



GCS Newcastle Office
1 Karbochem Rd, Newcastle, 2940
Cell: +27 (0) 71 102 3819 Fax: +27 (0) 31 764 7140 Web: www.gcs-sa.biz

Geohydrological Assessment for the Proposed Co-Disposal Facility & Water Treatment Plant at Kangra Maquasa East Operations

Version - Final 1
17 November 2023

Kangra Coal
GCS Project Number: 22-0161_GW
Client Reference: 111862



Geohydrological Assessment for the Proposed Co-Disposal Facility & Water Treatment Plant at Kangra Maquasa East Operations


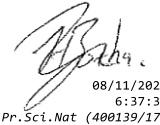

**Report
Version - Final 1**



17 November 2023

Kangra Coal
22-0161_GW

DOCUMENT ISSUE STATUS

Report Issue	Final 1		
GCS Reference Number	GCS Ref - 22-0161_GW		
Client Reference	111862		
Title	Geohydrological Assessment for the Proposed Co-Disposal Facility & Water Treatment Plant at Kangra Maquasa East Operations		
	Name	Signature	Date
Author 1 (Hydrogeologist)	Shuaib Dustay (MSc, PriSciNat)		17 November 2023
Author 2 / Director	Hendrik Botha (MSc, PriSciNat)	 08/11/2022 6:37:36 Pr.Sci.Nat (400139/17)	17 November 2023
Proof Reader	Lisa Botha (BSc, Hons.)		17 November 2023

LEGAL NOTICE

This report or any proportion thereof and any associated documentation remain the property of GCS until the mandator effects payment of all fees and disbursements due to GCS in terms of the GCS Conditions of Contract and Project Acceptance Form. Notwithstanding the aforesaid, any reproduction, duplication, copying, adaptation, editing, change, disclosure, publication, distribution, incorporation, modification, lending, transfer, sending, delivering, serving or broadcasting must be authorised in writing by GCS.

DECLARATION OF INDEPENDENCE

GCS (Pty) Ltd was appointed to conduct this specialist groundwater study and to act as the independent groundwater specialist. GCS objectively performed the work, even if this results in views and findings that are not favourable. GCS has the expertise in conducting the specialist investigation and does not have a conflict of interest in the undertaking of this study. This report presents the findings of the investigations which include the activities set out in the scope of work.

APPENDIX 6 OF THE EIA REGULATION - CHECKLIST AND REFERENCE FOR THIS REPORT

Table 1 - Requirements from Appendix 6 of GN 326 EIA Regulation 2017

Requirements from Appendix 6 of GN 326 EIA Regulation 2017	Chapter
(a) Details of: (i) The specialist who prepare the reports; and (ii) the expertise of that specialist to compile a specialist report including a curriculum vitae	Appendix G.
(b) Declaration that the specialist is independent in a form as may be specialities by the competent authority	Appendix G.
(c) Indication of the scope of, and purpose for which, the report was prepared	Section 2
(cA) Indication of the quality and age of base data used for the specialist report	Sections 1, 2, 4 and 5.
(cB) A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Sections 6, 7 and 8
(d) Duration, Date and seasons of the site investigation and the relevance of the season to the outcome of the assessment	Section 1.2
(e) Description of the methodology adopted in preparing the report or carrying out the specialised process include of equipment and modelling used	Section 4
(f) Details of an assessment of the specifically identified sensitivity of the site related to the proposed activity or activities and its associate's structures and infrastructure, inclusive of a site plan identifying alternative	Sections 1, 2, 4 and 5
(g) Identification of any areas to be avoided, including buffers	Section 10.2.
(h) Map superimposing the activity and associated structures and infrastructure on environmental sensitivities of the site including areas to be avoided, including buffers	Section 1, 3, 5 6, 7 and 8.
(i) Description of any assumptions made and uncertainties or gaps in knowledge	Sections 1, 7, and 8.
(j) A description of the findings and potential implications of such findings on the impact of the proposed activity including identified alternatives on the environment or activities	Sections 7, 8 and 10.
(k) Mitigation measures for inclusion in the EMPr	Sections 9 and 10.
(l) Conditions for inclusion in the environmental authorisation	Refer to recommendations in Section 10.
(m) Monitoring requirements for inclusion in the EMPr or environmental authorisation	Refer to recommendations in Section 10.
(n) Reasoned opinion - (i) as to whether the proposed activity, activities or portions thereof should be authorised. (iA) regarding the acceptability of the proposed activity or activities; and (ii) if the opinion is that the proposed activity, activities or portions thereof should be authorised, and avoidance, management, and mitigation measures should be included in the EMPr, and where applicable, the closure plan	Section 10.3.
(o) Description of any consultation process that was undertaken during preparing the specialist report	None required.
(p) A summary and copies of any comments received during any consultation process and where applicable all responses thereto	None required.
(q) Any other information requested by the competent authority	None required.

CONTENTS PAGE

Declaration of Independence	iii
Appendix 6 of the EIA Regulation - CHECKLIST and Reference for this Report	iv
CONTENTS PAGE.....	i
List of Figures.....	ii
List of Tables.....	iii
List of Appendices	iv
Glossary of Terms	v
LIST OF ACRONYMS	viii
1 Introduction	1
1.1 Project background.....	1
1.1.1 <i>Water Treatment Plant</i>	1
1.1.2 <i>Co-Disposal Facility</i>	2
1.2 Study relevance to the season in which it was undertaken	3
1.3 Objectives	4
1.4 The layout of this report.....	4
2 Scope of work	6
3 Area of investigation	8
3.1 Sub-catchments / hydrological response units (HRUs)	8
3.2 Local geology & soils.....	8
3.3 Climate.....	12
3.3.1 <i>Temperature</i>	12
3.3.2 <i>Wind speed and direction</i>	13
3.3.3 <i>Rainfall and evaporation</i>	13
3.3.4 <i>Runoff</i>	15
4 Methodology	16
4.1 Literature review and desktop study	18
4.2 Hydrological overview	18
4.3 Groundwater users in the study area.....	19
4.4 Field investigation	19
4.4.1 <i>Field hydrocensus</i>	20
4.4.2 <i>Geophysical assessment findings</i>	22
4.4.3 <i>Aquifer slug testing</i>	26
4.5 Geochemical assessment.....	29
4.5.1 <i>ABA</i>	29
4.5.2 <i>NAG</i>	32
4.6 Mineralogy and total element analyses	33
4.7 Acid potential.....	33
4.8 Static leach testing	35
4.9 Numerical model development.....	36
4.9.1 <i>Model software package</i>	36
4.9.2 <i>Governing Equations</i>	36
4.9.3 <i>Model confidence level classification</i>	37
4.10 Geohydrological risk assessment	38
4.11 Water monitoring plan	38
5 Prevailing groundwater conditions.....	39
5.1 Aquifer characteristics, classification, and groundwater recharge	39
5.2 Aquifer transmissivity	42
5.3 Groundwater recharge	42
5.4 Aquifer storage	43
5.5 Depth to groundwater	43
5.6 Wetland areas	44

5.7	Present ecological state (PES) and environmental sensitivity and ecological importance (EIS) - quaternary scale	44
5.8	Aquifer contextualization and extent	45
5.9	Groundwater quantity	45
5.9.1	<i>Quaternary catchment</i>	45
5.9.2	<i>Sub-catchment delineation</i>	46
5.9.3	<i>Groundwater balance</i>	46
5.10	Hydrochemistry	47
5.10.1	<i>Groundwater Levels</i>	47
5.10.2	<i>Groundwater Quality</i>	48
5.10.3	<i>Surface Water Quality</i>	49
6	Site conceptual model	53
6.1	Sources	53
6.2	Pathways	53
6.3	Receptors.....	54
7	Numerical groundwater model	56
7.1	Model objective	56
7.2	Assumptions and limitations	56
7.3	Conceptualisation and Model Grid	58
7.3.1	<i>Boundary Conditions</i>	58
7.3.2	<i>Construction of the Finite Difference Grid</i>	59
7.3.3	<i>Vertical Discretization</i>	59
7.3.4	<i>Time Discretization</i>	60
7.3.5	<i>Transient State Model Simulation Time</i>	60
7.3.6	<i>Input Parameters / Initial Model Conditions</i>	64
7.3.7	<i>Model Calibration</i>	65
7.4	Calibrated flow models.....	69
7.5	Simulated 2022 plume and 20-year plumes	69
8	Geohydrological Risks Assessment & Mitigation Measures	72
8.1	Pre-mining/development phase.....	72
8.2	Operational Phase	73
8.3	Closure and Post-Closure Phase	74
9	Groundwater monitoring	79
10	Conclusions	81
10.1	Proposed Groundwater Management Aspects	82
10.1.1	<i>Operational / Decommission</i>	82
10.1.2	<i>Groundwater closure objectives</i>	82
10.2	Recommendations.....	83
10.3	Identification of any areas that should be avoided	84
10.4	Reasoned opinion on whether WULA should not be granted	85
11	Bibliography	85

