ENVIRONMENTAL IMPACT MANAGEMENT SERVICES

HYDROGEOLOGICAL ASSESSMENT FOR THE PROPOSED GOLD RECLAMATION FROM THE KHUSASALEKA AND DEELKRAAL TAILINGS FACILITIES AND THE REDEPOSITION ON A NEW TAILINGS STORAGE FACILITY

FINAL REPORT

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SPECIALIST DECLARATION

This report has been drafted as per the latest requirements for specialist reports as set by the Department of Environmental Affairs and listed in the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) Environmental Impact Assessment Regulations (2014 as amended). As per Government Gazette No. 40713, dated 24 March 2017 and Government Gazette No. 40772 dated 07 April 2017 in terms of the NEMA.

I, Dr. Marius van Biljon, hereby 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 Act, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other 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; and
- I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 49A of the Act.

A signed specialist declaration and specialist curriculum vitae is attached in **Appendix A.**

EXECUTIVE SUMMARY

The proposed West Wits Reclamation and Deposition Project will reclaim the existing Deelkraal and Kusasalethu tailings storage facilities (TSF) and deposit reprocessed material at the approximately 430 ha Deelkraal II facility. Reclamation can reduce legacy groundwater contamination over time, but the new TSF and return water dam require effective containment. The unlined scenario predicts that the >500 mg/L sulphate plume reaches the sensitive dolomite aquifer within 50 years.

The groundwater system includes shallow weathered and deeper fractured aquifers and the regional Malmani dolomitic aquifer. Groundwater generally flows northwards at Deelkraal and southwards at Kusasalethu. Low bulk permeability limits regional flow, but fractures and dykes may provide preferential pathways. Monitoring gaps prevent a definitive assessment of groundwater quality within the dolomite.

September 2025 monitoring confirms contamination near the existing waste facilities. At Deelkraal, sulphate reaches 3 101 mg/L and manganese 44.8 mg/L in the deeper TSF borehole. Several Kusasalethu boreholes exceed the listed Water Use License (WUL) values for sulphate, salinity or manganese. The available data do not demonstrate mine-related contamination at sampled private boreholes, but microbiological exceedances occur at six Kusasalethu hydrocensus points. Nickel at MBH5 and aluminium, iron and manganese at the sampled Deelkraal-area dam exceed the chemical comparison values shown in the report.

The FEFLOW scenarios predict declining sulphate concentrations after removal of the existing tailings sources. For Deelkraal II, the lined scenario predicts substantially less migration than the unlined scenario, conditional on leakage of 6 L/ha/day and an assumed sulphate source concentration of 1 500 mg/L. Neither parameter is established here by full-scale performance evidence. Improved processing alone does not demonstrate reduced contaminant release.

Priorities are to verify the reprocessed-tailings source term, confirm the containment design, reconcile the model with the final footprint and operating sequence, and strengthen monitoring north and south of Deelkraal II and at the dolomite contact. Defined early-warning levels and response actions are needed for seepage, pipeline incidents and adverse water-quality trends. Monitoring should continue through closure until agreed recovery criteria are achieved.

The findings support a contained and monitored development subject to these measures. They do not justify omitting a liner or guaranteeing that receptors will remain unaffected. Calibration statistics have been corrected, but forecast confidence remains limited by source assumptions, parameter uncertainty, incomplete monitoring and the absence of independent validation. Final impact ratings should reflect these limitations and the long-term sensitivity of the dolomite aquifer.

The report was independently reviewed by Dr. Rainier Dennis from Quantophi (Pty) Ltd. A copy of the review document is attached as Appendix B and issues highlighted in this review was corrected and updated in this Revision 3 report.

REASONED OPINION

Based on the findings of this hydrogeological assessment, it is my reasoned opinion that the proposed Reclamation Project may be authorised from a groundwater perspective, provided that the recommended avoidance, management, mitigation and monitoring measures are implemented through the Environmental Management Programme and, where applicable, incorporated into the closure plan.

The hydrogeological findings support further development of a contained, monitored reclamation and deposition scheme. They do not support an unlined facility or an unconditional assurance of no receptor impact. Final design and authorisation decisions should be based on verified source terms, an approved containment design and a monitoring programme capable of detecting migration before sensitive receptors are affected.

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ABBREVIATIONS

Abbreviation	Description
Al	Aluminium
BH	Borehole
Ca	Calcium
CI	Cumulative impact
Cl	Chloride
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EAP	Environmental Assessment Practitioner
EC	Electrical conductivity
EIMS	Environmental Impact Management Services
Fe	Iron
GQM	Groundwater Quality Management
GRA II	Groundwater Resource Assessment Phase II
ha	Hectare
K	Potassium
km	Kilometre
L/ha/day	Litres per hectare per day
LC	Leachable concentration
LCT	Leachable concentration threshold
LOM	Life of mine
LR	Irreplaceable loss of resources
MALK	Methyl orange alkalinity
mamsl	Metres above mean sea level
MAP	Mean annual precipitation
mbc	Metres below collar
ME	Mean error
Mg	Magnesium
mg/L	Milligrams per litre
Mn	Manganese
Na	Sodium
NEMA	National Environmental Management Act
NGA	National Groundwater Archive
NH4	Ammonium
NO3	Nitrate
PDF	Portable Document Format
PF	Prioritisation factor

Abbreviation	Description
PhD	Doctor of Philosophy
PO4	Orthophosphate
Pr. Sci. Nat.	Professional Natural Scientist
RMS	Root mean square
RWD	Return water dam
SO4	Sulphate
SWL	Static water level
TC	Total concentration
TCT	Total concentration threshold
TDS	Total dissolved solids
tpm	Tonnes per month
TSF	Tailings storage facility
WRD	Waste rock dump
WUL	Water Use Licence
WWR	West Wits Reclamation

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1. INTRODUCTION AND TERMS OF REFERENCE

1.1 Project Description

Randfontein Estates Limited (a subsidiary of Harmony Gold Mining Company) (hereafter referred to as the applicant) has appointed Environmental Impact Management Services (Pty) Ltd (EIMS) as the Environmental Assessment Practitioner (EAP) to assist with undertaking the required authorisation processes and to compile and submit the required documentation in support of application for the proposed new Deelkraal II Tailings Storage Facility (TSF) project and associated infrastructure on a site located approximately 13km southwest of Carletonville in the Merafong City Local Municipality, West Rand District Municipality, Gauteng Province (i.e. the Proposed Harmony West Wits Reclamation and Deposition Project).

The Applicant requires additional deposition capacity for West Wits region's operations. The applicant plans on constructing the Deelkraal II Tailings Storage Facility (TSF) to cater for the additional future capacity. This TSF will receive residue from Kusasalethu, and Savuka plants and will also assist in returning process water for reclaiming the existing Deelkraal 1 TSF and Kusasalethu TSF for processing at Kusasalethu plant. Additional planned infrastructure includes slurry, potable, sewage and return water pipelines, access roads, pump stations, a return water dam and a power line. Proposed upgrades to the existing Kusasalethu plant are also proposed as part of the project.

The Savuka Plant treats tailings from the Savuka Dormant TSFs (Old North TSFs) at a rate of 330 000 tpm and deposits the subsequent tailings on Savuka 5 & 7 TSFs. Harmony plans on remining Deelkraal 1 Dormant TSF and Kusasalethu TSF amongst other potential future sources. These TSFs will be processed through the Kusasalethu Plant at 500 000 tpm. The planned Life of Mine (LOM) for the West Wits region exceed the available deposition capacity of the existing TSFs. Therefore, additional depsotion capacity is required.

The Kusasalethu Plant will accommodate future reclamation operations and will therefore need site/s to deposit the tailings. Harmony owns ground, located adjacent to the Deelkraal 1 Dormant TSF, that can be used i.e. for the proposed Deelkraal II TSF. The Deelkraal 1 Dromant TSF and adjacent virgin ground footprint combined geometry will accommodate the future reclamation operations deposition rate and capacity. The proposed TSF will cover an area of approximately 430 ha.

The West Wits Reclamation (WWR) Concept Study explores ways to unlock the potential of recycling historic gold tailings using the existing Kusasalethu and Savuka process plants and infrastructure. The Concept Study (SGS Bateman, 2024) evaluated different options for the treatment of the Deelkraal 1 and Kusasalethu

Tailings Storage Facilities (TSF) at the existing processing plants. The reworked tailings will be deposited on a new TSF, referred to as Deelkraal II, assumed to be constructed on a site adjacent to the existing Deelkraal TSF. While reviewing the preliminary metallurgy testwork results it became evident that the Deelkraal TSF contained higher grades of accessible gold and it was agreed that that TSF would be reclaimed first, with the Kusasalethu TSF being reclaimed thereafter (SGS Bateman, 2024).

2. GEOGRAPHICAL SETTING

2.1 Site Locality

The Kusasalethu and Deelkraal operations lie southwest of Carletonville in Gauteng (Figure 2.1). The proposed Deelkraal II site is approximately 13 km from Carletonville. The operations are collectively managed as Kusasalethu Mine; the Deelkraal mining operations have been decommissioned.

The Kusasalethu TSF is less than 1 km south of the Kusasalethu Mine Plant. Between the plant and the TSF is a quartzite ridge. The TSF lies on the southern foot slope of the ridge, which has a gentle gradient of approximately 4° to the south.

The Deelkraal TSF lies approximately 7 km west of the Kusasalethu TSF, consistent with the borehole coordinates in Table 4.5. The terrain around Deelkraal is relatively flat and slopes gently northwards.

The site infrastructure and proposed slurry pipelines are shown in Figure 2.2.

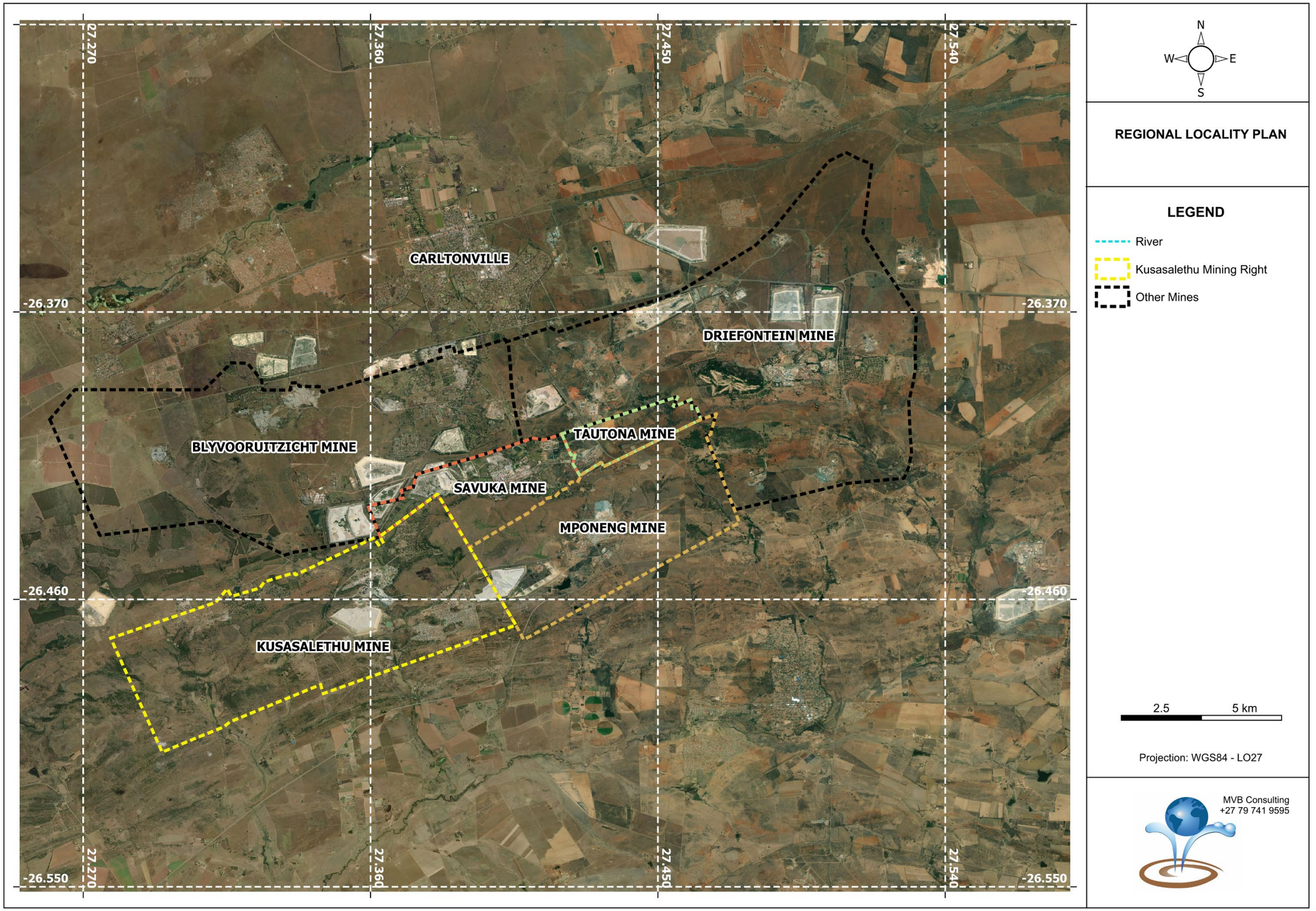
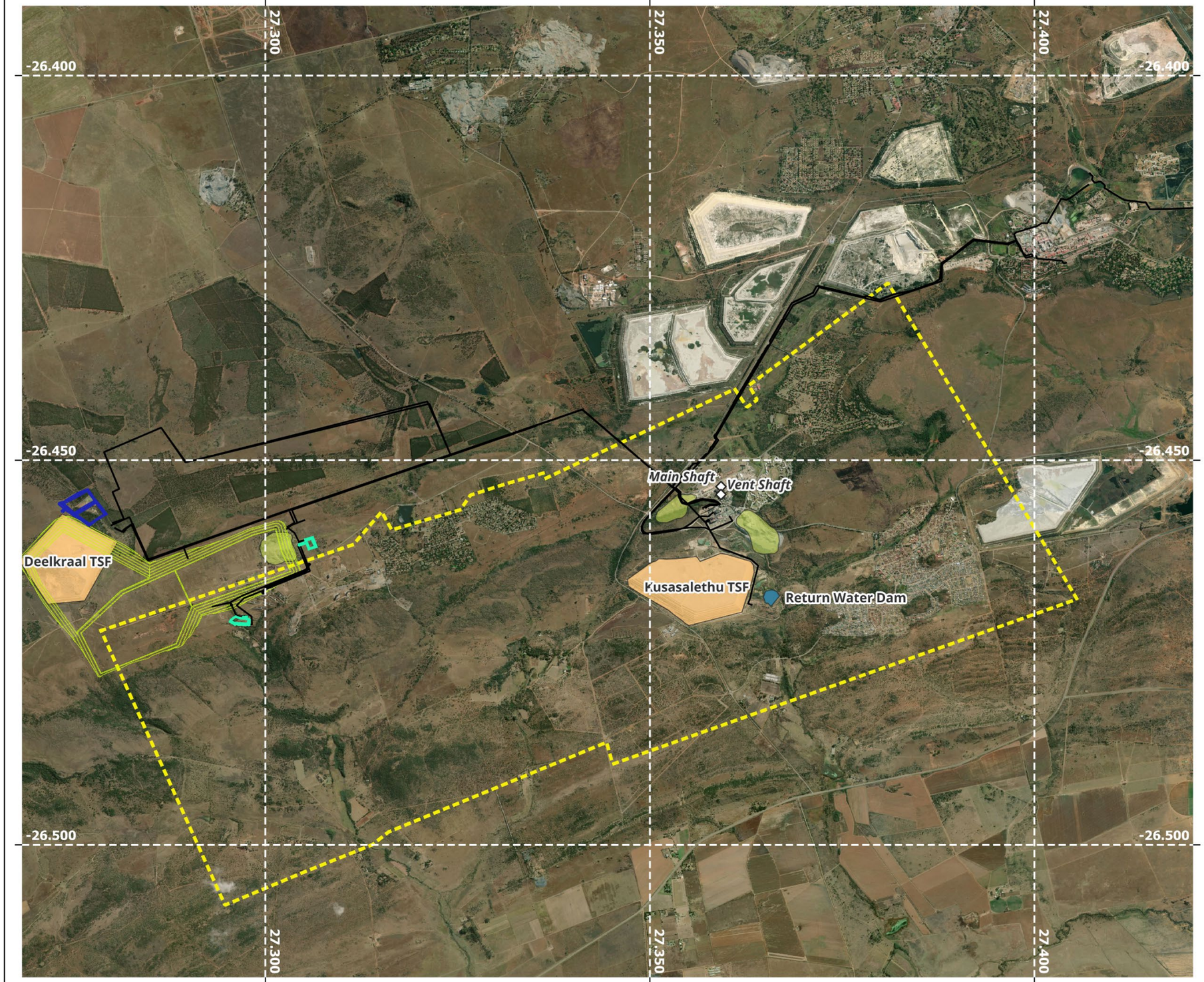


Figure 2.1: Regional locality of the study area



N
W E
S

SITE LAYOUT PLAN

LEGEND

- Kusasalethu Shafts
- Pipelines
- Proposed Deelkraal II TSF
- Proposed Deelkraal RWD
- Lined Emergency Sumps
- Tailings Facility
- Current WRD
- Return Water Dam
- Kusasalethu Mining Right

1.5 3 km

Projection: WGS84 - LO27

MVB Consulting
+27 79 741 9595

Figure 2.2: Site layout and infrastructure

2.2 Climate and Rainfall

The area has warm to hot summers and cold, often frosty winter nights. Rain falls mainly during summer thunderstorms. Table 2.1 gives annual station totals of 570 mm for Fochville, 566 mm for Carletonville and 559 mm for Westonaria, with an arithmetic mean of 565 mm/year. The rounded monthly averages total 563 mm/year. The modelling adopts 563 mm/year as its rainfall reference; the small rounding difference does not materially change the quoted recharge percentage.

Table 2.1: Annual rainfall

Station	Fochville	Carletonville	Westonaria	Average
January	115	113	103	**110**
February	90	83	82	**85**
March	80	87	77	**81**
April	37	37	37	**37**
May	10	9	9	**9**
June	0	0	0	**0**
July	0	0	0	**0**
August	1	1	0	**1**
September	11	9	11	**10**
October	57	52	51	**53**
November	78	81	85	**81**
December	91	94	104	**96**

2.3 Topography and Drainage

The study area drains northwards and southwards (Figure 2.3). The Deelkraal and Kusasalethu operations fall within quaternary catchments C23E and C23J, respectively, in the Vaal drainage system.

Drainage from the decommissioned Deelkraal residue deposits is mainly north (Quaternary catchment C23E). Varkenslaagte Spruit, a tributary of the Wonderfontein Spruit, flows westward along the northern boundary of the Harmony property. The Wonderfontein Spruit flows into the Mooi River and eventually into the Vaal River.

Drainage from the operational Kusasalethu residue deposits is mainly south (Quaternary catchment C23J), into the Loop Spruit. The Loop Spruit flows in a westerly direction and joins the Mooi River at Potchefstroom from where it flows to the Vaal River.

The topography changes rapidly over short distances from 1600 metres above sea level (mamsl) at the top of the ridge to 1 560 mamsl at the Varkenslaagte Spruit and 1 420 mamsl in the Loopspruit.

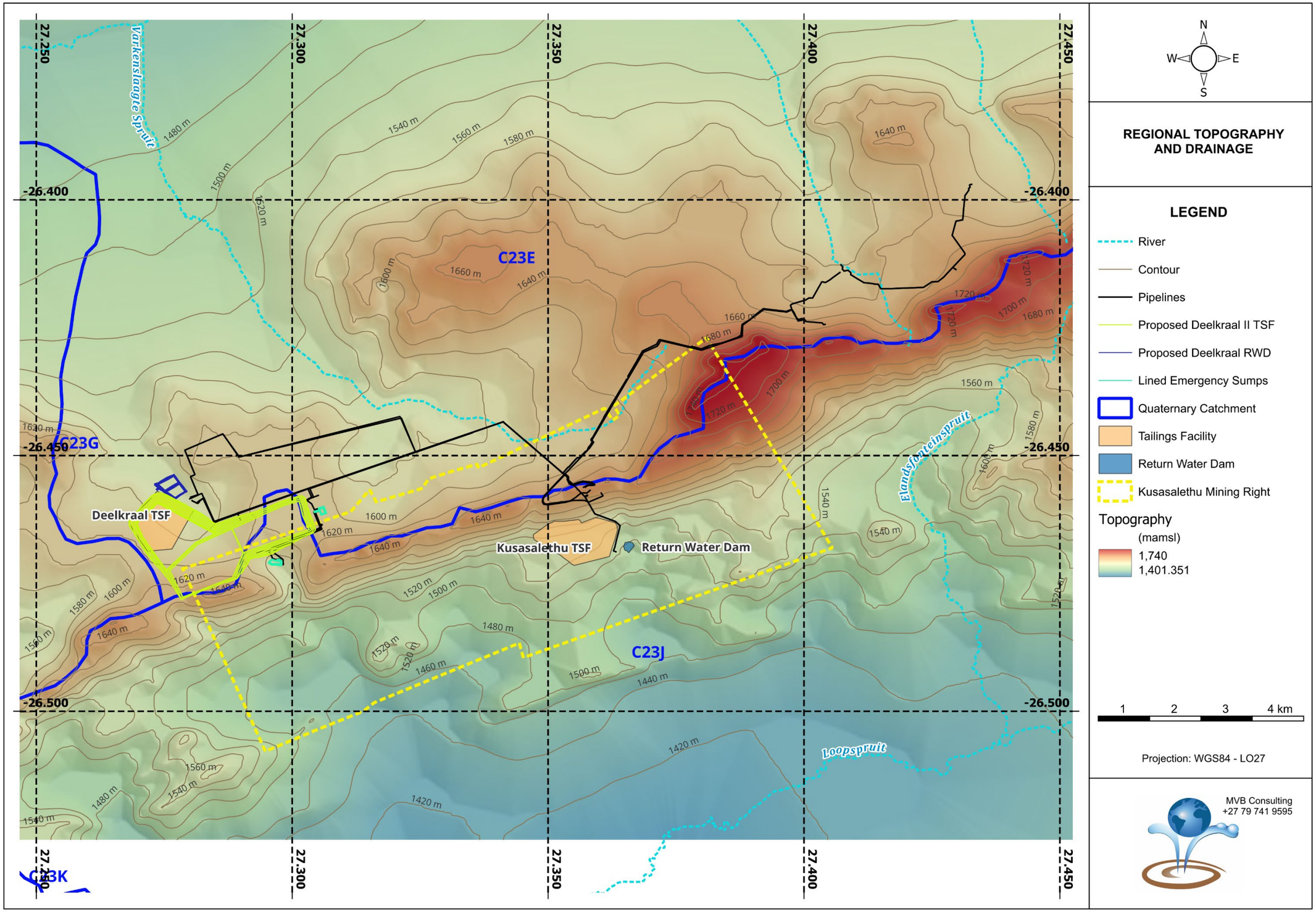


Figure 2.3: Study area topography and drainage

3. SCOPE OF WORK

3.1 Introduction

The assessment characterises the groundwater environment, evaluates existing contamination and predicts the potential effects of reclaiming the existing TSFs and depositing reprocessed tailings at Deelkraal II. It also identifies measures to protect groundwater users, streams and the dolomite aquifer.

3.2 Regional Resource Determination

A key aspect of any groundwater assessment is a thorough understanding of the groundwater resource. The groundwater resource is described according to the following criteria:

- Aquifer boundaries.
- Aquifer type.
- Aquifer parameters.
- Hydrochemistry.
- Aquifer recharge.
- Aquifer classification.

4. METHODOLOGY

4.1 Desk study

The following data sources were consulted to complete the study:

- Analysis and Evaluation of Pumping Test Data (Kruseman and de Ridder, 1990).
- Groundwater Monitoring Assessment Report for Kusasalethu and Deelkraal Operations compiled by Jones and Wagener, 2017.
- Kusasalethu Borehole Drillling Technical Note, compiled by MVB Consulting (2021) Report No: A079_TN01_r1_Kusasalethu_Drilling_Nov2021
- Kusasalethu and Deelkraal Tailings Facilities Feasibility Study for Cut-off Drains to Collect Groundwater Seepage compiled by M van Biljon for Jones & Wagener (2014) Report No: JW038/14/E137-Rev1
- National Groundwater Archive (NGA) Groundwater Level Data (2429CA).
- South African Water Quality Guidelines Volume 4: Agricultural Use: Irrigation and Volume 5: Agricultural Use: Livestock Watering (DWAF, 1996).
- The Groundwater Assessment Project II (GRA II) (DWAF, 2006).
- Vegter Maps (Groundwater Baseflow and Recharge).
- 1: 500 000 Geohydrological Map Series of South Africa.
- 1:250 000 Geological Map Series of South Africa

4.2 Hydrocensus and Borehole Information

Auctus Consulting (Van Biljon, 2011) conducted a hydrocensus within 2 km of the Kusasalethu TSF. The identified private boreholes are shown in Figure 4.1 and summarised in Table 4.1.

The mine subsequently incorporated the hydrocensus boreholes into its monitoring programme, with sampling reported twice a year. Table 4.2 presents the available average chemistry for 2024 (Groundwater Complete, 2025).

The following is concluded in terms of the hydrocensus groundwater quality:

- Table 4.1 identifies nine boreholes as currently monitored, consistent with the nine analytical records in Table 4.2.
- The reported chemical results are generally below the selected drinking-water comparison values. This does not establish potability: microbiological exceedances occur, and the tables do not present a complete drinking-water compliance assessment.
- Most reported chemical results are below the WUL comparison limits listed in this report. Annual averages may conceal individual sampling exceedances and should not be used alone to demonstrate compliance.
- Variations in major-ion concentrations may reflect water–rock interaction, aquifer heterogeneity or mining-related inputs. The data do not isolate the contribution of each source.
- Calcium and magnesium are prominent cations, with bicarbonate alkalinity, sulphate and chloride contributing to the anion composition. A formal hydrochemical facies interpretation should use concentrations converted to milliequivalents per litre.
- The reported microbiological results exceed the stated comparison values at HYD2, HYD3, HYD11, HYD12, HYD13 and HYD14. E. coli is reported at all of these except HYD3, which exceeds the total-coliform value. These results require prompt follow-up at water supplies used for domestic purposes.

The Deelkraal hydrocensus identified seven boreholes, including three dry boreholes, and a fountain east of the existing TSF (Figure 4.2 and Table 4.3). The survey extended south of the proposed footprint to identify potential receptors. Remnants of illegal mining were observed near the fountain (Photo 1).

Water samples were collected from the boreholes, as well as from the fountain and from one of two dams downgradient from the proposed TSF.

The hydrocensus information is summarised in Table 4.3 and the groundwater chemistry is shown in Table 4.4.

Against the comparison values printed in Table 4.4, nickel in MBH5 is elevated at 0.094 mg/L, exceeding 0.07 mg/L. In Dam 2 (MSW2), aluminium (0.666 mg/L), iron (3.790 mg/L) and manganese (0.675 mg/L) exceed their listed values of 0.3, 2 and 0.4 mg/L, respectively. The other reported borehole results are below the listed values. The table presents selected chemical limits and excludes microbiological results; it therefore does not demonstrate drinking-water suitability.

The fountain sample is below all comparison values listed in Table 4.4. This finding is limited to the sampled chemical parameters and does not establish microbiological safety or year-round water quality.

Table 4.4 uses selected 2015 comparison values; it omits the lower aesthetic values for iron (0.3 mg/L) and manganese (0.1 mg/L). MBH2 and MBH5 also exceed the

2015 iron aesthetic value. A full drinking-water assessment requires the applicable standard and microbiological testing.



