) and consists predominantly of lavas. Groundwater in these harder rock aquifers is mostly associated with secondary porosity such as fracture zones, fault zones, and deformation areas formed from intrusive dolerite dykes and sills. Recharge to these aquifers is low, and groundwater depletion (over-exploitation) is a common problem. Both formations form part of the Pretoria Group (Transvaal Supergroup). The expected borehole yields for this aquifer unit also range between about 0.1 and 5 L/s.

3.3.3 Asbestos Hill Aquifer

The semi-confined, fractured Asbestos Hill aquifer unit is overlain by the Hotazel / Ongeluk aquifer units except towards the eastern catchment boundary where the unit outcrops. Rocks of the Asbestos Hill Subgroup dip 30° in a western direction and form a geological boundary on the west of the catchment area. Thin layer Kalahari sediments cover the Asbestos Hill Subgroup. The expected borehole yields for this aquifer unit range between 0.5 and 2.0 L/s. The Asbestos Hill aquifer has not been encountered on site due to the unknown depth of the Hotazel / Ongeluk aquifer overlaying this aquifer unit. The Asbestos Hill aquifer outcrops approx. 20 km north east of the mine site area.

3.4 BASELINE GROUNDWATER CONDITIONS

As described by SLR Consulting in 2017, 710.20002.00039 UMK Groundwater Study, Water quality sampling was undertaken by Metago in June 2006 and by AGES during the drilling of the site characterisation boreholes. This was to characterise the baseline or pre-mining environment. The results were compared to Department of Water Affairs (DWAF)'s Water Quality classes for domestic use (1996) and the South African drinking water standard (SABS 0241 of 2001). DWAF's water quality classes are defined as Ideal (Class 0) to completely unacceptable (Class 4) which relates to the suitability of the water for domestic use and takes into account the health risk at certain concentrations. The SABS standard defines three classes of water, namely Class 0 (ideal drinking water), Class 1 (acceptable) and Class 2 (maximum allowable).

- The pre-mining water quality was considered to be poor (Class 3) when compared to DWAF's water quality classes and not suitable for human drinking purposes. More detail is provided below (Metago, 2007):
- On the mine property, prospecting boreholes RP19, RP26, RP40 and RP46 ranged from a Class 1 (good) (RP40) to a Class 3 (poor) (RP26). RP19 and RP40 can be classified with a Class 2 (marginal) water quality.
- Boreholes JB9, JB12, JB14 and JB25 all contained high concentrations of nitrates and total hardness rendering the water unsuitable for drinking purposes (Class 4). The proximity of these boreholes to old workings and waste dumps suggested that nitrates in the groundwater were associated with the mining activities.
- Borehole UMK1 showed high concentration of nitrates, chloride and total hardness rendering this water unsuitable for human drinking purposes (Class 4).

- Water quality in borehole UMK6 was poor (Class 3), with nitrate and total hardness concentrations above the Class 3 guideline values.
- The site characterisation boreholes (W0, W1, W2 and W5) had a water quality falling within the Class 4 range (unsuitable for use). This was based on high nitrate concentrations (more than 100 mg/ℓ). Metal concentrations within these samples were within acceptable range or below the detection limit. Average chloride concentration in all the samples was 600mg/L. The total dissolved solids (TDS) averaged 2100 mg/L and the electrical conductivity (EC), 300mg/ℓ, which is a Class 2 water quality.

UMK has continued to monitor groundwater quality. The second quarterly monitoring event for 2017 was conducted during July 2017 (2017-Q2). Groundwater samples were collected from four (4) of the seven (7) WUL required boreholes and all of the additional boreholes during the July 2017 quarterly monitoring event.

Constituents with concentrations above the drinking water standards during the July 2017 monitoring are:

- Electrical conductivity (EC)
- Total dissolved solids (TDS)
- Chloride (Cl)
- Sulphate (SO_4)
- Nitrate (NO_3)
- Fluoride (F)
- Sodium (Na)
- Iron (Fe)
- Manganese (Mn)

Prior to mining, groundwater flow (baseline) at the site was from south-west to north-east towards the Gamogara River with the average water level in the area approximately 25 metres below ground level (mbgl) (AGES, 2007). This is indicative of low rainfall in the area and highly permeable soils. The presence of the non-perennial Witleegte does not appear to have an influence on the water levels, as the water levels do not become shallower with the presence of the stream. This indicates that the stream is not fed by baseflow from the aquifer (SLR, 2016).

The overall groundwater trend was established by subtracting the initial groundwater level with the latest measured groundwater level. Groundwater levels for the second quarter of 2017 and the overall groundwater trend since the commencement of monitoring are presented by SLR Consulting in 2017 in the report 710.20002.00039 UMK Groundwater Study.

From the water level results the following observations were noted:

- Results show that over the 2017-Q2 water levels varied between 21.36 mbgl in UMK2017-06 and 65.2 mbgl in UMK2017-02. However, it was noted that the water level measured in UMK2017-06 after it was constructed may be incorrect. This assumption will have to be confirmed during the following monitoring event;
- The water level in the majority of the boreholes have increased compared to the initial water levels; and
- There has been a decrease ranging from 2.3 to 7.8 m in the water levels of boreholes W5, UMK10, SMARTT1 and RISSIK2 compared to their initial water levels.

3.5 DRILLING AND TESTING

A groundwater exploration drilling programme was conducted to support this groundwater study and modelling exercise between 30/03/2017 and 11/04/2017. The position of the boreholes was marked out clearly on site and prepared for drilling. Monitoring boreholes were drilled and completed according to drilling specifications as prepared by SLR. Gubora drilling conducted the exploration drilling under SLR hydro-geologist supervision. Drilling of six boreholes was conducted with an air percussion drilling rig, and this was followed by pump testing.

Figure 4 shows the positions of the drilled monitoring boreholes.

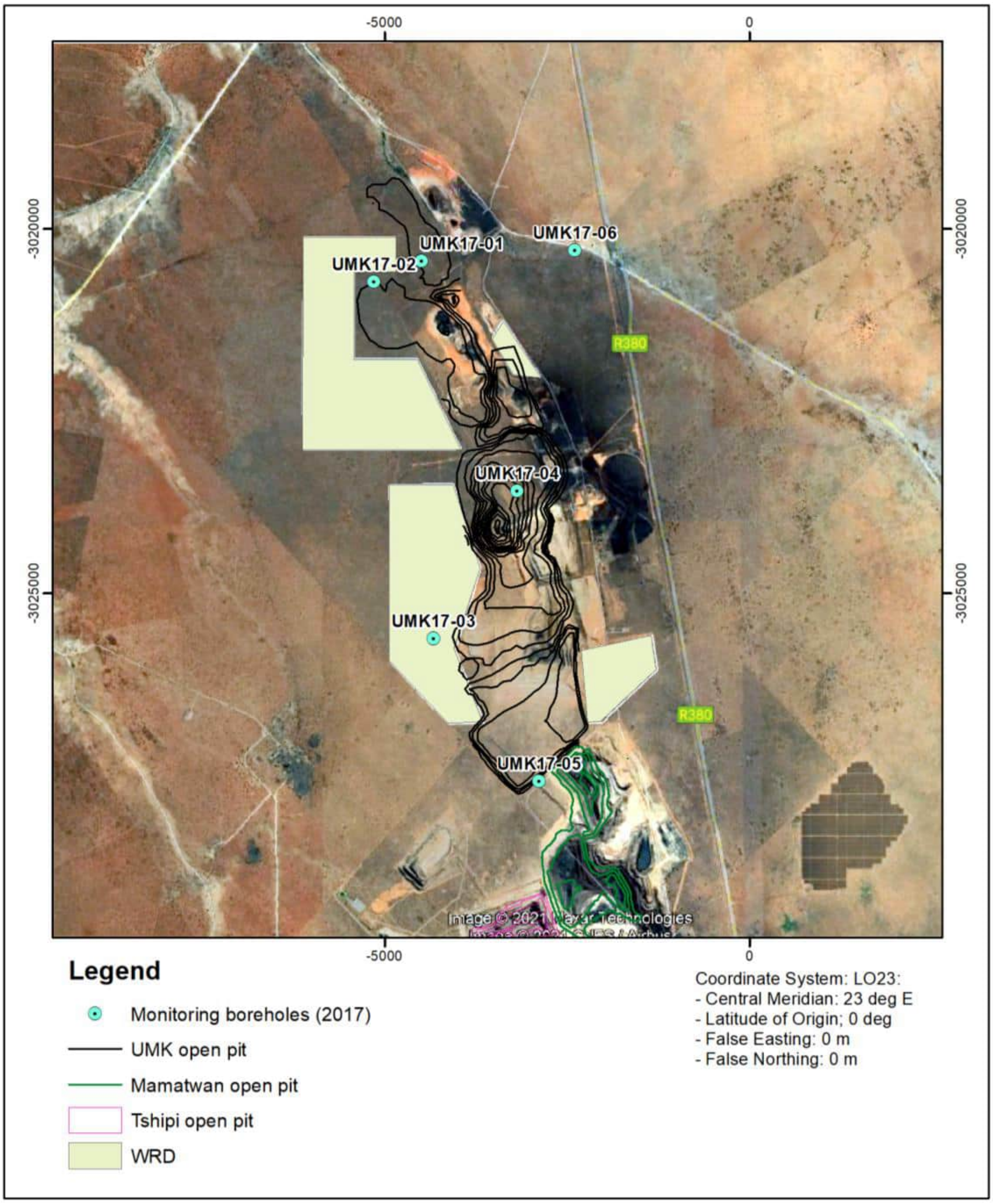

Figure 4: Location of monitoring boreholes drilled around UMK Pit

Chip samples recovered during the drilling were logged and details of all primary and secondary geological features were recorded. Generally, the study area is covered by yellowish brown Kalahari sands to an average depth of about 4 m. Underlying the residual Kalahari sands is medium grained calcrete which is underlined by clay. Banded Iron Formation (BIF) rocks directly underline both the clay and calcrete, and Dolomite forms the basement rock of the study area. Intrusive andesitic lava is present within the study area in places.

Lithological units encountered during the drilling of all of the boreholes, with the exception of UMK17-06, comprised (from surface to depth):

- Reddish brown, fine grained sand (Kalahari sand)
- Calcrete
- Redish brown clay
- Reddish grained BIF
- Basement dolomite.

Lithological units encountered when drilling borehole UMK17-06 comprised calcrete, which is directly underlined by highly fractured and fragmented andesetic lava.

UMK17-01 was found to be dry.

Table 3 summarizes the drilling details and Table 4 provides the pump testing results.