LIST OF FIGURES

Figure 1-1:	Proposed WTP and possible brine evaporation pond.....	2
Figure 1-2:	Proposed Co-Disposal Facility (Phase 1 already approved, Phase 2 & 3 will be co-disposal)	3
Figure 1-3:	Site locality and drainage	5
Figure 3-1:	Local geology	10
Figure 3-2:	Sub-catchments and land cover types	11
Figure 3-3:	Average yearly temperatures (Meteoblue, 2022)	12
Figure 3-4:	Wind rose (Meteoblue, 2022).....	13

Figure 3-5:	Average rainfall for Station 0407639W & WR2012 evaporation	14
Figure 3-6:	Simulated natural (unmodified) runoff for W51B	15
Figure 4-1:	Hydrocensus borehole locations	21
Figure 4-2:	Mag line 1	23
Figure 4-3:	Mag line 2	23
Figure 4-4:	Mag line 3	24
Figure 4-5:	Mag line 4	24
Figure 4-6:	Mag line 5	25
Figure 4-7:	Mag line 6	25
Figure 4-8:	Mag line 7	26
Figure 4-9:	Geophysical investigation area	28
Figure 4-10:	Slurry deposit at discard dump	29
Figure 4-11:	Dry discard deposit	29
Figure 4-12:	Acid Potential - based on sample AP/NP and %S.....	34
Figure 4-13:	Numerical groundwater modelling process	36
Figure 4-14:	Monitoring Process	38
Figure 5-1:	Local hydrogeology	41
Figure 5-2:	Groundwater elevation vs topography elevation - correlation (Kangra Monitoring Holes)	43
Figure 5-3:	Groundwater base-flow concept (DWS, 2011)	44
Figure 5-4:	Groundwater level time trend graph for Maquasa East	47
Figure 5-5:	Maquasa East logarithmic groundwater sulphate graph	49
Figure 5-6:	Maquasa East logarithmic surface water TDS graph	50
Figure 5-7:	Maquasa East logarithmic surface water sulphate graph.....	51
Figure 5-8:	Monitoring Network for Maquasa East	52
Figure 6-1:	Site conceptual model	55
Figure 7-1:	Model grid & conductivity	62
Figure 7-2:	Model boundary conditions	63
Figure 7-3:	Steady-state model calibration achieved	66
Figure 7-4:	Flow model calibration achieved (2022).....	66
Figure 7-5:	Sulphate plume calibration achieved (2017-2018 period).....	67
Figure 7-6:	PEST Sensitivity Analysis - Histogram	68
Figure 7-7:	PEST Sensitivity Analysis - Weighted Parameter Sensitivity	68
Figure 7-8:	Calibrated flow model	70
Figure 7-9:	Calibrated 2022 SO ₄ plumes, 50Y and 100Y unmitigated plumes from proposed developments	71
Figure 9-1:	Proposed groundwater monitoring points	80

LIST OF TABLES

Table 3-1:	MAP of nearest rainfall stations	13
Table 4-1:	Project methodology flow diagram	17
Table 4-2:	Groundwater users within a 2.5 km radius of the site.....	19
Table 4-3:	Field hydrocensus boreholes identified in the project area	20
Table 4-4:	Geophysical Survey Record Summary	22
Table 4-5:	Summary of slug test results	27
Table 4-6:	ABA and NAG screening criteria (adapted from (Price, 1997) and (Fourie, 2014)	31
Table 4-7:	NAG screening methods used (Edited from (Miller, et al., 1997)	32
Table 4-8:	XRD results and mineral classification	33
Table 4-9:	Summary of ABA and NAG screening results	34
Table 4-10:	Summary of 1:20 DW Leachate Analytical Results.....	35
Table 5-1:	Aquifer characteristics and classification	39
Table 5-2:	Summary of aquifer transmissivity	42
Table 5-3:	Summary of PES and EIS for the Quaternary Catchment	44
Table 5-4:	Summarised Quaternary Catchment Information.....	45
Table 5-5:	Groundwater reserve determination	46
Table 7-1:	Summary of the target water quality range as per DWAF guidelines.....	57

Table 7-2: Identification of the real-world boundaries and the adopted model boundary conditions	59
Table 7-3: Model Simulation Time	61
Table 7-4: Input parameters to the flow model	64
Table 8-1: Risk rating scale.....	72
Table 8-2: Pre-mining / construction phase hydrogeological risk.....	76
Table 8-3: Operational phase hydrogeological risk.....	77
Table 8-4: Closure Phase Hydrogeological Risks	78
Table 9-1: Proposed monitoring points	79
Table 11-1: Proposed Criteria and Rating Scales to be used in the Assessment of the Potential Impacts	126
Table 11-2: Explanation of Assessment Criteria.....	128

LIST OF APPENDICES

Appendix A: Photographic Log	87
Appendix B: Geophysical Investigation.....	92
Appendix C: Laboratory Certificates	113
Appendix D: Risk Assessment Methodology.....	126
Appendix E: Model Confidence MATRIX	130
Appendix F: Disclaimer	131
Appendix G: Details OF THE SPECIALIST, DECLARATION OF INTEREST AND UNDERTAKING UNDER OATH	132
Appendix H: CV of Specialist	134

GLOSSARY OF TERMS

A **confined aquifer** is a formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations; confined groundwater is generally subject to a pressure greater than atmospheric pressure.

Advection is the process by which solutes are transported by the bulk motion of the flowing groundwater.

An **unconfined, water-table** or phreatic aquifer are different terms used for the same aquifer type, which is bounded from below by an impermeable layer. The upper boundary is the water table, which is in contact with the atmosphere so that the system is open.

Aquifer - A body of rock, consolidated or unconsolidated, that is sufficiently permeable to conduct groundwater and to yield significant quantities of water to wells and springs.

Aquifuge: An impermeable body of rock which contains no interconnected openings or interstices and therefore neither absorbs nor transmits water.

Compartment - In a slope-aquifer system, an area formed by the undulation of the water table generally conforms to undulation in the overlying topography. The crests of the water-table undulations represent natural groundwater divides that, under natural conditions, restrict the movement of groundwater to the boundaries of the compartment.

Cone of Depression - A depression in the potentiometric surface of a body of groundwater that has the shape of an inverted cone and develops around a well/mineshaft/open-pit mine from which water is being withdrawn.

Discharge Area - An area in which there is an upward component of the hydraulic head in an aquifer. Groundwater flows toward the land surface in a discharge area and escapes as a spring, seep, or baseflow to streams, or by evaporation and transpiration.

Dispersion is the measure of the spreading and mixing of chemical constituents in groundwater caused by diffusion and mixing due to microscopic variations in velocities within and between pores.

Drawdown - The decline of the water table or potentiometric surface as a result of withdrawals from wells or excavations.

Effective porosity is the percentage of the bulk volume of a rock or soil that is occupied by interstices that are connected.

Equipotential line - A line in a two-dimensional groundwater flow field on which the total hydraulic head is the same at all points.

Fault - A fracture or fracture zone along which there has been displacement of the sides relative to one another parallel to the fracture.

Fracture - A crack, joint, fault or another form of break-in rocks caused by mechanical failure.

The groundwater table is the surface between the zone of saturation and the zone of aeration, also the surface of an unconfined aquifer.

Heterogeneous indicates non-uniformity in a structure.

Hydraulic conductivity (K) 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 perpendicular to the area [L/T]. Hydraulic conductivity is a function of permeability and the fluid's density and viscosity.

The hydraulic gradient is the rate of change in the total head per unit distance of flow in each direction.

Hydraulic Head - Generally, the altitude of the free surface of a body of water above a given datum.

Hydrodynamic dispersion - Processes of mechanical dispersion and molecular diffusion.

Interflow - The lateral movement of water in the unsaturated zone during and immediately after precipitation. Interflow occurs when the zone above a low permeability horizon becomes saturated and lateral flow is initiated parallel to the barrier.

Joint - A fracture in rock along which there has been no visible movement.

Mechanical dispersion is the process whereby a group of pollutants are spread in a longitudinal as well as a transverse direction because of velocity distributions.

Metamorphic Rock - A rock formed at depth in the earth's crust from pre-existing rocks by mineralogical, chemical and structural changes caused by high temperature, pressure and other factors. Examples include slate, schist and gneiss.

An observation borehole is a borehole drilled at a selected location to observe parameters such as water levels.

Perched Water Table - The upper surface of a body of unconfined groundwater is separated from the main body of groundwater by the unsaturated material.

Permeability is related to hydraulic conductivity but is independent of the fluid density and viscosity and has the dimensions L^2 . Hydraulic conductivity is therefore used in all the calculations.

pH is a measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity.

Piezometric head (ϕ) is the sum of the elevation and pressure head. An unconfined aquifer has a water table, and a confined aquifer has a piezometric surface, which represents a pressure head. The piezometric head is also referred to as the hydraulic head.

Porosity - The ratio of the aggregate volume of interstices in a rock or soil to its total volume. It is usually stated as a percentage.