Photo 1: Photograph of fountain

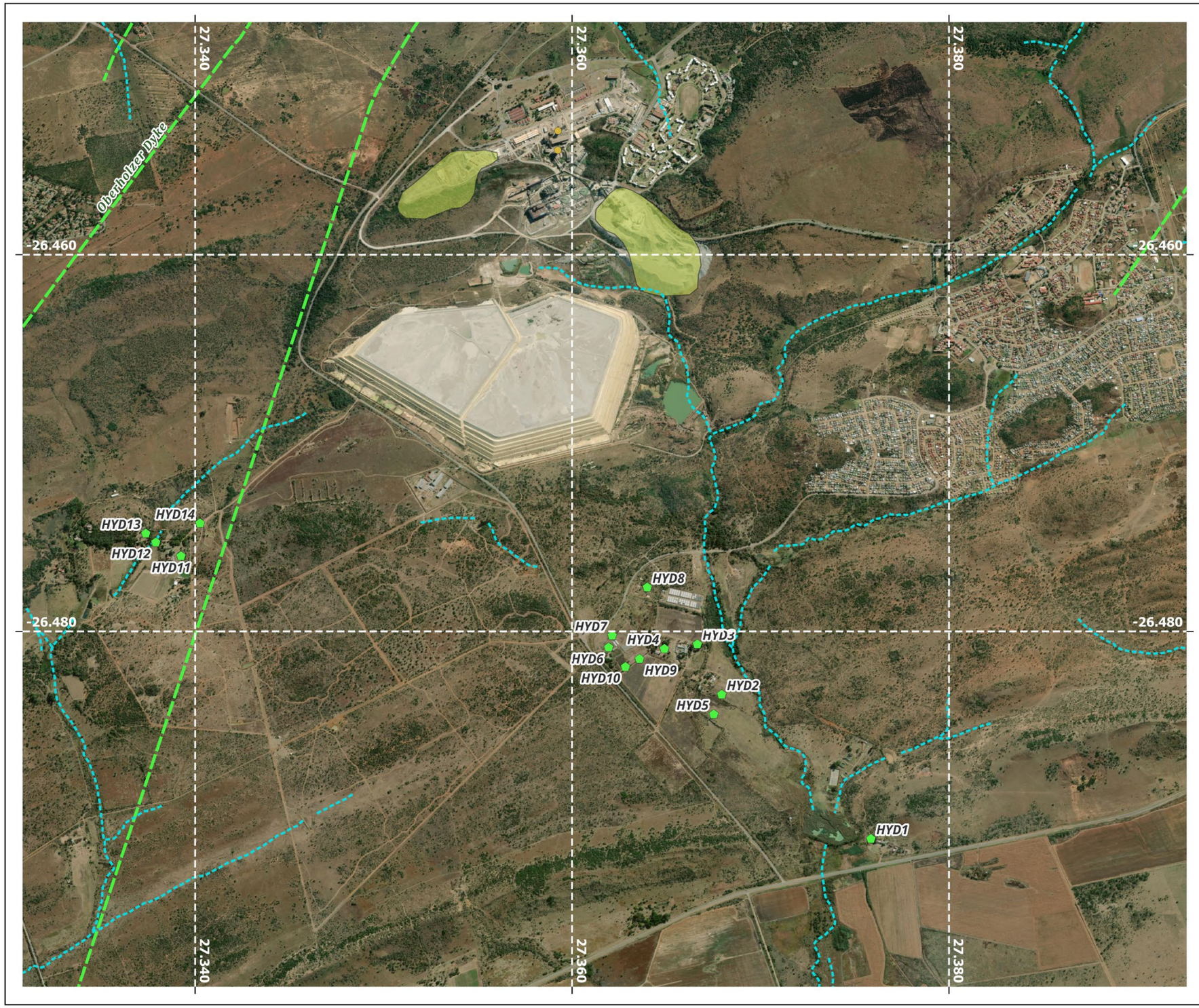


Figure 4.1: Hydrocensus borehole locality – Kusasalethu area

Table 4.1: Hydrocensus boreholes – Kusasalethu area

BH ID	Longitude	Latitude	Z	SWL (mbc)	BH Depth (m)	Owner	Tel No.	BH Use	Volume Abstracted (Lit/day)	Comments	Current Monitoring
HYD1	27.37586	-26.491	1453	No access	Unknown	Hugo	071 678 5904	Domestic	Unknown	Electric pump	**Yes**
HYD2	27.36794	-26.4834	1462	5.46	18	A J Nel	082 857 5259	Domestic	2500	Electric pump.	**Yes**
HYD3	27.36665	-26.4807	1473	3.92	50	J P Cronje	082 463 1761	Domestic / Livestock	5000	Electric pump.	**Yes**
HYD4	27.3649	-26.4809	1481	9.92	48.15	J P Cronje	082 463 1761	Not used	0	Open BH.	**Blocked**
HYD5	27.36752	-26.4844	1477	5.21	39.52	J P Cronje	082 463 1761	Not used	0	Open BH.	**Demolished**
HYD6	27.36194	-26.4809	1489	19.69	Unknown	Wadela Agricultural Project		Not used	0	Electric pump, broken.	**Damaged**
HYD7	27.36213	-26.4802	1488	18.85	Unknown	Wadela Agricultural Project		Not used	0	Windmill, broken.	**Yes**
HYD8	27.36399	-26.4777	1490	11.57	Unknown	Wadela Agricultural Project		Not used	0	Electric pump, broken.	**Yes**
HYD9	27.36358	-26.4815	1479	17.29	40.93	Wadela Agricultural Project		Not used	0	Open BH.	**Blocked**
HYD10	27.36283	-26.4819	1479	18.62	Unknown	Wadela Agricultural Project		Domestic / Livestock	Unknown	Electric pump.	**Demolished**
HYD11	27.33925	-26.476	1515	No access	70	DD Modibedi	082 960 4692	Domestic / Livestock	5000	Mono pump	**Yes**
HYD12	27.33791	-26.4753	1504	1.68	28.71	DD Modibedi	082 960 4692	Not used	0	Open BH.	**Yes**
HYD13	27.33738	-26.4748	1507	17.28	30	VRD Williams	082 717 5573	Domestic / Livestock	5000	Electric pump	**Yes**
HYD14	27.34026	-26.4743	1524	9.97	17.84	J P Cronje	082 463 1761	Not used	0	Windmill, broken.	**Yes**

Table 4.2: Hydrocensus groundwater chemistry (Groundwater Complete, 2025)

BH	pH	EC mS/m	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	MALK CaCO3/l	Cl mg/l	SO4 mg/l	NO3 mg/l	F mg/l	Al mg/l	Fe mg/l	Mn mg/l
HYD1	7.9	75.3	554.0	65.3	37.1	52.1	0.7	240.4	65.8	69.8	0.9	<0.466	<0.002	<0.009	0.016
HYD2	7.6	71.8	522.0	71.1	41.0	16.7	1.0	111.8	59.3	157.9	5.1	0.427	<0.002	<0.009	0.008
HYD3	8.2	76.0	646.0	81.3	49.8	28.0	0.4	160.7	83.4	174.0	1.9	<0.466	<0.002	<0.009	0.001
HYD7	7.9	53.4	420.0	49.3	32.2	26.5	1.5	168.8	47.9	56.3	1.1	<0.466	<0.002	<0.009	<0.001
HYD8	8.2	82.1	594.0	88.2	49.8	27.3	0.9	289.6	48.2	81.7	3.6	<0.466	<0.002	<0.009	<0.001
HYD11	7.1	38.0	300.0	31.3	14.3	19.7	1.6	34.2	79.1	33.1	<0.194	0.446	0.213	<0.009	<0.001
HYD12	6.6	23.1	158.0	15.4	13.9	7.4	0.3	26.1	54.2	0.2	0.5	0.252	<0.002	<0.009	0.282
HYD13	6.5	3.8	18.0	3.5	2.3	1.1	0.1	16.6	0.7	<0.452	0.5	<0.466	0.004	<0.009	0.007
HYD14	8.0	45.2	298.0	66.9	14.4	11.3	0.9	161.5	30.7	27.6	0.5	0.285	<0.002	<0.009	0.057

BH	NH4 mg/l	Thard mg/l	B mg/l	Ba mg/l	Cd mg/l	Co mg/l	Cr mg/l	Cu mg/l	Ni mg/l	Pb mg/l	U mg/l	V mg/l	Zn mg/l	T.coli / 100ml	E.coli / 100ml
HYD1	0.036	315.9	0.047	0.035	<0.002	<0.003	<0.007	<0.005	<0.005	<0.009	<0.015	0.045	<0.005	3	0
HYD2	<0.008	346.1	<0.013	<0.002	<0.002	0.016	<0.007	0.020	<0.005	<0.009	<0.015	<0.002	0.024	**47000**	**11000**
HYD3	0.071	408.0	<0.013	0.004	<0.002	0.018	<0.007	<0.005	<0.005	<0.009	<0.015	0.002	0.028	**13**	0
HYD7	0.169	255.8	<0.013	<0.002	<0.002	<0.003	<0.007	0.012	<0.005	<0.009	<0.015	0.025	<0.005	0	0
HYD8	0.028	425.5	-	-	<0.002	<0.003	<0.007	<0.005	<0.005	<0.009	<0.015	-	0.039	0	0
HYD11	0.099	137.3	<0.013	0.064	<0.002	<0.003	<0.007	<0.005	<0.005	<0.009	<0.015	0.020	<0.005	**370**	**170**
HYD12	0.015	95.7	<0.013	0.004	<0.002	<0.003	<0.007	<0.005	<0.005	<0.009	<0.015	0.021	0.013	**61**	**8**
HYD13	0.025	18.2	<0.013	<0.002	<0.002	<0.003	<0.007	<0.005	<0.005	<0.009	<0.015	0.004	0.014	1	**1**
HYD14	0.067	226.6	<0.013	0.010	<0.002	<0.003	<0.007	<0.005	<0.005	<0.009	<0.015	0.022	0.003	**244**	**9**

- *Red – Value exceeds SANS 241 drinking water limit.*
- *Maximum Total Coliform (T. coli) count allowed in drinking water is 10 per 100 ml (SANS 241:2015).*
- *No E. coli should be present in drinking water (SANS 241:2015).*

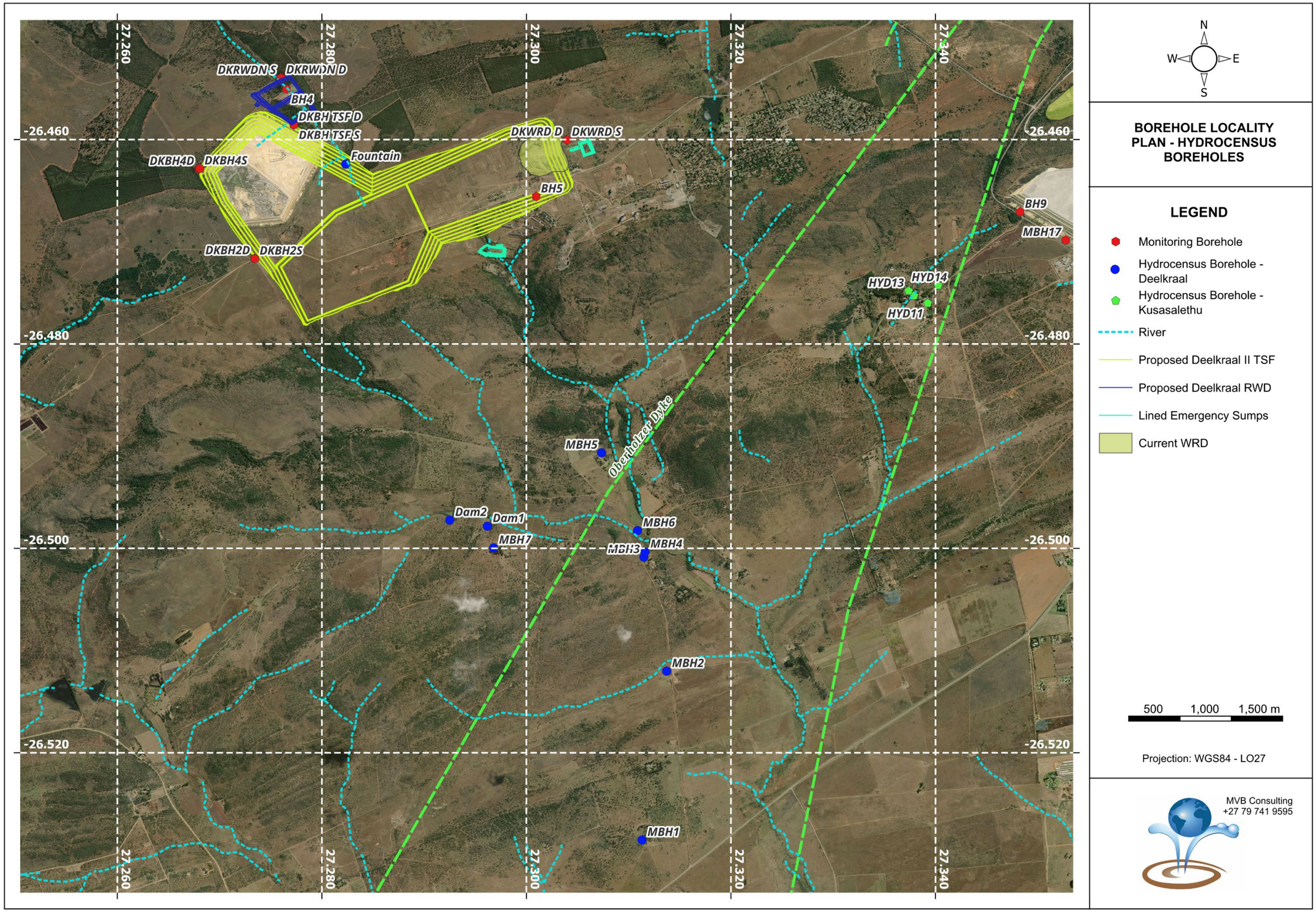


Figure 4.2: Hydrocensus borehole locality – Deelkraal area

Table 4.3: Hydrocensus boreholes – Deelkraal area

Borehole ID	Coordinates			Owner	Bore Depth	Borehole Use and Abstraction		Hydrogeological information	
	Latitude	Longitude	Elevation			Primary Use	Abstraction Rate	Static Water Level	
			[mamsl]		[m]	[-]	[L/s]	[mbgl]	[mamsl]
MBH1	-26.528537	27.311375	1430.94	Unknown	20.5	Dry	Dry	-	-
MBH2	-26.512012	27.313774	1433.81	Pieter	25.42	Agricultural	0.019	25.12	1408.69
MBH3	-26.500856	27.311551	1454.39	Elaine	10	Domestic	0.34	9.88	1444.51
MBH4	-26.500348	27.311662	1445.00	Unknown)	Unknown	Dry	Dry	-	-
MBH5	-26.490646	27.307413	1464.16	Willem	15	Agricultural	0.23	14.77	1449.39
MBH6	-26.498257	27.310941	1443.67	Unknown	Unknown	Dry	Dry	-	-
MFS (Fountain)	-26.462401	27.282395	1567.30	Unknown	Fountain	Not in use	Unknown	0.00	1567.30
MBH7	-26.499948	27.296855	1470.72	Tinus	21	Agricultural	0.46	20.79	1449.93
MSW2 (Dam 2)	-26.497234	27.292568	1468.27	Tinus	Dam	Agricultural	Unknown	-	-

Table 4.4: Hydrocensus groundwater chemistry – Deelkraal

Analyses in mg/ℓ (Unless specified otherwise)	SANS 241	MBH 2	MBH 3	MBH 5	MBH 7	MFS	MSW 2
pH - Value @ 25 ºC	≥ 5 to ≤ 9.7	8.60	8.30	7.30	7.70	7.40	7.60
Electrical Conductivity in mS/m @ 25°C	≤ 170	19	63	46	38	39	16
Total Dissolved Solids @ 180°C	≤ 1 200	124	364	284	252	270	148
Total Alkalinity as $CaCO_3$	-	96	296	124	184	52	124
Chloride as Cl	≤ 300	4	27	43	9	33	7
Sulphate as SO_4	≤ 500	<2	19	35	6	77	3
Fluoride as F	≤ 1.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate as N	≤ 11	0.30	0.20	0.20	1.30	<0.1	0.10
Ortho Phosphate as P	-	<0.1	<0.1	0.10	<0.1	<0.1	0.10
Free and Saline Ammonia as N	≤ 1.5	0.10	<0.1	<0.1	<0.1	<0.1	0.40
Sodium as Na	≤ 200	7	36	23	21	24	7
Potassium as K	-	0.60	0.80	0.70	0.50	2.80	4.40
Calcium as Ca	-	19	37	36	41	34	20
Magnesium as Mg	-	12	49	26	19	14	7
Aluminium as Al	≤ 0.3	<0.100	<0.100	<0.100	<0.100	<0.100	0.666
Arsenic as As	≤ 0.01	0.001	<0.001	<0.001	0.002	<0.001	0.002
Barium as Ba	≤ 0.7	0.030	0.030	0.120	<0.025	0.050	0.148
Boron as B	≤ 2.4	<0.025	0.228	<0.025	<0.025	<0.025	<0.025
Total Chromium as Cr	≤ 0.05	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Cobalt as Co	-	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Copper as Cu	≤ 2	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron as Fe	≤ 2	1.020	0.054	0.328	<0.025	0.206	3.790
Lead as Pb	≤ 0.01	<0.001	<0.001	0.001	<0.001	<0.001	0.006
Manganese as Mn	≤ 0.4	<0.025	<0.025	0.039	<0.025	0.056	0.675
Mercury as Hg	≤ 0.006	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel as Ni	≤ 0.07	<0.025	<0.025	0.094	<0.025	<0.025	<0.025
Strontium as Sr	-	0.034	0.092	0.136	0.142	0.066	0.052
Uranium as U	≤ 0.03	<0.001	0.004	<0.001	0.001	0.002	<0.001
Zinc as Zn	≤ 5	0.048	<0.025	<0.025	<0.025	<0.025	<0.025

4.3 Borehole Drilling

The mine has an extensive groundwater monitoring network and no additional boreholes were drilled during this investigation. The existing mine monitoring network is summarised in Table 4.5 and shown in Figure 4.3 and Figure 4.4. Boreholes were positioned to investigate seepage from the waste facilities. Differences in identifiers and coordinates between monitoring datasets require reconciliation before the network is used for detailed plume interpretation.

Table 4.5: Mine monitoring boreholes

Monitoring Point	Longitude	Latitude
Deelkraal TSF, RWD and WRD		
DKTSF(S)	27.27727	-26.4585
DKTSF(D)	27.27716	-26.4585
DKRWD(S)	27.27411	-26.4545
DKRWD(D)	27.27449	-26.4544
DKWRD(S)	27.30397	-26.4600
DKWRD(D)	27.30398	-26.4600
DK BH 2(S)	27.27344	-26.47165
DK BH 2(D)	27.27343	-26.47162
DK BH 4(S)	27.26806	-26.46283
DK BH 4(D)	27.26798	-26.46287
BH4	27.27662	-26.4552
BH5	27.30096	-26.46557
Kusasalethu TSF, RWD and WRD		
MBH14	27.36583	-26.4653
MBH15	27.36688	-26.4706
MBH16	27.36178	-26.4715
MBH17	27.35275	-26.4698
BH6	27.35982	-26.4599
BH7	27.36519	-26.4625
BH 8(S)	27.3664	-26.4756
BH 8(D)	27.3664	-26.4765
BH9	27.348	-26.467

Note: (S) denotes a shallow borehole monitoring the weathered aquifer
(D) denotes a deep borehole monitoring the fractured aquifer

4.4 Geophysical survey and results

Magnetic and electrical resistivity surveys informed earlier siting of the mine monitoring boreholes. No additional geophysics were conducted during this investigation.

4.5 Aquifer Testing

Aquifer testing was completed during previous investigations. Constant rate and recovery tests were conducted, and transmissivity and hydraulic conductivity values were estimated for the weathered and fractured aquifer. This is discussed in more detail in Section 5.2.3.

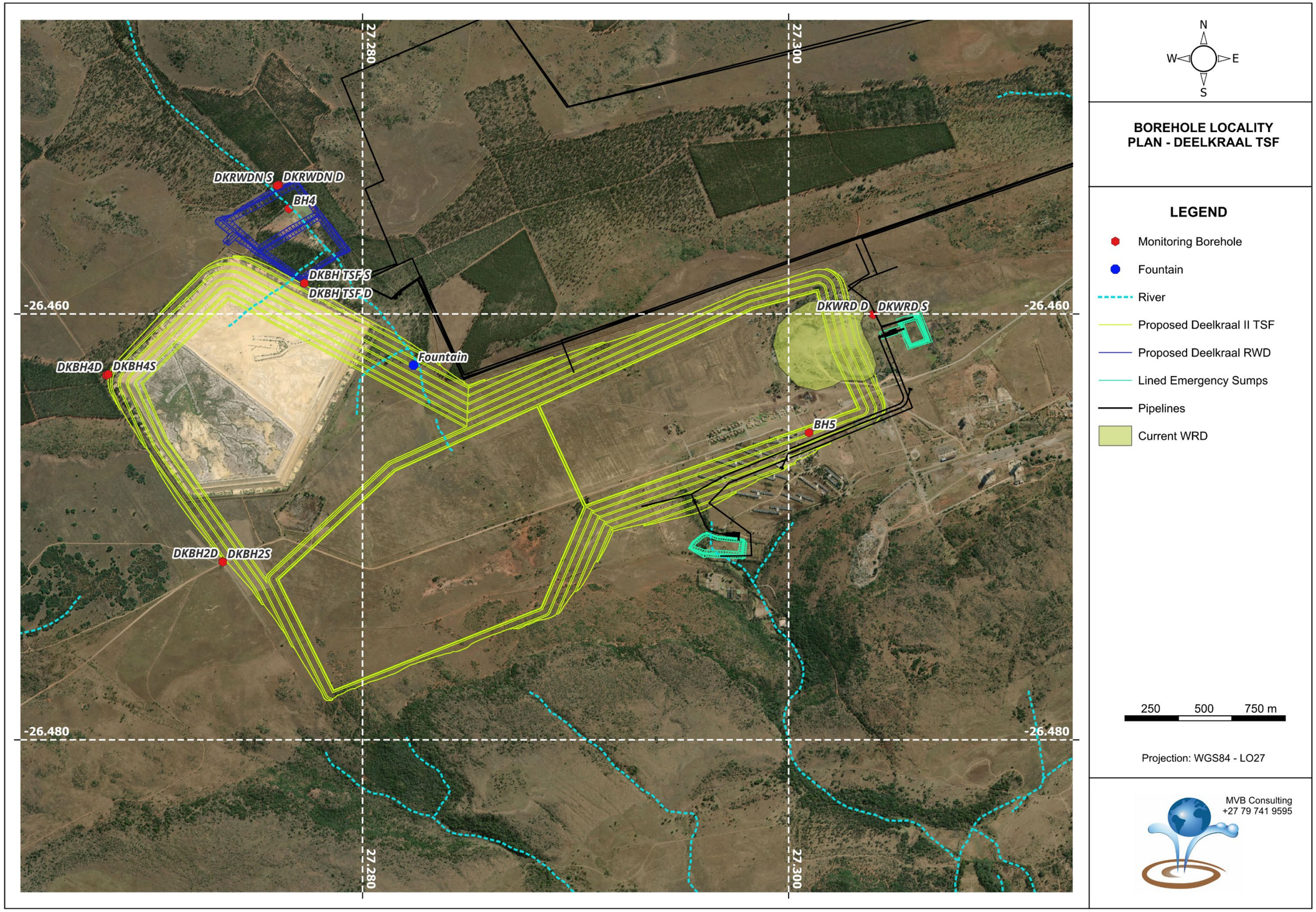


Figure 4.3: Deelkraal TSF monitoring boreholes



Figure 4.4: Kusasalethu Boreholes

4.6 Sampling and Chemical Analysis

Groundwater is sampled routinely from the mine monitoring boreholes. Section 5.2.6 describes potential contaminant sources, and Section 7 evaluates the available monitoring results.

4.7 Groundwater Recharge Calculations

Recharge is defined as the process by which water is added from outside to the zone of saturation of an aquifer, either directly into a formation, or indirectly by way of another formation. Groundwater recharge (R) for the study area was calculated using the chloride method (Bredenkamp et al., 1995) and is expressed as a percentage of the Mean Annual Precipitation (MAP). The method is based on the following equation:

$$\mathrm{R} = \frac{\text{Chloride concentration in rainfall}}{\text{Harmonic mean of Cl concentration in ground water}} \times 100$$

The average chloride in rainfall for areas inland is approximately 0.5 mg/L and the harmonic mean of the chloride concentration values in (uncontaminated) groundwater samples obtained from the mining area is 13.384 mg/L.

$$R = \frac{0.5}{13.4} \times 100 = 3.7\%$$

4.8 Numerical Groundwater Model

A three-dimensional groundwater flow and solute-transport model was constructed using FEFLOW. The model evaluates the potential effects of existing and proposed waste facilities on groundwater quality and downgradient receptors.

- The scenarios consider existing contamination and its evolution over a 50-year simulation period, including source removal and lined and unlined configurations for the new TSF and RWD.

The basic steps involved in modelling can be summarised as:

- Collecting and interpreting field data: Field data are essential to understand the natural system and to specify the investigated groundwater problem. The numerical model develops into a site-specific groundwater model when real field parameters are assigned. The quality of the simulations depends largely on the quality of the input data.
- Calibration compares simulated heads or concentrations with observations and adjusts uncertain parameters within defensible ranges. A good fit constrains the model but does not remove uncertainty or demonstrate a unique parameter set.
- Independent validation requires comparison with observations that were not used in calibration. No separate validation dataset or validation results are presented here. Predictive results should therefore be treated as conditional scenario estimates.
- Modelling scenarios: Alternative scenarios for a given area may be assessed efficiently. When applying numerical models in a predictive sense, limits exist in model application. Predictions of a relative nature are often more useful than those of an absolute nature.

5. PREVAILING GROUNDWATER CONDITIONS

5.1 Regional Geology

Regional geology controls aquifer development and groundwater movement. Figure 5.1 shows the surface geology. The principal geological units are described below.

- Witwatersrand Supergroup.
- Ventersdorp Supergroup.
- Transvaal Supergroup.
- Karoo Supergroup

5.1.1 Witwatersrand Supergroup

The geology of the Witwatersrand Supergroup is well understood and documented as a result of extensive mining and exploratory drilling. Truswell, 1977 describes the geology in the region of the study area.

The development and preservation of the Witwatersrand basin is structurally controlled. The structural patterns control the influx of groundwater into the underground workings and as a result it is important to understand which features act as conduits and which features act as flow barriers. Dykes and sills of at least four different ages have also intruded the Witwatersrand strata. The intrusion of the dykes has often taken place along fault planes. The oldest dykes are usually diabase, representing feeder dykes to the overlying Ventersdorp lavas. There are intrusions of pyroxenite, gabbro and dolerite probably of Bushveld age. A third group belongs to the basic or alkaline dyke swarm related to the Pilanesberg alkaline complex. Finally, the youngest intrusions are of Karoo dolerite.

The Witwatersrand basin is a thick sequence of shale, quartzite and conglomerate. The average dip of the strata is 30° south. There are two main divisions, a lower predominantly argillaceous unit, known as the West Rand Group and an upper unit, composed almost entirely of quartzite and conglomerates, known as the Central Rand Group.

The West Rand Group is divided into three subgroups namely the Hospital Hill, Government Reef and Jeppestown. These rocks comprise mainly shale, but quartzite, banded ironstones, tillite and intercalated lava flows are also present. The rocks were subjected to low - grade metamorphism causing the shale to become more indurated and slaty. The original sandstone was recrystallised to quartzite.

The Central Rand Group is divided into the Johannesburg and Turffontein Subgroups and is composed largely of quartzites, within which there are numerous conglomerate zones. The conglomerate zones may contain any number of conglomerate bands, with individual bands interbedded with quartzite. The upper conglomerates are usually thicker with coarser fragments. An argillaceous zone known as the Booysens Shale (also known as the Kimberley Shale) separates the Johannesburg and Turffontein Subgroups. The economic gold deposits (reefs) are contained within the Central Rand Group.

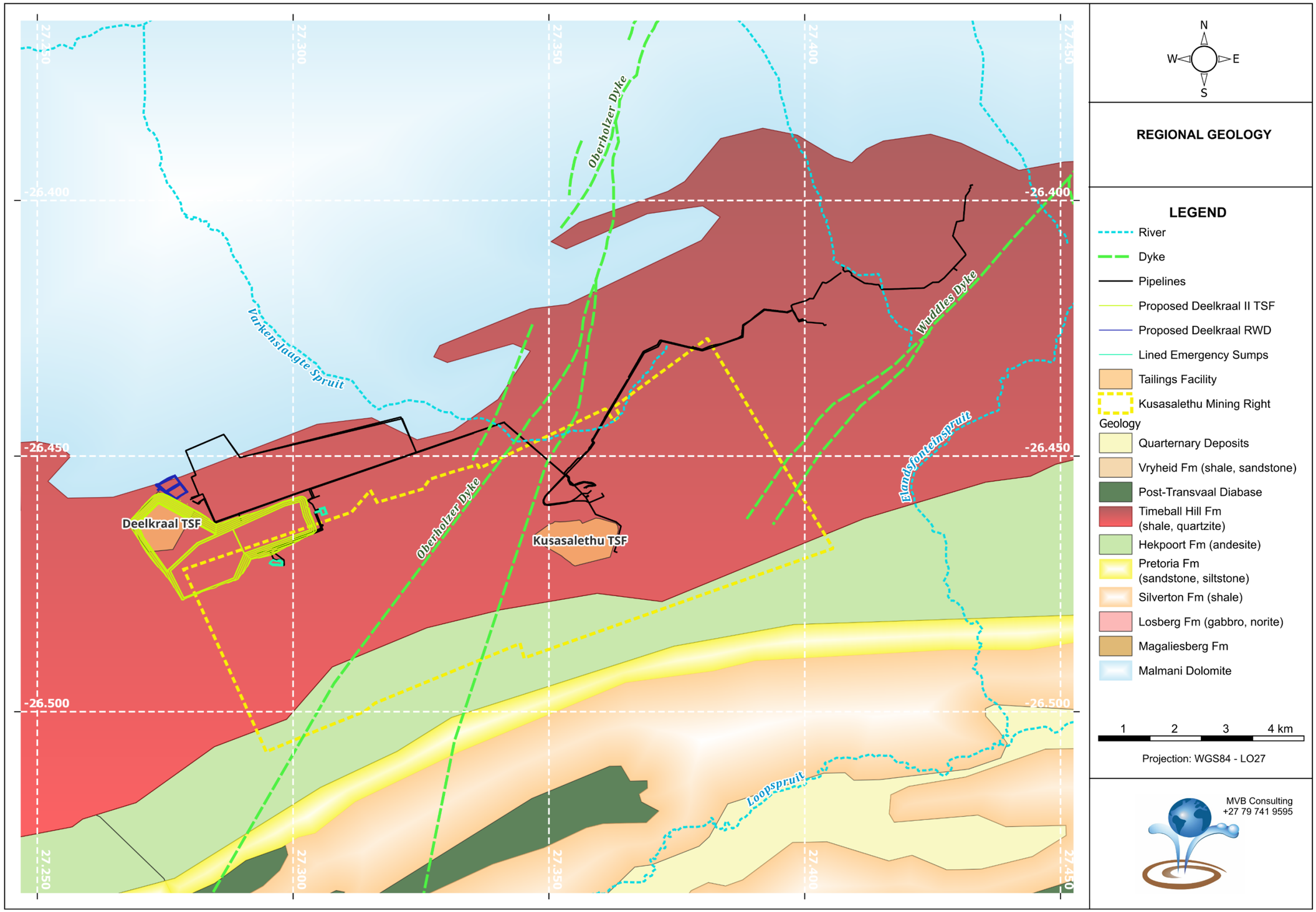


Figure 5.1: Regional surface geology

5.1.2 Ventersdorp Supergroup

The younger Ventersdorp Supergroup overlies the Witwatersrand rocks. Although acid lavas and sedimentary intercalations occur, the Ventersdorp is composed largely of andesitic lavas and related pyroclastics. The Ventersdorp Supergroup consists of the Platberg Group and the Klipriviersberg Group. The Klipriviersberg Group consists of the Alberton and Westonaria Formations.

The Alberton Formation is composed of green – grey amygdaloidal andesitic lavas, agglomerates and tuffs. The thickness amounts to 1500m. The lack of sediments in this sequence indicates a rapid succession of lava flows, which probably came from fissure eruptions. Material of similar composition forms the oldest dykes that have intruded the Witwatersrand rocks. The abundant agglomerates provide indications of periodic explosive activity. The removal of huge volumes of volcanic material from an underlying magma chamber gave rise to tensional conditions and as a result a number of faulted structures, horst and grabens, were formed.

5.1.3 Transvaal Supergroup

Overlying the Ventersdorp Lavas are the Black Reef quartzite and dolomite of the Transvaal Supergroup. The Black Reef quartzite comprises coarse to gritty quartzite with occasional economically exploitable conglomerates (reefs). The entire area was peneplained in post-Ventersdorp time and it was on this surface that the Transvaal Supergroup was deposited, some 2200 million years ago. The deposition commenced with the Kromdraai Member with the Black Reef at its base. The occurrence of the gold is not as widespread as in the Witwatersrand and mainly restricted to north-south trending channels. The Black Reef is overlain by a dark, siliceous quartzite with occasional grits or small pebble bands. The quartzite grades into black carbonaceous shale. The shale then grades into the overlying dolomite through a transition zone of approximately 10m thick.