Table 3: Summary of UMK Drilling (SLR 2017)

Borehole Number	Co-ordinates		Depth	Drilling information							
	Y	X		Drill (254)	Drill (203)	Drill (165)	Cas. (219)	Cas. (177)	W/S	Blow Yield	WL
			mbgl	mm	mm	mm	mm	mm	mbgl	l/s	mbgl
UMK17-01	-3020441.2	-4494.7	100.0	35		65	35		dry	-	-
UMK17-02	-3020721.0	-5148.0	83.0	50	33		50	83	81	8	68.94
UMK17-03	-3025624.4	-4331.8	100.0	38	55	45	18	70	61	0.7	31.56
UMK17-04	-3023591.0	-3182.0	100.0	30	40	30	30	40	38	0.5	36.29
UMK17-05	-3027573.3	-2885.9	100.0	50		50	50		87	0.89	43.25
UMK17-06	-3020291.0	-2392.0	75.0	50	-	25	50	-	-	-	34.7
TOTAL			**558.0**	**253**	**128**	**215**	**233**	**193**	**267**	**10.1**	

Table 4: Summary of SLR Testing (2017)

Borehole Number	Co-ordinates		Borehole Depth	Aquifer testing				Date Completed
	Y	X		CDT Yield	CDT Duration	Transmissivity	Storativity	
			mbgl	l/s	min	m²/d		
UMK17-01	-3020441.2	-4494.7	100.0	Not tested				2017/04/03
UMK17-02	-3020721.0	-5148.0	83.0	5	2760	21	7.00E-03	2017/04/07
UMK17-03	-3025624.4	-4331.8	100.0	0.5	1440	1.4	2.72E-05	2017/04/24

UMK17-04	-3023591.0	-3182.0	100.0	0.5	720	0.4	9.77E-03	2017/04/18
UMK17-05	-3027573.3	-2885.9	100.0	1.5	2880	2.4	1.2-02	2017/04/26
UMK17-06	-3020291.0	-2392.0	75.0	Step tests only				2017/03/27
TOTAL			**558.0**	**7.5**	**7800**			

Drilling logs and Testing data and interpretation are detailed in SLR UMK Groundwater Study 2017, and thus not repeated here.

4. AQUIFER CHARACTERIZATION

4.1 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 UMK 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.

The least vulnerable area is restricted to the east and moderately vulnerable to the west of the site.

4.2 AQUIFER SUSCEPTIBILITY

The Aquifer Susceptibility Map of South Africa (Conrad *et al*, 1999b), indicates the qualitative measure of the relative ease with which a groundwater body can be potentially contaminated by anthropogenic activities and includes both aquifer vulnerability and the relative importance of the aquifer in terms of its classification.

The map indicates that the UMK project area (poor and minor aquifers with least and moderate vulnerability) has 'low' susceptibility to the east and medium vulnerability to the west of the site as presented in Table 5.

Table 5: Aquifer Susceptibility Matrix

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

		3 Medium	6 High	9 High

4.3 AQUIFER CLASSIFICATION

The classification scheme (refer to Table 6) 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 6: Aquifer Classification (South Africa)

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 (<150mSm).	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 those aquifers seldom produce large quantities of water, they are important both for local supplies and in supplying base flow for rivers.	Moderately yielding aquifer (1-5 L/s) of acceptable quality or high yielding aquifer (5-20 L/s) of poor water quality.
Non-Aquifer	These are formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be to 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 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.

Aquifer System	Defined by Parsons (1995)	Defined by DWAF Min Requirements (1998)
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.

In terms of the Aquifer Classification Map of South Africa (Conrad *et al*, 1999), the UMK project area is classified as a poor and minor aquifer region which implies the following:

- Poor aquifer region: low to negligible yielding aquifer system of moderate to poor water quality; and
- Minor aquifer region: moderately-yielding aquifer system of variable water quality.

The poor aquifer region is limited to the east of the site and the minor aquifer to the west. Although borehole yields in the deeper aquifer are generally considered low, structural features such as faults and fractures can produce higher yielding boreholes.

5. GROUNDWATER NUMERICAL MODELLING

5.1 SOFTWARE MODEL CHOICE

The FEFLOW (Finite Element subsurface FLOW and transport system v 7.3.0.18422) modelling code developed by DHI-WASY (Diersch, 2015) was used for the UMK groundwater model update. This code is an industry standard groundwater modelling tool widely used in mining and environmental applications. FEFLOW handles a broad variety of physical processes for subsurface flow and transport modelling and simulates groundwater level behaviour indirectly by means of a governing equation that represents the Darcy groundwater flow processes that occur in a groundwater system.

5.1.1 Governing Equation

In the Finite Element (FE) method, the problem domain is subdivided into elements that are defined by nodes. The dependent variable (e.g., head) is defined as a continuous solution within elements in contrast to the Finite Difference (FD) method where head is defined only at the nodes and is considered piecewise constant between nodes. The FE solution is piecewise continuous, as individual elements are joined along edges. The governing flow equation for three-dimensional saturated flow in saturated porous media is:

$$\frac{\partial}{\partial_x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial_y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial_z}\left(K_{zz}\frac{\partial h}{\partial x}\right)\pm W=S_s\frac{\partial h}{\partial t} \qquad \text{Equation 1}$$

where:

Kxx, Kyy, and Kzz are values of hydraulic conductivity along the x, y, and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity (L/T);

- h is the potentiometric head (L).
- W is a volumetric flux per unit volume representing sources and/or sinks of water, with:
  - W < 0.0 for flow out of
  - W > 0.0 for flow in the groundwater system
- Ss is the specific storage of the porous material (L-1).

- t is time (T).

5.1.2 Solver

FEFLOW offers multiple iterative and two direct equation solvers. By default, FEFLOW uses iterative solvers because they are suited for problems of arbitrary size. Separate iterative solver types can be selected for the symmetric (flow) and unsymmetric (transport) equation systems.

The UMK model solver options were set to preconditioned conjugate-gradient (PCG) solver for flow and a BICGSTABP-type solver for transport. PCG show fast convergence and have proven efficient for typical problems over a wide range of applications in subsurface flow and transport problems (Diersch, 2015).

5.2 MODEL SETUP AND BOUNDARY CONDITIONS

The groundwater model domain for UMK 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 western model boundary was 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.

The model domain covers a complex mining area, with several open pit mines being present in close proximity. Mamatwan Mine is situated immediately to the East of Tshipi and UMK Mine is situated approximately 2 km to the North of Tshipi.

From a groundwater flow point of view, all these mines will have a cumulative effect on groundwater flow and therefore the groundwater model has to take all these into consideration for a reasonable impact assessment.

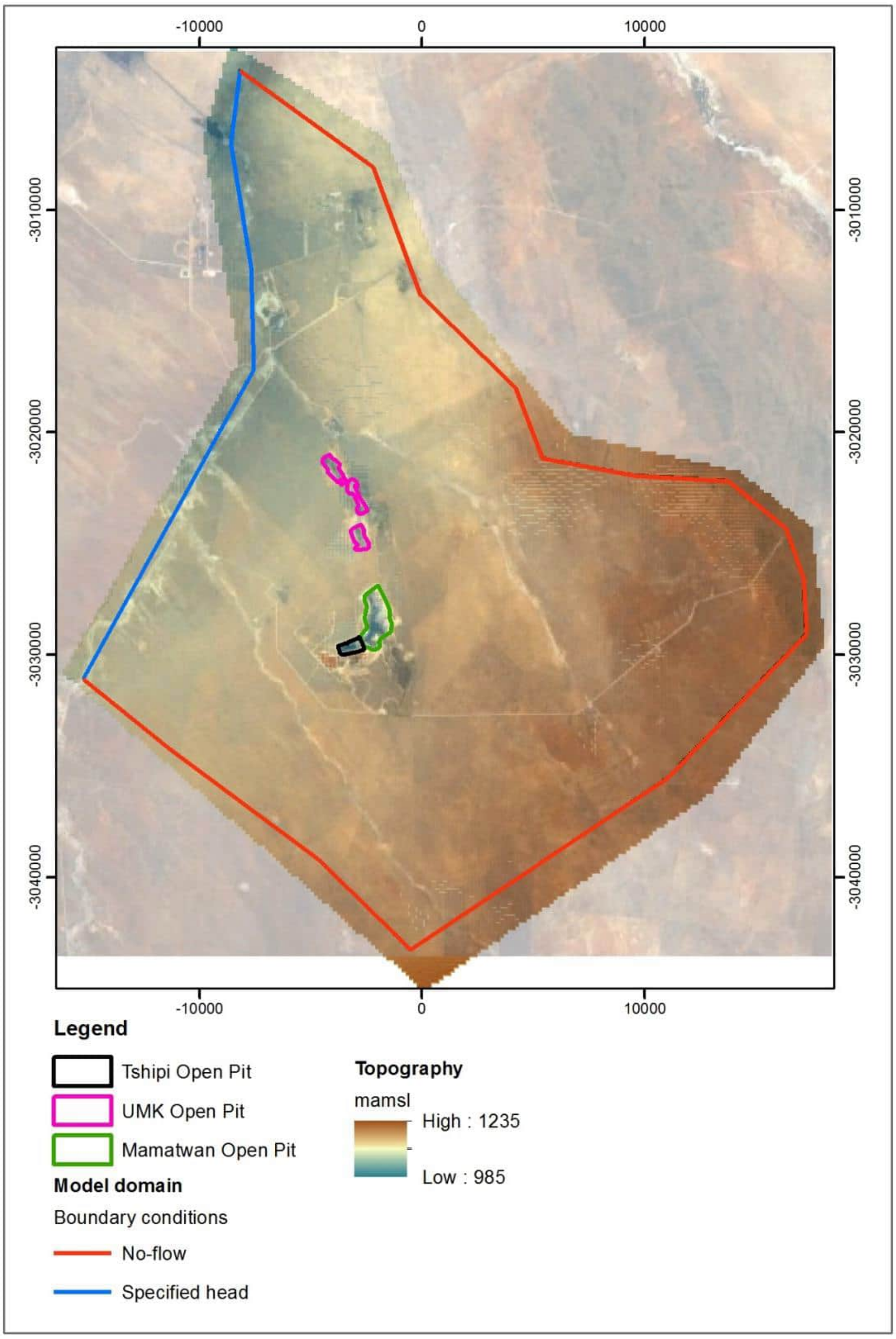

Figure 5: UMK Model Domain

5.3 GROUNDWATER ELEVATION AND GRADIENT

The groundwater elevation over the whole model domain was interpolated from the existing borehole groundwater measurements, and compared with groundwater elevations from previous work in the catchment (AGES, 2007 and SLR, 2014 - 2017). The initial (pre-mining) groundwater elevations computed for the model domain is shown in Figure 6.