Potentiometric Surface - An imaginary surface representing the total head of groundwater and defined by the level to which water rises in tightly-based wells. The water table is a potentiometric surface.

Pumping tests are conducted to determine aquifer or borehole characteristics.

Recharge is the addition of water to the zone of saturation through the vadose/unsaturated zone.

Sandstone is a sedimentary rock composed of abundant rounded or angular fragments of sand set in a fine-grained matrix (silt or clay) and firmly united by a cementing material.

Sedimentary Rock - A layered rock resulting from the consolidation of sediment deposited by some geologic agent such as water, wind, or ice. Typical sedimentary rocks include sandstone, limestone and shale.

Shale is a fine-grained sedimentary rock formed by the consolidation of clay, silt or mud. It is characterised by a finely laminated structure and is sufficiently indurated so that it will not fall apart on wetting.

Specific storage (S_0), of a saturated confined aquifer, is the volume of water that a unit volume of aquifer releases from storage under a unit decline in hydraulic head. In the case of an unconfined (phreatic, water-table) aquifer; specific yield is the water that is released or drained from storage per unit decline in the Finite Difference water table.

The static water level is the level of water in a borehole that is not affected by the withdrawal of groundwater.

Storativity is the two-dimensional form of the specific storage and is defined as the specific storage multiplied by the saturated aquifer thickness.

Total dissolved solids (TDS) is a term that expresses the quantity of dissolved material in a sample of water.

Transmissivity (T) is the two-dimensional form of hydraulic conductivity and is defined as the hydraulic conductivity multiplied by the saturated aquifer thickness.

The vadose zone is the zone containing water under pressure less than that of the atmosphere, including soil water, intermediate vadose water, and capillary water. This zone is limited above the land surface and below the surface of the zone of saturation, that is, the water table.

Water-table is the surface between the vadose zone and the groundwater, that surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere.

LIST OF ACRONYMS

Acronym	Description
DEM	Digital Elevation Model
DWA	Department of Water Affairs
DWAF	Department of Water and Forestry
DWS	Department of Water and Sanitation (previously DWA and DWAF)
DWS	Department of Water and Sanitation
EMPR	Environmental Management Plan Report
FD	Finite Difference
GCS	GCS Water and Environment Consultants (Pty) Ltd
GRIP	Groundwater Information Project
GW	Groundwater
h	Potentiometric head
ha	Hectare
HDPE	High-Density Polyethylene (Plastic)
HMP	Hydrogeological Management Plan
HRU	Hydrological Response Unit
IWULA	Integrated Water Use License Application
IWWMP	Integrated Waste and Water Management Plan
K (k)	Hydraulic Conductivity (m/day)
K _{xx}	Hydraulic Conductivity on the x-axis (m/day)
K _{yy}	Hydraulic Conductivity on the y-axis (m/day)
K _{zz}	Hydraulic Conductivity on the z-axis (m/day)
m	Metres
m ³	Cubic Metres
MAE	Mean annual evaporation
mamsl	Meters above mean sea level
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
mbgl	Meters below ground level
n	Porosity
NEMA	National Environmental Management Agency
NGDB	National Groundwater Database
n-Value	Manning's Roughness Coefficients
NWA	National Water Act, 1998 (Act No. 36 of 1998)
PCD	Pollution Control Dam
PCD	Pollution Control Dam
PEST	Parameter Estimation Simulation
PFD	Process flow diagram
Re	Recharge (%)
S	Storativity
SANS	South African National Standards
S _s	Specific Storage
SW	Surface Water
S _y	Specific Yield
T	Transmissivity (m ² /d)
t	Time (days)
TDS	Total dissolved solids
USG	Unstructured Grid
W	Groundwater Flux
WMA	Water Management Area
WQ	Water Quality
WR2012	Water Resources of South Africa 2012
Y (Yr.)	Years
ZOI	Zone of Influence
θ	Porosity

1 INTRODUCTION

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Kangra Coal (Pty) Ltd to undertake a geohydrology assessment for the proposed development of a Co-Disposal Facility and Water Treatment Plant (WTP) in the Maquasa East, near Driefontein, Mpumalanga Province (refer to Figure 1-3). The project falls in quaternary catchment W51B of the Pongola to Mtamvuna Water Management Area (WMA) (DWS, 2016).

1.1 Project background

Kangra Coal is an existing coal mine located in Driefontein, near Piet Retief, in the Mkhondo Local Municipality within the Gert Sibande District Municipality. The Maquasa East (MQE) operations include the historical opencast and underground operations. Kangra is proposing to construct a water treatment plant as well as a co-disposal facility at their Maquasa East operations. The treatment plant will be used to treat water from the existing decant point as well as any surplus water within the mining operations.

1.1.1 Water Treatment Plant:

Decant is currently observed in the form of clear groundwater discharge emanating from the old underground workings at MQE close to the Heyshope Dam. This decant is observed at an elevation range of approx. 1303 to 1306 mamsl and is contained in an unlined contamination dam. This excess decant is currently pumped from the unlined dam back to the MQE PCDs. Based on available data from previous studies undertaken at the mine decant observed emanating from the old workings occurs at a rate ranging from 1 220 to 2 700 m³/d (average 1 800 m³/d), depending on the rainfall season.

Kangra intends to upgrade the current contamination dam with a correctly lined dam as approved by the Department of Water and Sanitation to prevent any seepages onto the Heyshope Dam. The decant will be pumped into the proposed wastewater treatment plant that will be situated close to the Maquasa East PCDs. Construction and operation of the discussed infrastructure will trigger listed activities that will require authorisation.

The master layout plan associated with the proposed water treatment plant and brine storage facilities proposed (and existing PCDs) is shown in Figure 1-1.

It should also be noted that Kangra is investigating the possibility of storing brine on the discard dump/co-disposal that will come from the water treatment plant. This is one of the two options, with the other being dedicated brine evaporation ponds. GCS has not yet received confirmation as to which option Kangra are opting for, thus impacts relating to both are considered in this assessment.

Treated water will be discharged into the Heyshope dam at the existing decant rate at pristine water quality (in line with GA limits for treated effluent discharge), and therefore will likely not have a negative impact on water quantity or quality. Compared to the active decant water quality, the proposed activity is predicted to improve the Heyshope water quality. Proposed discharge will take place at an existing abstraction point west of Driefontein, that is no longer in use.

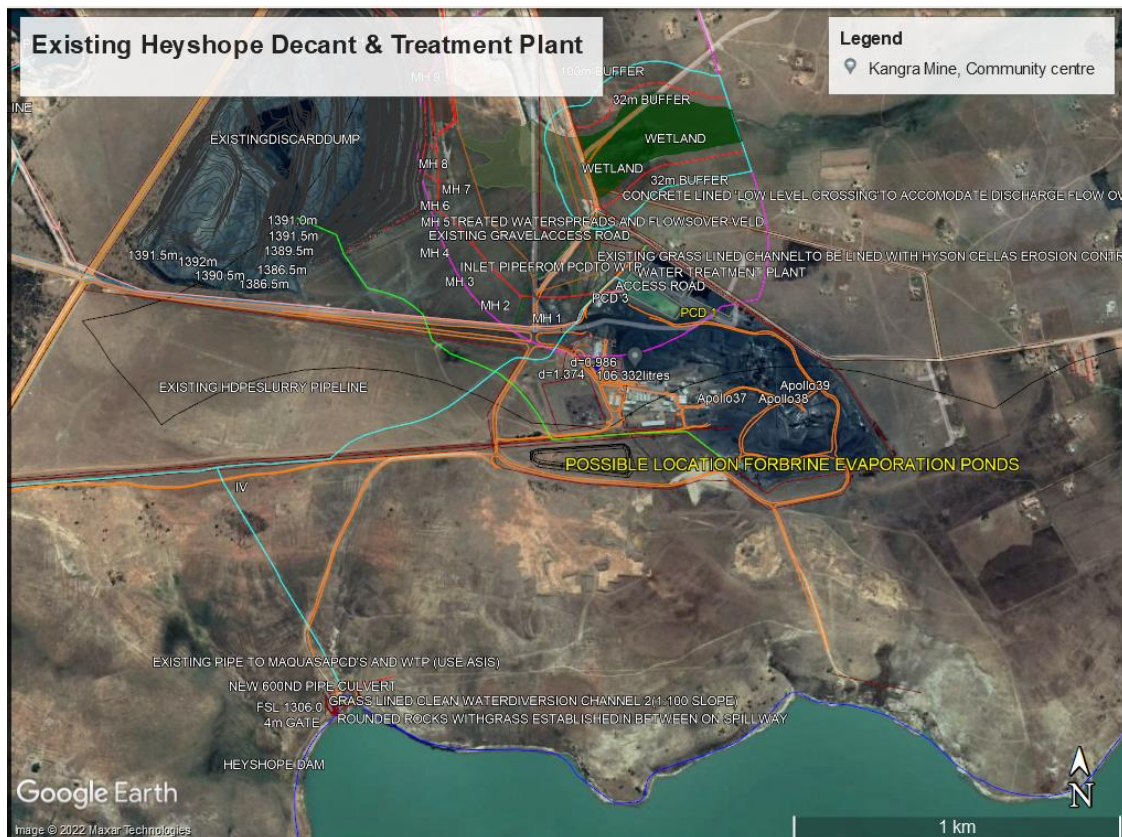


Figure 1-1: Proposed WTP and possible brine evaporation pond

1.1.2 Co-Disposal Facility

The discard dump at MQE has an approved environmental authorisation and a water use license. As a result of changing operational requirements, there is now a need for a co-disposal facility at MQE, this co-disposal facility is not authorised.