Malmani Subgroup dolomite of the Chuniespoort Group overlies the Black Reef succession and outcrops approximately 500 m north of the Deelkraal TSF. Faults and dykes influence groundwater compartmentalisation and may act as barriers or preferential pathways. The nearby Boskop–Turffontein dolomitic groundwater system is a sensitive receptor requiring protection from mining-related contamination.

The dolomites are overlain in the south by the Pretoria Group rocks. The Rooihoogte Formation forms the basal member of the Pretoria Group, consisting of the Bevets conglomerate, shale and quartzite. The Bevets conglomerate varies in thickness between 3m and 60m (Parsons and Killick, 1985). Overlying the Bevets conglomerate is shale and sporadically developed quartzite, referred to as the Pologround quartzite. Where developed the Pologround quartzite is overlain by 150m – 200m of pink to purple shales, forming the basis of the Timeball Hill Formation. The shale is overlain by quartzite, which forms the linear north-easterly trending ridges in the south of the study area.

The Kusasalethu surface lease area is predominantly underlain by the sediments of the Pretoria Group. Figure 5.2 shows the near surface relationship between the Pretoria sediments and the Malmani dolomite, particularly as it relates to the localities of the Kusasalethu waste facilities (AGES, 2013). The depth to dolomite at the Deelkraal TSF varies between 80 – 120m. The potential impact on the dolomite aquifer from the mine infrastructure, especially the Deelkraal TSF, is discussed in more detail in Section 7.3.1 of this report.

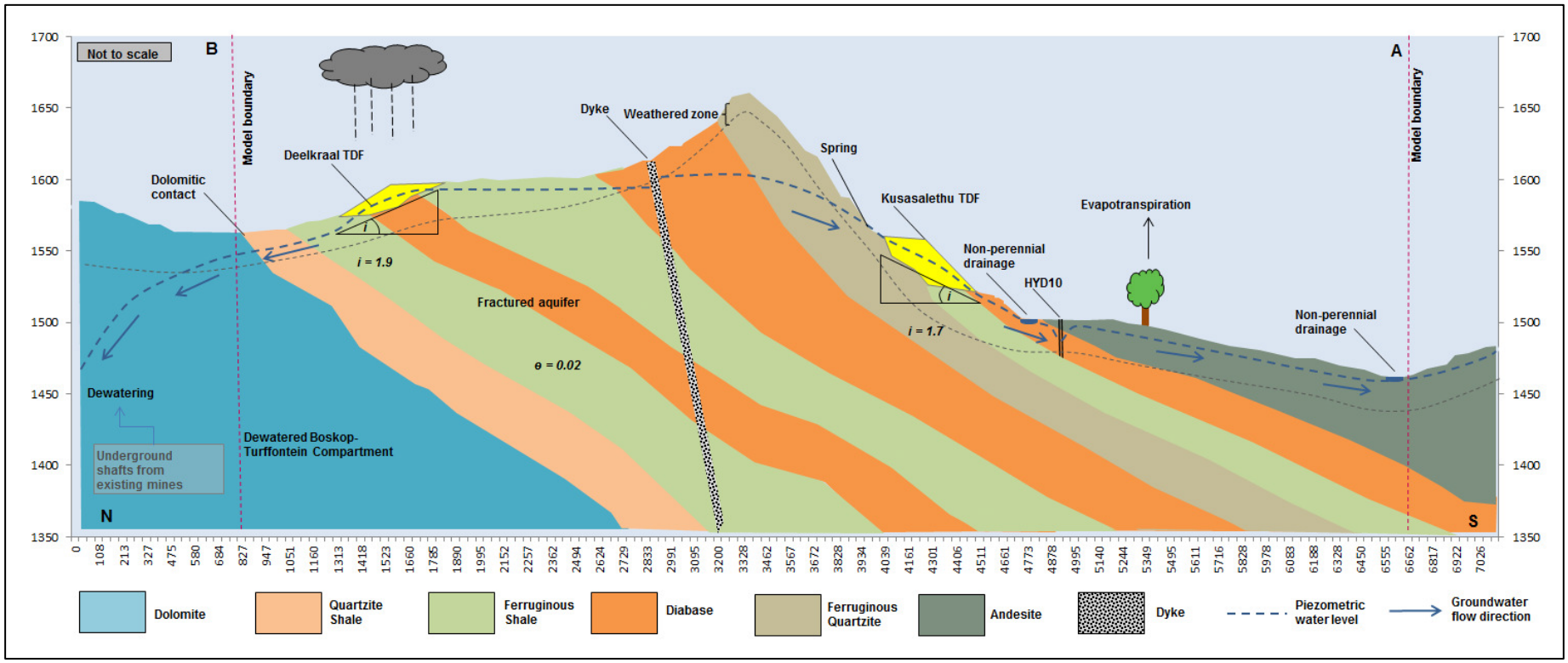


Figure 5.2: North-south geological section (AGES, 2013)

5.2 Hydrogeological Setting

5.2.1 Introduction

The hydrogeological setting and conceptual model of the study area is described according to the following criteria:

- Aquifer type.
- Aquifer parameters.
- Groundwater gradients and flow.
- Aquifer classification.

5.2.2 Aquifer Type

Three aquifer types occur in the study area: shallow weathered rock, deeper fractured rock and dolomitic karst. The non-dolomitic formations generally have limited bulk permeability, but productive local fractures support groundwater use and may provide preferential contaminant pathways.

- Weathered aquifer. Groundwater occurs in the weathered shale and quartzite and at the weathering–bedrock interface. Across the project area these rocks are predominantly associated with the Pretoria Group. Water levels respond to seasonal recharge and generally follow topography. Clay-rich horizons may locally restrict vertical flow; confinement should be established from site-specific borehole information.
- Fractured aquifer. Groundwater occurs in joints, faults and other fractures in the less-weathered bedrock. These structures can transmit water more rapidly than the surrounding rock. Weathered and fractured zones may be hydraulically connected, although shale and clay-rich layers can locally separate them and create confined conditions.
- Dolomitic karst aquifer. Dissolution enlarges fractures and creates cavities in dolomite, producing locally high secondary permeability. Weathering may leave silica-rich and iron- and manganese-rich residual material, including wad. Aquifer productivity and contaminant movement depend on the distribution and connectivity of fractures, cavities and compartment boundaries.

The weathered and fractured aquifers underlie the mine infrastructure. The dolomite is deeper beneath Kusasalethu but approaches the surface north of Deelkraal. Its separation from the shallow aquifers cannot be assumed to exclude lateral contaminant migration near the dolomite contact.

5.2.3 Aquifer Parameters

Important aquifer parameters are obtained from borehole or test pumping and include Hydraulic Conductivity (K), Transmissivity (T) and Storativity (S). These parameters are defined as follows (Krusemann and De Ridder, 1991):

- *Hydraulic Conductivity (K):* This is the volume of water that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow. It is normally expressed in metres per day (m/day).
- *Transmissivity (T):* This is the rate of flow under a unit hydraulic gradient through a cross-section of unit width over the full, saturated thickness of the aquifer. Transmissivity is the product of the average hydraulic conductivity and the saturated thickness of the aquifer. Transmissivity is expressed in metres squared per day (m^2/day).

- *Storativity (S):* The storativity of a saturated confined aquifer is the volume of water released from storage per unit surface area of the aquifer per unit decline in the component of hydraulic head normal to that surface. Storativity is a dimensionless quantity.

The calculated aquifer parameters, based on previous investigations are presented in Table 5.1.

Table 5.1: Summarised aquifer parameters obtained from pump tests

Borehole	Transmissivity (m^2/d)			Hydraulic Conductivity (m/d)		
	Constant Rate	Recovery	Average	Constant Rate	Recovery	Average
Kusasalethu TSF Boreholes						
BH6	7.94×10^{-1}	3.46×10^{-1}	**5.70×10^{-1}**	2.83×10^{-2}	1.24×10^{-2}	**2×10^{-2}**
BH7	9.93×10^{-1}	1.99×10^{0}	**1.49×10^{0}**	4.15×10^{-2}	8.35×10^{-2}	**6×10^{-2}**
BH8D	4.32×10^{-1}	1.33×10^{-1}	**2.80×10^{-1}**	1.56×10^{-2}	4.78×10^{-3}	**1×10^{-2}**
BH8S	1.77×10^{0}	5.63×10^{-1}	**1.17×10^{0}**	1.15×10^{-1}	3.67×10^{-2}	**9×10^{-2}**
BH9	7.18×10^{-1}	5.02×10^{-1}	**6.10×10^{-1}**	2.42×10^{-2}	1.69×10^{-2}	**2×10^{-2}**
MBH14	9.93×10^{-1}	1.01×10^{-1}	**5.50×10^{-1}**	5.02×10^{-2}	5.12×10^{-3}	**3×10^{-2}**
Deelkraal TSF Boreholes						
KBH1	2.8×10^{-1}	1.49×10^{-1}	**2.15×10^{-1}**	7.99×10^{-3}	4.24×10^{-3}	**6.12×10^{-3}**
DKBH 1S	Pumped dry	1.79×10^{-1}	**1.79×10^{-1}**	Pumped dry	1.89×10^{-2}	**1.89×10^{-2}**
DKBH 1D	4.42×10^{0}	2.95×10^{0}	**3.69×10^{0}**	1.47×10^{-1}	9.84×10^{-2}	**1.23×10^{-1}**
DKBH 2S	Pumped dry	8.71×10^{-1}	**8.71×10^{-1}**	Pumped dry	1.45×10^{-1}	**1.45×10^{-1}**

Note: (S) denotes a shallow borehole monitoring the weathered aquifer
(D) denotes a deep borehole monitoring the fractured aquifer

The calculated aquifer parameters indicate variable transmissivity between the weathered formation and the fracturing. Based on the above information the following average aquifer parameters were calculated:

Aquifer	Transmissivity (T)	Hydraulic Conductivity (K)
Weathered Aquifer	0.740 m^2/day	0.085 m/day
Fractured Aquifer	1.058 m^2/day	0.038 m/day

The calculated parameters for the weathered and fractured aquifers are indicative of poorly developed aquifers that underlie the study area. These aquifers do not constitute economically sustainable and exploitable hydrological units. It is, however, important to note that individual fractures may yield higher volumes of water and flow rates may be faster within these features as seen in borehole DKBH1D.

5.2.4 Groundwater Recharge

The chloride mass-balance calculation is described in Section 4.7. The same rainfall and groundwater chloride values are used below to distinguish the calculated recharge estimate from the rounded model input.

$$R = \frac{\text{Chloride concentration in rainfall}}{\text{Harmonic mean of Cl concentration in ground water}} \times 100$$

Rainfall chloride of 0.5 mg/L and groundwater chloride of 13.384 mg/L give approximately 3.74% recharge, equivalent to 21.0 mm/year at 563 mm/year MAP. The adopted model recharge is 20 mm/year, or approximately 3.55% of MAP.

$$R = \frac{0.5}{13.4} \times 100 = 3.7\%$$

5.2.5 Groundwater Gradients and Flow

Table 5.2 presents the latest available (September 2025) groundwater-level dataset.

Table 5.2: Groundwater levels

BH ID	X	Y	Z	Groundwater Level	
	Longitude	Latitude		mbs	mamsl
DK BH TSF D	27.27726	-26.45855	1560.80	23.92	1536.878
DK BH TSF S	27.27727	-26.45855	1560.80	4.03	1556.768
DKBH 02D	27.27343	-26.47162	1601.40	Locked	
DKBH 02S	27.27344	-26.47165	1601.40	Locked	
DKBH 04D	27.26798	-26.46287	1585.00	Dry	
DKBH 04S	27.26806	-26.46283	1585.00	Dry	
DKRWDN D	27.27606	-26.45394	1553.28	Dry	
DKRWDN S	27.27599	-26.45397	1552.92	3.73	1549.19
DKWRD D	27.30396	-26.46001	1601.49	2.18	1599.31
DKWRD S	27.30398	-26.46003	1601.49	1.39	1600.10
KL BH	27.35384	-26.45405	1626.23	15.06	1611.17
MBH14	27.36578	-26.46525	1518.26	2.26	1515.99
MBH15	27.36677	-26.47048	1493.94	1.68	1492.26
MBH16	27.36186	-26.47136	1515.64	6.62	1509.02
MBH17	27.35275	-26.46983	1550.51	16.84	1533.67
BH4	27.27654	-26.45505	1555.00	Locked	
BH5	27.30096	-26.46557	1610.00	Not located	
BH6	27.35938	-26.45979	1612.18	16.1	1596.08
BH7	27.36402	-26.46379	1538.15	Not located	
BH8 (Deep)	27.36638	-26.47559	1480.01	4.09	1475.92
BH8 (Shallow)	27.36638	-26.47559	1480.01	4.09	1475.92
BH9	27.34828	-26.46707	1553.60	2.33	1551.27

Note: mbs = metres below surface; mamsl = metres above mean sea level

For boreholes with numerical measurements in Table 5.2, depth to groundwater ranges from 1.39 to 23.92 m below ground level. Dry, locked and unlocated boreholes are excluded from this range.

Groundwater elevations broadly follow topography. Figure 5.3 presents the reported relationship between borehole elevation and groundwater head. This regional association does not exclude local vertical gradients or flow along geological structures.

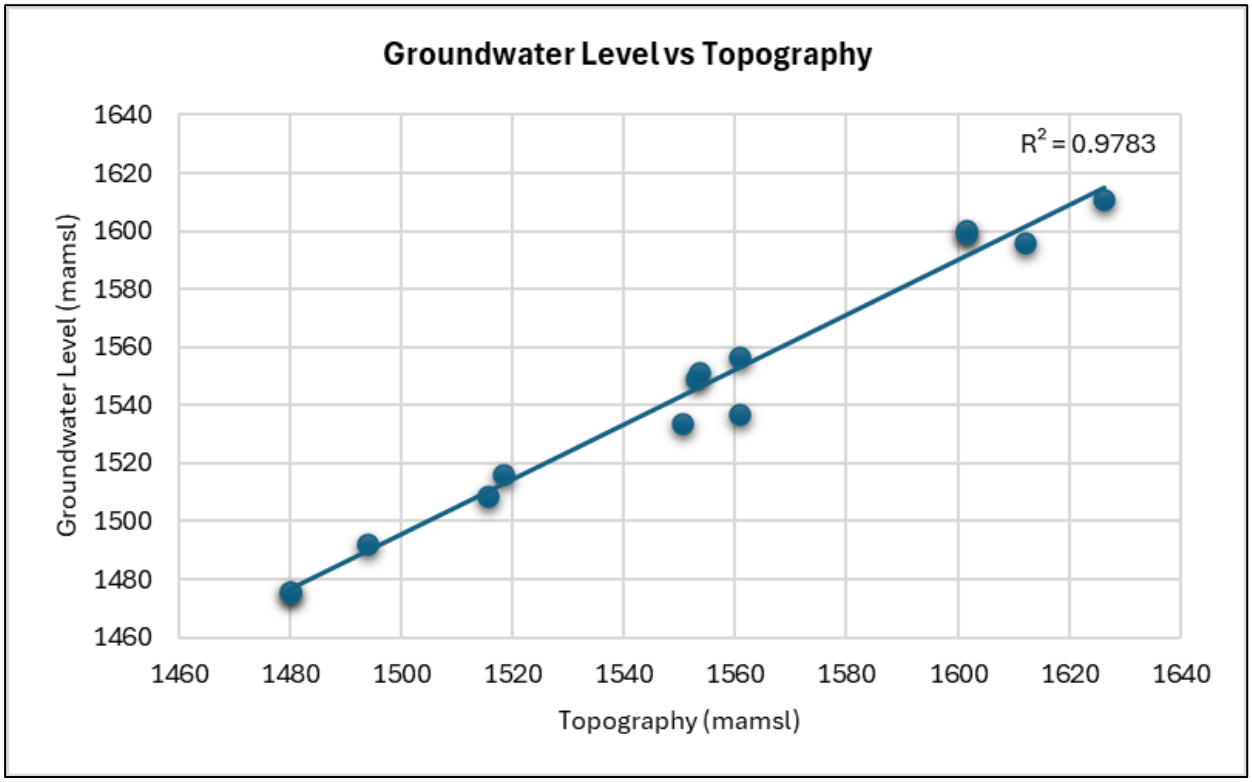


Figure 5.3: Relationship between groundwater table and topography

The measured heads and topography were used to interpolate the regional groundwater surface. The resulting pattern indicates flow from higher ground towards drainage lines. Shallow water levels suggest that groundwater may contribute to stream baseflow where hydraulic connections exist.

The interpolated regional groundwater gradient is shown in Figure 5.4.

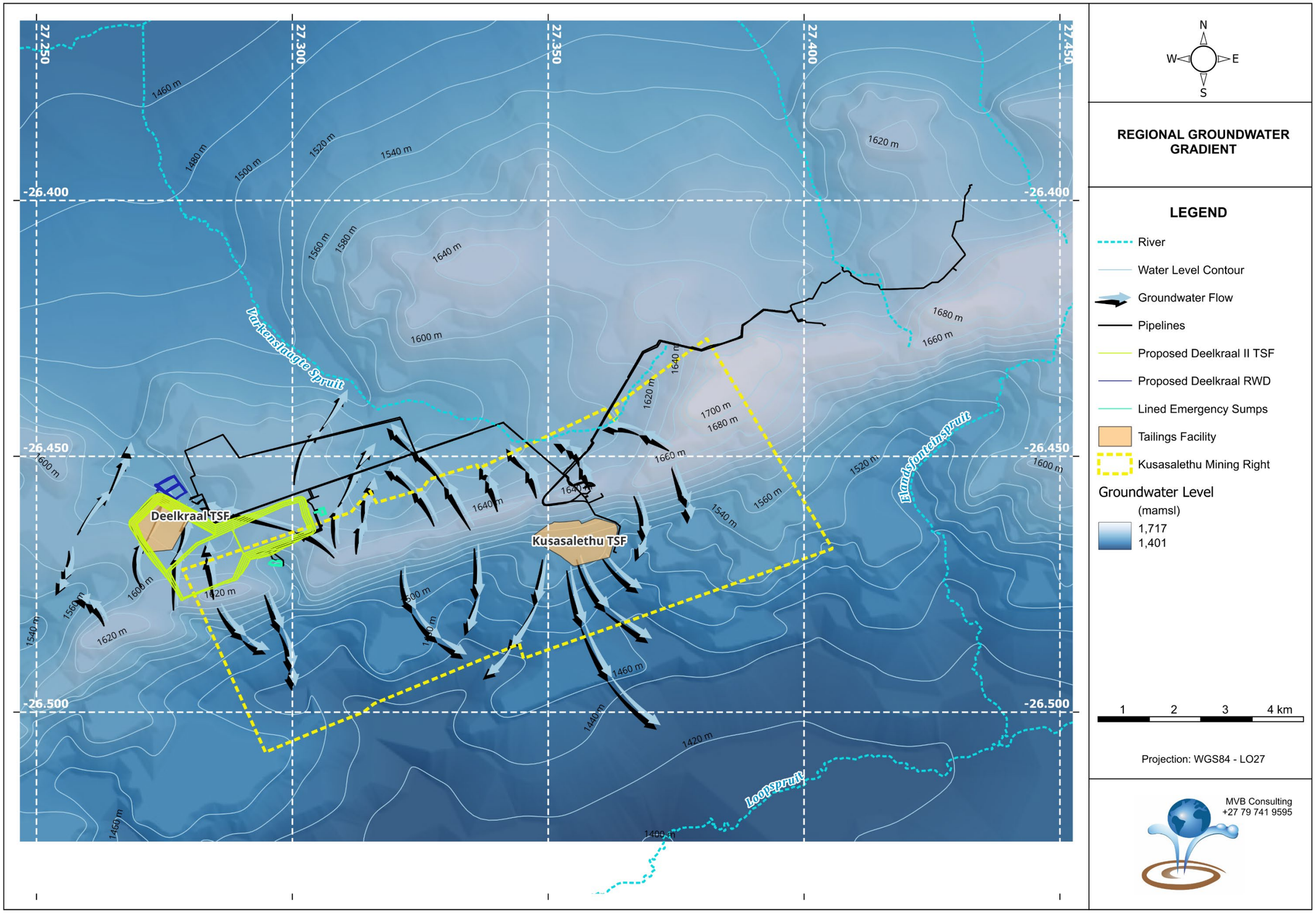


Figure 5.4: Regional groundwater gradient

5.2.6 Groundwater Chemistry

5.2.6.1. Potential Contaminant Sources

Historically, unregulated impoundment on land was the preferred option for waste disposal. Gold mining waste was estimated to account for 221 million tons or 47% of all mineral waste produced in South Africa, making it the largest, single source of waste and pollution (Viljoen, 2009).

Seepage from gold-mine residue deposits may contain sulphate, major ions and metals released during mineral weathering. Sulphide oxidation can generate acidity, while buffering reactions may maintain a near-neutral pH even where salinity and metal concentrations are elevated. The potential impact therefore cannot be assessed from pH alone (Viljoen, 2009; Groundwater Abstract, 2019).

Mine dewatering and subsequent recovery can alter oxygen exposure, groundwater gradients and the mobilisation of oxidation products. The resulting water quality depends on the available sulphides, buffering capacity and flow paths (Banks et al., 1996).

Nitrate may originate from explosives residues, agricultural inputs or sewage. Sewage-related inputs may also contain bacteria, ammonia and phosphate. These possible sources should be distinguished from tailings seepage when interpreting monitoring results.

5.2.6.2. Acid Generation Capacity

Oxidation of sulphide minerals can release sulphate, metals and acidity.

Sulphide minerals are formed and stable under reducing conditions (Dold, 2017). Acid mine drainage commonly occurs when sulphide minerals (pyrite, chalcopyrite, galena, covellite and sphalerite) are exposed to oxidizing conditions. The oxidizing conditions are created by exposure to moisture and oxygen. The oxidation process results in the release of dissolved Fe^{2+}, SO_4^{2-} and H^+ (ABA, 2001). The oxidation of sulphide-minerals containing iron produce net acidity via its oxidation, except for common sulphides such as molybdenite, enargite and stibnite (Dold, 2017). The process of acid rock drainage is generated by a series of the following chemical reactions:

$$\mathrm{FeS_{2(s)}} + \frac{7}{2}\mathrm{O_{2(aq)}} + \mathrm{H_2O} \rightarrow \mathrm{Fe^{2+}} + 2\mathrm{SO_4^{2-}} + 2\mathrm{H^+} \qquad \textit{Equation 1}$$

The liberated Fe^{2+} can oxidize automatically at pH>4 or when catalyzed by bacterial activity <4 (*Acidithiobacillus* spp. or *Leptosprillum* spp,) (Equation 2) (Dold, 2017). Iron-oxidizing bacteria greatly accelerate iron oxidation which, in turn, speeds up the acid generation.

$$Fe^{2+} + \frac{1}{4}O_{2(aq)} + H^+ \rightarrow Fe^{3+} + H_2O \qquad \textit{Equation 2}$$

Ferric iron is not soluble above pH values of ~3. The produced ferric iron can hydrolyse and produce Fe (III) Hydroxides which liberates 3 mol protons per mole of iron according to Equation 3:

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_{3(s)} + 3H^+ \qquad \textit{Equation 3}$$

The overall reaction liberates 16 mole of protons per mole of pyrite oxidized:

$$FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2\mathrm{SO_4^{2-}} + 16H^+ \qquad \textit{Equation 4}$$

The rate of pyrite oxidation depends on a majority of factors, the main factors being reactive surface area of pyrite, oxygen concentration and solution pH, presence of bacteria and catalytic agents (Skousen J., Sextone A. and Ziemkiewics, 2000).

Where mine-water pumping is constant and mine water level is stable, little pyrite oxidation occurs below the water level, and few metals are leached resulting in a relatively non-environmentally aggressive mine water. Active pyrite oxidation will, however, continue to occur in the unsaturated zone and, if pumps are turned off, the rising water level will leach out heavy metals, resulting in highly acid and contaminating solution (Banks et al., 1996)

In some geological settings the alkaline content of surrounding lithologies could act as buffering systems, countering the acid produced from pyrite oxidation. Carbonates and Clays have proven to sufficiently neutralize acid rock drainage (Skousen J., Sextone A. and Ziemkiewics, 2000). The balance between acid-producing potential and neutralizing capacity should provide reasonable indication of the potential acidity or alkalinity that may occur from the weathering of mined material.

5.2.6.3. Groundwater Quality

Aquatico Scientific (Pty) Ltd routinely monitors groundwater near the Kusasalethu and Deelkraal TSFs. The facility chemistry evaluated here is from September 2025 and represents that sampling period rather than conditions verified in September 2026.

The groundwater quality specific to the Kusasalethu and Deelkraal TSF's is discussed in Section 7.

5.2.7 Aquifer Classification

An aquifer classification system provides a framework and objective basis for identifying and setting appropriate levels of groundwater resource protection. This would facilitate the adoption of a policy of differentiated groundwater protection.

Other uses could include:

- Defining levels of investigation required for decision making.
- Setting of monitoring requirements.
- Allocation of manpower resources for contamination control functions.

The aquifer classification system used to classify the aquifers is the proposed National Aquifer Classification System of Parsons (1995). This system has a certain amount of flexibility and can be linked to second classifications such as a vulnerability or usage classification. Parsons suggests that aquifer classification forms a very useful planning tool that can be used to guide the management of groundwater issues. He also suggests that some level of flexibility should be incorporated when using such a classification system.

The South African Aquifer System Management Classification is presented by five major classes:

- Sole Source Aquifer System.
- Major Aquifer System.
- Minor Aquifer System.
- Non-Aquifer System.
- Special Aquifer System.

The following definitions apply to the aquifer classification system:

- Sole source aquifer system: “An aquifer that is used to supply 50 % or more of domestic water for a given area, and for which there are no reasonable alternative sources should the aquifer become depleted or impacted upon. Aquifer yields and natural water quality are immaterial”.
- Major aquifer system: “Highly 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”.
- Minor aquifer system: “These can be fractured or potentially fractured rocks that do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although this aquifer seldom produces large quantities of water, they are both important for local supplies and in supplying base flow for rivers”.
- Non-aquifer system: “These are formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks does occur, although imperceptible, and needs to be considered when assessing risk associated with persistent pollutants”.
- Special aquifer system: “An aquifer designated as such by the Minister of Water Affairs, after due process”.

A second variable classification is needed for sound decision making, as the ability of an aquifer to yield water to a particular user is not adequately stated. In this case it was decided to use the vulnerability of the aquifer to contamination as a second parameter (Table 5.3). A weighting and rating approach is then used to decide on the appropriate level of groundwater protection (Table 5.4).

Table 5.3: Ratings for the aquifer quality management classification system

Class	Points	Class	Points
Sole Source Aquifer System	6	**High**	3
Major Aquifer System	4	**Medium**	2
Minor Aquifer System	2	**Low**	1
Non-Aquifer System	0		
Special Aquifer System	0-6		

Table 5.4: Appropriate level of groundwater protection required

GQM Index	Level of Protection
<1	Limited Protection
1 – 3	Low Level Protection
3 – 6	Medium Level Protection
6 – 10	High Level Protection
>10	Strictly Non-degradation

After rating the aquifer system management and the aquifer vulnerability, the points are multiplied to obtain a Groundwater Quality Management (GQM) index.

Based on the above, the aquifers in the study area are classified as follows:

Description	Aquifer	Vulnerability	Rating	Protection
Weathered Aquifer	Minor (2)	1	2	Low
Fractured Aquifer	Minor (2)	1	2	Low

6. NUMERICAL GROUNDWATER MODELLING

6.1 Introduction

The FEFLOW model represents regional groundwater flow and sulphate transport from existing and proposed waste facilities. This section describes its construction, calibration and predictive assumptions.

The basic steps involved in modelling can be summarised as:

- *Collecting and interpreting field data:* Field data are essential to understand the natural system and to specify the investigated groundwater problem. The numerical model develops into a site-specific groundwater model when real field parameters are assigned. The quality of the simulations depends largely on the quality of the input data.
- *Calibration compares simulated heads or concentrations with observed data and adjusts uncertain parameters within geologically plausible ranges. Calibration statistics describe fit to the selected observations; they do not demonstrate that the conceptual model or future source terms are uniquely correct.*
- Independent validation results are not presented. Forecasts should be tested against subsequent monitoring and updated as the project design, source characterisation and groundwater datasets improve.
- *Modelling scenarios:* Alternative scenarios for a given area may be assessed efficiently. When applying numerical models in a predictive sense, limits exist in model application. Predictions of a relative nature are often more useful than those of an absolute nature.

6.2 Assumptions and Limitations

The following conditions typically need to be described in a model:

- Geological and geohydrological features.
- Boundary conditions of the study area (based on the geology and geohydrology).
- Initial groundwater levels of the study area.
- The processes governing groundwater flow.
- Assumptions for the selection of the most appropriate numerical code.

The conceptual model and parameter estimates draw on available geological and hydrogeological information. Important limitations are:

- The upper model surface follows topography, while simulated hydraulic heads define the groundwater surface.
- Available geological mapping and borehole records simplify a heterogeneous system. Preferential flow through fractures, dykes and karst features may not be fully represented.
- Many aquifer parameters have not been determined in the field and therefore have to be estimated.

To develop a model of an aquifer system, certain assumptions have to be made. The following assumptions were made:

- The initial flow solution assumes steady conditions, although existing mining and seasonal recharge have disturbed the natural system.
- No abstraction boreholes were included in the initial model.

- The assigned boundary conditions approximate the regional flow system; their influence on predicted migration requires sensitivity testing.
- The impacts of other activities (e.g. agriculture) have not been considered.

Model predictions are conditional on the conceptualisation, source history, hydraulic properties, effective porosity and barrier leakage assumptions. The 50-year results are scenario forecasts and do not establish the absence of impacts beyond that period or along unresolved preferential pathways.

6.3 Model Set-up

FEFLOW was selected to simulate three-dimensional groundwater flow and solute transport using a finite-element mesh. The model couples the groundwater flow solution to sulphate transport for the scenarios described in Section 7.

The model supports comparison of source-removal and containment scenarios and helps identify monitoring priorities. It is not a substitute for field verification of receptor conditions or barrier performance.

The modelling area was selected based on a combination of topographical and drainage control and covers an area of approximately 655 km^2 (Figure 6.1).

A finite element network (grid) was designed to provide a high resolution of the numerical solution, while at the same time, accommodating the large model area. The finite element grid was compiled using the FEFLOW pre-processing software, which facilitated the construction of 6-noded triangular prism elements over the area of investigation. The triangular grid consists of 1 430 328 elements and 957 384 nodes. The positions of the different geological units, the TSFs and WRDs are incorporated in the modelling grid as well as the various surface catchments. The elevation of the top slice was set equal to the topographic elevation.

The data gathered during the desk study and data evaluation phase of the study has been used to develop a hydrogeological conceptual model for the area, which forms the basis for the numerical modelling. The conceptual model is outlined below.