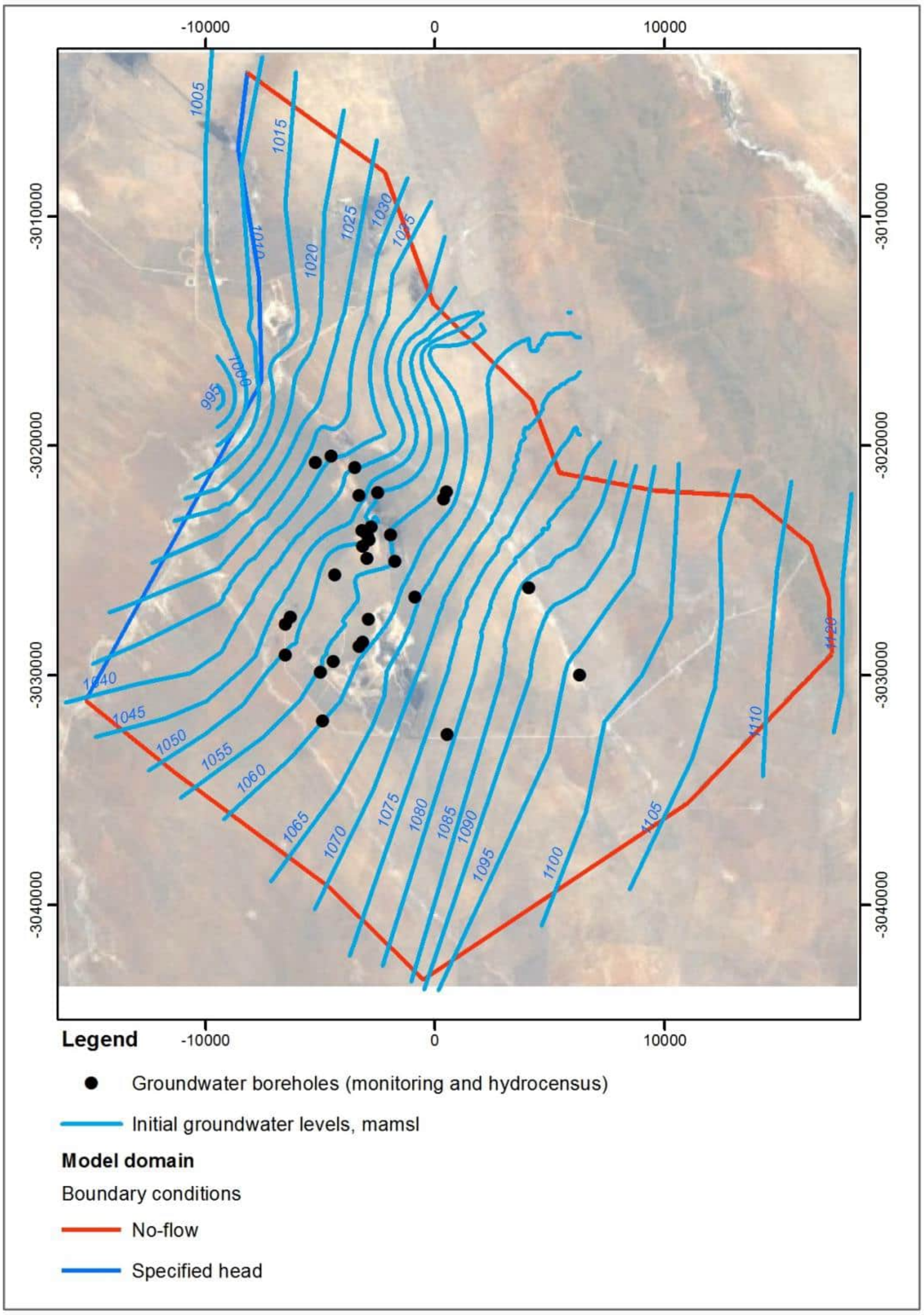

Figure 6: Initial Groundwater Levels

The groundwater flow is from South-East to North-West with a calculated gradient of 0.003 towards North-West.

5.4 GROUNDWATER SOURCES AND SINKS

Groundwater sources for the UMK 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 mean annual precipitation (M.A.P).

The groundwater sinks are represented by the existing open pits and future open pits. The current EMPR requires that the open pit be completely backfilled to ground level.

The other permanent sinks are taken into consideration for the UMK Groundwater Numerical Model (Figure 7):

- Mamatwan existing open pit.
- Tshipi existing open pit.

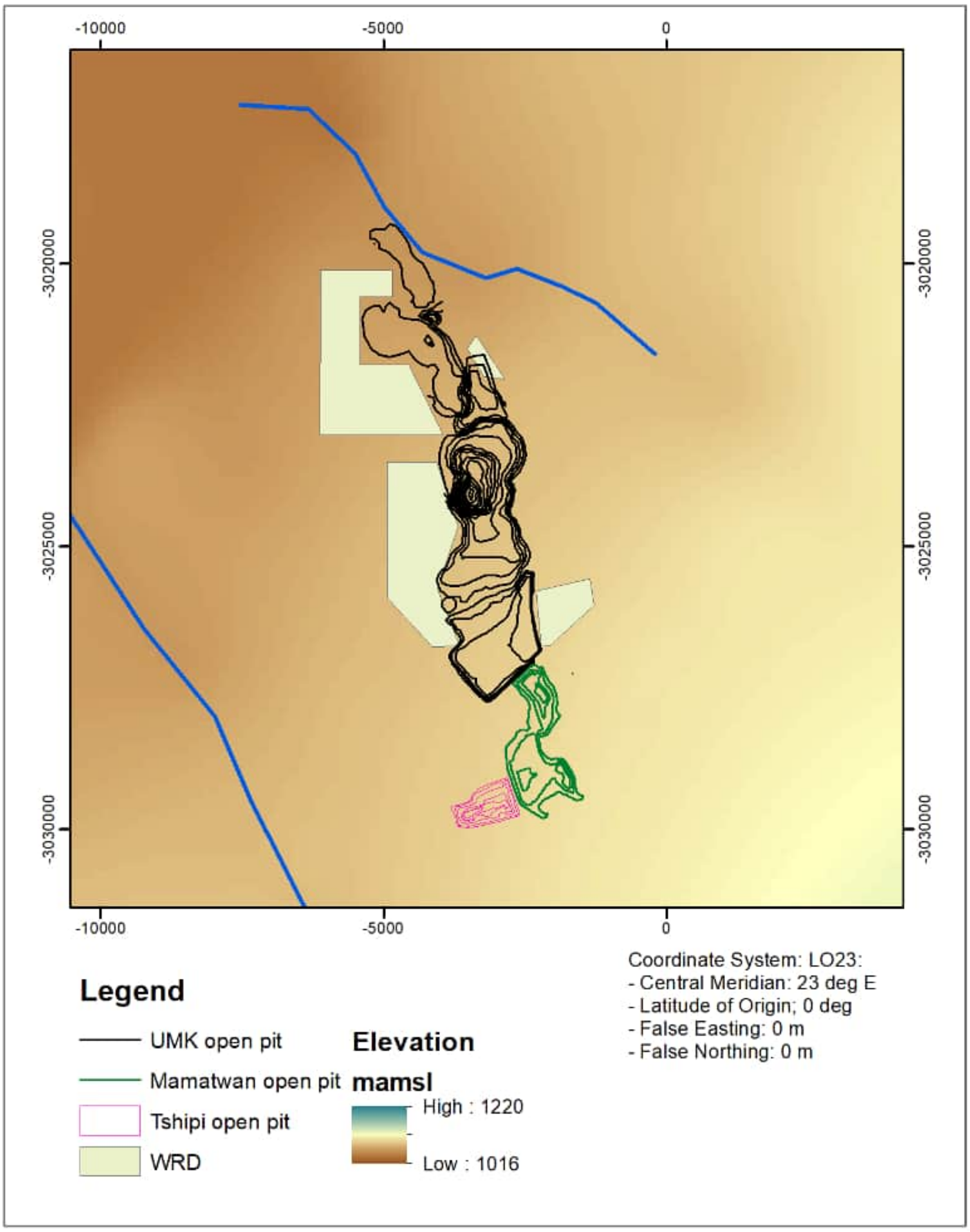

Figure 7: UMK Groundwater Model - Model Stresses

5.5 CONCEPTUAL MODEL

A Hydrogeological Conceptual Model (HCM) can be defined as a “representation of a real system” (Fetter, 2001). It can be used as a tool to assist with the assessment of impacts and the management of potential sources of pollution and is used as a base for the groundwater numerical model. The HCM was constructed using information gathered during the baseline study and should be updated once new information becomes available.

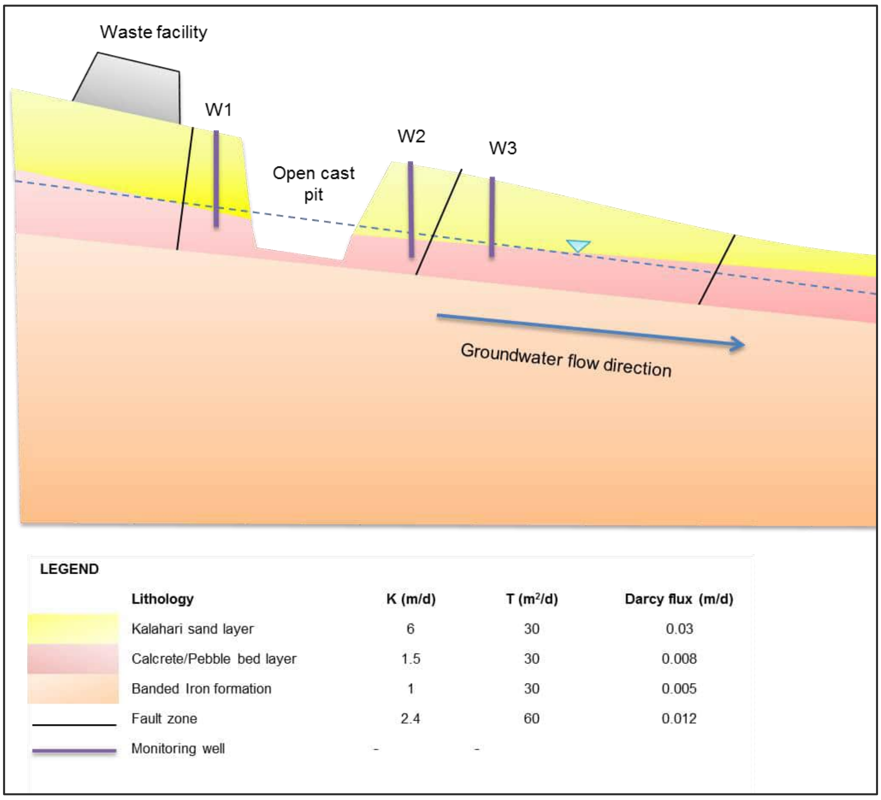

Figure 8: Hydrogeological Conceptual Model

Key aspects are:

- Recharge from rainfall is estimated at 2 % of M.A.P.
- Groundwater flows from the South West to the North East.