- The co-disposal facility will be located within the MQE operation on the remaining (RE) portion of the farm Rooikop 18 HT. The co-disposal facility will accommodate discarded produced from the benefaction plant located at Maquasa East, which currently washes and processes coal from the surrounding Kangra Coal operations and will receive coal from future expansion areas.

- This discard dump was originally designed as a three-compartment side hill-type dump with a footprint of approximately 65ha. The three-compartment layout allows for a modular implementation approach with the benefit of delaying capital expenditure. The implementation of this project will be done in two phases:
- Phase 1 will entail the use of the approved discard dump, and
- Phases 2 and 3 will entail the use of a co-disposal facility that requires authorisations.

In the phases, the plan is to build the full waste dump over 20 years. Phase 1 (7 years capacity), Phase 2 (7 years capacity), and Phase 3 (6 years capacity). GFK are undertaking detailed designs of the dump, as well as stormwater sizing. The facility will be lined with an impermeable barrier. The layout plan for the co-disposal facility is shown in Figure 1-2.

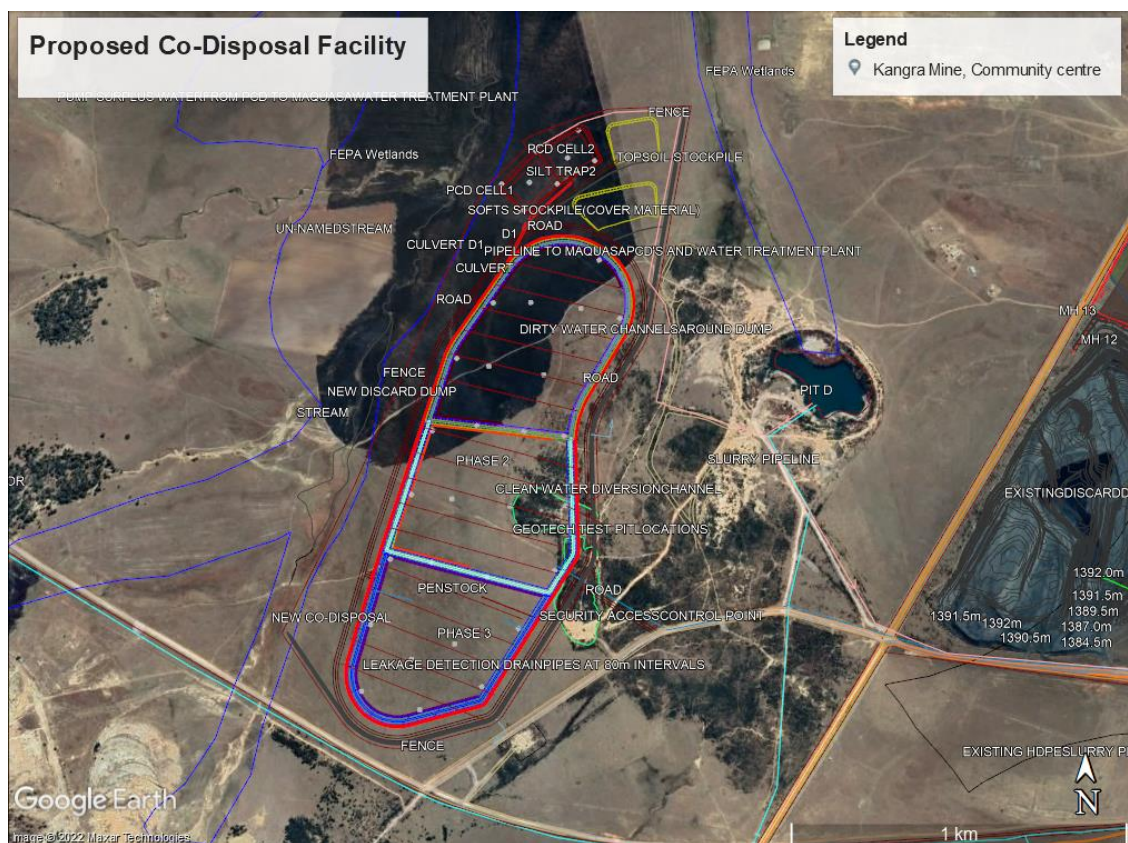


Figure 1-2: Proposed Co-Disposal Facility (Phase 1 already approved, Phase 2 & 3 will be co-disposal)

1.2 Study relevance to the season in which it was undertaken

This study was undertaken as a once-off study and relies on field-generated data, backed by historical geohydrological and climate data for the site, as well as recognised geo-hydrological and water resource databases for South Africa. Data generated during the time of this study is not seasonally bound as average yearly data was applied where required and as scientifically acceptable.

1.3 Objectives

The objectives of this study, were as follows:

- Undertake a site walkover assessment to identify natural and man-made drainage lines and establish baseline surface water quality.
- Evaluate the site's hydrological setting (i.e., climate, rainfall, drainage, etc.).
- Understand and characterize the geohydrological setting, to set a basis for evaluating potential impacts relating to the proposed activities.
- Review existing specialist groundwater reports for Maquasa East and monitoring data for the existing groundwater monitoring system, to verify groundwater quantity and quality and impacts thereon.
- Develop a site conceptual model (CSM) to illustrate the geohydrological setting, underlying aquifers and groundwater flow paths.
- Understand all risks associated with the Maquasa East activities on the groundwater environment:
 - The groundwater model was developed to more fully characterize the groundwater flow systems (i.e. particle flow analyses); and
 - To determine the Zone of Influence (ZOI)/impact area of the proposed dump on the groundwater environment (i.e. pumping borehole zones of influence [ZOIf] and potential pollution migration - zone of impact [ZOIp]).
 - The Australian Groundwater Modelling Guidelines (Barnett, et al., 2012) were considered to ensure that the numerical model adheres to international norms and standards.
- Produce a comprehensive report which can be used for decision-making purposes and input into the WULA.

1.4 The layout of this report

The report has been structured, as far as possible, as per *Annexure D of the Government Gazette (GN267 of 24 March 2017)* applicable to geohydrological studies for environmental impacts assessment/water use license applications. This report further considers Appendix 6 of EIA guidelines.