The model has two layers with geological parameter zones, as listed in Table 6.1:

- Layer 1 represents the upper 10 m, including weathered materials.
- Layer 2 represents the underlying 100 m of fractured rock. Table 6.1 also assigns dolomite and dyke properties within both layers. The correspondence between these zones and the mapped dipping dolomite contact requires confirmation.

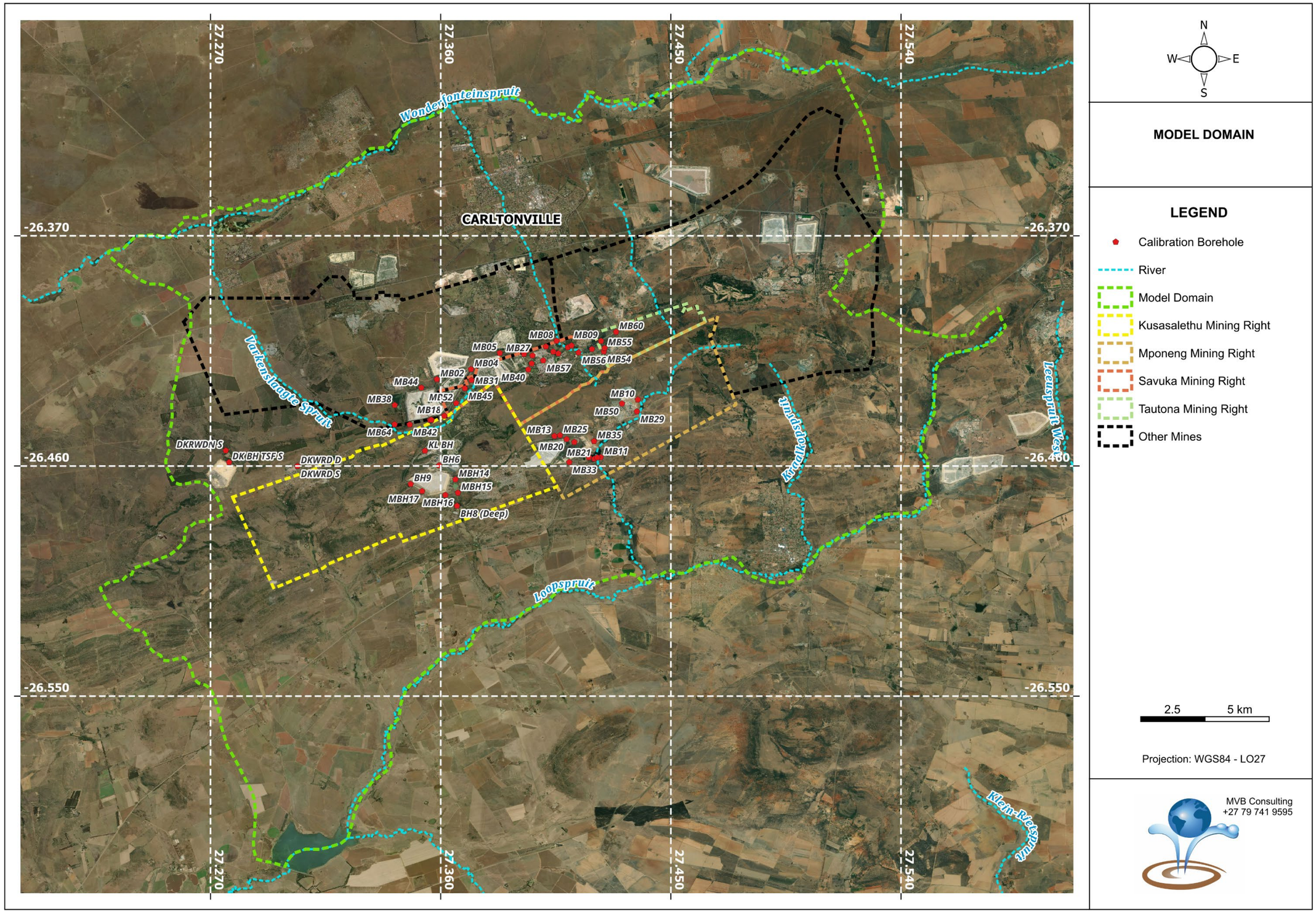


Figure 6.1: Model domain

6.4 Model Boundary Conditions

One of the first and most demanding tasks in groundwater modelling is that of identifying the model area and its boundaries. Consequently, a model boundary is the interface between the model area and the surrounding environment. Conditions on the boundaries, however, must be specified. Boundaries occur at the edges of the model area and at locations in the model area where external influences are represented, such as rivers, wells, and leaky impoundments.

Criteria for selecting hydraulic boundary conditions are primarily topography, hydrology and geology. The topography, geology, or both, may yield boundaries such as impermeable strata or potentiometric surface controlled by surface water, or recharge/discharge areas such as inflow boundaries along mountain ranges. The flow system allows the specification of boundaries in situations where natural boundaries are a great distance away.

Boundary conditions should be specified for the entire boundary and may vary with time. At a given boundary section just one type of boundary condition can be assigned. As a simple example, it is not possible to specify groundwater flux and groundwater head at an identical boundary section. Boundaries in groundwater models can be specified as:

- Dirichlet (also known as constant head or constant concentration) boundary conditions.
- Neumann (or specified flux) boundary conditions.
- Cauchy (or a combination of Dirichlet and Neumann) boundary conditions.

The groundwater system within the study area is largely recharged via infiltration of precipitation. It is thought that most of the groundwater recharge occurring within the study area discharges internally to the surface drainage systems via discharge to the base of river drainage systems (base flow). Constant head boundary conditions were therefore specified along the major surface drainages, which are known to receive base flow from groundwater. The constant head boundary condition allows groundwater to discharge, in this case, from the model area at a rate dependent on the hydraulic conductivity and hydraulic gradient across the boundary. The constant head boundaries were constrained so that water can only be removed from the system – a reversal of the hydraulic gradient back towards the aquifer from the surface system would therefore not allow water to enter the aquifer from the surface water system. This therefore represents a true “drain type” boundary condition.

6.5 Initial Conditions

Initial conditions are vital for modelling flow problems. Initial conditions should be specified for the entire area. Generally, the initial groundwater level / head distribution acts as the starting distribution for the numerical calculation. The groundwater levels shown in Figure 5.4 were used as initial conditions for the model.

6.6 Sources and Sinks

Sources and sinks can be defined as recharge and abstraction sources in the aquifer. Sources can be precipitation and inflow from surface water and recharging boreholes. Sinks can be abstraction boreholes, springs, evapotranspiration and outflow to surface water.

Background recharge of 20 mm/year was assigned for steady-state calibration, equivalent to approximately 3.55% of the adopted MAP of 563 mm/year. Table 6.1 also reports an estimated 40 mm/year for TSF footprints.

6.7 Aquifer Parameters

Initial hydraulic parameters were informed by Section 5.2.3. Simulated heads depend on aquifer geometry, hydraulic conductivity, recharge and boundary conditions. Different combinations may fit the same observations, so calibration alone does not resolve uncertainty in aquifer thickness or permeability.

The simulated groundwater level distribution is compared to the measured head distribution and the hydraulic conductivity or recharge values can be altered until an acceptable correlation between measured and simulated heads is obtained. The calibration process was done by adjusting the model parameters for hydraulic conductivity (K) and recharge within a narrow range compatible with the test results and hydrogeological situation.

The final calibrated aquifer parameters are shown in Table 6.1.

Table 6.1: Calibrated aquifer parameters

Model Layer	Hydrostratigraphic unit	Layer thickness (m)	Hydraulic Conductivity (K)		Recharge (Re)	Specific storage (Sc)
			Kx,y 1:1 (m/d)	Kz 1:10 (m/d)	In/Outflow on top/bottom (mm/a)	Sc (1/m)
Layer 1	Malmani Dolomite	10.00	0.600	0.060	Regional: 20.00	1.0E-03
	Pta Group: Siliciclastic rocks		0.025	0.003		
	Pta Group: Volcanic rocks		0.200	0.020		
	Pta Group: Silverton formation		0.400	0.040	TSF footprints: 40.00 (estimate)	
	Dykes		0.010	0.010		
	Dykes (weathered perimeter)		0.750	0.750		
Layer 2	Malmani Dolomite	100.00	0.300	0.030	0.00	1.0E-05
	Pta Group: Siliciclastic rocks		0.013	0.001		
	Pta Group: Volcanic rocks		0.100	0.010		
	Pta Group: Silverton formation		0.200	0.020		
	Dykes		0.005	0.005		
	Dykes (weathered perimeter)		0.375	0.375		

6.8 Mathematical Flow Model

A steady state groundwater flow model for the study area was constructed to simulate undisturbed groundwater flow conditions. These conditions serve as starting heads for the transient simulations of groundwater flow where the effect of for example the discard dumps are considered.

The three-dimensional groundwater flow equation solved by FEFLOW can be expressed as follows, using hydraulic conductivity along the principal coordinate directions:

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y \frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_z \frac{\partial h}{\partial z}\right)\pm W = S\frac{\partial h}{\partial t} \qquad (1)$$

where

h = hydraulic head [L]

Kx,Ky,Kz = Hydraulic Conductivity [L/T]

S = storage coefficient

t = time [T]

W = source (recharge) or sink (pumping) per unit area [L/T]

x,y,z = spatial co-ordinates [L]

For steady state conditions, the groundwater flow Equation (1) reduces to the following equation:

$$\frac{\partial}{\partial x}(K_x \frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(K_y \frac{\partial h}{\partial y}) + \frac{\partial}{\partial z}(K_z \frac{\partial h}{\partial z}) \pm W = 0 \qquad (2)$$

6.9 Calibration of the Steady State Model

The steady state head distribution is dependent upon the recharge, transmissivity, sources, sinks and boundary conditions specified. For a given recharge component and set of boundary conditions, the head distribution across the aquifer under steady-state conditions can be obtained for a specific transmissivity value. The simulated head distribution can then be compared to the measured head distribution and the transmissivity or recharge values can be altered until an acceptable correspondence between measured and simulated heads is obtained. An advantage of a steady state model is that the parameter for storativity is not required to solve the groundwater flow equation therefore, there are fewer unknown parameters to determine.

The steady-state flow calibration uses 55 head observations, as listed in Table 6.2. Hydraulic parameters and recharge were adjusted to fit the observed head distribution.

The displayed observations give a squared Pearson correlation coefficient of approximately 0.941 (Figure 6.2).

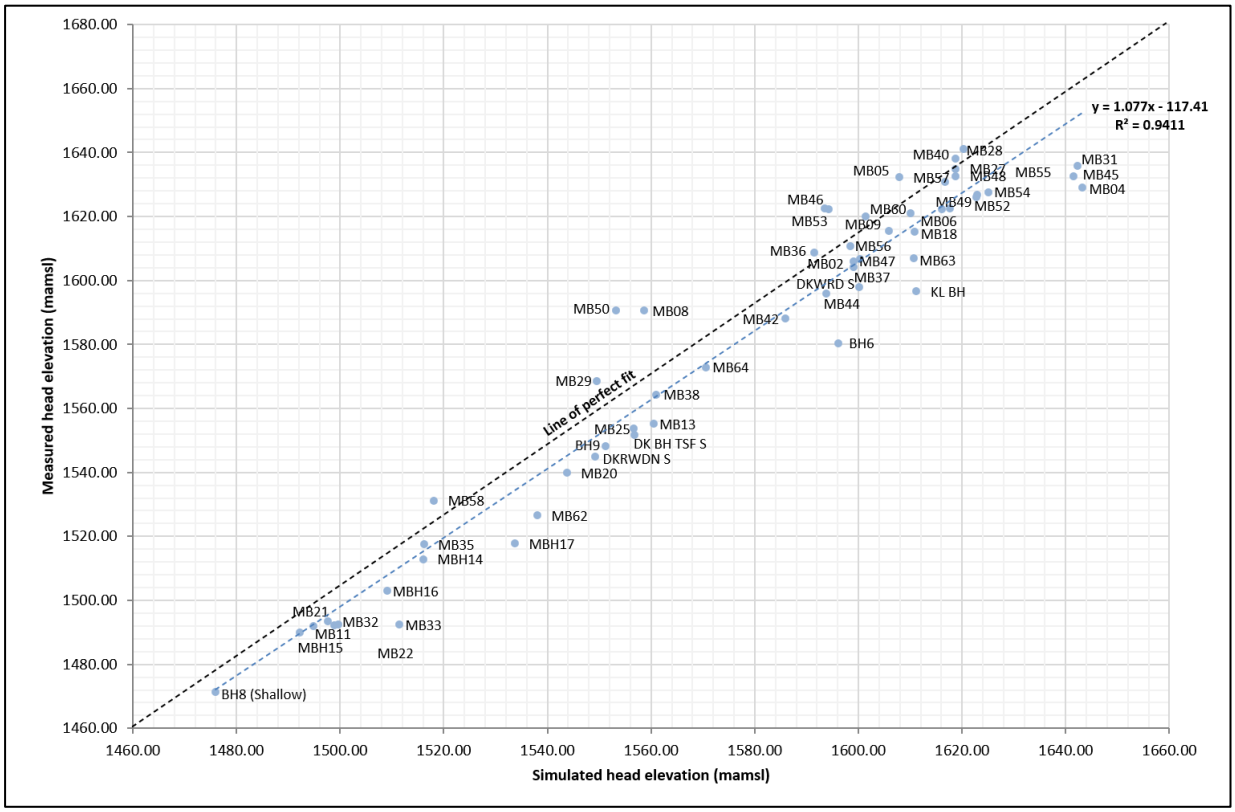


Figure 6.2: Correlation between simulated and observed groundwater levels

For Table 6.2, residuals are defined as measured minus simulated head. The mean error (ME) indicates bias, the mean absolute error (MAE) describes average absolute mismatch, and the root mean square error (RMSE) gives greater weight to large residuals. The statistics below are calculated from the 55 displayed head pairs.

ME = 1/n Σ(WLm- WLs)i

For i=1 to n, the number of calibration targets.

A small ME is not necessarily an indication of a good calibration, because negative and positive residuals, even if large, can cancel each other out, resulting in a small ME. The MAE addresses this as the mean of the absolute value of the differences in measured and simulated water levels.

Table 6.2: Steady state calibration measures for steady state Kusasalethu model

Calibration BH	Longitude	Latitude	Topographical Elevation (mamsl)	Water Level (mbgl)	Measured head elevation (mamsl)	Simulated head elevation (mamsl)	Residual (m)	Absolute residual (m)	Squared residual (m)²
MB02	27.359	-26.426	1628.60	17.89	1610.71	1606.87	3.84	3.84	14.75
MB04	27.372	-26.422	1659.80	16.66	1643.14	1629.14	14.00	14.00	196.11
MB18	27.361	-26.440	1613.50	2.60	1610.90	1615.15	-4.25	4.25	18.05
MB36	27.356	-26.442	1604.40	5.28	1599.12	1605.90	-6.78	6.78	46.02
MB37	27.356	-26.442	1605.00	4.75	1600.25	1606.68	-6.43	6.43	41.32
MB38	27.342	-26.436	1581.20	20.28	1560.92	1564.40	-3.47	3.47	12.08
MB42	27.348	-26.444	1599.60	13.64	1585.96	1588.16	-2.20	2.20	4.83
MB44	27.352	-26.429	1606.30	12.54	1593.76	1595.89	-2.13	2.13	4.52
MB45	27.369	-26.430	1641.50	0.00	1641.50	1632.67	8.83	8.83	77.95
MB52	27.366	-26.435	1623.70	0.90	1622.80	1625.98	-3.18	3.18	10.10
MB05	27.383	-26.416	1640.00	23.35	1616.65	1630.91	-14.25	14.25	203.21
MB27	27.393	-26.416	1620.00	1.30	1618.70	1634.86	-16.16	16.16	261.24
MB31	27.372	-26.426	1648.20	6.00	1642.20	1635.77	6.43	6.43	41.31
MB64	27.342	-26.444	1581.50	10.92	1570.58	1572.73	-2.15	2.15	4.64
MB06	27.401	-26.413	1619.50	9.38	1610.12	1621.14	-11.02	11.02	121.37
MB28	27.396	-26.420	1619.90	1.18	1618.72	1638.01	-19.29	19.29	372.22
MB46	27.404	-26.415	1600.20	6.77	1593.43	1622.44	-29.01	29.01	841.41
MB48	27.396	-26.417	1619.80	1.04	1618.76	1632.61	-13.85	13.85	191.82
MB08	27.405	-26.411	1593.40	1.86	1591.54	1608.75	-17.21	17.21	296.25
MB47	27.410	-26.414	1600.00	1.00	1599.00	1604.11	-5.11	5.11	26.07
MB09	27.423	-26.411	1625.10	9.00	1616.10	1622.18	-6.08	6.08	36.92
MB49	27.419	-26.414	1619.70	2.10	1617.60	1622.50	-4.90	4.90	24.05
MB54	27.424	-26.415	1631.80	6.74	1625.06	1627.67	-2.61	2.61	6.83
MB55	27.424	-26.414	1630.60	7.64	1622.96	1626.71	-3.75	3.75	14.03
MB56	27.414	-26.416	1607.70	1.83	1605.87	1615.49	-9.62	9.62	92.58
MB60	27.429	-26.408	1634.10	32.70	1601.40	1619.90	-18.50	18.50	342.32
MB10	27.437	-26.434	1564.80	6.13	1558.67	1590.75	-32.08	32.08	1029.25
MB29	27.437	-26.439	1554.60	5.17	1549.43	1568.66	-19.23	19.23	369.60
MB32	27.418	-26.457	1507.10	9.43	1497.67	1493.36	4.31	4.31	18.60
MB50	27.431	-26.436	1568.00	14.82	1553.18	1590.75	-37.57	37.57	1411.58
MB11	27.423	-26.457	1502.80	4.00	1498.80	1492.17	6.63	6.63	43.98
MB13	27.404	-26.448	1561.70	1.22	1560.48	1555.18	5.30	5.30	28.11
MB62	27.412	-26.451	1539.50	1.49	1538.01	1526.63	11.38	11.38	129.57
MB20	27.409	-26.450	1546.00	2.30	1543.70	1539.93	3.77	3.77	14.20
MB21	27.420	-26.457	1500.80	6.00	1494.80	1491.95	2.85	2.85	8.13
MB22	27.421	-26.457	1501.00	1.42	1499.58	1492.38	7.20	7.20	51.83
MB25	27.407	-26.448	1558.30	1.74	1556.56	1553.63	2.93	2.93	8.61
MB33	27.410	-26.459	1522.30	10.85	1511.45	1492.41	19.04	19.04	362.45

Calibration BH	Longitude	Latitude	Topographical Elevation (mamsl)	Water Level (mbgl)	Measured head elevation (mamsl)	Simulated head elevation (mamsl)	Residual (m)	Absolute residual (m)	Squared residual (m)²
MB35	27.420	-26.450	1517.70	1.56	1516.14	1517.49	-1.35	1.35	1.83
MB40	27.394	-26.422	1633.80	13.48	1620.32	1641.14	-20.82	20.82	433.56
MB57	27.400	-26.419	1611.10	3.28	1607.82	1632.21	-24.39	24.39	595.02
MB58	27.422	-26.448	1520.00	1.94	1518.06	1531.21	-13.15	13.15	173.00
MB53	27.406	-26.416	1602.50	8.18	1594.32	1622.24	-27.92	27.92	779.30
MB63	27.411	-26.413	1602.40	4.00	1598.40	1610.63	-12.23	12.23	149.57
DK BH TSF S	27.277	-26.459	1560.80	4.03	1556.77	1551.65	5.12	5.12	26.21
DKRWDN S	27.276	-26.454	1552.92	3.73	1549.19	1544.97	4.22	4.22	17.81
DKWRD S	27.304	-26.460	1601.49	1.39	1600.10	1597.96	2.14	2.14	4.58
KL BH	27.354	-26.454	1626.23	15.06	1611.17	1596.67	14.50	14.50	210.25
MBH14	27.366	-26.465	1518.26	2.26	1516.00	1512.89	3.11	3.11	9.67
MBH15	27.367	-26.470	1493.94	1.68	1492.26	1489.94	2.32	2.32	5.38
MBH16	27.362	-26.471	1515.64	6.62	1509.02	1503.01	6.01	6.01	36.12
MBH17	27.353	-26.470	1550.51	16.84	1533.67	1517.73	15.94	15.94	254.08
BH6	27.359	-26.460	1612.18	16.10	1596.08	1580.40	15.68	15.68	245.86
BH8 (Shallow)	27.366	-26.476	1480.01	4.09	1475.92	1471.26	4.66	4.66	21.72
BH9	27.348	-26.467	1553.60	2.33	1551.27	1548.11	3.16	3.16	9.99
Sum of residual terms (n = 55)							-217.34	564.08	9751.74
Mean residual terms (ME, MAE, MSE)							-3.95	10.26	177.30
RMSE (m)							—	—	13.32
NRMSE (% of observed range)							—	—	7.96
Pearson r and squared Pearson r²							r = 0.9701	—	r² = 0.9412

Note: MAE = 1/n Σ |(WLm- WLs)i|.
RMSE is the square root of the mean squared residual. Individual squared residuals have units of m²; the aggregate RMSE has units of m.
RMS = [1/n Σ(WLm- WLs)i2]0.5.

6.10 Sensitivity Analysis

Sensitivity analysis examines how plausible changes in uncertain inputs affect plume migration. Figure 6.3 presents the reported 50-year sensitivity results for the Deelkraal II area. Parameter ranges, baseline values and receptor-specific outcomes should accompany the figure so that the analysis can be reproduced.

The reported analysis identifies effective porosity as a principal control on migration. The narrative cites 2%–15%, whereas Figure 6.3 labels porosity values of 0.015 and 0.02 (1.5% and 2%). The figure also labels a conductivity range extending to 0.6 m/day. These ranges must be reconciled with the model inputs before the sensitivity results are used quantitatively. For a given Darcy flux, lower effective porosity produces faster pore-water movement.

Migration is also sensitive to hydraulic conductivity. Table 6.1 gives horizontal conductivities of 0.013 to 0.400 m/day for the Pretoria Group zones across both layers; dolomite and dyke zones have different values. Interpretation at Deelkraal II must use the parameters assigned to its actual geological zones.

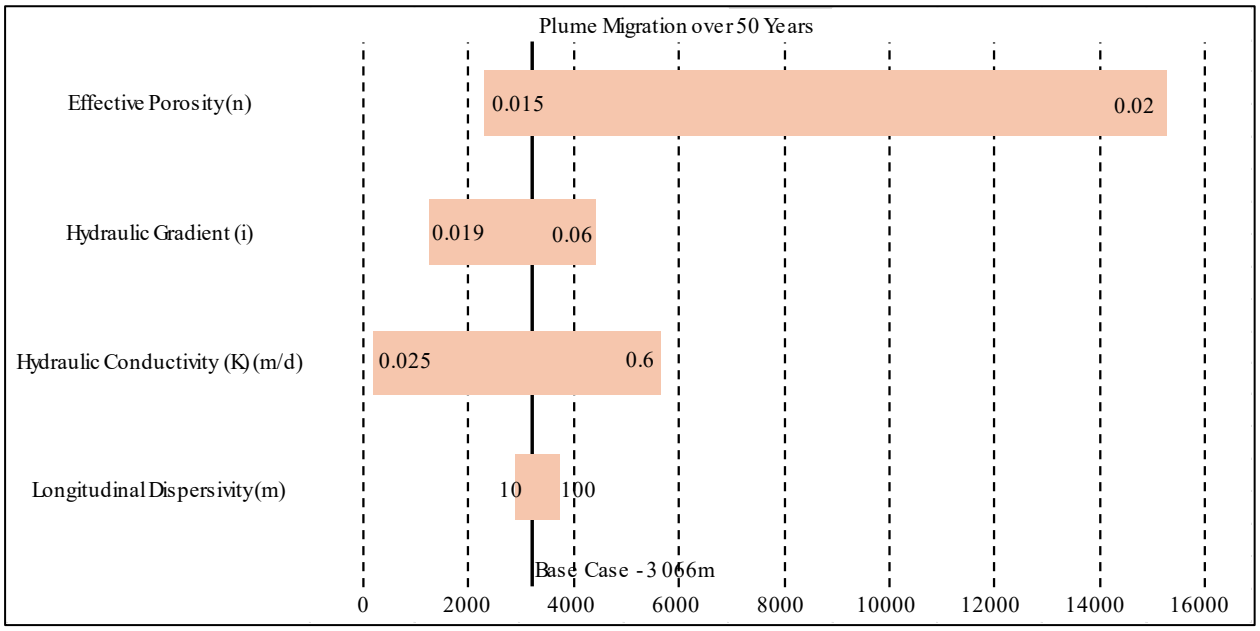


Figure 6.3: Parameter sensitivity

6.11 Numerical Groundwater Mass Transport Model

6.11.1 Introduction

Solute transport describes the movement and spreading of dissolved constituents in groundwater. The sulphate simulations represent the following principal processes:

- Advection transports dissolved constituents with groundwater. The average pore-water velocity is the Darcy flux divided by effective porosity; under uniform conditions, travel distance equals pore-water velocity multiplied by time.
- Hydrodynamic dispersion comprises two processes:
  - Mechanical dispersion is the process whereby the initially close group of labelled particles are spread in a longitudinal as well as in a transverse direction because of the velocity distribution (as a result of varying microscopic streamlines) that develops at the microscopic level of flow around the grain particles of the porous medium. Although this spreading is both in the longitudinal and transversal direction of flow, it is primarily in the former direction. Very little spreading can be caused in the transversal direction by velocity variations alone.
  - Molecular diffusion moves solute down concentration gradients and can occur in any direction, including where advective flow is negligible. Its relative importance generally decreases as groundwater velocity increases.

In addition to advection, mechanical dispersion and molecular diffusion, several other phenomena may affect the concentration distribution of a contaminant as it moves through a medium. The contaminant may interact with the solid surface of the porous matrix in the form of adsorption of contaminant particles on the solid surface, deposition, solution of the solid matrix and ion exchange. All these phenomena cause changes in the concentration of a contaminant in a flowing fluid.

The FEFLOW software was used to provide numerical solutions for the concentration values in the aquifer in time and space. The required input into the model includes:

- Input concentrations of contaminants.
- Transmissivity values.
- Porosity values.
- Longitudinal dispersivities.

- Transversal dispersivities.
- Hydraulic heads/water levels in the aquifer over time.

Hydraulic properties were taken from the calibrated flow model. The simulations adopt longitudinal dispersivity of 50 m and transverse dispersivity of 5 m, based on the cited literature (Spitz and Moreno, 1996; Bear and Verruijt, 1992). Their suitability at the scale of individual receptors should be tested.

6.11.2 Waste Classification and Source Term

The source term concentration is based on a waste assessment by Gomelelo Consulting (2024) as well as the mine monitoring data. The Gomelelo findings can be summarised as follows:

- Gomelelo Consulting collected two tailings samples, two waste-rock samples and one return-water sample on 8 March 2024. Waterlab (Pty) Ltd analysed total and leachable concentrations. The reported methods included acid digestion followed by elemental analysis and deionised-water leaching at a liquid-to-solid ratio of 20:1.
- To identify the classification of the waste, the Total Concentration (TC) and Leachate Concentration (LC) of the elements and chemical substances present in the waste were compared with the established Total Concentration Threshold (TCT) and Leachate Concentration Threshold (LCT) limits.
- Gomelelo Consulting (2024) reports a Type 3 classification for the assessed materials. Table 6.3 presents leachate results.
- The 2013 disposal norms link Type 3 waste to Class C containment requirements, subject to their provisions. The norms were amended in 2024 (GN 5523). Applicability to the proposed mine-residue facilities and any alternative barrier must be confirmed through the authorisation process. A favourable model result alone does not establish a right to omit containment.

Table 6.3 summarises the leachable concentrations and the LCT0 and LCT1 comparison values used in the waste assessment. These laboratory results represent the sampled materials and test conditions, rather than a measured long-term field seepage concentration.

Parameters that exceed the LCT are highlighted in blue.

Table 6.3: Leachate concentrations in mg/L for the tailings and waste rock material against the LCT (Gomelelo Consulting, 2024)

Parameter	Units	Detection Limit	Tailings		Waste Rock		Kusasalethu Return Water Dam	Leachable Concentrations Threshold	
			Deelkraal Tailings	Kusasalethu Tailings	Deelkraal Waste Rock	Kusasalethu Waste Rock		LCT 0	LCT 1
Inorganic Anions									
pH	-		3.6	3.8	8.2	8.8	7		
EC	mS/m		33	139	66	7.1	298		
Alkalinity	mg/L as $CaCO_3$	<5	<5	<5	24	24	36		
TDS	mg/L		344	1 470	538	80	2 512	1 000	12 500
Cl	mg/L	<2	<2	43	<2	<2	172	300	15 000
SO_4	mg/L	<2	126	682	286	8	1 284	250	12 500
NO_3-N	as N mg/L	<0.1	<0.1	1.1	<0.1	0.3	13	11	550
F	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	0.5	1.5	75
Total CN	mg/L	<0.07	<0.07	<0.07	<0.07	<0.07		0.07	3.5
Metal Ions									
As	mg/L	<0.001	<0.001	<0.001	0.002	0.007	0.004	0.01	0.5
B	mg/L	<0.025	0.09	0.28	0.03	0.08	<0.025	0.5	25
Ba	mg/L	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.7	35
Cd	mg/L	<0.001	<0.001	0.02	<0.001	<0.001	0.001	0.003	0.15
Co	mg/L	<0.025	0.09	0.71	<0.025	<0.025	0.36	0.5	25
Cr tot	mg/L	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.1	5
Cr VI	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	0.01	0.05	2.5
Cu	mg/L	<0.010	0.11	1.37	<0.010	<0.010	0.26	2	100
Hg	mg/L	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.006	0.3
Mn	mg/L	<0.025	0.54	4.69	<0.025	<0.025	5.12	0.5	25
Mo	mg/L	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.07	3.5
Ni	mg/L	<0.025	0.15	2.05	<0.025	<0.025	0.32	0.07	3.5
Pb	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	0.5
Sb	mg/L	<0.001	<0.001	<0.001	<0.001	0.001	0.002	0.02	1
Se	mg/L	<0.001	<0.001	<0.001	<0.001	0.002	0.004	0.01	0.5
V	mg/L	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.2	10
Zn	mg/L	<0.001	0.16	3.21	<0.001	<0.001	0.56	5	250

Input concentrations in the model were specified at cells over the areas where contamination is expected. Sulphate (SO_4) is considered a conservative parameter, associated with gold mining impact, and was used as a tracer to simulate the migration of the contaminant plume.