Conservative hydraulic parameters were assigned.

5.6 MODEL DISCRETIZATION

The horizontal discretization of the model domain takes into consideration several hydraulic and geochemical stress elements critical for the numerical simulations:

- Existing open pit mines.
- Existing waste rock dumps.
- Future mining.
- Geology.

- Surface water bodies.

The initial vertical discretization was based on the simplified geology described in the area (Table 7).

This was further refined considering the mining levels (existing and future).

Table 7: Vertical layers

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 the UMK groundwater model is shown in Table 8.

Table 8: UMK groundwater model - vertical discretization

Slice/Layer	Layer Description	Layer elevation	Formation
1	Topo pre-mining	topo	Kalahari sands
2	Slice1 minus 1m	1080	
3	slice 3 (mining 1060)	1060	
4	slice 4 (mining 1040)	1040	Kalahari calcrete + pebbles
5	bottom Kalahari	1030	Dwyka
6	top_bif1a (mining 1020)	1020	BIF1
7	mining 1000	1000	
8	bottom biff (mining 980)	980	
9	960	960	Hotazel
10	940	940	
11	920	920	
12	900	900	
13	880	880	BIF2
14	860	860	
15	700 mamsl	700	Basement
16	500 mamsl	500	

The resulting horizontal finite elements mesh is showed in Figure 9.

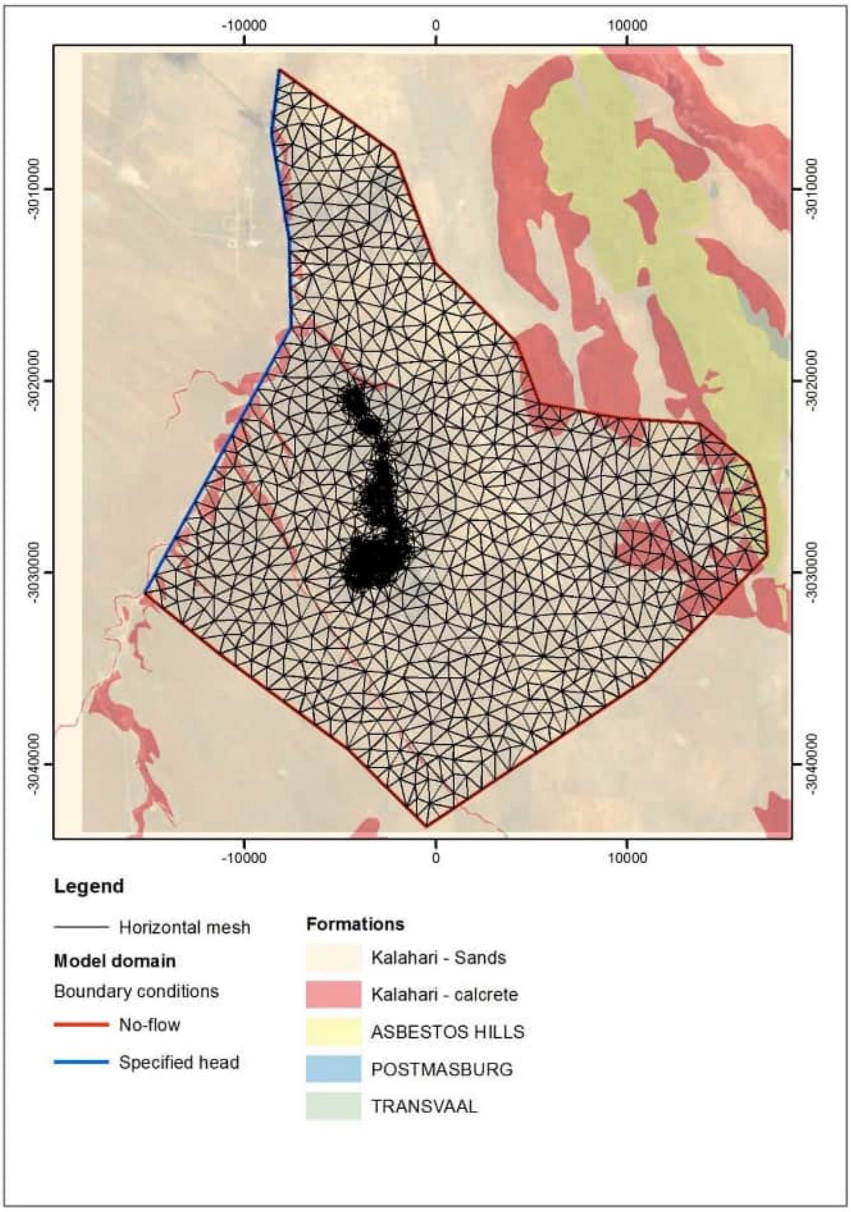

Figure 9: UMK Groundwater Model - Horizontal Mesh

The resulting three-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

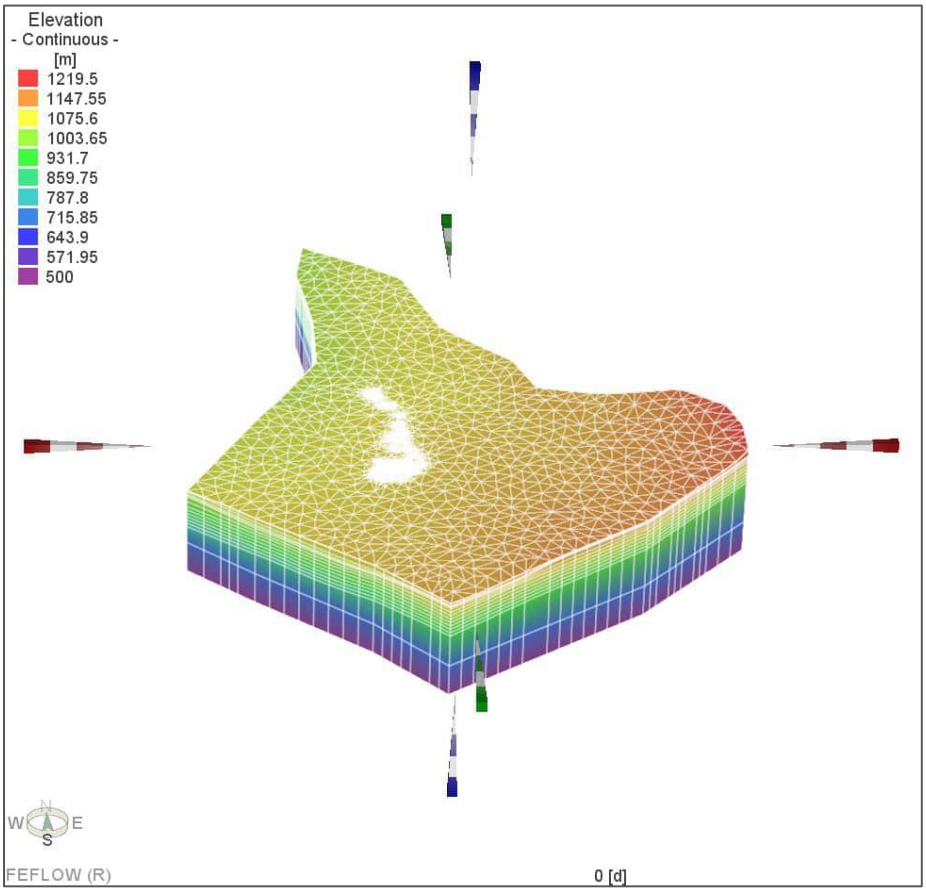

Figure 10: UMK: 3-dimensional finite elements mesh

5.7 GROUNDWATER NUMERICAL MODEL

5.7.1 Model Initials

Once the three dimensional numerical model is constructed, hydraulic properties are assigned to the model elements. Table 9 details the hydraulic properties assigned to the formations represented in the model.

Table 9: Hydraulic Parameters

Formation	K_h/K_v (m/d)	Storativity
Kalahari sands	1.0/1.0	0.01
Kalahari calcrete + pebbles	0.5/0.05	0.001
BIF1 Hotazel	0.05/0.005 0.001/0.0001	0.001
BIF2	0.01/0.001	0.001
Basement	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.

5.7.2 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 measured hydraulic heads in the observation points.

The calibration of the UMK 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. Figure 11 shows the plot of measured hydraulic heads vs. simulated hydraulic heads.

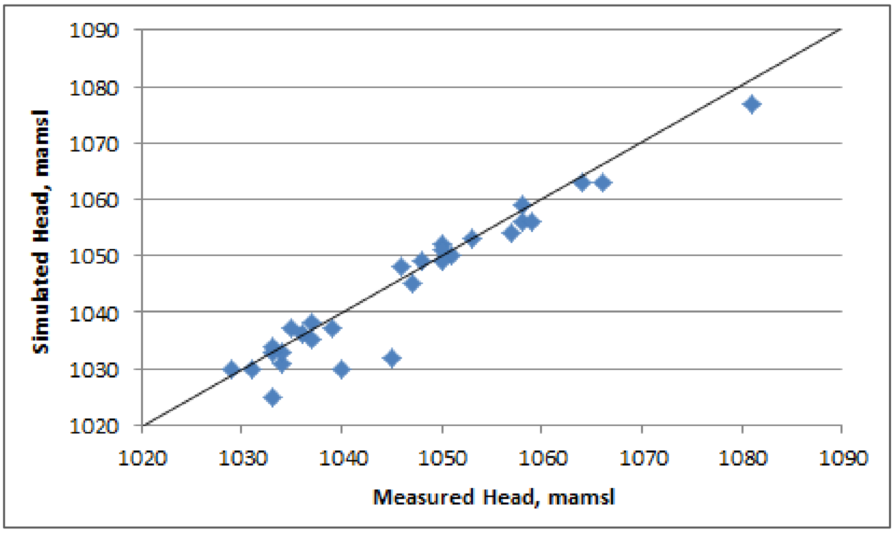

Figure 11: Hydraulic Head - Measured vs. Simulated

The differences between the measured hydraulic head and computed hydraulic head are very small, and the calibration was considered satisfactory. The Residual Mean Squared Error (RMSE) and Normalised Residual Mean Squared Error (NRMSE), which represent the quantitative measure of the model calibration are within the prescribed groundwater model calibration guidelines (ASTM Guidelines) – Table 10. A NRMSE value below 10% is considered as an acceptable calibration.