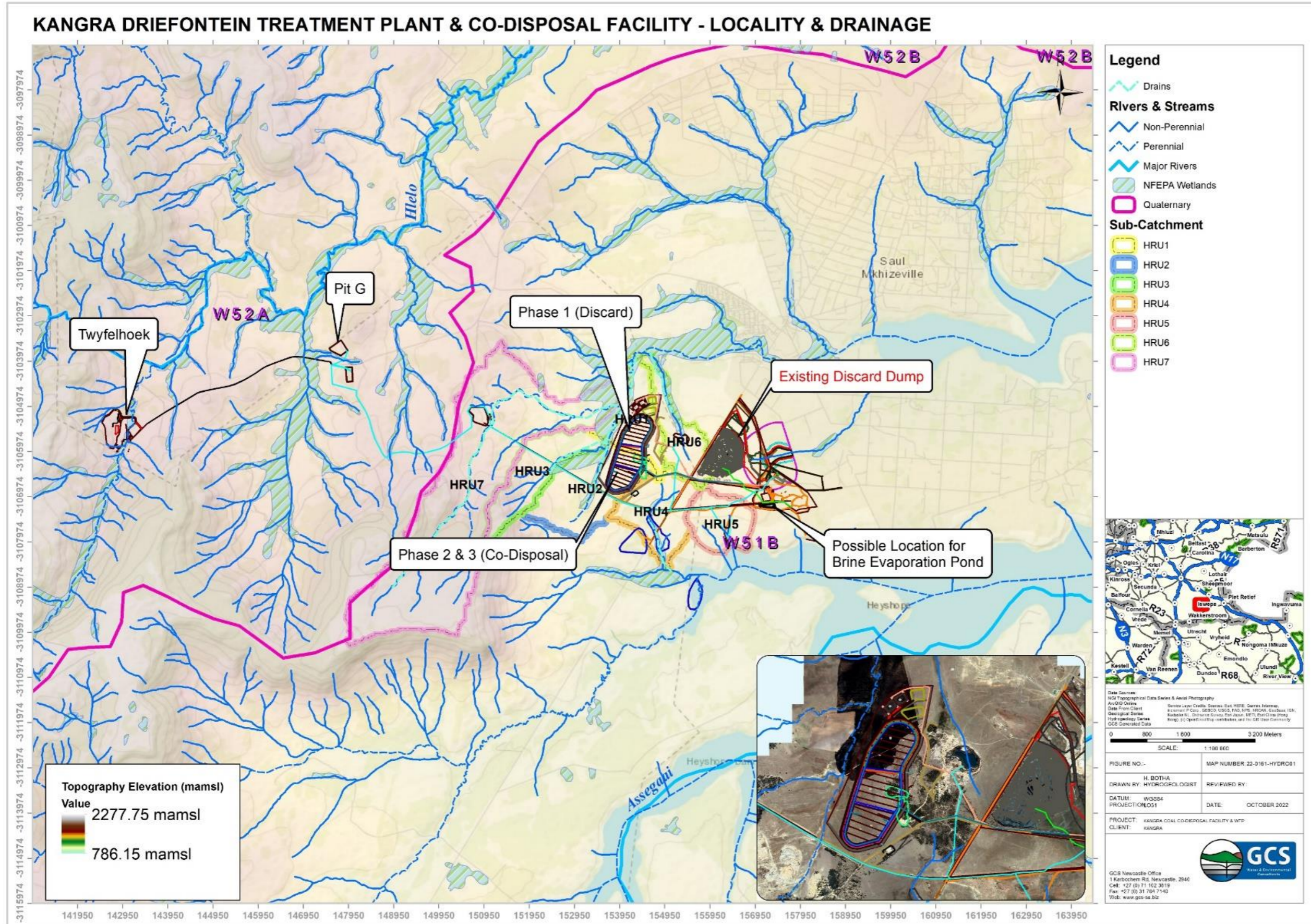


Figure 1-3: Site locality and drainage

2 SCOPE OF WORK

The scope of work completed is as follows:

1. Desktop data review:

- a. All available reports relating to the site were assessed, including a review of all geohydrology, hydrology, hydrochemistry, and geology literature data.
- b. GCS water monitoring data for the site were assessed and integrated into this investigation.
- c. A desktop-level hydrocensus was conducted. The National Groundwater Archive (NGA, 2019), Groundwater Resource Information Project (GRIP, 2016) and the Southern African Development Community Groundwater Information Portal (SADAC GIP) databases were assessed to identify existing groundwater users in the area.

2. Baseline Hydrology Review:

- a) Hydro-meteorological data collection and analysis.
- b) Catchment delineation and drainage characteristics.
- c) Determination of catchment hydraulic and geometric parameters.

3. Field investigation:

- a) A site walk-over assessment was undertaken to map sensitive groundwater-surface water interaction zones identified on a desktop level.
- b) Several geophysical traverses were conducted to identify preferential groundwater flow paths and to site future monitoring boreholes.
- c) Slug testing was conducted on suitable boreholes at the site.
- d) A groundwater hydrocensus was conducted within a 5 km radius of the proposed development.

4. Hydrogeological and geological conceptual model:

- a. A hydrogeological and geological site conceptual model was developed with data obtained for the study area - focussing on the proposed co-disposal facility.

5. Groundwater numerical flow and transport modelling:

- a. A steady-state model was developed and calibrated with data available for the study area. The steady-state model was converted to a transient-state model to enable scenario modelling. The following were evaluated:
 - i. Groundwater flow velocities and directions;

- ii. Groundwater depth; and
- iii. Likely source term impacts.

6. Geohydrological risk and impact assessment:

- a) A risk assessment was conducted based on the source-pathway-receptor principle.
- b) The potential impacts associated with the development of the co-disposal facility on the groundwater and subsequent surface water environments were evaluated.

7. Monitoring plan:

- a) A groundwater and surface water monitoring plan, with mitigation measures, was developed for the site based on the baseline assessment of the site conditions.

8. Reporting:

- a) This report encompassing all work done as well as a risk assessment and monitoring plan was compiled.

3 AREA OF INVESTIGATION

The following section supplies a brief overview of the regional setting, topography, climate, and geological and soil occurrences in the project area. The information in this section was obtained from the public domain, fieldwork and reports for the project.

3.1 Sub-catchment hydrological response units (HRUs)

Seven (7) hydrological response unit (HRUs) describes the natural drainage for the study area (using a 1:1 000 stream count and 30 m DTM fill) - refer to Figure 1-3. The sub-catchment relates well to desktop-delineated drainage lines for the project area, as well as verified streams associated with the project area.

Primary drainage from the position of the proposed co-disposal site, and much of the MQE area is towards the northeast, to the perennial Egude River, which makes up the bottom inflow of the Heyshope Dam. Drainage from the southern portions of the MQE area, and Maquasa West (MQW) is towards the south, via several perennial and non-perennial drainage lines, towards the southern inflow of the Heyshope Dam. The Heyshope Dam is therefore the end received of any surface water-related pollution that may take place at the MQE operations. The sub-catchments that are associated with the proposed co-disposal facility are HRU1 to 3, and HRU6. The sub-catchment associated with the proposed treatment area is HRU5.

3.2 Local geology & soils

According to the 1:250 000 geological series (2730 Vryheid), the local surface geology is characterised by occurrences of dolerite, and sediments associated with the Vryheid Formation, of the Eccca Group, of the Karoo Sequence (DMEA, 1998g) - refer to Figure 3-1.

Numerous Jurassic-age dolerite dykes and sills intruded the Vryheid Formation at various stratigraphic levels. In general, the area has been divided into two (2) lithological units:

- arenite - siliciclastic coal-bearing rocks of the Eccca Group; and
- dolerite - late-stage igneous rock which has been emplaced into the sedimentary rocks.

During the deposits of sediments in the still sagging basin, the tension in the crust due to continuing sagging led to failure and subsequently intrusion of the Post-Karoo dolerite sills and dykes along weak zones (e.g. fault/fracture zones). Consequently, dykes and sills varying between a few centimetres to a couple of metres in thickness intruded. Although the proposed Project is situated within the Ermelo Coalfield, the coal seams of interest have been logged as the Utrecht Coalfield seams of Gus and Dundas. The Gus seam lies stratigraphically above the Dundas seam with a parting of ~15 to 20 m. The Gus seam occurs at a depth of approximately 100 m from the surface with an average width of ~1 to 2 m, whilst the Dundas seam occurs at a depth of approximately 45 m from the surface with varying thickness.

According to the Land types of South Africa databases (Land Type Survey Staff, 1972 - 2006c), the soils in the area typically conform to land types of the Bb36 group, which typically entail red and yellow, dystrophic/mesotrophic, apedal soils with plinthic subsoils (plinthic soils comprise > 10% of land type, red soils comprise < 33% of land type). According to WR2012 soil data for the area, the erodibility of the soils for the area can be considered medium (WRC, 2015) - refer to Figure 3-2.

In terms of Hydrological Soil Types, the soils in the project area are classified as Type C, with an erosion factor of 7 and runoff factor of about 0.39.