Based on the leachate tests the sulphate concentrations in the various waste bodies are as follows:

- Tailings:
  - Deelkraal 126 mg/L SO_4.
  - Kusasalethu 682 mg/L SO_4.
- Return water dam:
  - Kusasalethu 1 284 mg/L SO_4.
- Waste Rock:
  - Deelkraal 286 mg/L SO_4.
  - Kusasalethu 8 mg/L SO_4.

These concentrations are regarded as low, based on the groundwater monitoring borehole results. Seepage concentrations from the Deelkraal tailings are thought to be in the order of at least 3 000 mg/L based on the measured concentrations in boreholes DKBH TSF-S (3 101 mg/L SO_4) and DKBH TSF-D (1 991 mg/L SO_4).

The Kusasalethu tailings are also regarded as low. The return water dam concentration of 1 284 mg/L SO_4 is considered more representative.

The concentrations in the monitoring boreholes closest to the waste rock dumps also suggests higher source concentrations. The source concentrations for the various sources are therefore as follows:

- Tailings:
  - Deelkraal 3 000 mg/L SO_4.
  - Kusasalethu 1 500 mg/L SO_4.
- Waste Rock:
  - Deelkraal 500 mg/L SO_4.
  - Kusasalethu 700 mg/L SO_4.

The expected leachate quality from the Deepkraal II TSF has not been investigated in detail. The impact from this TSF is expected to be less than the older TSF's due to improved metallurgical processes, but in the absence of a detailed assessment a source term of 1 500 mg/L SO_4 (similar to the Kusasalethu TSF) was assigned to the Deelkraal II TSF.

6.11.3 Transport Model Calibration

Table 6.4 contains 14 measured and simulated sulphate pairs, plotted in Figure 6.4. Recalculation gives ME = 27.21 mg/L, MAE = 61.36 mg/L and RMSE = 81.42 mg/L. The RMSE is 2.63% of the measured concentration range and the squared Pearson correlation is approximately 0.992.

Table 6.4: Mass transport calibration measures for the Kusasalethu model

Calibration BH	Measured concentration (mg/L)	Simulated concentration (mg/L)	Residual (mg/L)	Absolute residual (mg/L)	Squared residual $(mg/L)^2$
BH9	1091.00	1000.00	91.00	91.00	8281.00
MBH17	303.00	390.00	-87.00	87.00	7569.00

Calibration BH	Measured concentration (mg/L)	Simulated concentration (mg/L)	Residual (mg/L)	Absolute residual (mg/L)	Squared residual (mg/L)²
MBH16	1152.00	1100.00	52.00	52.00	2704.00
MBH15	470.00	468.00	2.00	2.00	4.00
MBH14	447.00	490.00	-43.00	43.00	1849.00
BH8S	888.00	686.00	202.00	202.00	40804.00
BH6	335.00	220.00	115.00	115.00	13225.00
KL-BH	3.00	1.00	2.00	2.00	4.00
DKBHTSF-D	3101.00	3000.00	101.00	101.00	10201.00
DKRWDN-S	51.00	83.00	-32.00	32.00	1024.00
DKBH 2D	240.00	221.00	19.00	19.00	361.00
DKBH 4D	134.00	208.00	-74.00	74.00	5476.00
DKWRD-S	92.00	95.00	-3.00	3.00	9.00
Fountain	77.00	41.00	36.00	36.00	1296.00
Sum of residual terms (n = 14)			381.00	859.00	92807.00
Mean residual terms (ME, MAE, MSE)			27.21	61.36	6629.07
RMSE (mg/L)			—	—	81.42
NRMSE (% of observed range)			—	—	2.63
Pearson r and squared Pearson r²			r = 0.9960	—	r² = 0.9920

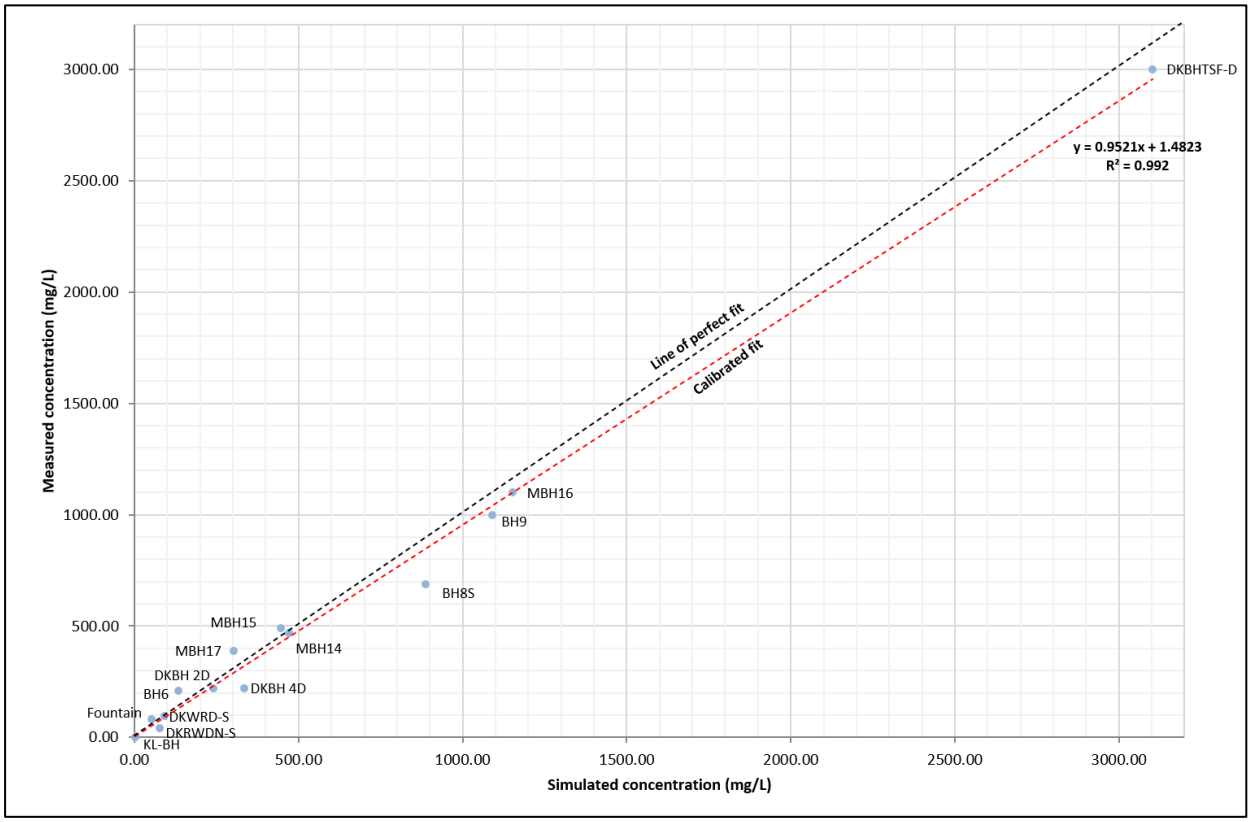


Figure 6.4: Correlation between simulated and observed sulphate concentrations

7. HYDROGEOLOGICAL ASSESSMENT

7.1 Introduction

The study area can be divided into the following management areas:

- Catchment C23E – Deelkraal TSF.
- Catchment C23J – Kusasalethu TSF.

The assessment considers existing groundwater contamination, the effects of reclaiming the two existing TSFs and the potential effects of the proposed Deelkraal II TSF and RWD.

The calibrated flow and mass transport model was used to simulate the waste infrastructure impact on the groundwater regime. The following scenarios were simulated:

- The current impacts from the existing waste facilities.
- The simulated impact in 50 years from the waste facilities, including the new TSF.
- The Deelkraal II TSF was modelled with and without a liner.

7.2 Compliance Monitoring Requirements

The groundwater quality is compared to the Kusasalethu and Deelkraal Water Use License (Licence No. 08/C23J/AJFG/10192). The SANS 241 (2015) Drinking Water Limits are also shown for comparative purposes (Table 7.1). The SANS 241 Drinking Water Specification is the definitive reference on acceptable limits for drinking water quality parameters (for a lifetime consumption) in South Africa and provides guideline levels for a range of water quality characteristics.

Table 7.1: Compliance limits

Parameters	Units	SANS 241 Drinking Water (2015)	Water Use License (2020)
pH	pH Units	≥ 5 to ≤ 9.7	≥ 5 to ≤ 9.7
Electrical Conductivity (EC)	mS/m	≤170	≤200
Total Dissolved Solids (TDS)	mg/l	≤1 200	≤1 200
Nitrate (NO_3 as N)	mg/l	≤11	≤10
Ammonia (NH_4)	mg/l	≤1.5	-
Orthophosphate (PO_4)	mg/l	-	-
Fluoride (F)	mg/l	≤1.5	≤1
Sulphate (SO_4)	mg/l	≤500	≤600
Chloride (Cl)	mg/l	≤300	≤300
Calcium (Ca)	mg/l	-	≤200
Magnesium (Mg)	mg/l	-	≤100
Sodium (Na)	mg/l	≤200	≤200
Potassium (K)	mg/l	-	-
Aluminium (Al)	mg/l	≤0.3	≤0.5
Iron (Fe)	mg/l	≤2	≤3
Manganese (Mn)	mg/l	≤0.4	≤0.5
Uranium (U)	mg/l	≤0.03	≤0.03

Below is a brief description of the relevance and influence of the different components of the water analysis.

7.2.1 Physical and Aesthetic Water Quality

This refers to the water quality properties such as temperature, electrical conductivity, pH and oxygen content. When referring to the physico-chemical quality we refer to the three parameters namely pH, EC or TDS. These parameters affect the aesthetic as well as chemical quality of the water.

Table 7.2: Physical and aesthetic water quality

Parameter	Relevance
pH	Affects the corrosivity and taste of water
EC / TDS	Serves as a general indicator of change in water quality and affects the "freshness" taste of the water. Indicates the salinity and quantity of dissolved substances.

7.2.2 Chemical Water Quality

The chemical quality of the water refers to the nature and concentrations of dissolved substances such as organic or inorganic compounds, including metals, in the water body. Many chemicals in water are essential for the biotic community and may form an integral part of the nutritional requirements. However, elevated levels may be limiting for some of the water users.

Table 7.3: Chemical water quality

Parameter	Relevance
Alkalinity	Indicative of intrinsic buffering capacity against acidification.
Hardness	Mainly affected by Calcium and Magnesium and affects the scaling and foaming quality of the water.
Major Anions	Typically, chloride, sulphate, fluoride and the nitrogen compounds, Impacts the salinity levels.
Major Cations	Typically, Calcium, Magnesium and Sodium - Elevated levels could affect the taste of water.
Heavy Metals	Toxic at low concentrations.

Parameters such as pH, hardness and salinity are used to describe the general quality of water. These are tabulated below (Table 7.4) and are based on the descriptions as proposed by the Department of Water and Sanitation (DWS).

Table 7.4: General water quality description parameters

Parameter	Category
pH	
pH > 8.5	Alkaline / Basic
pH 6.0 – 8.5	Neutral
pH <6	Acidic
Hardness	
Hardness <50 mg/l	Soft
Hardness 50 – 100 mg/l	Moderately soft
Hardness 100 – 150 mg/l	Slightly hard
Hardness 150 – 200 mg/l	Moderately hard

Parameter	Category
Hardness 200 – 300 mg/l	Hard
Hardness 300 – 600 mg/l	Very hard
Hardness >600 mg/l	Extremely hard
Salinity	
EC <70 mS/m	Non saline
EC 70 – 150 mS/m	Saline
EC 150 – 370 mS/m	Very saline
EC >370 mS/m	Extremely saline

The following sections evaluate the groundwater quality impacts from the two management areas.

7.3 Catchment C23E – Deelkraal TSF

Table 7.5 presents the September 2025 chemistry for the Deelkraal TSF, RWD and WRD monitoring network. Red highlighting identifies exceedances of the WUL comparison values reproduced in the table. Figure 7.1 shows the spatial distribution of sulphate.

With reference to Table 7.5 and Figure 7.1 the groundwater quality at the Deelkraal TSF and WRD can be described as follows:

- Deelkraal TSF.
    - Several of the boreholes are either dry or cannot be accessed for monitoring.
    - DK BH TSF S exceeds the listed WUL values for EC, TDS, fluoride, magnesium and manganese. Its sulphate concentration is 554 mg/L, below the listed WUL value of 600 mg/L but above the 500 mg/L sulphate contour used in the impact assessment.
    - DK BH TSF D exceeds the listed WUL values for EC, TDS, sulphate, calcium, magnesium and manganese. Sulphate is 3 101 mg/L and manganese is 44.8 mg/L. Manganese is also elevated in the shallow borehole at 7.40 mg/L.
    - Contamination occurs in both the shallow and deeper monitoring intervals, with greater salinity in the deeper borehole. This is consistent with contaminant penetration into the fractured aquifer but does not, by itself, prove a particular hydraulic connection or pathway.
    - DKRWDN S exceeds the listed WUL manganese value, with 2.32 mg/L against 0.5 mg/L; its other reported parameters are below the listed limits.
- Deelkraal WRD.
    - One WRD borehole has chemistry results in Table 7.5. The deeper borehole is recorded as having a water-level measurement only.
    - No listed WUL exceedance is shown for DKWRD S. This single sampled point provides limited evidence and does not exclude impacts elsewhere around the WRD.

The general physical water quality of the C23E (Deelkraal TSF) groundwater monitoring localities can be described as neutral and alkaline (DKWRD S), non-saline (DKRWDN S, DKWRD S and KL BH), very saline (DK BH TSF S) to extremely saline (DK BH TSF D).

The simulated present-day sulphate plume extends mainly northwards, with a smaller eastward component (Figure 7.2). It is reported to lie within Harmony property, but it approaches the sensitive dolomite contact.

The existing Deelkraal TSF is proposed for reclamation, with reprocessed tailings deposited at Deelkraal II. The project description includes both the existing footprint and adjacent land.

- Scenario 1, without a liner (Figure 7.3), removes the existing TSF source and introduces the new TSF and RWD sources. Plumes migrate northwestwards and southwards. Section 7.3.1 predicts that the >500 mg/L sulphate plume reaches the dolomite within 50 years. This scenario therefore indicates a potential impact on a sensitive receptor and does not support an unqualified conclusion of no downgradient impact.
- Scenario 2 (Figure 7.4) assumes containment beneath both the new TSF and RWD. A reference leakage estimate of 140 L/ha/day is cited for a conventional composite barrier (Legge, 2024). This is a design-dependent estimate, not a

universal Class C leakage rate; actual performance depends on construction quality, defects, hydraulic head and long-term integrity.

The alternative inverted-barrier calculation assumes three 10 mm holes per hectare, a 1.5 mm double-textured geomembrane, 1 m of compacted tailings with hydraulic conductivity of 8×10^{-8} m/s, and overlying drainage. The cited leakage estimate is 6 L/ha/day, approximately 23 times lower than 140 L/ha/day. These estimates require verification against the proposed design and loading conditions.

The simulation using 6 L/ha/day predicts limited additional plume migration. This result is conditional on that leakage performance and the assumed source concentration.

7.3.1 Potential Impact to the Dolomite Aquifer

The dolomites outcrop approximately 500m north of the Deelkraal TSF. This is a sensitive aquifer (Boskop – Turffontein Groundwater Compartment) that needs to be protected against impacts from the mines and other contaminant sources.

A borehole drilled in 2017 near the mapped dolomite boundary was intended to investigate northward contaminant migration and provide a dolomite monitoring point. Difficult drilling conditions led to abandonment at 89 m below ground level, with casing installed to 84 m. The dry borehole supports the geological interpretation but provides no groundwater-quality evidence for the dolomite aquifer.

The model interpretation places the present >600 mg/L (WUL limit) sulphate contour approximately 200 m from the dolomite, although lower concentrations may already extend to the contact. Direct monitoring is needed to verify groundwater quality at and within the dolomite.

The unlined scenario predicts that the >600 mg/L sulphate plume reaches the dolomite within 50 years. The low-leakage lined scenario predicts substantially less migration. Protection of the dolomite therefore depends on effective containment and should be verified by monitoring.

It is recommended to install monitoring points between Deelkraal II and the dolomite contact, together with a suitable point in the dolomitic aquifer where practicable. These locations should provide warning of plume migration and test the assumed hydraulic separation.

Table 7.5: Groundwater chemistry in the C23E catchment (Deelkraal TSF and WRD) monitoring boreholes (Aquatico, Sep 2025)

BH ID	Physical and Aesthetic Quality				Major Cations & Anions									Heavy Metals										
	pH	EC	TDS	Total Alkalinity	Chloride	Sulphate	Nitrate	Ammonia	Fluoride	Calcium	Magnesium	Sodium	Potassium	Aluminium	Iron	Manganese	Chromium	Copper	Cadmium	Lead	Nickel	Cobalt	Zinc	Total Cyanide	Uranium
Unit	pH units	mS/m	mg/l	mg/l $CaCO_3$	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
WUL (2020)	≥ 5 to ≤ 9.7	≤ 200	≤ 1 200	-	≤300	≤600	≤10	-	≤1	≤200	≤100	≤200	-	≤0.5	≤3	≤0.5	-	-	-	-	-	-	-	-	≤0.03
Deelkraal TSF Complex																									
DK BH TSF S	8.29	257	1 806	718	80.3	554	<0.194	1.18	1.65	108	207	71.9	28.6	0.074	0.09	7.40	<0.003	<0.002	<0.002	<0.004	<0.002	0.02	0.003	<0.005	<0.015
DK BH TSF D	7.14	516	5 000	589	158	3 101	0.261	0.291	<0.263	474	605	185	16.1	0.084	<0.004	44.8	<0.003	<0.002	0.002	<0.004	0.002	<0.003	0.009	<0.005	<0.015
DKRWDN S	6.24	25.9	164	54.8	21.1	51.2	0.202	0.057	<0.263	17.6	8.22	18.2	3.45	0.010	0.071	2.32	<0.003	<0.002	<0.002	<0.004	0.010	0.017	<0.002	<0.005	<0.015
DKRWDN D	Dry																								
KL BH	6.42	4	24	12.5	3.22	3	0.336	0.037	<0.263	1.89	2.89	2.06	<0.015	<0.003	<0.004	0.024	<0.010	<0.003	<0.002	<0.004	<0.007	0.003	<0.006	<0.005	<0.015
DKBH 02D	Gate Locked																								
DKBH 02S																									
DKBH 04D	Dry																								
DKBH 04S																									
BH4	Locked																								
Deelkraal WRD																									
DKWRD S	8.53	36.5	346	55.4	22.6	91.8	0.242	0.544	<0.263	35.8	18.2	12.8	3.29	0.016	<0.004	0.076	<0.003	<0.002	<0.002	<0.004	<0.002	<0.003	<0.002	<0.005	<0.015
DKWRD D	Water Level Only																								

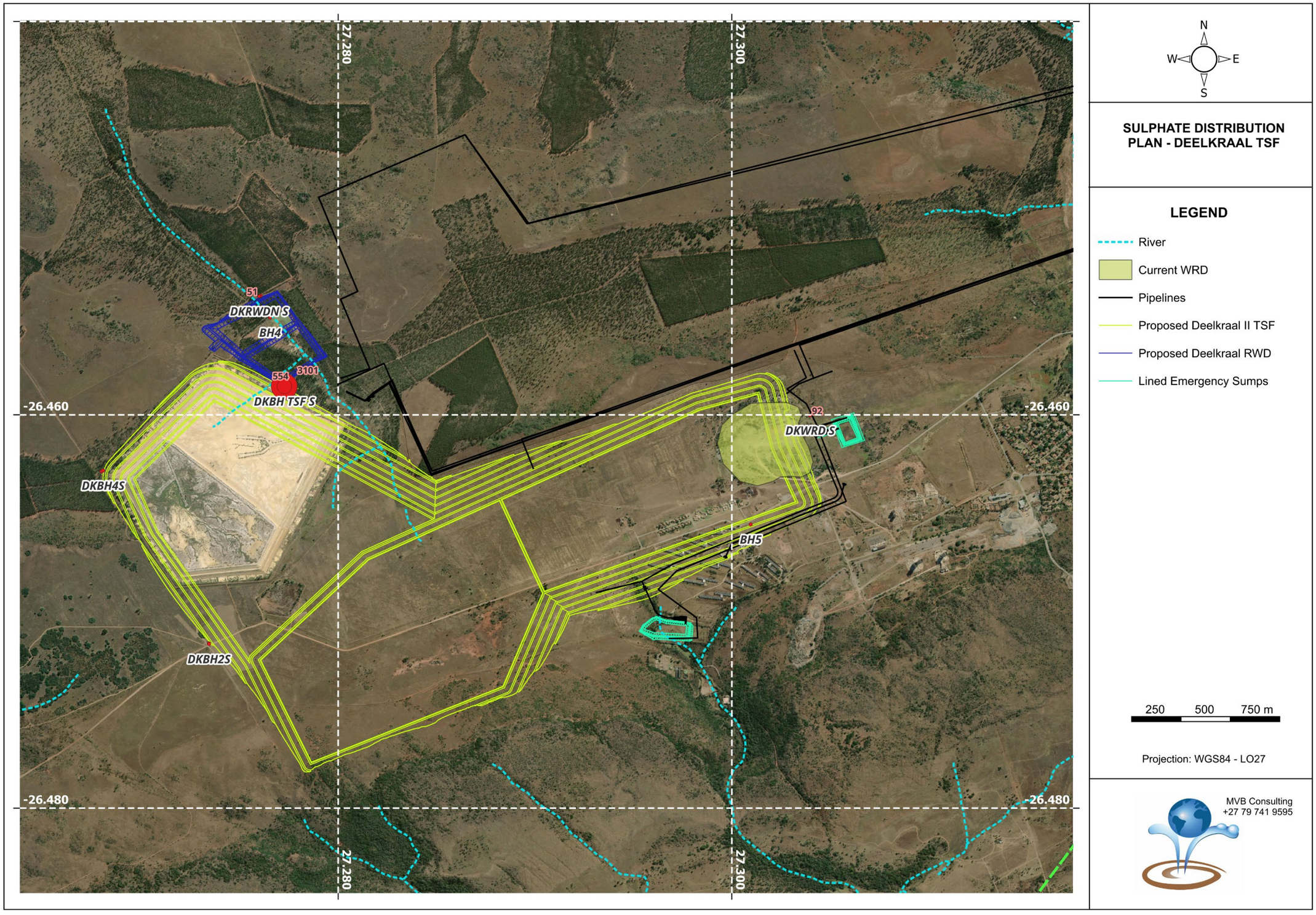


Figure 7.1: Sulphate concentrations in the Deelkraal TSF and WRD monitoring boreholes

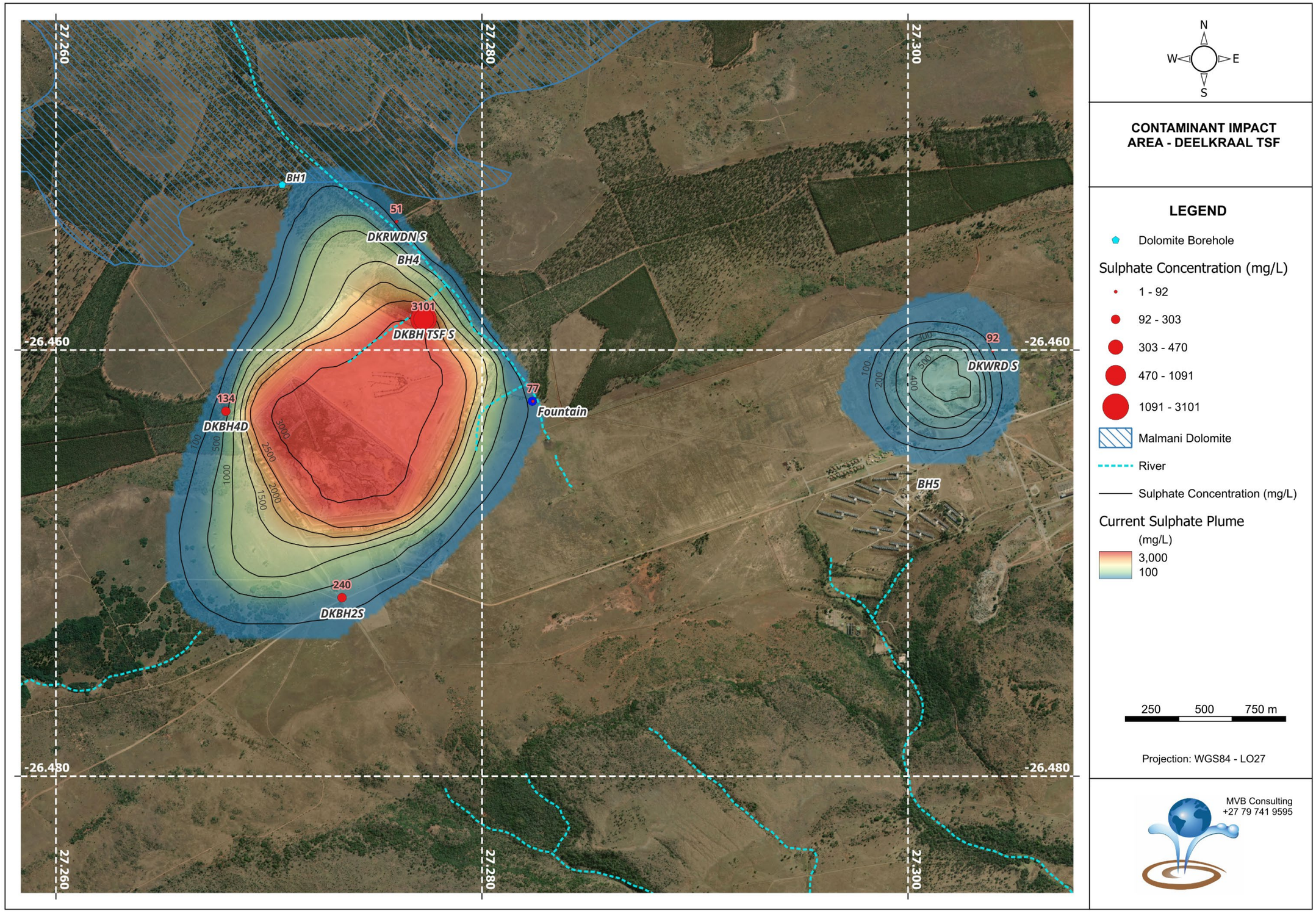


Figure 7.2: Current sulphate contamination plume at the Deelkraal TSF and WRD

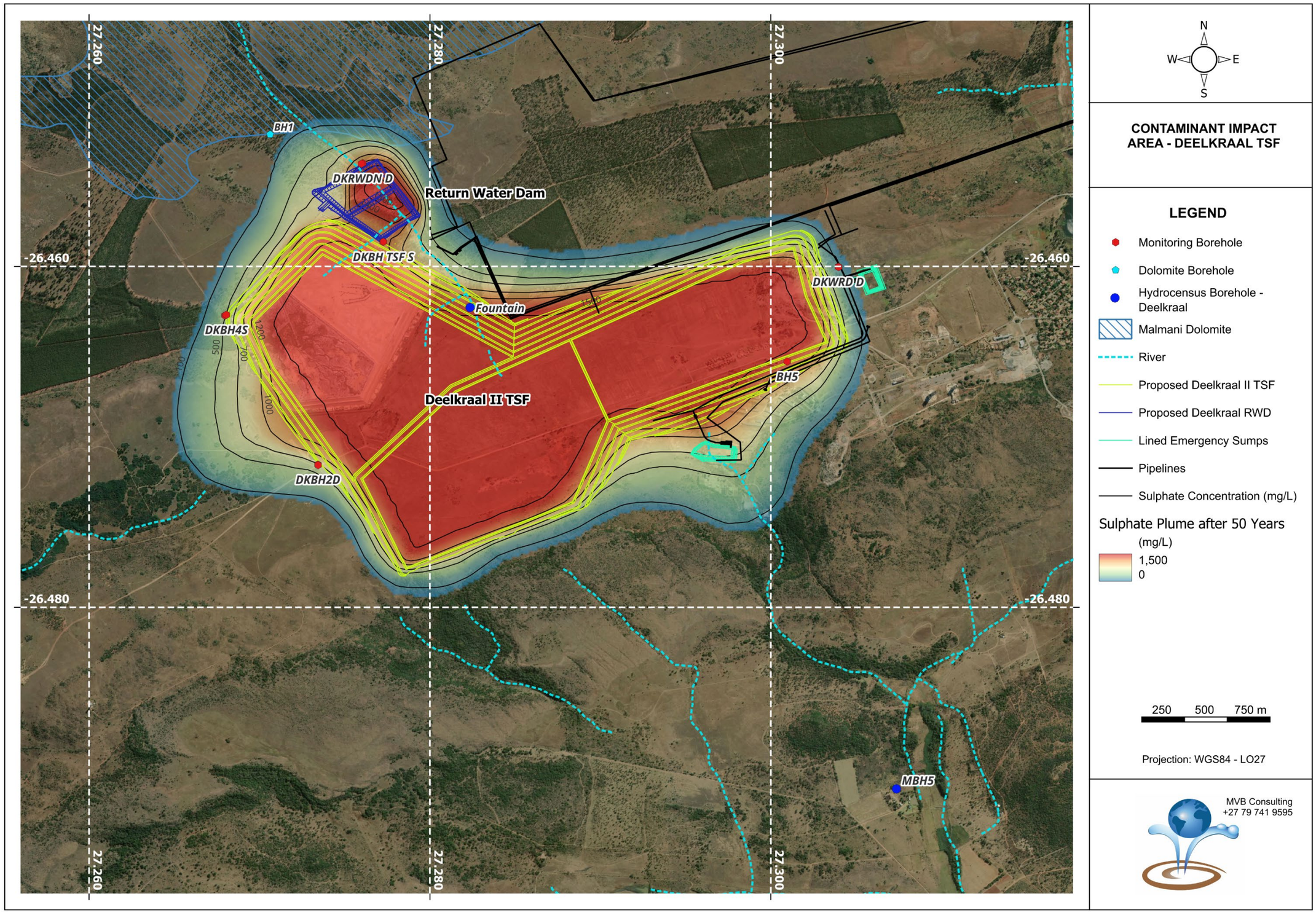


Figure 7.3: Sulphate contamination plume at the Deelkraal TSF and WRD after 50 years (No mitigation)

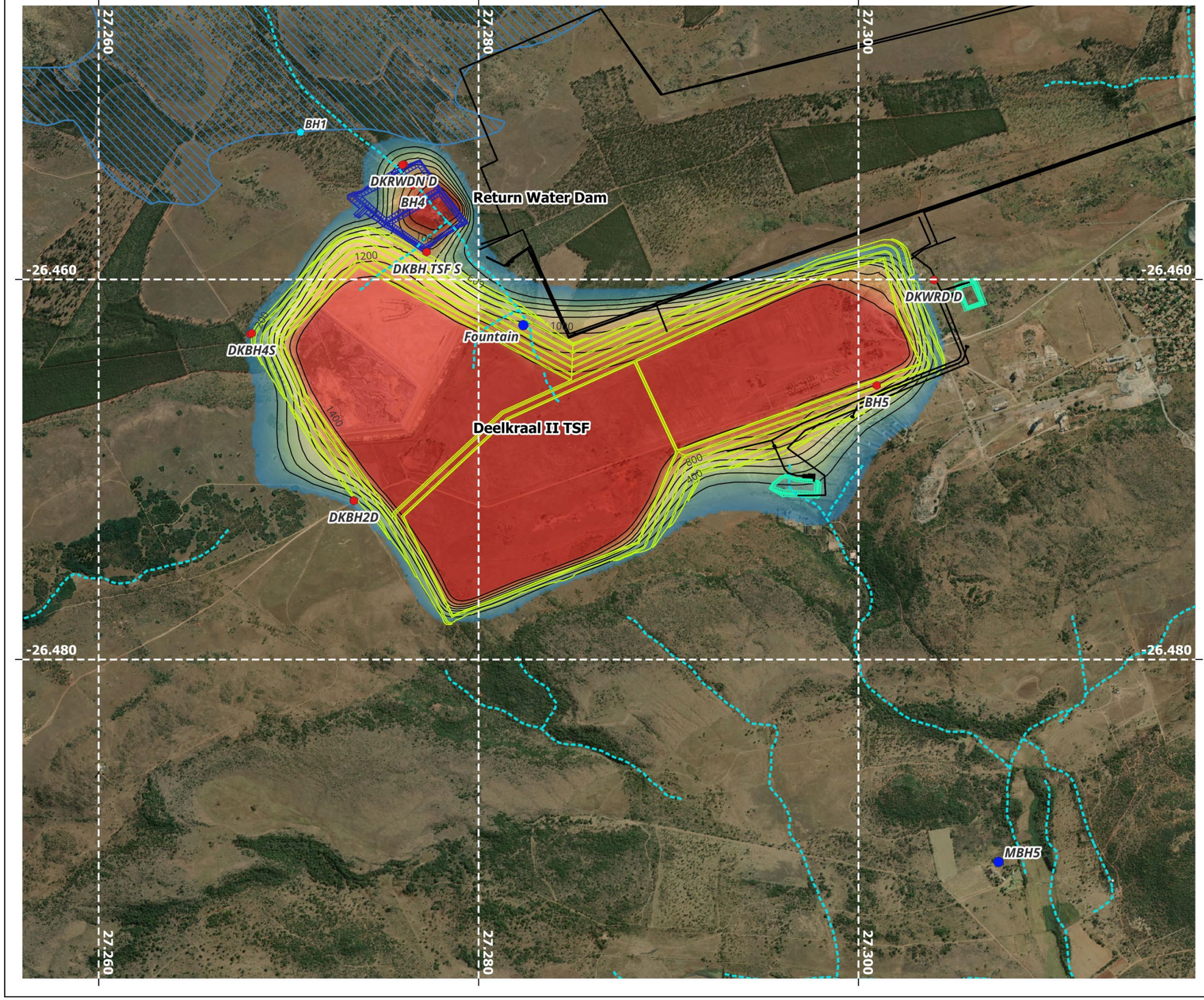


Figure 7.4: Sulphate contamination plume at the Deelkraal TSF and WRD after 50 years (TSF & RWD lined)

7.4 Catchment C23J – Kusasalethu TSF

The latest available chemistry results for the monitoring boreholes at these facilities are presented in Table 7.6.