Table 10: UMK Groundwater Model Calibration

BH	Head	Head_sim	Head_diff	Head diff^2
UMK1	1046	1048	-2	4
UMK2	1064	1063	1	1
UMK3	1058	1056	2	4
UMK4	1066	1063	3	9
UMK5	1081	1077	4	16
JB25	1048	1049	-1	1

BH	Head	Head_sim	Head_diff	Head diff^2
JB9	1031	1030	1	1
JB12	1034	1031	3	9
UMK2017-1	1034	1033	1	1
UMK2017-2	1033	1025	8	64
UMK2017-6	1040	1030	10	100
UMK2017-4	1045	1032	13	169
UMK2017-3	1033	1033	0	0
UMK2017-5	1033	1034	-1	1
BH04	1039	1037	2	4
UMK09	1037	1035	2	4
UMK10	1037	1038	-1	1
NT1	1047	1045	2	4
NT8	1036	1036	0	0
NT15	1058	1059	-1	1
TSH01	1035	1037	-2	4
TSH02	1057	1054	3	9
TSH03	1029	1030	-1	1
TSH04	1059	1056	3	9
TSH06	1050	1049	1	1
			RMSE	**3.80**
			NRMSE	**7%**

5.7.3 Simulation of Mining

Open pit mining was simulated as follows:

- Existing open pits, Mamatwan and Tshipi, were simulated as permanent inactive elements (permanent excavations) with drain (seepage) nodes on the pit faces; the seepage face nodes will only allow negative flow; negative flow constraint is translated by groundwater entering the open pits and pumped out of the system.
- Existing UMK open pits and future UMK open pits were simulated as transient inactive elements with seepage face nodes.

- The transient nature of active/inactive elements will allow activation of the element for backfilling; the inactive elements become active as pit backfilling takes place.
- The seepage face nodes will remain active on the pits faces for as long as open pit mining take place; these are switched-of as backfilling takes place, allowing groundwater to flow into the backfill volumes, at respective times.
- The Waste Rock dumps have been updated as per latest transmitted footprints (2021)
- The backfill has been simulated as full pit backfill.

5.7.4 Simulation of Recharge – Transient Mode

In transient mode, the recharge was assigned as cyclic monthly time series, as shown in Figure 12, considering 2 % of monthly rainfall averages.

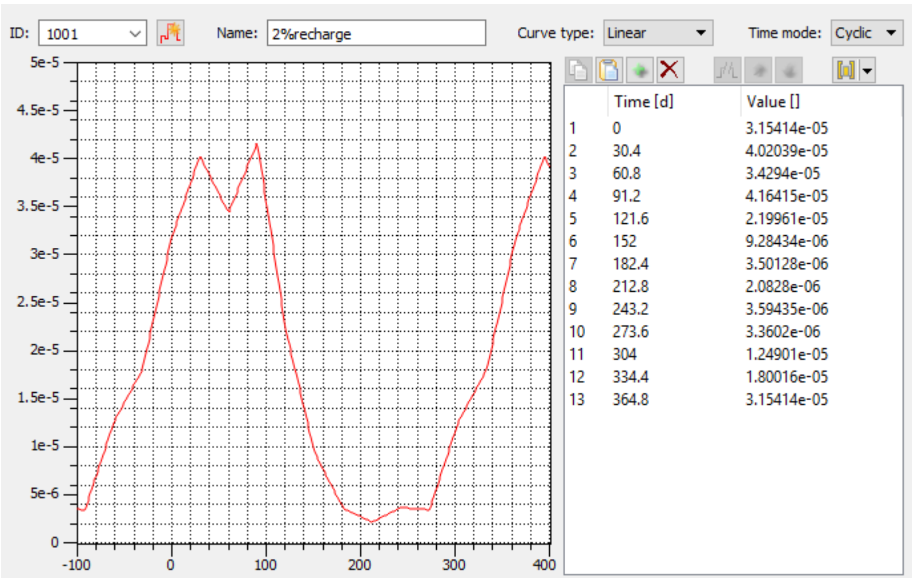

Figure 12: Time series – UMK Transient Recharge

5.7.5 Simulation of Source Terms

The Source Term has been simulated in transient mode as follows:

- Updated Waste Rock Dumps: permanent Sulphate Concentration Boundary Condition for the whole duration of the simulation; this can be adjusted if UMK decides to remove the existing Waste Rock Dumps
- Open pit backfill: the Concentration Boundary Condition is turned-on at the end of mining when full backfilling (to ground level) occurs in the open pit; the concentration is maintained after that, until the end of the simulation.

Sulphate was identified by the Source Term Study (SLR, 2017) as the critical parameter with the highest concentration.

The mass transport simulation was run in non-reactive mode.

5.8 MODEL RESULTS

The UMK 3-dimensional groundwater numerical model has been run in transient mode for a period of 100 years. This will cover 20 years of mining and 80 years post-mining.

The model results were extracted at the following relevant time-steps:

- Year 32 (2053) – End of mining.
- Year 100 (2121) – End of simulation: 68 years post-mining.

5.8.1 Cone of Drawdown

As mining progresses and open pit becomes deeper, it is expected that a cone of drawdown will develop as a result of the groundwater passive inflows (ingress) into the open pit excavation.

Figure 13 shows the extent of the cone of drawdown at the end of mining (2053) and Figure 14 shows the extent of the cone of drawdown at the end of the simulation (2121).