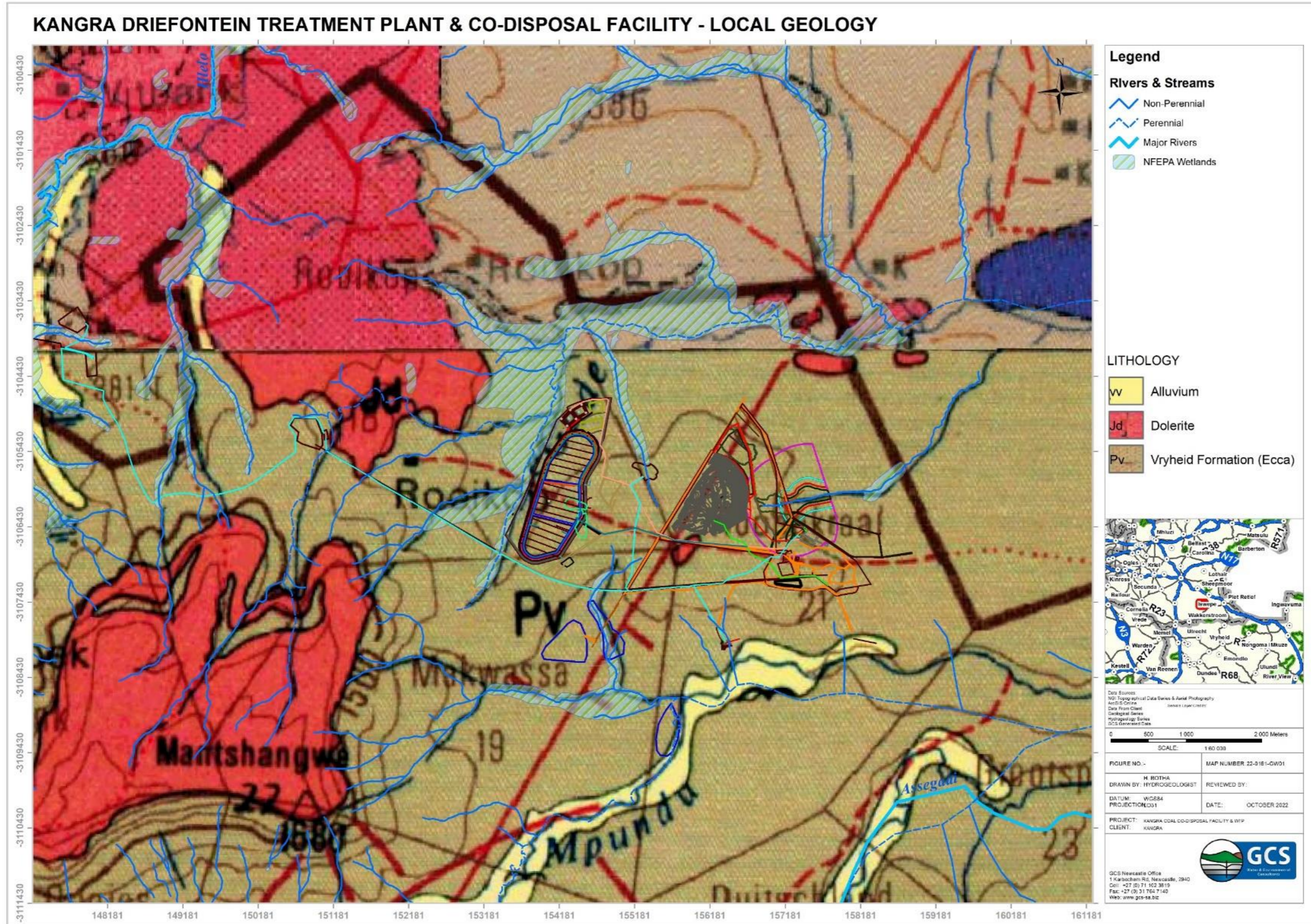


Figure 3-1: Local geology

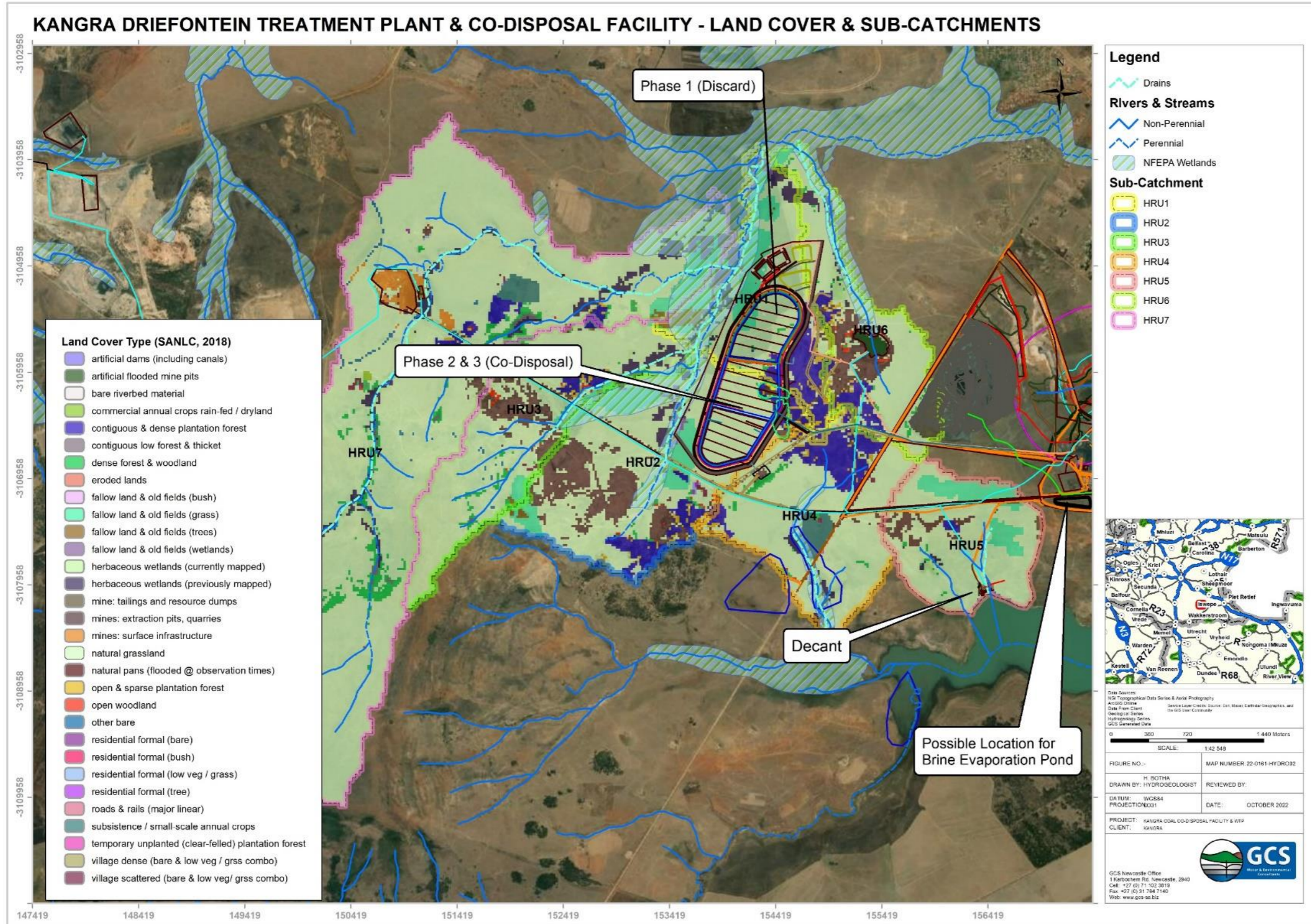


Figure 3-2: Sub-catchments and land cover types

3.3 Climate

Climate, amongst other factors, influences soil-water processes. The most influential climatic parameter is rainfall. Rainfall intensity, duration, evaporative demand and runoff were considered in this study to indicate rainfall partitioning within the project area.

3.3.1 Temperature

The average yearly temperature (refer to Figure 3-3) for the project area ranges from 25 to 33°C (high) and -4 to -2°C (Low). The study area is situated in a subtropical highland climate or temperate oceanic climate with dry winters (Cwb) area, as per the Köppen Climate Classification (Kottek, et al., 2006). The project area receives summer rainfall.

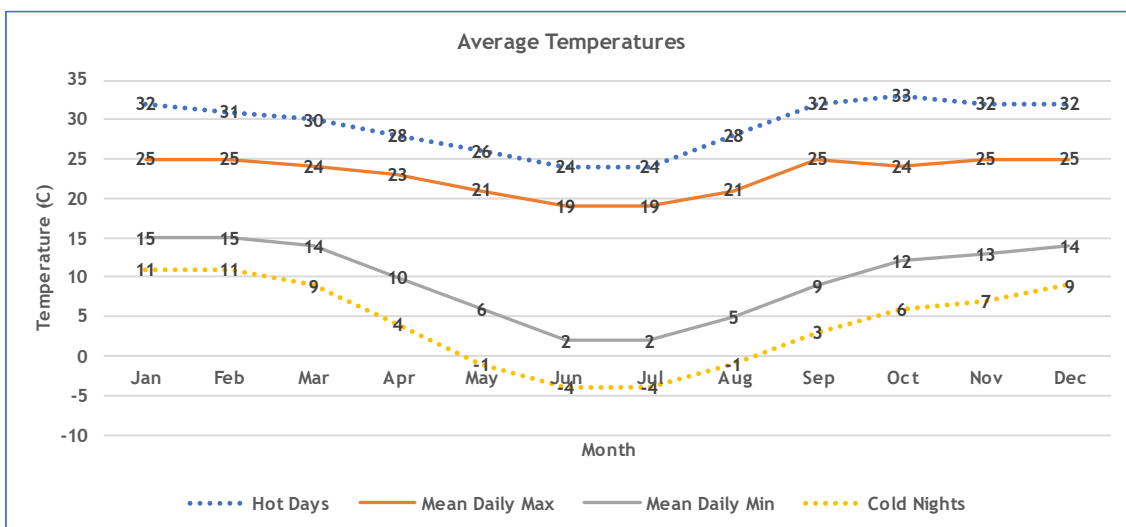


Figure 3-3: Average yearly temperatures (Meteoblue, 2022)

3.3.2 Wind speed and direction

Figure 3-4 shows the wind rose for the project area (Vryheid used as reference) and presents the number of hours per year the wind blows from the indicated direction. The wind blows from WW, ENE and E more often, at velocities ranging from 1 km/hr to 28 km/hr; and from other directions but less frequently and at lower velocities (< 19 km/hr).