Red highlighting in Table 7.6 identifies exceedances of the WUL comparison values printed in that table. Selected drinking-water comparisons are discussed separately.

Figure 7.5 shows the distribution of sulphate concentrations in the Kusasalethu monitoring network.

With reference to Table 7.6 and Figure 7.5 the groundwater quality at the Kusasalethu operations can be described as follows:

- MBH17 (pH 5.32), BH9 (5.62) and BH6 (5.26) are acidic under the descriptive categories in Table 7.4, although all remain within the reproduced WUL pH range of 5 to 9.7.
- The salinity in the groundwater varies between non-saline in the up-gradient borehole (KL BH) to very saline in the down-gradient boreholes (BH8 Deep).
- Several downgradient boreholes have elevated sulphate relative to the background borehole KL BH. MBH16, BH8 Deep, BH8 Shallow and BH9 exceed the listed WUL sulphate value of 600 mg/L. Other exceedances include salinity, major ions and manganese at several points; BH6 also exceeds the listed nitrate value.
- BH8 Deep contains 1 491 mg/L sulphate, compared with 888 mg/L in BH8 Shallow. Higher contamination in the deeper interval may reflect preferential flow, source history or local recharge conditions. Geological pathways and possible stream-related inputs require investigation; the available data do not identify a unique mechanism.

The current contaminant plume, as represented by the sulphate concentrations, is shown in Figure 7.6 and the simulated 50-year plume in Figure 7.7 (after source removal).

The simulated plume extends mainly southwards and southwestwards and is interpreted to affect two small streams. The available observations do not demonstrate a mine-related impact at the monitored private boreholes, but sampling coverage and historical data limit that conclusion.

Reclamation is expected to reduce the main Kusasalethu tailings source after removal and rehabilitation. Existing dissolved contamination and residual material may continue to release contaminants. The model predicts a substantial reduction in sulphate over 50 years under its source-removal assumptions; this is not a guarantee of recovery for all contaminants or locations.

The WRD is assumed to remain. Its contribution requires continued monitoring, particularly because BH6 exceeds the listed nitrate limit and BH7 could not be located. The available dataset does not justify excluding the WRD from ongoing management.

Table 7.6: Groundwater chemistry in the C23J catchment (Kusasalethu TSF and WRD) monitoring boreholes (Aquatico, 2025)

BH ID	Physical and Aesthetic Quality				Major Cations & Anions									Heavy Metals										
	pH	EC	TDS	Total Alkalinity	Chloride	Sulphate	Nitrate	Ammonia	Fluoride	Calcium	Magnesium	Sodium	Potassium	Aluminium	Iron	Manganese	Chromium	Copper	Cadmium	Lead	Nickel	Cobalt	Zinc	Total Cyanide	Uranium
Unit	pH units	mS/m	mg/l	mg/l $CaCO_3$	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
WUL (2020)	≥ 5 to ≤ 9.7	≤ 200	≤ 1 200	-	≤300	≤600	≤10	-	≤1	≤200	≤100	≤200	-	≤0.5	≤3	≤0.5	-	-	-	-	-	-	-	-	≤0.03
Kusasalethu TSF Complex																									
AS BH	Locked																								
MBH14	6.83	134	974	103	112	447	0.391	0.56	<0.263	157	30.7	108	9.79	0.026	0.183	1.60	<0.003	<0.002	<0.002	<0.004	<0.002	0.016	<0.002	<0.005	<0.015
MBH15	7.23	123	1 038	73.1	98.5	470	1.57	0.056	<0.263	175	47.7	31.4	13.6	0.028	<0.004	0.069	<0.003	<0.002	<0.002	<0.004	<0.002	<0.003	<0.002	<0.005	<0.015
MBH16	7.30	244	2 230	53	211	1 152	1.93	0.063	<0.263	286	150	122	7.67	0.030	<0.004	3.32	<0.003	<0.002	<0.002	<0.004	0.064	0.061	0.016	<0.005	<0.015
MBH17	5.32	69.5	642	30.3	14.1	303	3.94	6.39	<0.263	40.2	56	22.2	3.26	0.309	<0.004	1.16	<0.003	0.013	<0.002	<0.004	0.192	0.093	0.295	<0.005	<0.015
BH8 (Deep)	6.47	308	2 672	77	314	1 491	0.515	0.10	<0.263	425	236	83.1	8.37	0.062	<0.004	0.101	<0.003	<0.002	0.002	<0.004	0.005	0.106	0.007	<0.005	<0.015
BH8 (Shallow)	7.82	214	1 854	125	188	888	0.657	0.065	0.593	269	157	55.6	8.91	0.042	<0.004	0.091	<0.003	<0.002	<0.002	<0.004	<0.002	0.058	0.006	<0.005	<0.015
BH9	5.62	297	2 286	25.6	292	1 091	<0.194	17.3	0.367	188	75.3	359	12.9	0.082	<0.004	42.6	<0.003	<0.002	<0.002	<0.004	0.050	0.530	0.130	<0.005	<0.015
Kusasalethu WRD																									
BH6	5.26	120	908	7.64	137	335	14.4	0.254	<0.263	110	11.4	137	22.1	0.478	<0.004	0.266	<0.003	<0.002	<0.002	<0.004	0.008	0.072	0.015	<0.005	<0.015
BH7	Unable to locate																								

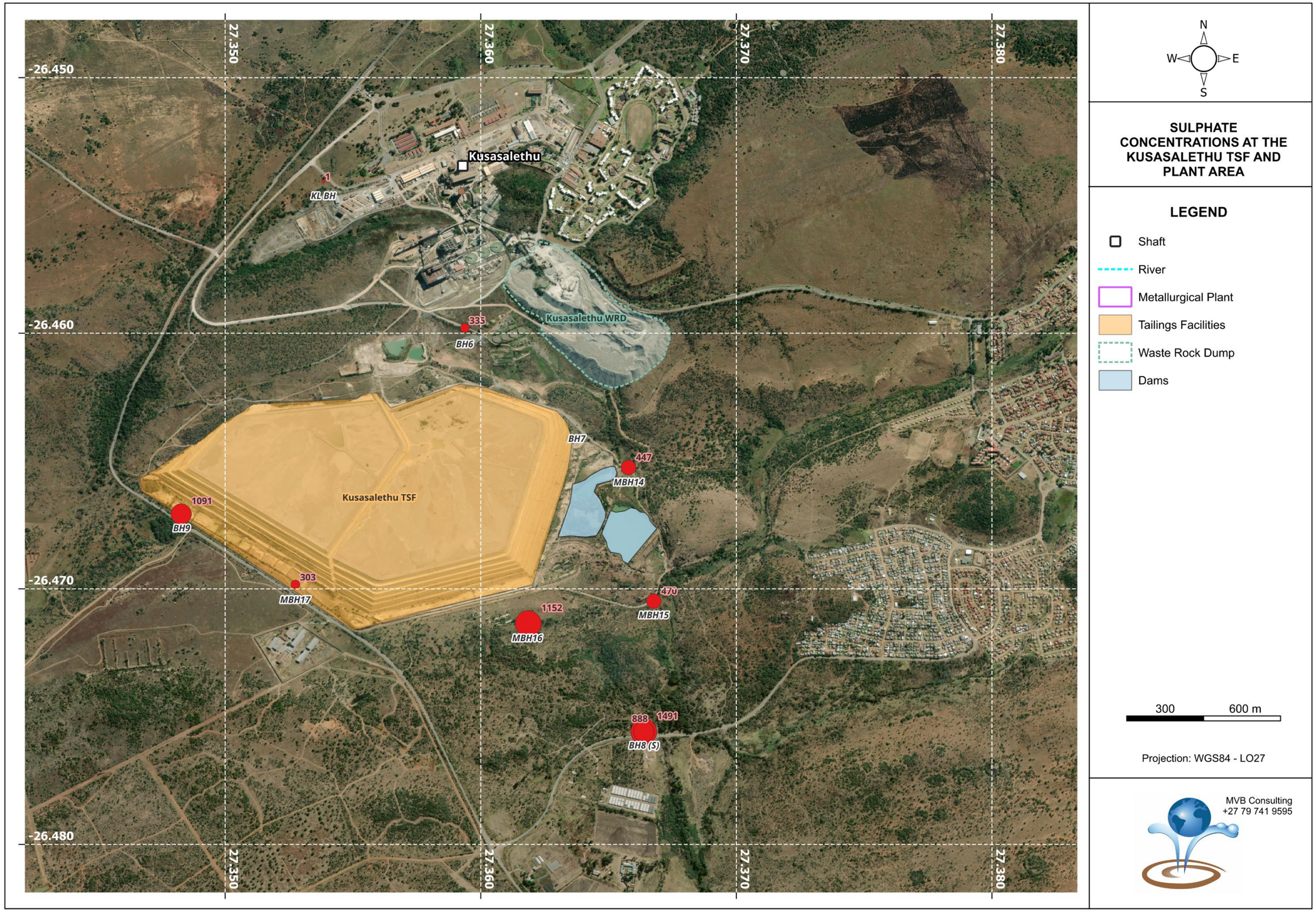


Figure 7.5: Sulphate concentrations in the Kusasalethu monitoring boreholes

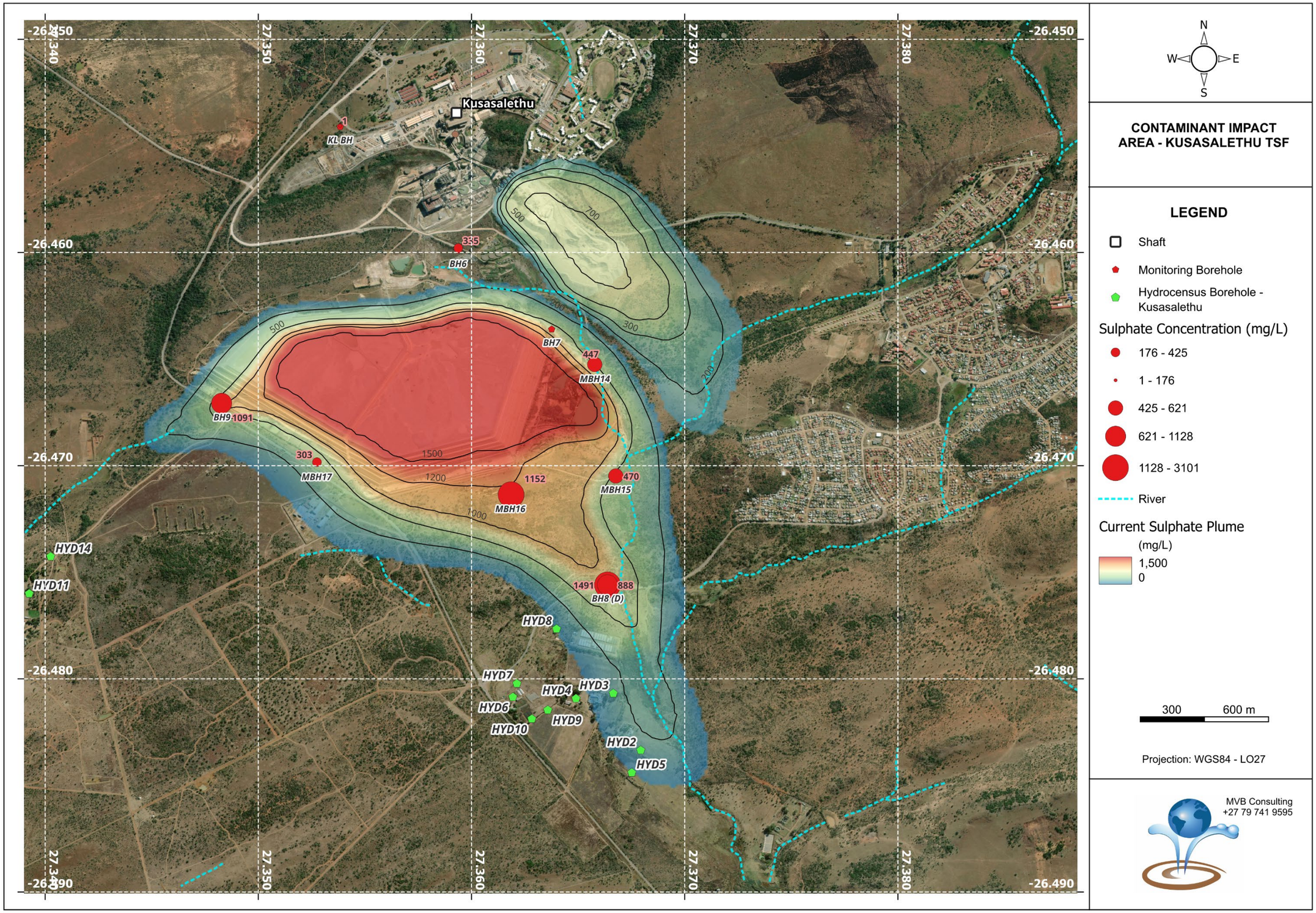


Figure 7.6: Current sulphate contamination plume in the Kusasalethu area

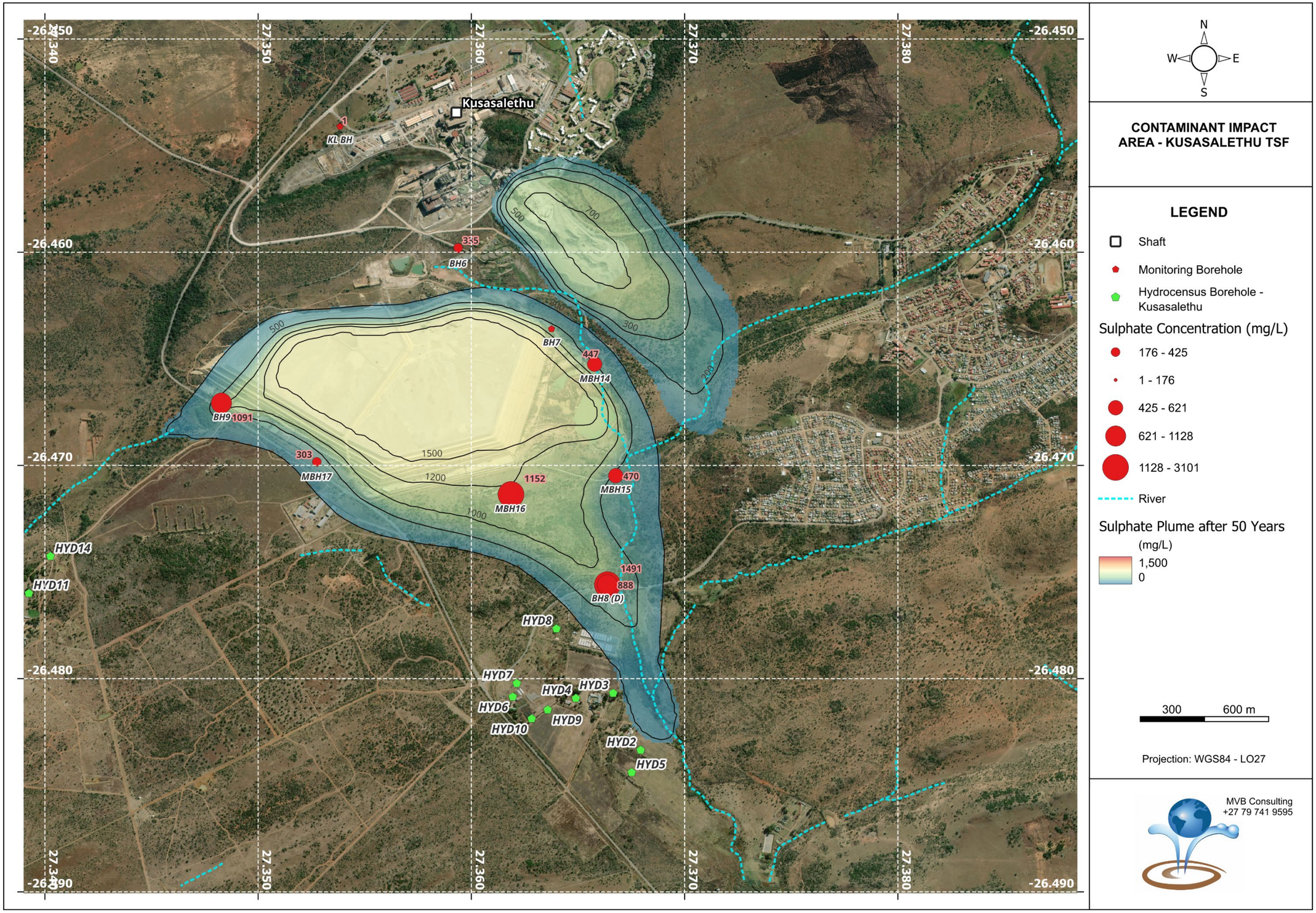


Figure 7.7: Sulphate contamination plume in the Kusasalethu area after 50 years

7.5 Risk Assessment

The impact significance rating methodology, as presented herein and utilised for all EIMS Impact Assessment Projects, is guided by the requirements of the NEMA EIA Regulations 2014 (as amended). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/ likelihood (P) of the impact occurring. The ER is determined for the pre- and post-mitigation scenario. In addition, other factors, including cumulative impacts and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S). The impact assessment will be applied to all identified alternatives.

7.5.1 Determination of the Environmental Risk

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER). The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and Reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$\boldsymbol{C} = \frac{(\boldsymbol{E}+\boldsymbol{D}+\boldsymbol{M}+\boldsymbol{R})*\boldsymbol{N}}{\boldsymbol{4}}$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 7.7 below.

Table 7.7: Criteria for determining Impact Consequence

Nature	-1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary)
	3	Local (i.e. the area within 5 km of the site)
	4	Regional (i.e. extends between 5 and 50 km from the site)
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years)
	3	Medium term (6-15 years)
	4	Long term (15-65 years, the impact will cease after the operational life span of the project)
	5	Permanent (>65 years, no mitigation measure of natural process will reduce the impact after construction)
Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected)
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected)
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way, moderate improvement for positive impacts)
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease, high improvement for positive impacts)
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease, substantial improvement for positive impacts)
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring prohibitively high time and cost.
	5	Irreversible Impact.

Once the C has been determined, the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P. Probability is rated / scored as per Table 7.8.

Table 7.8: Probability scoring

Probability		1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),
		2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
		3	Medium probability (the impact may occur; >50% and <75%),
		4	High probability (it is most likely that the impact will occur- > 75% probability), or
		5	Definite (the impact will occur),

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated as follows:

$$ER = C \times P$$

Table 7.9: Determination of Environmental Risk

Consequence	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
	Probability					

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in Table 7.10.

Table 7.10: Environmental Risk Scores

ER Score	Description
<9	Low (i.e. where this impact is unlikely to be a significant environmental risk/ reward).
≥9 ≤17	Medium (i.e. where the impact could have a significant environmental risk/ reward),
>17	High (i.e. where the impact will have a significant environmental risk/ reward).

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

7.5.2 Impact Prioritisation

Further to the assessment criteria presented in the section above, it is necessary to assess each potentially significant impact in terms of:

- Cumulative impacts; and
- The degree to which the impact may cause irreplaceable loss of resources.

To ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented.

Table 7.11: Criteria for Determining Prioritisation

Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/ definite that the impact will result in spatial and temporal cumulative change.
Irreplaceable Loss of Resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 5. The impact priority is therefore determined as follows:

$$\boldsymbol{Priority = CI + LR}$$

The result is a priority score which ranges from 2 to 6 and a consequent PF ranging from 1 to 2 (refer to Table 7.12).

Table 7.12: Determination of Prioritisation Factor

Priority	Prioritisation Factor
2	1
3	1.125
4	1.25
5	1.375
6	1.5

In order to determine the final impact significance, the PF is multiplied by the ER of the post mitigation scoring. The ultimate aim of the PF is an attempt to increase the post mitigation environmental risk rating by a factor of 0.5, if all the priority attributes are high (i.e. if an impact comes out with a high medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance).

Table 7.13: Final Environmental Significance Rating

Significance Rating	Description
<-17	High negative (i.e. where the impact must have an influence on the decision process to develop in the area).
≥-17 ≤-9	Medium negative (i.e. where the impact could influence the decision to develop in the area).
>-9 < 0	Low negative (i.e. where this impact would not have a direct influence on the decision to develop in the area).
0	No impact
>0 <9	Low positive (i.e. where this impact would not have a direct influence on the decision to develop in the area).
≥9 ≤17	Medium positive (i.e. where the impact could influence the decision to develop in the area).
>17	High positive (i.e. where the impact must have an influence on the decision process to develop in the area).

The significance ratings and additional considerations applied to each impact provide a quantitative comparative assessment of the alternatives being considered.

7.5.3 Impact Assessment Result

Table 7.14 presents the assessment scores. Numerical calculations and category labels have been aligned with the stated method. The underlying judgement scores require reassessment where they assume short-lived, site-confined impacts despite the 50-year plume forecasts and the sensitivity of the dolomite receptor.

- The primary risk that this proposed project poses is the seepage of contaminants into the aquifer, and the migration of these contaminants into down-gradient receptors.

The following mitigation measures were included in the assessment:

- Identifier 1 covers reclamation of the existing TSFs. Added reclamation water may temporarily increase seepage. Long-term improvement depends on removing the contaminant source, managing residual contaminated material and rehabilitating the footprint. The table rates negative impacts; it does not separately quantify the potential long-term benefit.
- Identifier 2 covers the new TSF and RWD. The unmitigated case is an unlined development, not the no-project alternative. The mitigated case assumes an effective barrier system. A separate no-project comparison should describe continued legacy contamination if reclamation and new deposition do not proceed.

Table 7.14: West Wits Reclamation groundwater impact assessment table

Identifier	Discipline	Impact	Alternative	Phase	Event	Pre-Nature	Pre-Extent	Pre-Duration	Pre-Magnitude	Pre-Reversibility	Consequence	Pre-Probability	Pre-Mitigation Significance Score	Pre-Mitigation Significance	Post-Nature	Post-Extent	Post-Duration	Post-Magnitude	Post-Reversibility	Consequence2	Post-Probability	Post-mitigation Significance Score	Post-Mitigation Significance	Confidence	Cumulative Impact	Irreplaceable loss	Priority Factor	Final score	Final Significance
1	Groundwater	Groundwater contamination from remining of existing TSF's		Construction	Normal operations or events	-1	1	2	3	2	-2	3	-6	Medium to low -	-1	1	2	3	2	-2	3	-6	Medium to low -	Medium	2	2	1.25	-7.50	Medium to low -
2	Groundwater	Groundwater contamination from from new TSF & RWD		Construction	Normal operations or events	-1	1	2	3	3	-2.25	3	-6.75	Medium to low -	-1	1	2	2	2	-1.75	2	-3.5	Low -	Medium	2	2	1.25	-4.38	Medium to low -
1	Groundwater	Groundwater contamination from remining of existing TSF's		Operation	Normal operations or events	-1	3	4	3	3	-3.25	4	-13	Medium to high -	-1	2	3	3	3	-2.75	3	-8.25	Medium to low -	Medium	2	2	1.25	-10.31	Medium to high -
2	Groundwater	Groundwater contamination from from new TSF & RWD		Operation	Normal operations or events	-1	3	5	4	4	**-4**	4	-16	High -	-1	2	3	2	2	-2.25	2	-4.5	Medium to low -	Medium	2	2	1.25	-5.63	Medium to low -
1	Groundwater	Groundwater contamination from remining of existing TSF's		Decommissioning	Normal operations or events	-1	3	4	3	3	-3.25	3	-9.75	Medium to high -	-1	2	3	3	3	-2.75	2	-5.5	Medium to low -	Medium	2	2	1.25	-6.88	Medium to low -
2	Groundwater	Groundwater contamination from from new TSF & RWD		Decommissioning	Normal operations or events	-1	3	5	4	4	**-4**	4	-16	High -	-1	2	3	2	2	-2.25	2	-4.5	Medium to low -	Medium	2	2	1.25	-5.63	Medium to low -
1	Groundwater	Groundwater contamination from remining of existing TSF's		Rehab and Closure	Normal operations or events	1	3	4	2	2	2.75	3	8.25	Low to medium +	1	3	4	2	2	2.75	3	8.25	Low to medium +	Medium	1	1	1.00	8.25	Medium to low +
2	Groundwater	Groundwater contamination from from new TSF & RWD		Rehab and Closure	Normal operations or events	1	3	4	2	3	3	3	9	Medium to high +	1	3	3	2	2	2.5	3	7.5	Low to medium +	Medium	1	1	1.00	7.50	Medium to low +

8. SUMMARY AND CONCLUSION

Reclamation of the Deelkraal and Kusasalethu TSFs offers a potential long-term reduction in legacy groundwater contamination, provided that source removal is followed by effective rehabilitation. The proposed Deelkraal II TSF and RWD introduce a new seepage source and require effective containment. The unlined scenario predicts migration of the >600 mg/L sulphate plume to the dolomite within 50 years; it cannot support a conclusion that a liner is unnecessary.

The assessment combines historical investigations, hydrocensus observations, September 2025 facility monitoring and FEFLOW flow and sulphate-transport modelling. The forecasts depend on the final footprint, source-removal sequence, leachate quality, effective porosity and long-term barrier performance.

8.1 Site Geology

The project area is predominantly underlain by Pretoria Group shale and quartzite, with volcanic units farther south. Malmani dolomite outcrops north of Deelkraal and dips beneath the overlying formations. Reported depth to dolomite beneath Deelkraal is approximately 80–120 m. Local structure and the geometry of the dolomite contact require confirmation where they control contaminant migration.

8.2 Site Hydrogeology

Groundwater occurs in shallow weathered materials, deeper fractures and the regional dolomitic karst aquifer. The non-dolomitic aquifers generally have low bulk permeability, but local fractures support water supplies and can transmit contaminants. Their limited regional yield does not reduce the need to protect local groundwater users.

The dolomite is a sensitive receptor north of Deelkraal. Its depth beneath the TSFs and possible vertical separation from shallow groundwater do not exclude lateral transport towards the exposed contact. The abandoned dry borehole provides no direct water-quality evidence that the dolomite is unaffected.

The adopted background recharge is 20 mm/year, approximately 3.55% of the model rainfall reference of 563 mm/year. Available heads indicate predominantly northward flow at Deelkraal and southward to southwestward and southeastward flow at Kusasalethu, with potential local departures along geological structures.

The Kusasalethu hydrocensus tables contain nine monitored boreholes. Six have reported microbiological exceedances requiring follow-up. The Deelkraal survey identified seven boreholes, three of them dry, as well as a fountain and a sampled dam. Nickel at MBH5 and aluminium, iron and manganese at MSW2 exceed the comparison values printed in Table 4.4. The fountain meets those selected chemical values, but microbiological safety is not established.

The September 2025 mine-monitoring results demonstrate existing contamination in both shallow and deeper intervals. At Deelkraal, sulphate reaches 3 101 mg/L and manganese 44.8 mg/L in DK BH TSF D. At Kusasalethu, multiple boreholes exceed the listed sulphate, salinity or manganese limits. MBH17, BH9 and BH6 are acidic under the descriptive pH categories used in the report.

No mine-related impact is demonstrated at the sampled private boreholes by the available dataset, but this conclusion is limited by monitoring coverage, the age of some records and unrelated water-quality problems. The Kusasalethu plume is interpreted to affect small streams, and the Deelkraal plume approaches the dolomite contact. Dry and inaccessible boreholes leave important monitoring gaps.