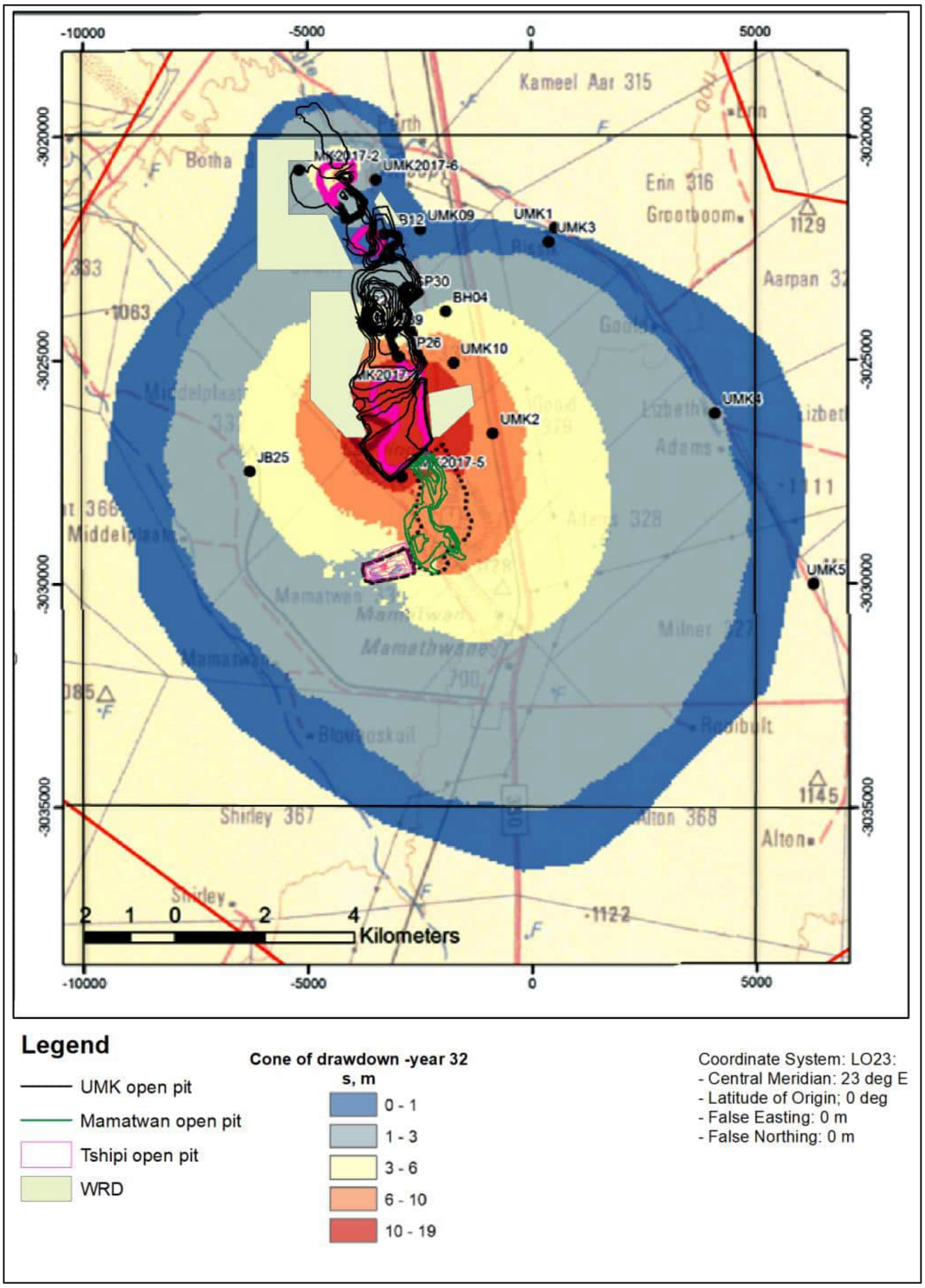

Figure 13: Predicted cone of drawdown - year 32 of simulation

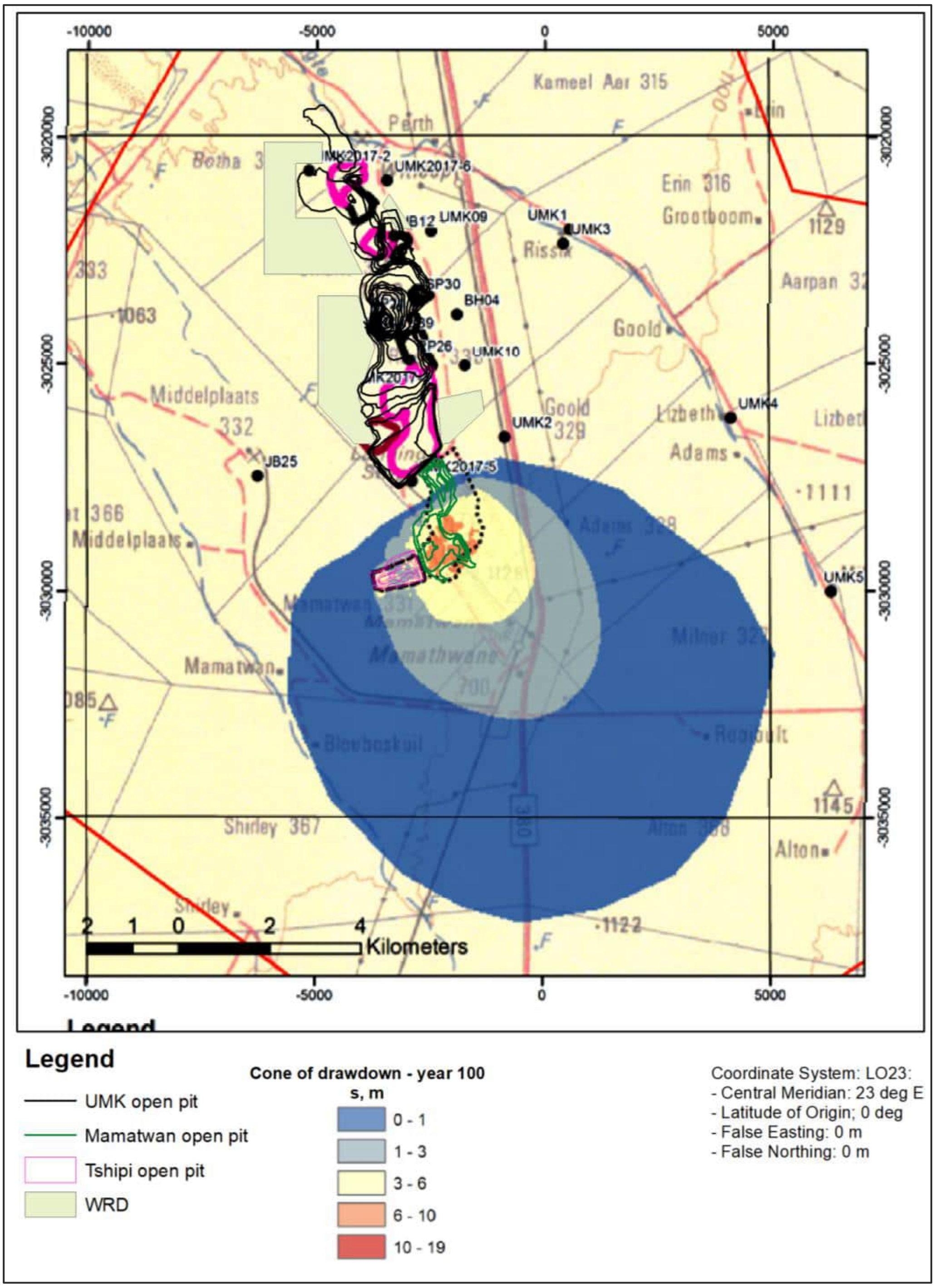

Figure 14: Predicted cone of drawdown - year 100 of simulation

5.8.2 Groundwater passive inflows into UMK pit

The predicted groundwater inflows are shown in Figure 15.

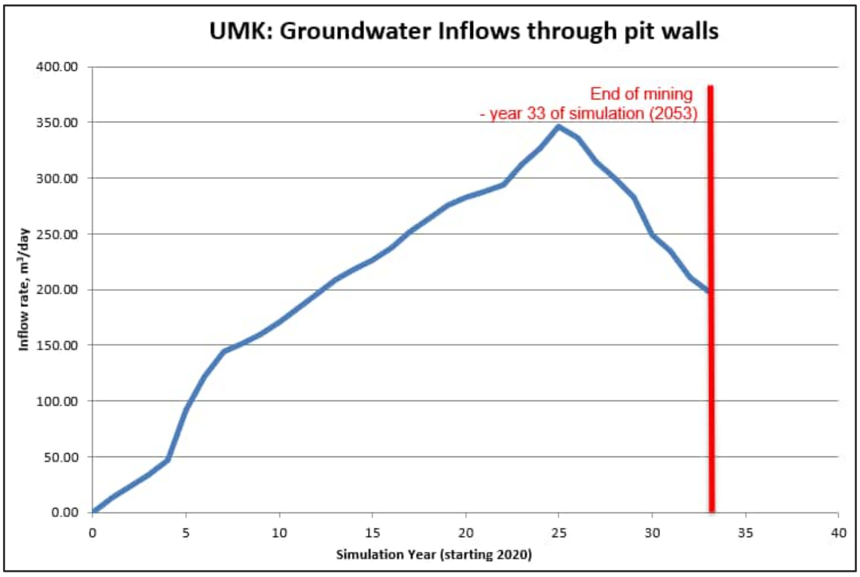

Figure 15: UMK - Passive groundwater inflows

Maximum inflow predicted is of 350 m^3/day, in year 25 of simulation (2046).

5.8.3 Predicted SO_4 Contaminant Plume

The predicted Sulphate plume developed from the Waste Rock Dumps and from the in-pit backfilling waste rock is shown in figures:

Year 32 (end of mining) - 2053: Figure 16.

Year 100 (end of simulation) – 2121: Figure 17.