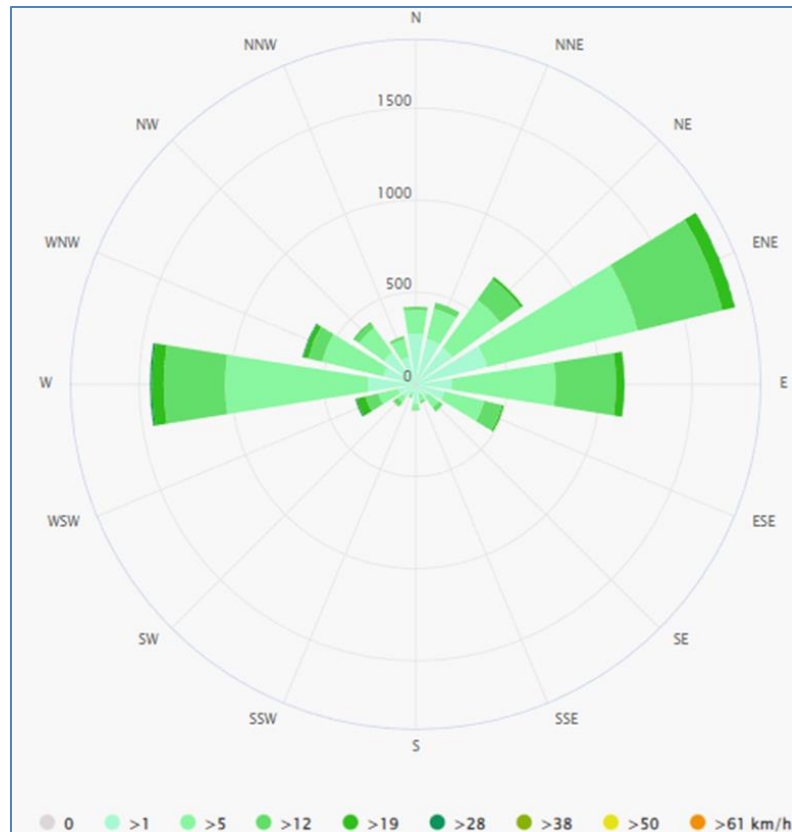


Figure 3-4: Wind rose (Meteoblue, 2022)

3.3.3 Rainfall and evaporation

The project area is situated in rainfall zone W5A. The mean annual precipitation (MAP) measured at several rainfall stations that fall close to the site is summarised in Table 3-1, below.

Table 3-1: MAP of nearest rainfall stations

Station Name	ID	MAP (mm/yr)
GROOT RIETVLEI	0407639_W	770
DIRKIESDORP (POL)	0407730_W	681
SPITSKOP	0407397_W	800
BRERETON PARK	0443807_W	900
Average		787.75

The monthly rainfall data used to calculate MAP was obtained from rainfall station 0407639W (Grootvlei). The rainfall record is for the period 1929 to 2003 (74 years). Monthly rainfall for the site is likely to be distributed as shown in Figure 3-5, below.

Available rainfall data suggest a MAP ranging from 482 (30th percentile) to 1372 (90th percentile) mm/yr. The average rainfall is in the order of 768 mm/yr. The project area falls within evaporation zone 13A, of which Mean Annual Evaporation (MAE) ranges from 1 200 to 1 300 mm/yr. The MAE far exceeds the MAP for the site, which implies greater evaporative losses when compared to incident rainfall. Monthly evapotranspiration for the site is likely to be distributed as shown in Figure 3-5, below.

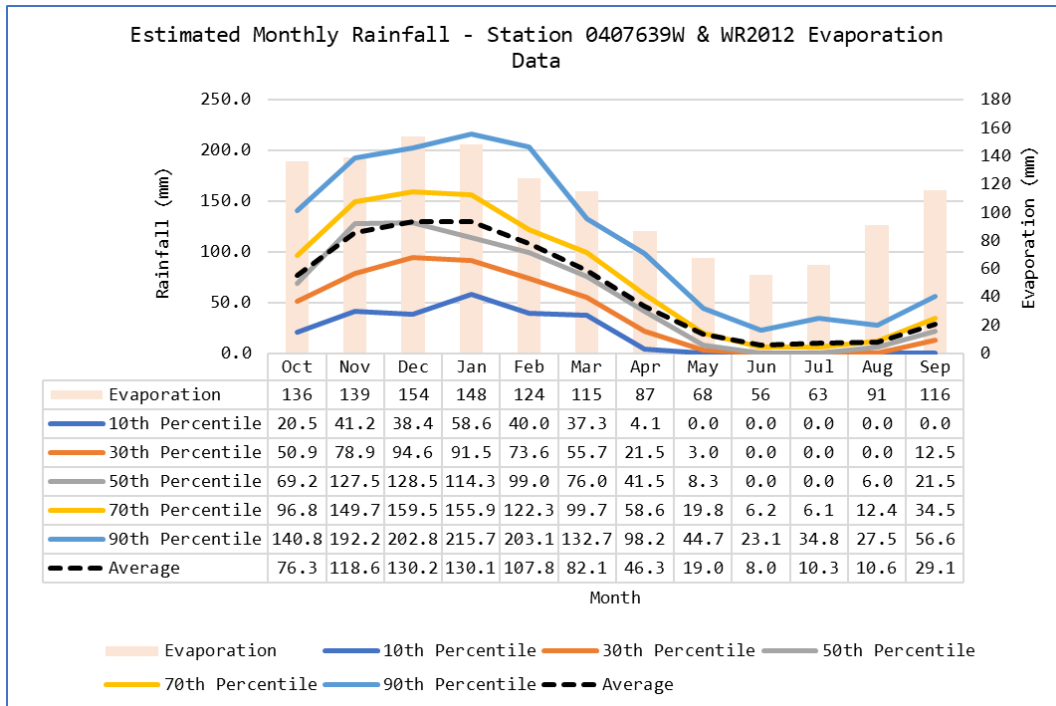


Figure 3-5: Average rainfall for Station 0407639W & WR2012 evaporation

3.3.4 Runoff

Runoff from natural (unmodified) catchments for quaternary catchment W51B is simulated in WR2012 (WRC, 2015) as being equivalent to 103.5 mm/yr (or 13% of the MAP). This is approximately 51.369 Mm³/yr NMAR for the surface area of W51B.

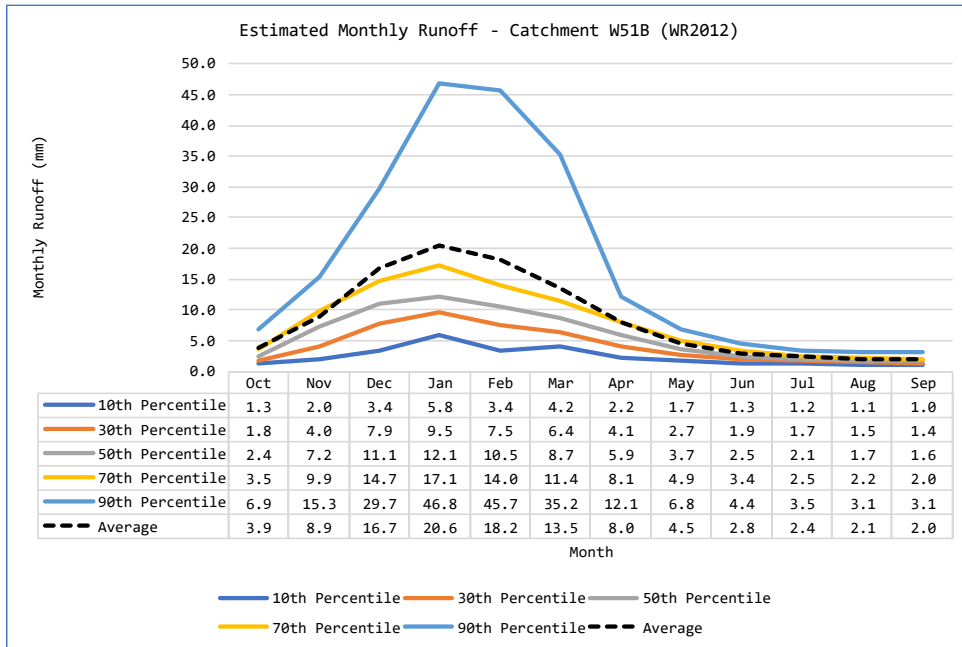
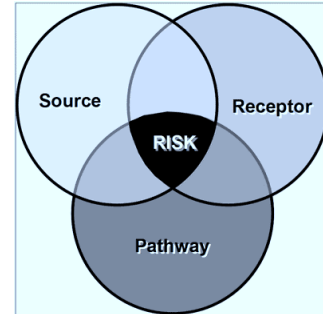


Figure 3-6: Simulated natural (unmodified) runoff for W51B

4 METHODOLOGY

A logical and holistic approach was adopted to assess the study area. The Best Practice Guidelines for Impact Prediction (G4) (Department of Water Affairs and Forestry [DWAF], 2008), were considered to define and understand the three basic components of the geohydrological risk associated with the site activities:

- **Source term** - The source of the risk;
- **Pathway** - The pathway along which the risk propagates;
and
- **Receptor** - The target that experiences the risk.