8.3 Impact Assessment

The flow model uses 55 calibration observations. Calculated statistics are ME -3.95 m, MAE 10.26 m and RMSE 13.32 m, with a squared Pearson correlation of 0.941. The 14-point sulphate calibration gives ME 27.21 mg/L, MAE 61.36 mg/L and RMSE 81.42 mg/L.

Under the source-removal scenario, the Kusasalethu sulphate plume is predicted to reduce substantially over 50 years. Recovery is conditional on removal of residual sources and the assumed flow and transport parameters. Sulphate dilution or flushing does not establish equivalent recovery for metals or other constituents.

At Deelkraal, the unlined new TSF and RWD scenario predict migration towards the dolomite and southwards. The reported arrival of the >600 mg/L sulphate plume at the dolomite within 50 years is a material adverse outcome requiring containment and receptor monitoring.

- The lined scenario predicts much less migration when leakage is set to 6 L/ha/day. This performance estimate is specific to the assumed inverted barrier and cannot be extended to all liners. Representative source testing and engineering verification of leakage, drainage, construction quality and long-term integrity are required.

The 1 500 mg/L sulphate source term for Deelkraal II remains unverified. Improved metallurgical processing has not been shown here to reduce sulphide content or leaching sufficiently to justify a lower-risk conclusion. Higher source concentrations, increased leakage and preferential flow should be included in the uncertainty assessment.

8.4 Reasoned Opinion

Based on the findings of this hydrogeological assessment, it is my reasoned opinion that the proposed Reclamation Project may be authorised from a groundwater perspective, provided that the recommended avoidance, management, mitigation and monitoring measures are implemented through the Environmental Management Programme and, where applicable, incorporated into the closure plan.

The hydrogeological findings support further development of a contained, monitored reclamation and deposition scheme. They do not support an unlined facility or an unconditional assurance of no receptor impact. Final design and authorisation decisions should be based on verified source terms, an approved containment design and a monitoring programme capable of detecting migration before sensitive receptors are affected.

9. RECOMMENDATIONS

Adopt an engineered containment system beneath the new TSF and RWD. Demonstrate its performance under the proposed loading, water chemistry and service life, including construction quality assurance, drainage capacity, defect scenarios and deterioration. Confirm the applicable regulatory requirements and obtain approval for any alternative barrier before construction.

Test representative reprocessed tailings and return water. Include the proposed feed blend, acid-generation and neutralisation potential, sulphate and metal release, and time-dependent leaching where warranted. Use these results to verify or revise the assumed Deelkraal II source term of 1 500 mg/L sulphate.

Reconcile the final TSF footprint and reclamation sequence with the numerical model. Record source areas, activation and removal dates, residual contamination, recharge and seepage fluxes, boundary conditions, adopted effective porosity and model water and solute balances. Distinguish the new facility, existing waste sources and no-project scenario.

Install at least four monitoring borehole pairs around Deelkraal II: two pairs north and two south, subject to geological siting and access. Each pair should distinguish shallow and deeper groundwater without creating a hydraulic connection between aquifers. Position northern points to intercept migration towards the dolomite and add a suitable dolomite monitoring point where practicable.

Restore access to locked boreholes and inspect, survey and reconcile all borehole identifiers and coordinates. Investigate dry, damaged and unlocated points and replace those necessary for receptor protection. Establish a baseline covering seasonal variability before new deposition begins and incorporate all additional results available since September 2025.

Update the monitoring plan to cover the TSFs, RWD, pipelines, streams, fountain, private supplies and the dolomite contact. As a proposed minimum, monitor groundwater levels monthly and chemistry quarterly during reclamation and operation, with greater frequency after incidents or adverse trends, subject to any more stringent licence conditions. Confirm sampling protocols, detection limits, quality control and responsibilities.

Investigate nickel at MBH5 and aluminium, iron and manganese at MSW2 through confirmatory sampling. Follow up the reported microbiological exceedances at private supplies, confirm actual domestic use, and arrange appropriate communication and corrective action through the responsible parties. Assess drinking-water suitability against the applicable standard, including microbiological and aesthetic requirements.

Define site-specific early-warning levels using background variability, licence limits and receptor sensitivity. Specify who investigates an exceedance, the confirmation-sampling timeframe and the response required. Responses should include inspection of containment and pipelines, source control and, where justified by testing, interception or treatment. Interception trenches should not be assumed effective for deeper fractured or karst pathways.

Update the model when new data or design changes become available. Test higher source concentrations, higher leakage rates, alternative porosity values, preferential flow and the dolomite geometry. Extend predictions beyond 50 years where loading or receptor risk persists, and validate forecasts against subsequent observations.

Reassess the impact significance scores with the EAP, including the unlined case, no-project alternative, long-term operation and post-closure conditions. Reclamation-water control, residual-source rehabilitation, liner maintenance and contingency measures should be explicit assumptions of the mitigated ratings.

Continue monitoring through closure and until agreed groundwater-recovery criteria are met. Closure should demonstrate stable or improving quality at receptors and effective control of residual seepage, rather than rely solely on completion of earthworks or the passage of a fixed period.

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APPENDIX A

SPECIALIST DECLARATION AND CV

DETAILS OF SPECIALIST AND DECLARATION OF INTEREST

Application for authorisation in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended and the Environmental Impact Assessment Regulations, 2014

PROJECT TITLE

ENVIRONMENTAL IMPACT MANAGEMENT SERVICES HYDROGEOLOGICAL ASSESSMENT FOR THE PROPOSED GOLD RECLAMATION FROM THE KHUSASALEKA AND DEELKRAAL TAILINGS FACILITIES AND THE REDEPOSITION ON A NEW TAILINGS STORAGE FACILITY

Name of the Specialist:	Marius van Biljon		
Qualifications:	BSc. Honours (Geology) MSc. Geohydrology PhD. Geohydrology		
Experience:	35 years		
Company Name:	MVB Consulting		
Physical Address:	32 La Paloma Estate, Falls Road		
	Homes Haven, Krugersdorp		
	Code	1759	
Postal address:	As above		
Postal code:	1759	Cell:	079 741 9595
E-mail:	marius@mvbconsult.co.za		
Professional affiliation(s) (if any)	Registered Professional Scientist (Pr. Sci. Nat.) Registration number: 400177/13		

The Geohydrological Specialist

I, **Marius van Biljon**, declare that –

General declaration:

- I act as the independent geohydrological 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 geohydrological studies, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, regulations and all other applicable legislation;
- I have no, 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;
- I will ensure that information containing all relevant facts in respect of the application is distributed or made available to interested and affected parties and the public and that participation by interested and affected parties is facilitated in such a manner that all interested and affected parties will be provided with a reasonable opportunity to participate and to provide comments on documents that are produced to support the application;
- I will ensure that the comments of all interested and affected parties are considered and recorded in reports that are submitted to the competent authority in respect of the application, provided that comments that are made by interested and affected parties in respect of a final report that will be submitted to the competent authority may be attached to the report without further amendment to the report;
- I will keep a register of all interested and affected parties that participated in a public participation process;
- I will provide the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not;
- All the particulars furnished by me in this form are true and correct;
- I will perform all other obligations as expected from an environmental assessment practitioner in terms of the Regulations; and
- I realise that a false declaration is an offence in terms of Regulation 48 and is punishable in terms of section 49A of the Act.

Disclosure of Vested Interest

- I do not have and will not have any vested interest (either business, financial, personal or other) in the proposed activity proceeding other than remuneration for work performed in terms of the Environmental Impact Assessment Regulations, 2014.



Signature of the Geohydrological Specialist:

MVB Consulting

Name of company:

30/05/2026

Date:

CURRICULUM VITAE

Marius van Biljon



Profession	Geohydrologist
Date of Birth	30 March 1964
Position in firm	Consultant
Years with the firm	8
Nationality	South African
Education / Qualifications	Senior Certificate (1981)
	B.Sc. Earth Science at the University of Johannesburg (1984)
	B.Sc. Hons (Geology) at the University of Johannesburg (1985)
	M.Sc. Hydrogeology at the University of the Free State (1995)
	PhD Hydrogeology at the Northwest University (2018)

Employment History

1987 – 1990	Mine geologist, Western Areas Gold Mine, JCI Group
1990 – 1992	Senior exploration geologist, JCI Services
1992 – 1995	Assistant chief geologist, HJ Joel Gold Mine, JCI Group
1995 – 1999	Group geohydrologist, JCI Services
1999 – 2008	Principal geohydrologist, Rison Groundwater Consulting
2008 – 2009	Senior geohydrologist, Golder Associates, Perth Australia
2009 – 2010	Senior geohydrologist, Golder Associates, South Africa
2010 – 2012	Principal geohydrologist, MVB Consulting
2012 – 2017	Jones & Wagener Engineering and Environmental Consultants (Associate)
2017 - current	Principal geohydrologist, MVB Consulting

Areas of Expertise

Experience in the mining, industrial, waste and environmental disciplines. Expertise includes mine water management, in particular deep underground mining environments. Duties included underground drilling, water sealing, pre-cementation, in-situ permeability testing and the development of dewatering programmes. Non-mining experience included waste site characterisation, chemical and petrochemical contamination, water supply, environmental auditing and environmental impact assessment.

Professional Affiliations

SACNASP	South African Council for Natural Scientific Professions (400177/13)

Declaration

I confirm that the above CV is an accurate description of my experience and qualifications.



_____	31 May 2026
Signature	Date

APPENDIX B

REPORT REVIEW

Independent Review of the Hydrogeological Assessment for the Proposed Gold Reclamation from the Khusasaleka and Deelkraal Tailings Facilities and the Redeposition on a new TSF

Review of MVB Consulting report MVB215/26/B072, Revision 2 (Final), June 2026

Prepared by	**Quantophi (Pty) Ltd**
Prepared for	**Environmental Impact Management Services (Pty) Ltd**
Reviewer	**Dr S.R. Dennis**
Date	**28 August 2026**
Document type	**Independent Specialist Review – Groundwater**
Status	**Revision 1**

Executive Summary

Quantophi (Pty) Ltd was appointed by Environmental Impact Management Services (Pty) Ltd (EIMS) to carry out an independent specialist review of the Hydrogeological Assessment prepared by MVB Consulting (Report MVB215/26/B072, Revision 2, Final, June 2026), referred to below as "the Report", in support of the Environmental Authorisation (EA), Atmospheric Emission Licence (AEL) and Water Use Licence (WUL) applications for the Harmony West Wits Reclamation Project. The review examined the Report's conceptual model, data basis, numerical flow and mass transport modelling, predictive scenarios, impact assessment and compliance with Appendix 6 of the Environmental Impact Assessment (EIA) Regulations, 2014 (as amended).

The Report is well organised, its regional geological and hydrogeological description of the Far West Rand is competent, and the groundwater model is appropriate to the data available. All calculations, where they can be reproduced, are correct: the aquifer parameter averages, the chloride mass balance, the steady-state calibration statistics and the impact rating arithmetic were all independently recalculated. The Report is considered fit for purpose.

Thirteen findings are recorded. Three carry high priority because they bear on conclusions that the authorisation decision will rest on. The first concerns the liner: Sections 7.5.4 and 8.3 state that a liner for the proposed 430 ha Deelkraal II tailings storage facility and return water dam is not a prerequisite, while the low residual significance in the post-mitigation column of Table 7.14 is scored on the basis that the liner is installed. The second concerns the Malmani dolomite, which Section 5.1 places in outcrop 500 m north of the Deelkraal tailings storage facility and identifies as a sensitive aquifer requiring protection, while Section 8.2 states that it plays no role at either site. The third concerns the mass transport inputs: neither the sulphate source concentration nor the effective porosity is stated for the existing facilities or for Deelkraal II, and predicted plume extent depends directly on both. Six findings are of medium priority and three findings are of lower priority. A final finding is editorial and concerns internal consistency and presentation.

None of these findings goes to the merits of the project, which may well prove favourable: reclaiming the two existing unlined facilities should improve groundwater quality over time, and a new lined facility may pose a low residual risk. What would strengthen the Report is setting out the evidence for those outcomes, so that the reviewing authority can follow the reasoning from the data through to the conclusions. A recommended action accompanies each finding, set out in a highlighted box alongside the relevant discussion in Section 3. None is disproportionate to a project of this scale, and most draw on work or data that already exist.

This review is subject to the limitations recorded in Section 1.4. If the model files, the monitoring database and the cited unpublished reports are provided, these findings may be refined or withdrawn.

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Abbreviations

Abbreviation	Definition
AEL	Atmospheric Emission Licence
EA	Environmental Authorisation
EC	Electrical conductivity
EIA	Environmental Impact Assessment
EIMS	Environmental Impact Management Services (Pty) Ltd
EMPr	Environmental Management Programme
FEFLOW	Finite element subsurface flow and transport simulation code
GN	Government Notice
MAE	Mean absolute error
MAP	Mean annual precipitation
MODFLOW	Modular three-dimensional finite difference groundwater flow model
NRMSE	Normalised root mean square error
POPIA	Protection of Personal Information Act, 2013 (Act 4 of 2013)
RMSE	Root mean square error
RWD	Return water dam
SANS	South African National Standard
TDS	Total dissolved solids
TSF	Tailings storage facility
WRC	Water Research Commission
WUL	Water Use Licence

1 Introduction

1.1 Appointment and terms of reference

Quantophi (Pty) Ltd was appointed by Environmental Impact Management Services (Pty) Ltd (EIMS) on 6 August 2026, under EIMS Assignment 1716, to provide Independent Groundwater Review Specialist Services in respect of the Harmony West Wits Reclamation Project. EIMS is the appointed Environmental Assessment Practitioner for Harmony Gold Mining Company, to obtain the Environmental Authorisation and Water Use Licence required for the proposed reclamation of the Deelkraal and Kusasalethu tailings storage facilities and the deposition of the reworked tailings on a new facility, Deelkraal II.

The purpose of this document is to comment independently on whether the groundwater specialist report submitted in support of those applications provides the support those applications require, and, where further work would strengthen it, to set out what we recommend be done.

1.2 Document reviewed

Table 1: The document subject to this review.

Item	Detail
Title	Hydrogeological Assessment for the Proposed Gold Reclamation from the Khusasaleka and Deelkraal Tailings Facilities and the Redeposition on a New Tailings Storage Facility
Report number	MVB215/26/B072 (cover and approval record); MVB186/25/B072 (running page header)
Revision	Revision 2 — Final Report
Date of issue	19 June 2026 (Revision 1 issued 22 May 2026)
Prepared by	Dr M van Biljon (PhD, Pr.Sci.Nat.), MVB Consulting
Prepared for	Environmental Impact Management Services (Pty) Ltd
Referred to below as	“the Report”

1.3 Approach

The scope of this review included:

- Verified internal consistency by cross-checking text, tables, figures, and ensuring the conclusions in Sections 8 and 9 are justified by the results.
- Independently recalculated all reproducible values in the Report, including the aquifer averages (Section 5.2.3), chloride mass balance (Sections 4.7 and 5.2.4), calibration statistics (Table 6.2), liner leakage rates (Section 7.3), and risk arithmetic (Table 7.14).
- Benchmarked the modelling methodology against generally accepted licensing standards for groundwater flow and mass transport.
- Audited the Report’s compliance with specialist report content requirements set out in Appendix 6 of the Environmental Impact Assessment Regulations, 2014 (as amended).

- Evaluated the conclusions against standard Water Use License application criteria for a new residue deposit.

1.4 Limitations of this review

The findings in this assessment are subject to the following limitations:

- No site visit was conducted, and no independent field data were collected.
- The model files-including the finite-element mesh, parameter and boundary-condition assignments, and mass transport source terms-were not provided. Consequently, the model could not be re-run, and our assessment is based solely on the information disclosed in the Report.
- The underlying monitoring database was not made available. Water quality has been assessed using only the values tabulated within the Report.
- The reviewer could not access several documents mentioned in the report, often because they were missing from the reference list in (Section 3.10).
- External data used as part of the review was sourced from public domain data and should be viewed in the context of a desktop study rather than being site specific.

1.5 Declaration of independence

Quantophi (Pty) Ltd and the author of this review have no financial or other interest in the Harmony West Wits Reclamation Project or Harmony Gold Mining Company, or in MVB Consulting, other than the professional fee payable by EIMS for this review. The author also had no prior involvement in the project that would compromise objectivity.

1.6 Priority classification

As shown in Table 2, the findings in this review are classified by a suggested priority assigned, rather than by the severity of the environmental impact concerned. A recommended action accompanies every finding, in Section 3.

Table 2: Priority classification used in this review.

Priority	Meaning
High	The point bears on a conclusion that the authorisation decision will rest on. It is recommend it be addressed before the Report is finalised for submission.
Medium	The data, methodology or compliance evidence would benefit from further substantiation. Addressing the point will improve the confidence that can be placed in the results.
Low	A limited deficiency that does not alter the core conclusions but is worth correcting for completeness.
Editorial	Presentation and consistency matters with no technical effect.

2 Summary of Findings

The findings identified during the review of the Report are summarised in Table 3, and are discussed in Section 3. A recommended action accompanies each one, set out in a highlighted box alongside the relevant discussion in Section 3.

Table 3: Summary and ranking of the findings of this review.

#	Identified issue	Reference in the Report	Priority	Section below
1	The Report states that a liner for the proposed Deelkraal II TSF and RWD is not a prerequisite, while the low residual risk in its the impact assessment table is scored on the basis that the liner is installed.	§7.5.4, §8.3, Table 7.14	High	3.6.1, 3.8
2	The Malmani dolomite aquifer is set aside without supporting data, although the Report places dolomite outcrop 500 m north of the Deelkraal TSF, models the plume as migrating north, and identifies that aquifer as needing protection.	§5.1, §5.2.2, §8.2	High	3.2
3	The source concentration used in the mass transport model is not stated anywhere and the predictive result depends on it.	§6.10, §7.3, §8.3	High	3.4
4	Calibration of the mass transport model is not presented.	§6.10, §7.3, §7.4	Medium	3.6.2
5	Cumulative impacts are scored as "Low" without being modelled, even though the model domain contains at least five other mining operations.	Figure 6.1, §6.2, Table 7.14	Medium	3.8
6	No sensitivity analysis on model parameters is presented in the Report.	§6, §7	Medium	3.5.3
7	The model uses a regional recharge rate (15 mm/a) that is unexplainedly 32% lower than the Report's chloride-method estimate (22 mm/a), while also incorporating three different values for mean annual precipitation.	§2.2, §4.7, §5.2.4, §6.6, §8.2	Medium	3.5.1
8	Several of the elements prescribed for specialist reports in Appendix 6 of the 2014 EIA Regulations (as amended) are not yet included.	throughout	Medium	3.1
9	Water Use Licence limit exceedances visible in Tables 7.5 and 7.6 are not addressed in the text interpreting those tables.	§7.3, §7.4	Medium	3.7.1
10	Steady-state calibration performance is presented in a way that may overstate the fit, and the systematic bias of −6.69 m in the Report's own statistics is not discussed.	§6.9, Figure 6.2, Table 6.2	Low	3.5.2
11	The 44 calibration targets lack names, locations, and dates, and do not match any boreholes listed elsewhere in the Report; also, the text states that only 41 were actually used.	§6.9, Table 6.2	Low	3.3.1
12	The document reference list omits approximately twenty cited sources.	§4.7, §5.2.4, §5.2.6.2, §6.8, §7.5.1, §10	Low	3.9.1
13	Internal consistency and editorial defects.	cover, title page, §6.8, Table 4.1	Editorial	3.9.2

3 Detailed Findings

3.1 Report compliance with Appendix 6 of the EIA Regulations

Specialist reports for environmental authorization must satisfy the mandatory requirements of Appendix 6 to the EIA Regulations, 2014 (GN R.982, as amended). Table 4 evaluates the Report against these standards.

Table 4: Report compliance against Appendix 6 of the EIA Regulations, 2014 (as amended).

Appendix 6 requirement	Present	Comment
(a) Details and expertise of the specialist, including a curriculum vitae	No	The author's name and professional registration appear on the signature page. No curriculum vitae and no statement of expertise are included.
(b) Declaration of independence	No	Absent.
(c) Scope of, and purpose for which, the report was prepared	Partly	Sections 1.1 and 3 describe the project and the scope of work. The purpose in relation to the three licence applications is not stated.
(cA) Date and season of the site investigation and the relevance of the season	No	The Deelkraal hydrocensus is reported in Section 4.2 without dates. Season materially affects water levels and spring flow.
(cB) Description of the methodology adopted	Yes	Sections 4 and 6.
(d) Assessment of the specific identified sensitivity of the site	Partly	An aquifer classification is given in Section 5.2.7. The dolomitic compartment and the spring east of the Deelkraal TSF are not assessed as sensitivities.
(e) Identification of any areas to be avoided, including buffers	No	Absent.
(f) Map superimposing the activity on the environmental sensitivities	No	Figures show infrastructure and modelled plumes. No sensitivity map is provided.
(g) Description of assumptions, uncertainties and gaps in knowledge	Partly	Section 6.2 lists modelling assumptions only. There is no gaps-in-knowledge statement and no uncertainty analysis (Finding 7).
(h) Description of the findings and potential implications	Yes	Sections 7 and 8.
(i) Mitigation measures for inclusion in the EMPr	Partly	A liner is simulated as mitigation but is not stated as an EMPr measure, and Section 8.3 states that it is not a prerequisite (Finding 1).
(j) Conditions for inclusion in the environmental authorisation	No	Absent.
(k) Monitoring requirements for the EMPr or the authorisation	Partly	Section 9 recommends additional boreholes only.
(l) Reasoned opinion on whether the activity should be authorised and on what conditions	No	Absent. Section 8.3 offers conclusions but not a reasoned opinion in the prescribed form.
(m) Description of the consultation process	No	Absent.
(n) Summary and copies of comments received during consultation	No	Absent.

Finding 8 : Appendix 6 content (Medium)

Add the outstanding Appendix 6 elements: the specialist's curriculum vitae and statement of expertise; a signed declaration of independence; the purpose of the report in relation to the EA, AEL and WUL applications; the date and season of the site investigation and its relevance; a map of environmental sensitivities with the activity superimposed; areas to be avoided and buffers; gaps-in-knowledge and uncertainty statement; mitigation measures phrased for inclusion in the EMPr; recommended conditions for the environmental authorisation; a reasoned opinion on whether the activity should be authorised and on what conditions. Table 4 above can be used as a checklist.

3.2 Conceptual model: treatment of the Malmani dolomite

The Report describes the dolomite in two ways for the Deelkraal site:

MVB Consulting, Report MVB215/26/B072, Section 5.1

"The dolomites are present on surface just 500m north of the Deelkraal TSF. … This is a sensitive aquifer that needs to be protected against impacts from the mines and other contaminant sources."

MVB Consulting, Report MVB215/26/B072, Section 8.2

"Although the dolomite aquifer is the most prominent aquifer in the region, it does not play any role in the activities at the Deelkraal and Kusasalethu TSF's."

Each statement may be defensible in its own context, but as drafted they leave the reader unable to establish what role, if any, the dolomite plays at Deelkraal.

To try and establish the role of the Dolomite as desktop study was carried out. **Figure** 1 shows the Deelkraal II site (plume obtained from Figure 7.3 in the Report) and shows the distribution of NGA boreholes with borehole log information surrounding the site.

The analysis when only considering the boreholes contained within the mapped Malmani Dolomite cover and analysing the depth to dolomite top is presented in **Figure** 2. No dolomite tops are mapped within 7.2km from the Deelkraal II site and the general trend shows the dolomites only reach surface level approximately 16 km away from the site. The mapped Malmani Dolomites (1:50,000 surface geology) start 500m north from the site, but from available data it seems the dolomites are still at depth underneath the site (**Figure** 2).

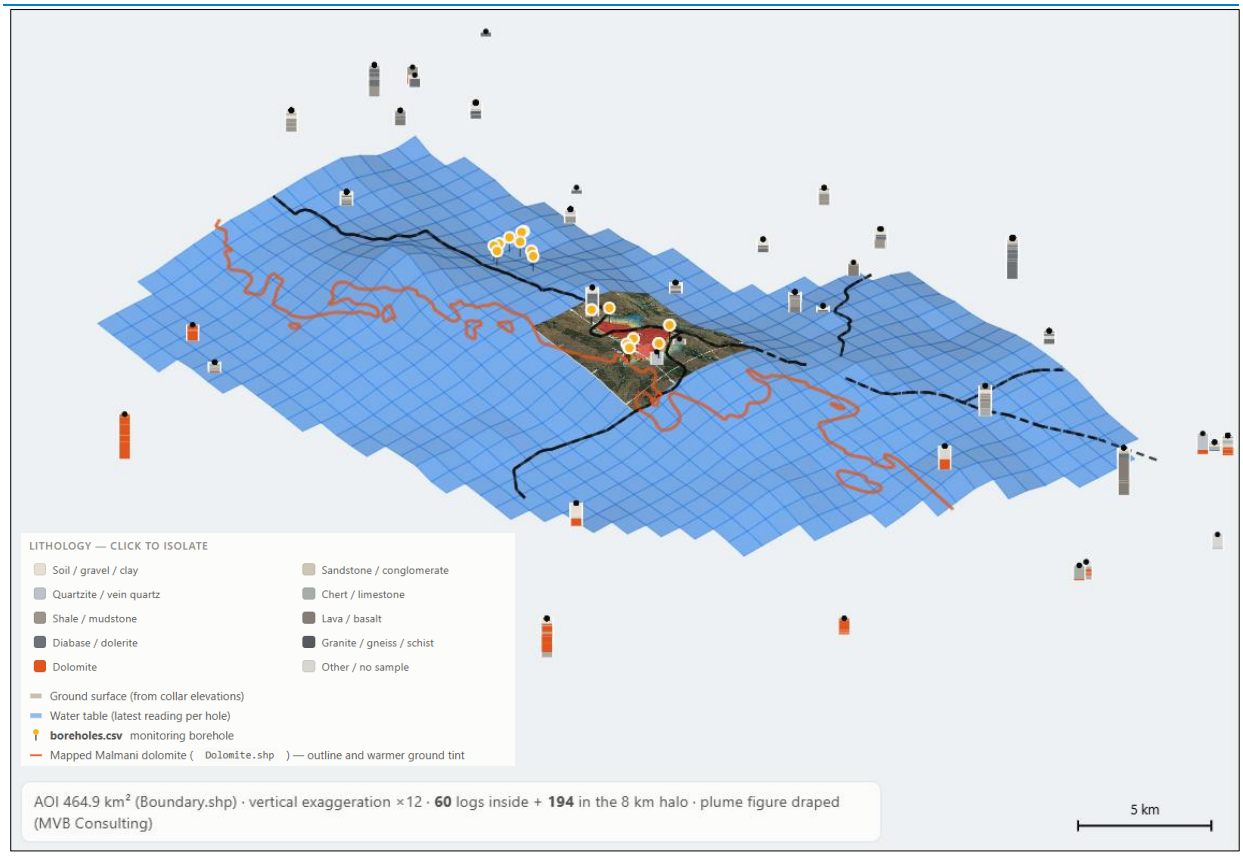


Figure 1: NGA borehole logs around study area.

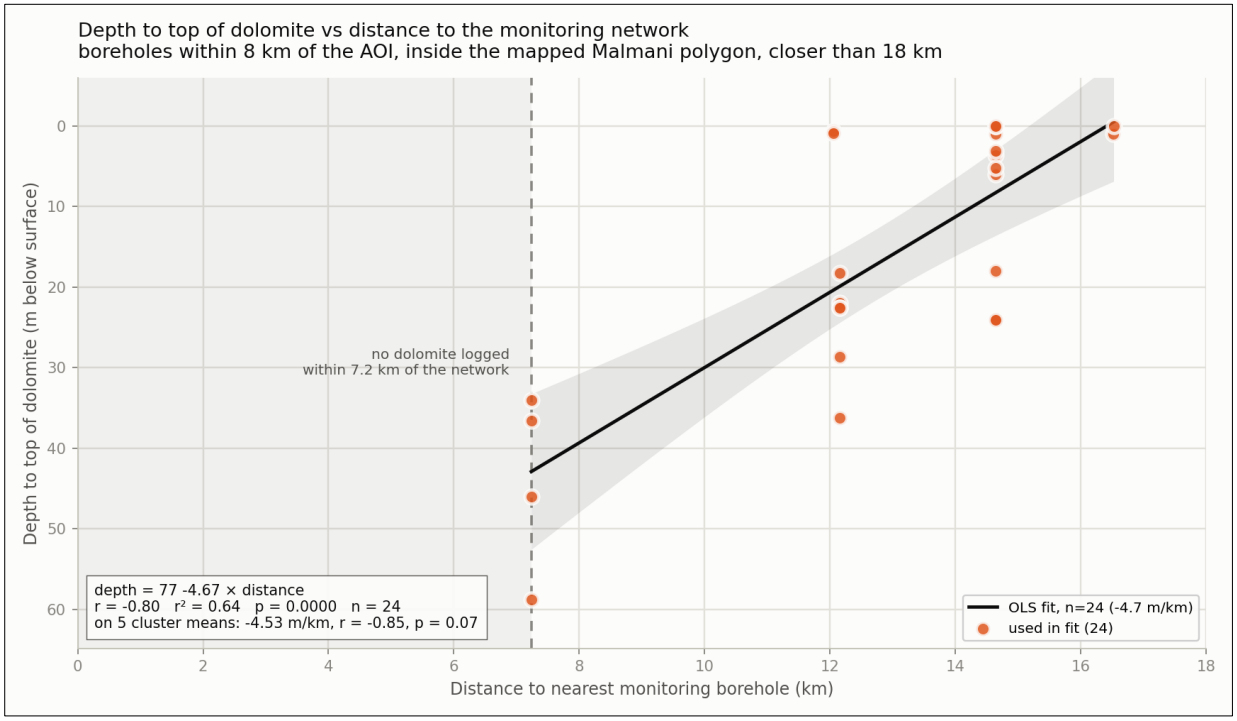


Figure 2: Top of dolomite vs distance to Deelkraal II monitoring network.

Finding 2 : Malmani Dolomite (High)

Align the two descriptions of the dolomite and update the wording of Sections 5.1 and 8.2 so that the Report is consistent on the dolomite. Retain the description in Section 8.2 based on provided assessment information.

3.3 Site characterisation and data adequacy

3.3.1 Calibration targets

A few discrepancies and gaps make the calibration difficult to follow. Table 6.2 lists 44 calibration boreholes, while Section 6.9 states that 41 were used. No coordinates or dates are given for these boreholes.

Finding 11 : Calibration targets (Low)

Tabulate the calibration targets: borehole name, coordinates, collar elevation, measured head and date of measurement. Reconcile the 44 targets in Table 6.2 with the 41 stated in Section 6.9, show their distribution on a map, and include the site monitoring boreholes listed in Tables 4.5 and 5.2.