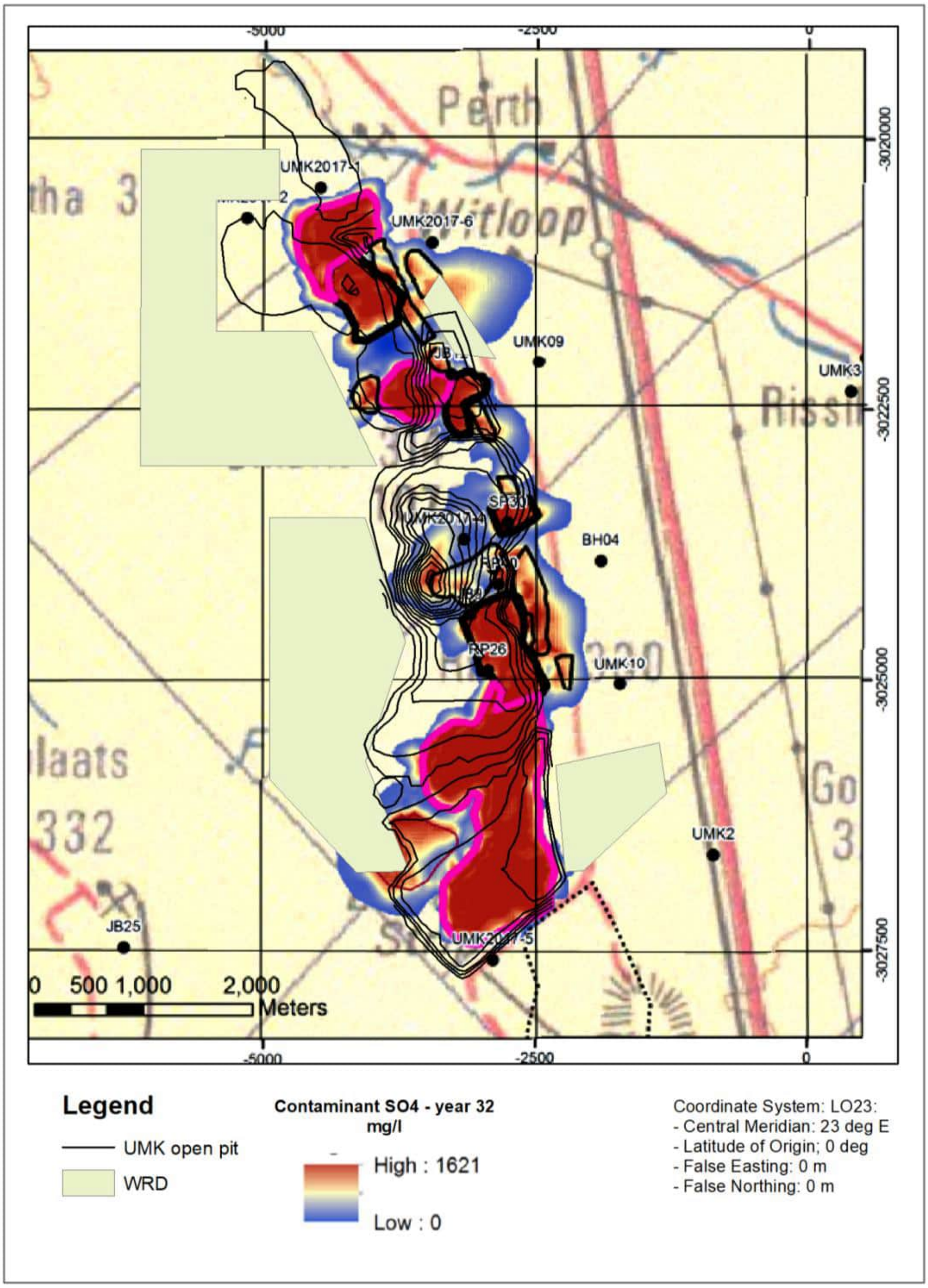

Figure 16: Predicted SO_4 plume - year 32 of simulation

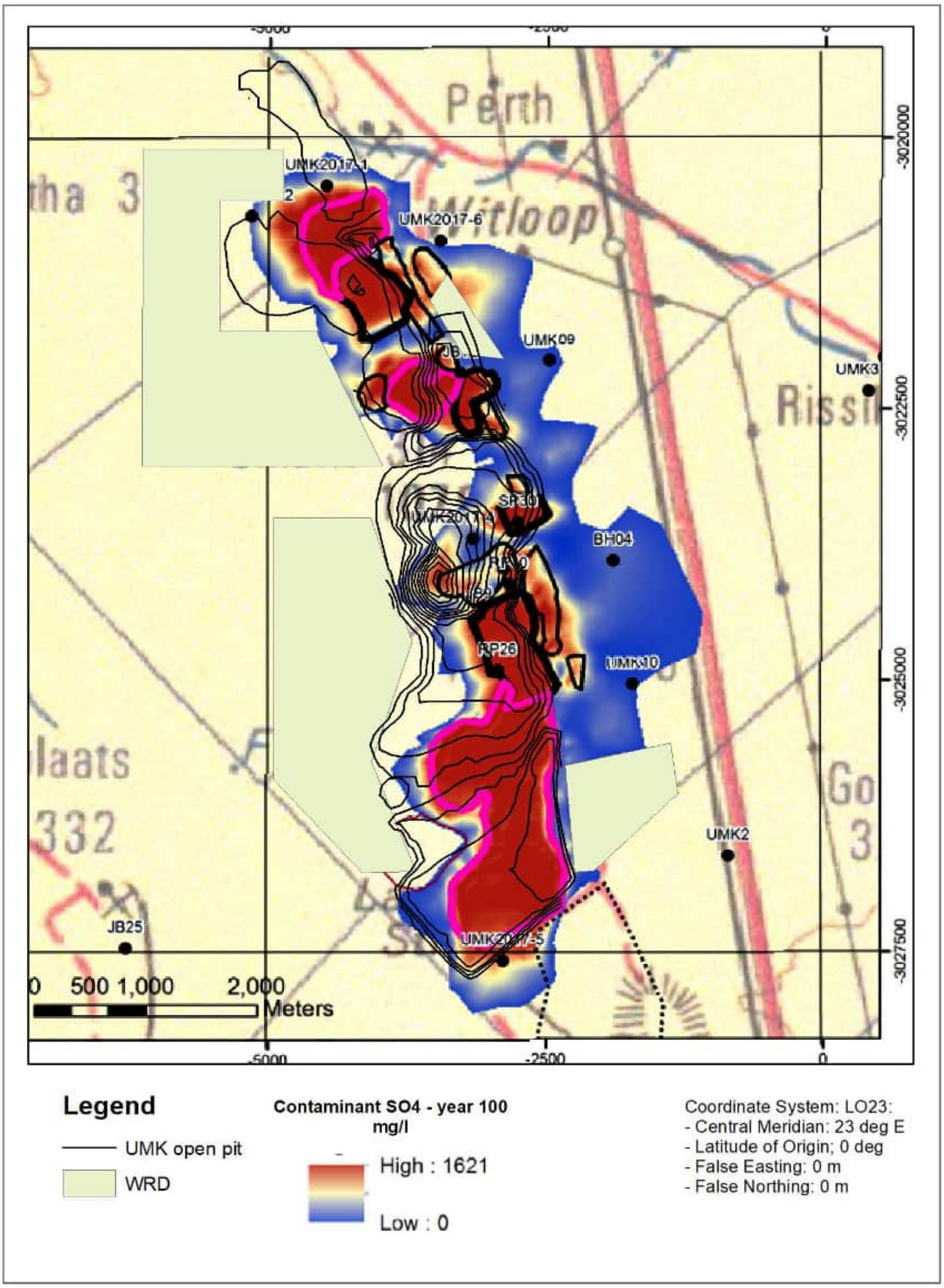

Figure 17: Predicted SO_4 plume - year 100 of simulation

6. GROUNDWATER IMPACTS

6.1 METHODOLOGY USED IN DETERMINING THE SIGNIFICANCE OF IMPACTS

Impact assessment methodology enables the assessment of environmental issues including cumulative impacts, the severity of impacts (including the nature of impacts and the degree to which impacts may cause irreplaceable loss of resources), the extent of the impacts, the duration and reversibility of impacts, the probability of the impact occurring, and the degree to which the impacts can be mitigated.

IMPACT ASSESSMENT METHODOLOGY

Note: Part A provides the definition for determining impact consequence (combining intensity, spatial scale and duration) and impact significance (the overall rating of the impact). Impact consequence and significance are determined from Part B and C. The interpretation of the impact significance is given in Part D.

PART A: DEFINITIONS AND CRITERIA*		
Definition of SIGNIFICANCE		Significance = consequence x probability
Definition of CONSEQUENCE		Consequence is a function of intensity, spatial extent and duration
Criteria for ranking of the INTENSITY of environmental impacts	VH	Severe change, disturbance or degradation. Associated with severe consequences. May result in severe illness, injury or death. Targets, limits and thresholds of concern continually exceeded. Substantial intervention will be required. Vigorous/widespread community mobilization against project can be expected. May result in legal action if impact occurs.
	H	Prominent change, disturbance or degradation. Associated with real and substantial consequences. May result in illness or injury. Targets, limits and thresholds of concern regularly exceeded. Will definitely require intervention. Threats of community action. Regular complaints can be expected when the impact takes place.
	M	Moderate change, disturbance or discomfort. Associated with real but not substantial consequences. Targets, limits and thresholds of concern may occasionally be exceeded. Likely to require some intervention. Occasional complaints can be expected.
	L	Minor (Slight) change, disturbance or nuisance. Associated with minor consequences or deterioration. Targets, limits and thresholds of concern rarely exceeded. Require only minor interventions or clean-up actions. Sporadic complaints could be expected.
	VL	Negligible change, disturbance or nuisance. Associated with very minor consequences or deterioration. Targets, limits and thresholds of concern never exceeded. No interventions or clean-up actions required. No complaints anticipated.
	VL+	Negligible change or improvement. Almost no benefits. Change not measurable/will remain in the current range.
	L+	Minor change or improvement. Minor benefits. Change not measurable/will remain in the current range. Few people will experience benefits.
	M+	Moderate change or improvement. Real but not substantial benefits. Will be within or marginally better than the current conditions. Small number of people will experience benefits.
	H+	Prominent change or improvement. Real and substantial benefits. Will be better than current conditions. Many people will experience benefits. General community support.
	VH+	Substantial, large-scale change or improvement. Considerable and widespread benefit. Will be much better than the current conditions. Favourable publicity and/or widespread support expected.
Criteria for ranking the DURATION of impacts	VL	Very short, always less than a year. Quickly reversible
	L	Short-term, occurs for more than 1 but less than 5 years. Reversible over time.
	M	Medium-term, 5 to 10 years.
	H	Long term, between 10 and 20 years (likely to cease at the end of the operational life of activity).
	VH	Very long, permanent, +20 years (Irreversible, Beyond closure).
Criteria for ranking the EXTENT of impacts	VL	A part of the site/property.
	L	Whole site.
	M	Beyond the site boundary, affecting immediate neighbours.

	H	Local area, extending far beyond site boundary.
	VH	Regional/National

PART B: DETERMINING CONSEQUENCE							
INTENSITY = VL							
DURATION	Very long	VH	Low	Low	Medium	Medium	High
	Long term	H	Low	Low	Low	Medium	Medium
	Medium term	M	Very Low	Low	Low	Low	Medium
	Short term	L	Very low	Very Low	Low	Low	Low
	Very short	VL	Very low	Very Low	Very Low	Low	Low
INTENSITY = L							
DURATION	Very long	VH	Medium	Medium	Medium	High	High
	Long term	H	Low	Medium	Medium	Medium	High
	Medium term	M	Low	Low	Medium	Medium	Medium
	Short term	L	Low	Low	Low	Medium	Medium
	Very short	VL	Very low	Low	Low	Low	Medium
INTENSITY = M							
DURATION	Very long	VH	Medium	High	High	High	Very High
	Long term	H	Medium	Medium	Medium	High	High
	Medium term	M	Medium	Medium	Medium	High	High
	Short term	L	Low	Medium	Medium	Medium	High
	Very short	VL	Low	Low	Low	Medium	Medium
INTENSITY = H							
DURATION	Very long	VH	High	High	High	Very High	Very High
	Long term	H	Medium	High	High	High	Very High
	Medium term	M	Medium	Medium	High	High	High
	Short term	L	Medium	Medium	Medium	High	High
	Very short	VL	Low	Medium	Medium	Medium	High
INTENSITY = VH							
DURATION	Very long	VH	High	High	Very High	Very High	Very High
	Long term	H	High	High	High	Very High	Very High
	Medium term	M	Medium	High	High	High	Very High
	Short term	L	Medium	Medium	High	High	High
	Very short	VL	Low	Medium	Medium	High	High
			VL	**L**	**M**	**H**	**VH**
			A part of the site/ property	Whole site	Beyond the site, affecting neighbours	Extending far beyond site but localised	Regional/ National
			EXTENT				

PART C: DETERMINING SIGNIFICANCE							
PROBABILITY (of exposure to impacts)	Definite/ Continuous	VH	Medium	Medium	High	Very High	Very High
	Probable	H	Low	Medium	Medium	High	Very High
	Possible/ frequent	M	Low	Low	Medium	Medium	High
	Conceivable	L	Very Low	Low	Low	Medium	Medium
	Unlikely/ improbable	VL	Negligible	Very Low	Low	Low	Medium
			VL	L	M	H	VVH
			CONSEQUENCE				

PART D: INTERPRETATION OF SIGNIFICANCE	
Significance	Decision guideline
Very High	Potential fatal flaw unless mitigated to lower significance.
High	It must have an influence on the decision. Substantial mitigation will be required.
Medium	It should have an influence on the decision. Mitigation will be required.
Low	Unlikely that it will have a real influence on the decision. Limited mitigation is likely required.
Very Low	It will not have an influence on the decision. Does not require any mitigation
Negligible	Inconsequential, not requiring any consideration.

***VH = very high, H = high, M= medium, L= low and VL= very low and + denotes a positive impact**

6.2 ISSUE: CONTAMINATION OF GROUNDWATER RESOURCES AS A RESULT OF THE PROPOSED ADDITIONAL SURFACE INFRASTRUCTURE

Introduction

There are a number of sources in all mine phases that have the potential to pollute groundwater. Some sources are permanent (WRDs) and some sources are transient (starting later and at different time-steps) and becoming permanent (pit backfilling). Even though some sources are temporary in nature, related potential pollution can be long term. The operational phase will present more long-term potential sources (waste rock dumps, as the major source term) and the closure phase included in the period of simulation will present final land forms, such as the backfilled open pit may have the potential to pollute water resources through long term seepage and/or run-off.

The rivers in the project area are not expected to be in hydraulic continuity with the main water table (SLR, 2016) and therefore no groundwater related quality impacts are expected on rivers. This impact is therefore not assessed further and the discussion below focusses on potential human health impacts.

Mine phase and link to project specific activities/infrastructure

Construction	Operational	Decommissioning	Closure
Mineralised waste management Non-mineralised waste management Water use and management Support services Transportation system	Mineralised waste management Non-mineralised waste management Water use and management Support services Transportation system Continued use of approved facilities and services Open pit mining and backfilling	Mineralised waste management Non-mineralised waste management Water use and management Support services Transportation system Continued use of approved facilities and services Backfilling of open pit	Final land forms

The groundwater quantity impact during the operational phase is summarised in Table 11.

Table 11: Operational & closure phase impact summary – Impact on groundwater quality.

Issue: CONTAMINATION OF GROUNDWATER RESOURCES AS A RESULT OF THE PROPOSED ADDITIONAL SURFACE INFRASTRUCTURE		
Phases: Operational & closure phases		
Criteria	**Without Mitigation**	**With Mitigation**
Intensity	Moderate	Low
Duration	High	High
Extent	Medium	Medium
Consequence	Medium	Medium
Probability	High	Low
Significance	Medium	Low
Nature of cumulative impacts	Minor contribution to cumulative impacts, impacts would remain within the range previously assessed	
Degree to which impact may cause irreplaceable loss of resources	Low during operational phase, but impact can be minimised if management measures are put in place and followed	
Degree to which impact can be mitigated	Low during operational phase, but impact can be minimised if management measures are put in place and followed	
Degree to which impact can be reversed	Low during operational phase, but impact can be minimised if management measures are put in place and followed	

Rating of impacts

Intensity

The impact associated with groundwater contamination was assessed as part of the approved EMPr (Metago, 2007). The contaminant transport modelling assumed that responsible housekeeping, management of diffuse pollution sources, and the draw down effect of the open cast pits on any contaminants from the temporary overburden/waste rock dumps, would limit the sources of significant groundwater contamination to the tailings dam facility. Modelling assumed a seepage rate that falls between that of the unlined and lined scenarios for the tailings dam facility. In fact, the tailings dam facility (including the return water dam) will be lined so the model would have over predicted the potential impact. The conservatively predicted impact was that over a thirty year period, contamination of total dissolved solids at 100 mg/ℓ concentrations would have migrated approximately 700 m from the tailings dam. This impact was rated as being insignificant. It should however be noted that subsequent to this groundwater study, UMK decided not to proceed with the development of the planned tailings dam, and this facility was therefore not constructed.

The mass transport modelling conducted for the project has been completed in a non-reactive mode, which is conservative, and eliminating any diffusion, dispersion, attenuation, etc. The model assumed no barrier systems on the pollution sources. A waste assessment conducted in terms of R 635 found that the leachable concentrations did not exceed the defined limit for any of the parameters assessed, and this included manganese. A source term study aimed at predicting the seepage quality from waste rock material predicted the highest concentrations with regard to the parameters sulphate. Therefore, sulphate was modelled.

The maximum possible sulphate source (1621 mg/ ℓ) is assumed to remain in place for the duration of the simulation, on:

- WRDs
- In-pit back filling.

The simulations show that the maximum sulphate plumes developed from the sources extend up to 1.7 km in an eastern direction from the UMK Mine, at the end of the simulation at year 100. Please note that this is SO4 concentration resulting from the WRD/backfill load/deposition, which is added to the general water chemistry. The predicted contamination plume at this maximum extent could impact on boreholes JB9 and 12, RP26, 21 and 40 as well as SP30, with sulphate concentrations of up to 1 631 mg/ℓ. These are however all UMK prospecting and monitoring boreholes. The predicted contamination plume is therefore not expected to impact on third party water users. When considered incrementally this has a low severity in the unmitigated and mitigated scenarios.

Table 12: Max. extent of contaminant plume

Year	Max extent of plume, m
Year 32	893
Year 100	1,700

The cumulative severity rating assessing the impact of the changes to the operation within the context of the approved mining operations is low in the unmitigated scenario because the migration of the pollution plume is not expected to impact on third party water users.

Duration

Groundwater contamination is long term in nature, occurring for periods longer than the life of mine in both the unmitigated and mitigated scenarios.

Spatial scale / extent

The pollution plume will extend beyond the mining area in both the unmitigated and mitigated scenarios.

Consequence

The consequence is moderate in the unmitigated and mitigated scenarios.

Probability

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

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

The first element is that contamination reaches the groundwater resources underneath or adjacent to the mining area. Pollution plume modelling shows that contaminants could reach groundwater resources.

The second element is that third parties and/or livestock use this contaminated water for drinking purposes. There are no known third party water users located within the predicted contaminant plume.

The third element is whether contamination is at concentrations which are harmful to users. Based on predicted groundwater modelling, mine related contamination could be at relatively high concentrations for a small area to the north of the mining right area.

As a combination, the unmitigated probability is high, and low with mitigation.

Significance

The unmitigated and mitigated scenario significance are medium and low, respectively.

Management objective

The objective is to prevent pollution of groundwater resources and related harm to other water users.

Management actions

UMK will continue to implement the following management actions:

- UMK will update the hydrocensus to check for any new third party water uses prior to initiating activities associated with the proposed surface infrastructural changes.
- UMK should continue groundwater monitoring per existing monitoring protocols for the existing monitoring network, taking note of recommendation made in section 6.3.
- All potentially affected boreholes will be included in the water monitoring programme for boreholes located both on and off the mine site.
- If any mine related loss of water supply through a reduction in quality is experienced by third party borehole users, UMK will provide compensation which could include an alternative water supply of equivalent water quality.
- Should any off-site contamination be detected, the mine will immediately notify DWS. The mine, in consultation with DWS and an appropriately qualified person, will then notify potentially affected users, identify the source of contamination, identify measures for the prevention of this contamination (in the short term and the long term) and then implement these measures.
- At decommissioning, the potential pollution sources (residual waste rock left on surface) will either be removed or rehabilitated to manage rainfall and seepage.
- The environmental manager is responsible for implementing these actions from prior to construction through to closure.

6.3 GROUNDWATER MONITORING NETWORK

Figure 18 shows the positions of historical monitoring boreholes (pre-2017) and the positions of monitoring boreholes drilled in 2017 (as recommended by SLR).

It can be noted that 7 (seven) monitoring boreholes will be mined out or covered by the proposed WRD.

In order to replace the monitoring boreholes which will be decommissioned and to augment the monitoring network with sufficient coverage permit early detection and monitoring outside the proposed WRD, SLR recommends drilling of 7 (seven) monitoring boreholes – at locations as shown in Figure 18 and detailed in Table 13

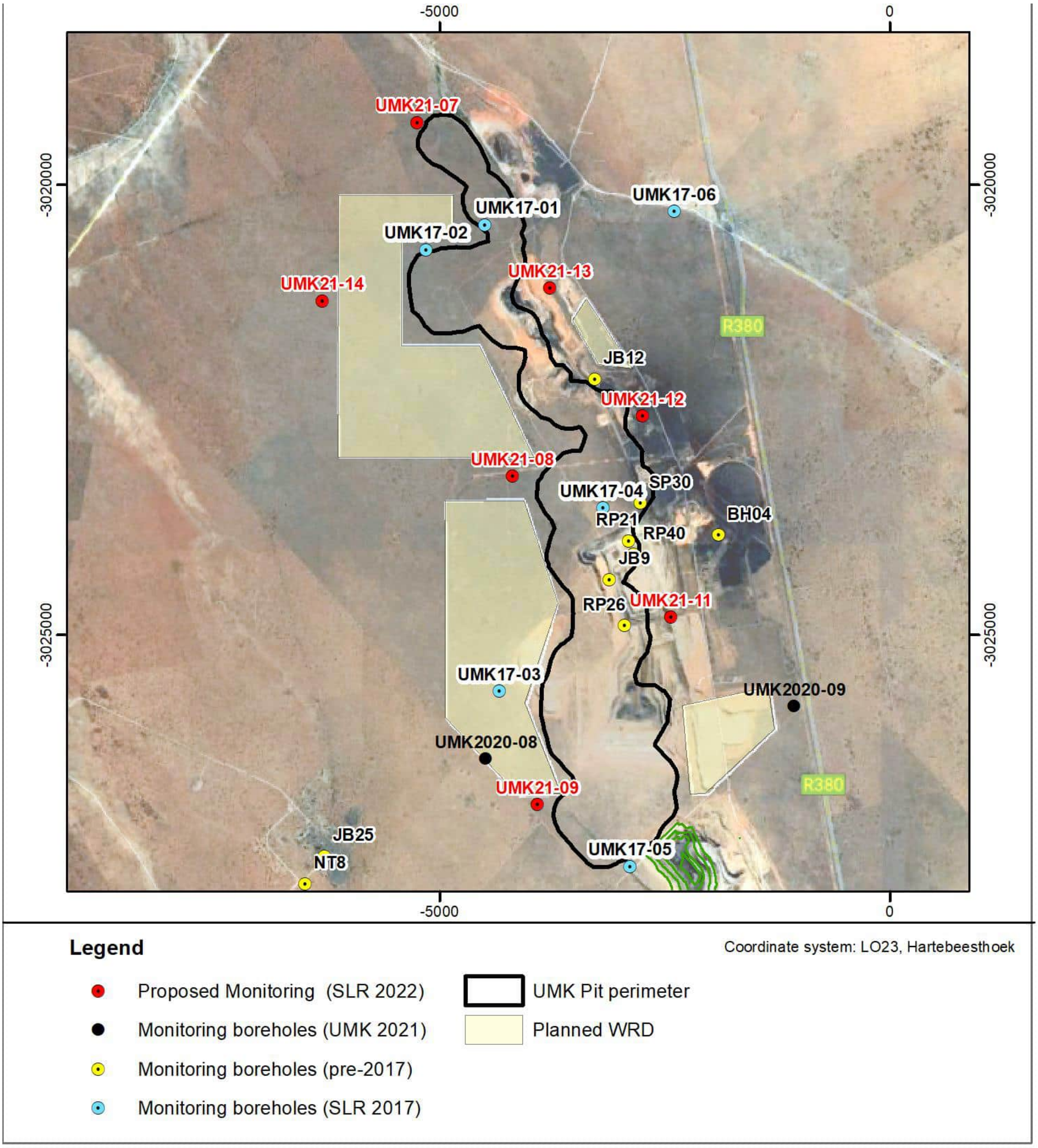

Figure 18: Positions of existing and proposed monitoring boreholes.

Table 13: Coordinates for proposed monitoring boreholes

	Proposed Name	X, m	Y, m	Proposed depth, m
1	UMK21-07	-5246.43	-3019303.36	100
2	UMK21-08	-4191.92	-3023234.74	150
3	UMK21-09	-3915.54	-3026888.11	75
4	UMK21-11	-2428.71	-3024802.79	150
5	UMK21-12	-2744.47	-3022567.29	150
6	UMK21-13	-3776.68	-3021145.88	100
7	UMK21-14	-6299.08	-3021287.46	50

Please note that these positions must be verified on site and moved accordingly to the site situation.

6.4 HYDROGEOLOGICAL SPECIALIST RECOMMENDATION

Based on the findings of the hydrogeological study, no fatal flaws have been identified that may limit the proposed activities. It is the opinion of the specialist that the proposed project may proceed on condition that all mitigation measures as outlined and discussed in this report be adhered to.

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Arnold Bittner (Reviewer)

7. REFERENCES

APPENDIX A: SPECIALIST CURRICULUM VITAE

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