3.4 Source term and characterisation of the reclaimed tailings

MVB Consulting, Report MVB215/26/B072, Section 6.10

"Input concentrations in the model were specified at cells over the areas where contamination is expected. Sulphate (SO4) is considered a conservative parameter, associated with gold mining impact, and was used as a tracer to simulate the migration of the contaminant plume."

Using sulphate as a conservative tracer is appropriate, but two of the model inputs are not reported. The Report does not give the source concentrations for the existing or proposed Deelkraal II facilities, nor does it define the effective porosity. Because plume extent depends directly on both, the results presented in Figures 7.2, 7.3, 7.4, 7.6 and 7.7 cannot be reproduced independently.

Acid generation is discussed in principle in Section 5.2.6.2 and the acceptability of the new facility rests on the following proposition:

MVB Consulting, Report MVB215/26/B072, Section 8.3

"The impact from the proposed new TSF and RWD is expected to be significantly less than the older TSF's due to improved metallurgical processes and reduced sulfide content."

Decades of oxidation in the existing tailings will have accumulated highly soluble sulphate salts, which will be mobilised during reclamation, slurrying and redeposition. Whether the net result is a lower source concentration is an empirical question that testing would settle. Over the long run the Report may well be right, because the new dump sits wet and saturated, and pyrite underwater oxidises far more slowly than pyrite in a dry, weathered heap. Making use of the data available in the Report the Sulphate in the tailings was analysed and the following was concluded (**Figure** 3):

- Panel A confirms the sulphate is from the tailings.
- Panel B shows there is a solid salt store sitting in the ground (already measured).
- Panel C establishes that nothing in the available chemistry limits the concentration.

None of this proves the new facility will be worse than the old ones, but also does not confirm a lower impact without additional information.

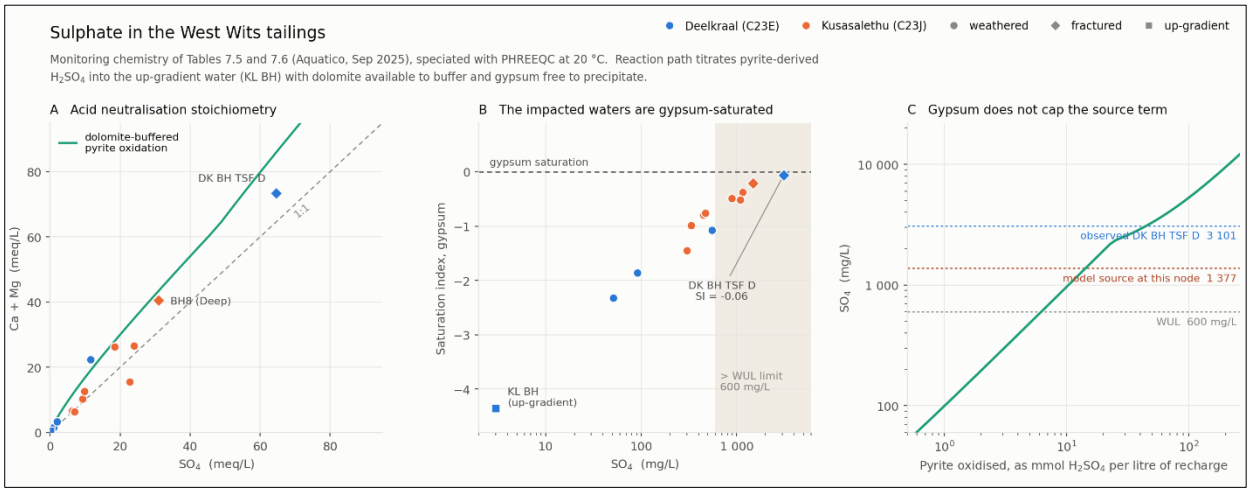


Figure 3: Stored sulphate in the TSF

Finding 3 : SO_4 Source term (High)

State the sulphate source concentration and the effective porosity applied to each source cell, for the existing facilities and for Deelkraal II. For the proposed facility, provide additional support for the expectation of a lower source concentration.

3.5 Numerical flow model

3.5.1 Rainfall and recharge

The Report uses three different values of mean annual precipitation and two different recharge rates as presented in Table 5.

Table 5: Rainfall and recharge values used in the Report.

Quantity	Value	Where stated	Consistent?
Mean annual precipitation	500–600 mm	Section 2.2	—
Mean annual precipitation	563 mm	Sum of the monthly averages of Table 2.1, recalculated in this review	—
Mean annual precipitation	600 mm	Section 8.2	No
Mean annual precipitation	652 mm (implied)	Section 6.6 states 15 mm/a is “about 2.3 %” of MAP	No
Recharge, chloride mass balance	22 mm/a (3.7 % of MAP)	Section 8.2	Reproduces: 0.5 ÷ 13.384 = 3.74 %

Quantity	Value	Where stated	Consistent?
Regional recharge applied in the model	15 mm/a	Section 6.6, Table 6.1	No — 32 % below the derived value
Recharge applied over the TSF footprints	40 mm/a	Table 6.1	Not derived or justified anywhere

The Report assumes a rainfall Chloride concentration of 0.5 mg/L and uses the Chloride mass balance method to calculate recharge. The model applies a recharge rate of 15 mm/a without a stated motivation. This matters because recharge and hydraulic conductivity trade off during head calibration. Matching heads with lower recharge and conductivity creates a model with lower groundwater velocities, slower travel times, and smaller simulated plumes.

Finding 7 : Recharge (Medium)

Adopt one value of mean annual precipitation, state its source and period of record, and use it consistently in Sections 2.2, 6.6 and 8.2. Motivate the 15 mm/a regional recharge against the 22 mm/a chloride-method estimate assuming Cl_{rain} = 0.5 mg/L. Where recharge has been calibrated rather than measured, explicitly state this in the report.

3.5.2 Calibration performance

The Report reports three different correlation figures within four pages, and one cross-reference appears to be misdirected: Section 6.9 cites a 93 % correlation (referencing Figure 5.2), Table 6.2 reports 0.97, and Section 5.2.4 reports a 98 % water-level-to-topography correlation. The reference in Section 6.9 appears to be intended for Figure 6.2 rather than Figure 5.2.

The Report's statistics are arithmetically correct (mean error: −6.69 m; MAE: 11.07 m; RMSE: 14.23 m; NRMSE: 9.59% of the 148.34 m observed head range). However, the two cited correlation values represent different metrics. The correlation coefficient r = 0.97 and the coefficient of determination r^2 = 0.93. The Report needs to specify which statistic it is quoting in each instance.

Figure 6.2 makes the fit difficult to judge. Plotting measured and simulated heads against borehole identifiers on a y-axis scaled from 1 400 to 1 700 mamsl flattens the series and obscures the difference between them. A 1:1 scatter plot is the better way of showing calibration results. Using the data from Table 6.2 in the Report, **Figure** 4 can be produced.

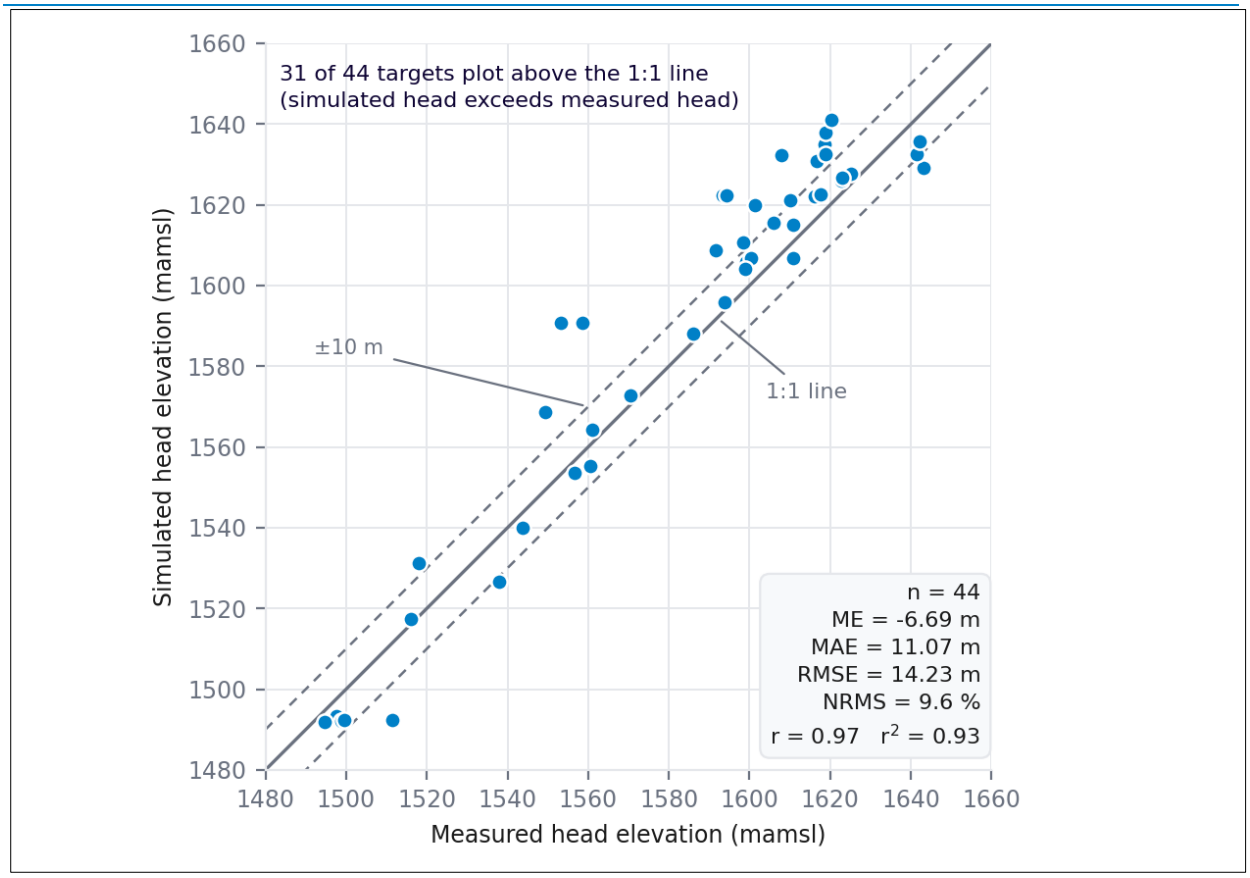


Figure 4: Measured against simulated steady-state heads.

Finding 10 : Calibration performance (Low)

Present the calibration as a 1:1 scatter plot of simulated against measured head with the 1:1 line shown, in place of or alongside Figure 6.2. Report r and r^2 separately and label each where it is quoted, and correct the cross-reference in Section 6.9 from Figure 5.2 to Figure 6.2.

3.5.3 Sensitivity analysis

Travel distance to the 10% sulphate front after 50 years was computed with the 1D Ogata–Banks solution for a continuous source of a conservative solute (**Figure** 5). This is the same conceptualisation the report states for sulphate. Seepage velocity is $v = K\,i\,/\,n_e$. The hydraulic gradient was derived from NGA water levels across the footprint (median 0.026; 10th–90th percentile 0.007–0.050). This is a screening calculation and it brackets sensitivity; it does not reproduce the FEFLOW model.

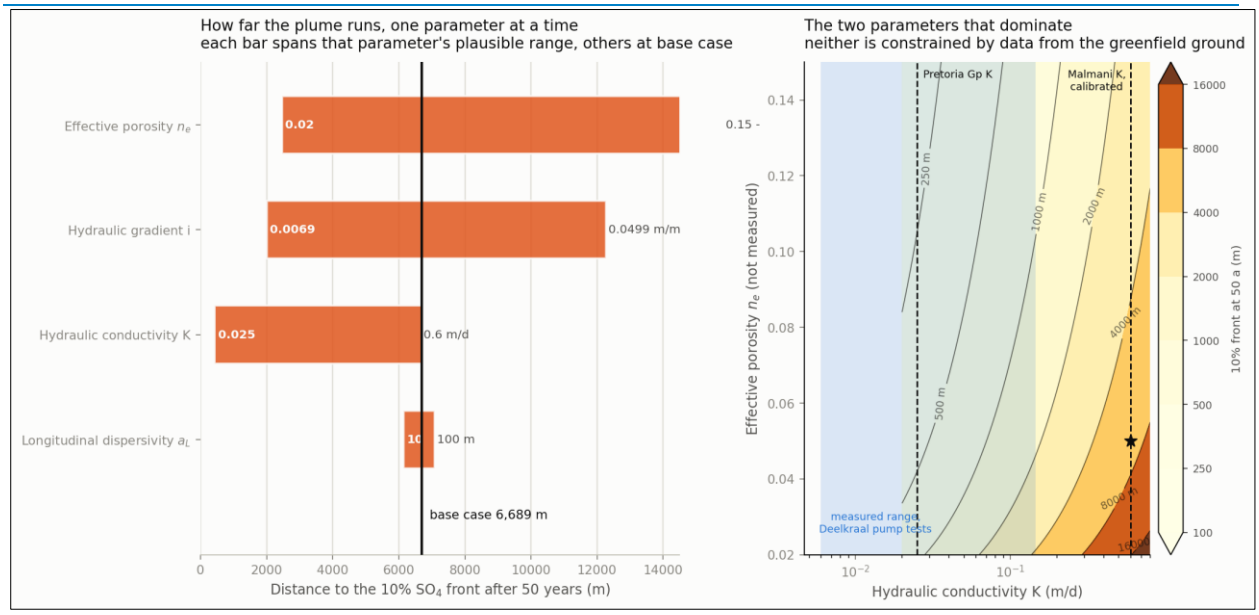


Figure 5: One-at-a-time sensitivity (left) and the joint K × n_e response surface (right).

The high-concentration core of the mapped 50-year plume covers approximately 482 ha, against a facility footprint of approximately 430 ha. Modelled migration beyond the source is therefore of the order of a few hundred metres. That is consistent with the low permeability end of the range and not with the Malmani Dolomite hydraulic conductivity, which would place the front several kilometres downgradient.

The prediction is in effect relying on the greenfield ground behaving as low-permeability Pretoria Group rock. That may well be correct: the only two NGA logs on the footprint record quartzite and slate and it was shown in **Figure** 2 that it is likely that the Dolomite is at depth at the site. If any part is represented by Malmani Dolomite, the 50-year front moves out by more than an order of magnitude.

Finding 6 : Sensitivity analysis (Medium)

Add the sensitivity analysis. Varying recharge, hydraulic conductivity, effective porosity, dispersivity and source concentration across defensible ranges, and reporting the resulting spread in plume extent and concentration, would show how much the predictions depend on the parameters that are least constrained.

3.6 Mass transport model and predictive scenarios

3.6.1 The liner

MVB Consulting, Report MVB215/26/B072, Section 8.3

"The installation of a liner will further improve the situation and lower the risk to the environment even further, although not considered a prerequisite."

Section 7.5.3 present the impact Identifier 2 (the new TSF and RWD): "For the 'do-nothing' option the new TSF as well as the RWD remains unlined. The installation of a liner system was simulated

as a mitigation measure." The post-mitigation column of Table 7.14 is therefore scored on the basis of a lined facility, and it is that column which yields the final significance of "Low -". The Report then concludes that the liner is not a prerequisite. Using a low residual risk score, which assumes the mitigation is in place, to conclude that the mitigation is not required is circular, and we suggest the two statements be brought into line.

Converting the Report's own parameters into a volume unit in Table 6 allows for comparison of the liner performances they relate to the 430 ha facility.

Table 6: Seepage flux from the proposed 430 ha facility

Case	Basis in the Report	Rate as given	Equivalent recharge	Volume over 430 ha
Unlined facility	Table 6.1, "TSF footprints"	40 mm/a	40 mm/a	172 000 m^3/a
Class C composite barrier	Section 7.3, after Legge (2024)	140 ℓ/ha/day	5.11 mm/a	22 000 m^3/a
Inverted barrier system	Section 7.3	6 ℓ/ha/day	0.22 mm/a	940 m^3/a

A liner therefore reduces the source flux by a factor of about eight for a Class C barrier, or about 180 for the inverted barrier system the Report also describes. Section 7.3 concludes that "There is no impact to down-gradient receptors for either of the scenarios modelled. The Report does not state which of the two leakage rates it modelled. Section 7.3 describes Scenario 2 as a Class C barrier, and the following paragraph describes an inverted barrier system at 6 ℓ/ha/day. Only one of them can be in the simulation. The source of both figures, Legge (2024), is not in the reference list.

Finding 1 : Liner (High)

Align the liner recommendation and the impact rating based on the intent of the liner recommendation through one of the suggested options:

1. Either state in Sections 7.5.4 and 8.3 that the liner is a required mitigation measure, consistent with the post-mitigation column of Table 7.14 which assumes it;
2. Rescore the post-mitigation column for an unlined facility and report the significance that follows.

State which of the two leakage rates was used in the liner simulation — 140 ℓ/ha/day for the Class C composite barrier, or 6 ℓ/ha/day for the inverted barrier system — and add Legge (2024) to the reference list so the rates can be traced.

3.6.2 Mass transport calibration

The calibration of the mass transport is not presented in the Report. Making use of the Report data an estimated calibration plot was generated and is shown in **Figure 6**. On the evidence in r^2, the SO_4 transport model is at the level of a plausible conceptual demonstration of plume geometry.

A factor of ~2.3 typical error (RMSE $\log_{10}$ 0.36–0.39), consistent across both management areas, with 11 of 12 targets inside half an order of magnitude. For a conservative-tracer plume built on a sparse network, that is a respectable order-of-magnitude result and it does support the report's spatial conclusions: plume direction, the finding that plumes are contained on Harmony property at Deelkraal, and the absence of impact on downgradient private users.

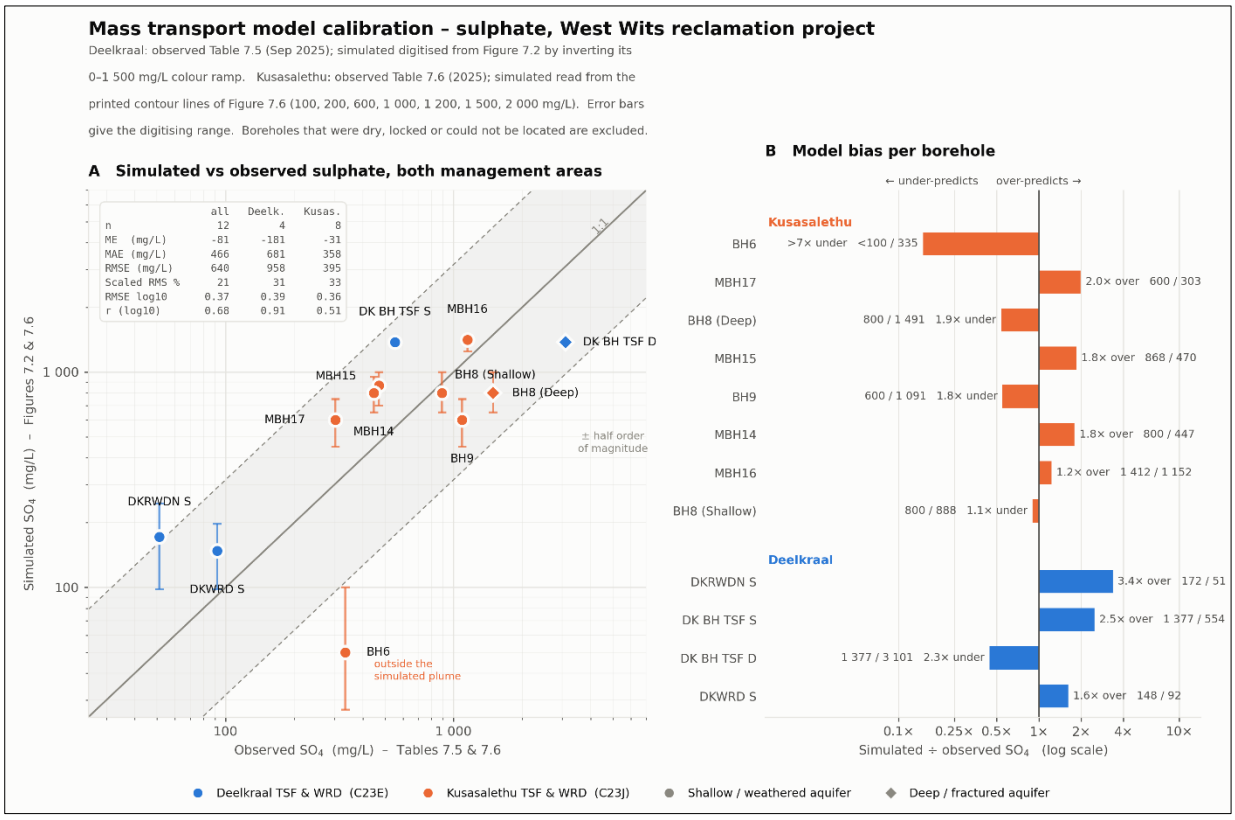


Figure 6: Estimated SO_4 calibration plot.

Finding 4 : Mass transport calibration (Medium)

Present actual calibration data from model.

3.7 Interpretation of the groundwater monitoring data

3.7.1 Unreported exceedances of the licence limits

Section 7.3 links the red highlighting in Table 7.5 to Water Use Licence (WUL) exceedances, while Section 7.4 links the red highlighting in Table 7.6 to SANS guidelines. Both tables share the same WUL limit row, so one of the two descriptions needs correcting. The narrative also leaves a substantial part of the data in both tables undiscussed. Table 7 sets out the licence exceedances alongside the parameters actually discussed in the Report.

Table 7: Exceedances of the Water Use Licence limits in Tables 7.5 and 7.6

Borehole	Parameter	Measured	WUL limit	Discussed in the text?
BH9	Manganese	42.6 mg/ℓ	0.5 mg/ℓ	No
BH9	Sodium	359 mg/ℓ	200 mg/ℓ	No
BH9	EC / TDS	297 mS/m / 2 286 mg/ℓ	200 / 1 200	Salinity only, in general terms
MBH16	Manganese	3.32 mg/ℓ	0.5 mg/ℓ	No
MBH16	Calcium / Magnesium	286 / 150 mg/ℓ	200 / 100	No

Borehole	Parameter	Measured	WUL limit	Discussed in the text?
BH8 (Deep)	Chloride	314 mg/ℓ	300 mg/ℓ	No
BH8 (Deep)	Calcium / Magnesium	425 / 236 mg/ℓ	200 / 100	No
BH8 (Shallow)	Calcium / Magnesium	269 / 157 mg/ℓ	200 / 100	No
MBH14, MBH17	Manganese	1.60, 1.16 mg/ℓ	0.5 mg/ℓ	No
BH6	Nitrate as N	14.4 mg/ℓ	10 mg/ℓ	No
DK BH TSF S	Fluoride	1.65 mg/ℓ	1 mg/ℓ	No
DK BH TSF S and D	Magnesium	207 / 605 mg/ℓ	100 mg/ℓ	Yes — magnesium is noted

Section 7.4 does not discuss the manganese concentration at BH9, which is the largest single exceedance across both tables at 85 times the licence limit. Section 7.3, by comparison, does note the manganese exceedances at the Deelkraal boreholes.

Finding 9 : Licence exceedances (Medium)

State consistently which standard the red highlighting in Tables 7.5 and 7.6 denotes, then discuss each exceedance listed in Table 7 above, including manganese at BH9, with the likely source of each and what it means for the impact assessment.

3.8 Impact assessment and risk rating

The arithmetic of Table 7.14 is correct. Several of the assigned ratings, however, warrant a second look, since they carry the final significance score.

- **Duration.** The post-mitigation duration rating of 2 ("Short term (1–5 years)") for both impacts is questioned. The report's own simulations span 50 years and describe contaminant attenuation as slow—characteristics that align far better with Table 7.7's rating of 4 ("Long term (15–65 years)") or 5 ("Permanent"). Groundwater contamination from a 430 ha residue facility is unlikely to be short term, and this single rating carries the final impact score.
- **Extent.** The post-mitigation extent score of 1 ("Activity-specific") appears low. The report itself states that existing contaminant plumes migrate beyond the facilities to impact two small streams, and Figure 7.3 clearly depicts the predicted plume spreading past the proposed footprint. The report's own data and figures indicate that the extent is regional or local, requiring a score of at least Extent 2 (site) or Extent 3 (local).
- **Reversibility.** Scoring the reversibility of both impacts as 2 ("reversible without significant time and cost") is questioned. The report itself states that the aquifer plume will take in excess of 50 years to dissipate by natural processes. An issue of this duration and scale is unlikely to be resolved without substantial time and cost. A rating of 3 ("reversible only by incurring significant time and cost") is the minimum rating that aligns with the report's own text.
- **Differentiation.** The report assigns identical scores to Identifiers 1 and 2 across all fields and phases. These activities are materially different: one is a remedial action (removing an existing contaminant source), while the other is a major new development (creating a 430 ha source on partially virgin ground). Scoring them identically obscures the difference between them and flattens the overall risk profile.

- **The positive impact is never assessed.** While Sections 7.5.4 and 8.3 explicitly describe the long-term positive impacts of reclamation on the groundwater regime, Table 7.14 evaluates Identifier 1 as negative throughout all project phases. The positive significance categories established in Table 7.13 are also not applied.
- **Confidence.** Confidence is rated High for the construction phase. Given an unstated source term, an uncalibrated transport model and no site-specific data within the proposed footprint, a Medium rating would be easier to defend.
- **Cumulative impact.** Cumulative impact is scored 1 (Low) for construction and 2 (Medium) elsewhere. Figure 6.1 shows the model domain containing Kusasalethu, Savuka, Tau Tona, Blyvooruitzicht, Mponeng and Driefontein, together with a further boundary marked "Other Mine". None is represented in the model as a source or a sink, and Section 6.2 states only that "The impacts of other activities (e.g. agriculture) have not been considered". Cumulative impact has therefore not yet been assessed in the model.

Finding 5 : The impact ratings — Table 7.14 (Medium)

Record in the text the reason for each rating that carries the final significance score, and revisit those that sit uneasily with the Report's own predictions: duration, where simulations spanning 50 years and slow attenuation point to Table 7.7 ratings of 4 or 5 rather than 2; extent, where plumes reaching two streams and Figure 7.3 point to at least 2 or 3; reversibility, where in excess of 50 years to dissipate naturally points to at least 3; and confidence for the construction phase.

Score Identifiers 1 and 2 separately, since one removes an existing source and the other creates a new one, and apply the positive significance categories of Table 7.13 to the reclamation benefit described in Sections 7.5.4 and 8.3.

Assess cumulative impact explicitly. Identify the other operations within the model domain — Kusasalethu, Savuka, Tau Tona, Blyvooruitzicht, Mponeng, Driefontein and the area marked "Other Mine" and represent as sources or sinks those that are material, report the combined predicted concentrations, and record why any are excluded. Rescore the cumulative-impact field against that assessment.

3.9 Presentation, internal consistency and referencing

3.9.1 Referencing

Approximately twenty works cited in the text are absent from Section 10, among them Legge (2024), on which the liner leakage rates depend; AGES (2013), the source of Figure 5.2; SGS Bateman (2024), the concept study on which the project description rests; Spitz and Moreno (1996) and Anderson and Woessner (1992), on which the calibration methodology and the dispersivity value rest; Bear and Verruijt (1992); Jones and Wagener (2017); MVB Consulting (2021); Van Biljon (2011); Parsons and Killick (1985); Dold (2017); Banks et al. (1996); Skousen et al. (2000); Viljoen (2009); and Groundwater Abstract (Pty) Ltd (2019). Conversely, Brink (1979), Tarika and Botha (2023) and Vegter (1995) are listed but not cited. The list gives SANS 241-2 (2011) where the text relies throughout on SANS 241:2015.

Finding 12 : Referencing (Low)

Complete Section 10 with the works cited in the text but not listed, beginning with those the analysis depends on — Legge (2024) for the liner leakage rates, AGES (2013) for Figure 5.2, SGS Bateman (2024) for the project description, and Spitz and Moreno (1996) and Anderson and Woessner (1992)

for the calibration methodology and dispersivity. Remove Brink (1979), Tarika and Botha (2023) and Vegter (1995), which are listed but not cited, and correct SANS 241-2 (2011) to SANS 241-1:2015 to match the text.

3.9.2 Internal consistency and editorial matters

The following items have no technical impact but may affect how the reviewing authority perceives the Report.

- The cover and approval record give report number MVB215/26/B072; the running header on every subsequent page gives MVB186/25/B072.
- The title page uses "Khusasaleka"; the body uses "Kusasalethu" and, in several places, "Kusaslethu". The new facility is "Deelkraal II" in Sections 1.1 and 7.3 and "Deelkraal #2" in Section 8.
- p.28 reads "*If a good linear relationship is proven, the regional groundwater level van be interpolated…"* change to "If a high correlation is established, the regional groundwater level can be interpolated.."
- Section 6.8 states that "The simulation model (MODFLOW) used in this modelling study" is based on the three-dimensional flow equation, while Sections 4.8 and 6.3 state that FEFLOW was used.
- In Table 4.1 remove Owner name and contact information as this could violate the POPIA.
- Figure 7.2 refers to "Current sulphate contamination plume…" but legend denotes "Sulphate Plume after 50 Years (Lined)"

Finding 13 : Consistency and presentation (Editorial)

Align the report number on the cover, in the approval record and in the running header. Standardise the facility names, using "Kusasalethu" and "Deelkraal II" throughout. Correct the reference to MODFLOW in Section 6.8 to FEFLOW, consistent with Sections 4.8 and 6.3. Correct the wording on p.28. Remove owner names and contact details from Table 4.1, in line with POPIA. Correct Figure 7.2 Sulphate legend.

4 Conclusion

The Report is well organised, featuring a competent geological description of the Far West Rand, and an appropriate groundwater model given the available data. The report is deemed fit for purpose, but it is recommended that findings with a medium and higher priority be addressed to strengthen the report.

Three findings carry the highest priority to address. First, the recommendation that a liner is not a prerequisite sits at odds with the impact table, which attributes the "low significance" residual rating to the liner being installed. Second, setting the Malmani dolomite aside is difficult to reconcile with the Report's own site description and with the simulated migration direction of the Deelkraal plume. Third, the source concentration that underpins the predictive simulations is not stated.

None of this reflects on the viability of the project, which may well be favourable. Reclaiming the two unlined facilities should improve groundwater quality, and a new lined facility may pose a low residual risk. What would strengthen it is setting out additional evidence, so that the reviewing authority can follow the reasoning from the data through to the conclusions. Each section in the detailed findings were furnished with guidelines of what to address.

This review is subject to the limitations specified in Section 1.4. If the model files, monitoring database, and cited unpublished reports are provided, these findings may be refined or withdrawn, and this review updated.

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