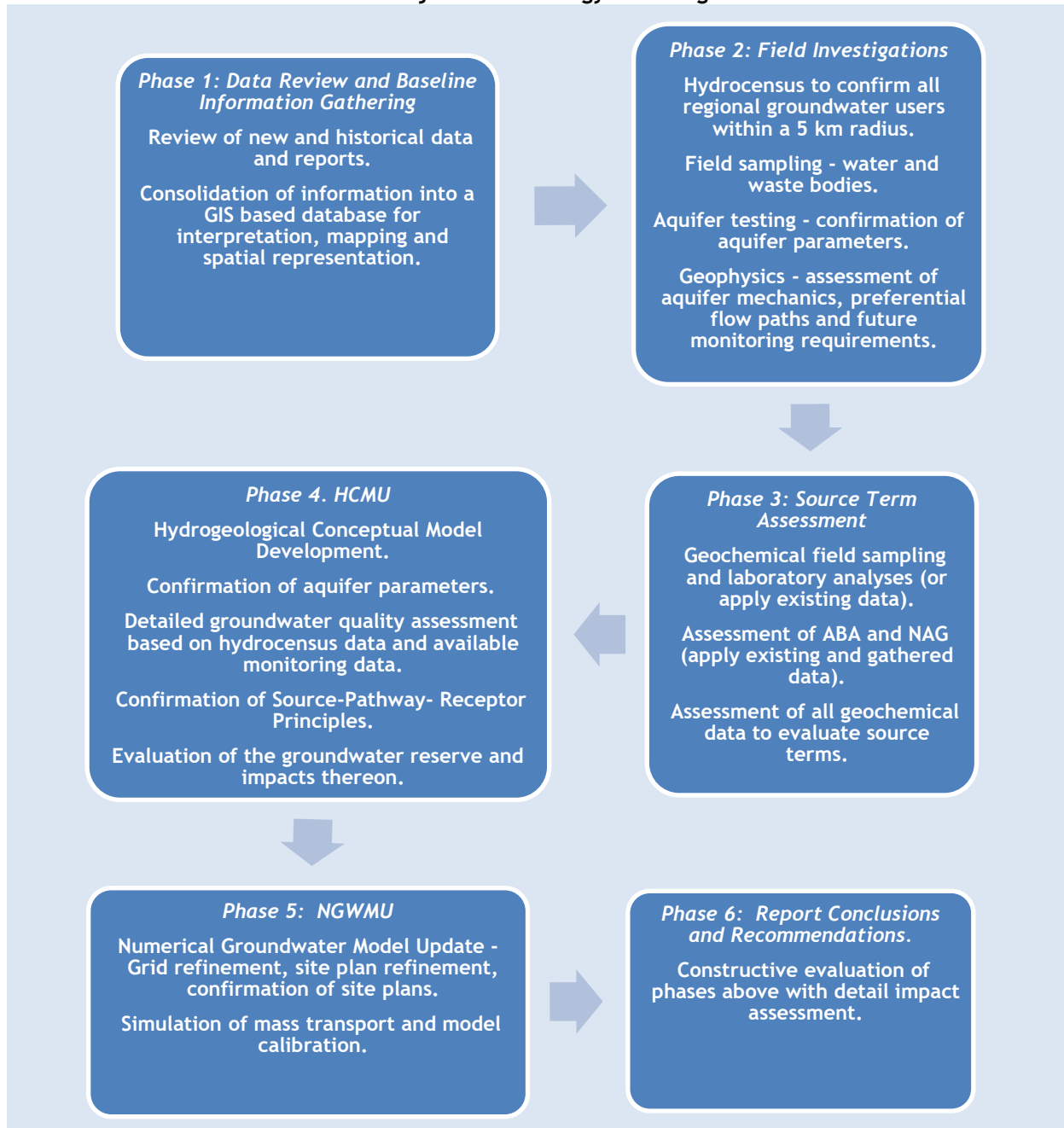


The approach was used to assess:

1. How the existing/proposed site activities could impact groundwater *Quality*; and
2. How the existing/proposed site activities could affect the groundwater *Quantity*.

Subsequently, a groundwater model was developed to illustrate the conceptual understanding of the groundwater flow system. Groundwater modelling is an efficient tool for groundwater management and remediation. Models are a simplification of reality to investigate certain phenomena or to predict future behaviour. The challenge is to simplify the reality in a way that does not adversely influence the accuracy and ability of the model output to meet the intended objectives. In terms of quality control, the Australian Groundwater Modelling Guidelines (Barnett, et al., 2012) were considered to ensure that the numerical model adheres to international norms and standards. Table 4-1 presents an overview of the project methodological approach followed.

Table 4-1: Project methodology flow diagram



4.1 Literature review and desktop study

The following sources supply an overview of the geohydrological conditions of the project area, as per the desktop information reviewed for this assessment:

- Groundwater Resource Information Project (GRIP, 2016)), National Groundwater Database Archives (NGA, 2019).
- SADC Groundwater Information Portal (SADC GIP) borehole data (SADC GIP, 2022)
- 2829 Vryheid - 1:500 000 Hydrogeological map series (King, et al., 1998).
- 2930 Vryheid - 1:250 000 Geological map series (DMEA, 1998g).
- Literature on similar geology and hydrogeology:
 - A South African Aquifer System Management Classification (Parsons, 1995);
 - Aquifer Classification of South Africa (DWA, 2012);
 - Karoo Aquifers: Their Geology, Geometry and Physical Properties. Water Research Council (WRC) Report No: 457/1/98 (Botha, et al., 1998);
 - Karoo Groundwater Atlas Volume 2 (Woodford, 2013); and
 - The relationship between South African geology and geohydrology (Lourens, 2013).
- GCS internal database and reports for Kangra (refer to reference list).

4.2 Hydrological overview

Hydrometeorological data for the study area were obtained from various sources including the South African Water Resources Study WR2012 database (Bailey & Pitman, 2015), South African Atlas of Agrohydrology, and Climatology (Schulze, 1997), and the Daily Rainfall Data Extraction Utility (Lynch, 2004). Moreover, sources such as the Köppen Climate Classification (Kottek, et al., 2006), World Climate Data CMIP6 V2.1 (Eyring, 2016), and Meteoblue (Meteoblue, 2022) were used to refine hydrological data.

These sources provided means of determining the Mean Annual Precipitation (MAP), Mean Annual Runoff (MAR), and Mean Annual Evaporation (MAE) of the study site as well as the design rainfall data. Data was applied to the site water balance calculations, runoff peak flow estimates for flood line modelling and stormwater runoff peak flow estimates for stormwater system sizing (where applicable to this study).

4.3 Groundwater users in the study area

According to Water Allocation Registration Management System (WARMS, 2019), there are no WARMS water users within a 5 km radius of the proposed activity. According to SADAC GIP and National Groundwater Activities (NGA) data, there are at least 3 registered boreholes within a 5 km radius of the proposed activities (refer to Figure 1-3 and Table 4-2).

Table 4-2: Groundwater users within a 2.5 km radius of the site

ID	Source	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Water Level (mbgl)
736675	SADAC GIP / NGA 2022	-27.06383	30.39031	1322	2.1
736687	SADAC GIP / NGA 2023	-27.02717	30.41504	1351	15
611988	SADAC GIP / NGA 2024	-26.974167	30.400833	1351	No Data

4.4 Field investigation

The field investigation took place from 6 to 21 October 2022. The following summarises the findings and work completed:

1. A hydrocensus was undertaken within the project area and within a 5 km radius of the proposed discard. Nine (9) boreholes could be located in the field, two (2) of which are fitted with pumps (FB7 and FB8) and the rest are used for monitoring. The boreholes fitted with pumps are sealed, and no water levels could be obtained.
2. A geophysical assessment with the use of magnetic methods was undertaken on the Maquasa East property, specifically focusing on the proposed co-disposal discard. The survey aims to identify any subterranean structures which promote/limit groundwater movement through the area. Future monitoring boreholes will be sited and drilled into structures identified, where possible.
3. Slug aquifer tests were conducted on MBH5 and MBH3 to determine hydraulic permeabilities to supplement the numerical groundwater model development as well as the risk assessment.

4.4.1 Field hydrocensus

Table 4-3 provides a list of field boreholes identified in the project area with the spatial distribution of boreholes shown in Figure 4-1. A photographic log of photos taken during the field investigation is available in **Appendix A**.

Table 4-3: Field hydrocensus boreholes identified in the project area

ID	Source	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Water Level (mbgl)
MBH4	Field	30.38519	-27.0081	1332	7.1
FB7	Field	30.41598	-26.998	1228.79	Could not measure/Sealed
FB8	Field	30.41766	-26.9991	1320.94	Could not measure/Sealed
FB9	Field	30.39507	-27.0236	1357.45	Could not measure/Sealed
FB10	Field	30.39573	-27.0231	1371.3	22.8
MQW1	Field	30.34877	-27.0078	1466.88	3.1
MBH5	Field	30.38149	-27.0157	1339.21	5.15
MBH3	Field	30.38799	-27.0158	1369.75	12.18
FB12	Field	30.34989	-27.0092	1469.62	17.1

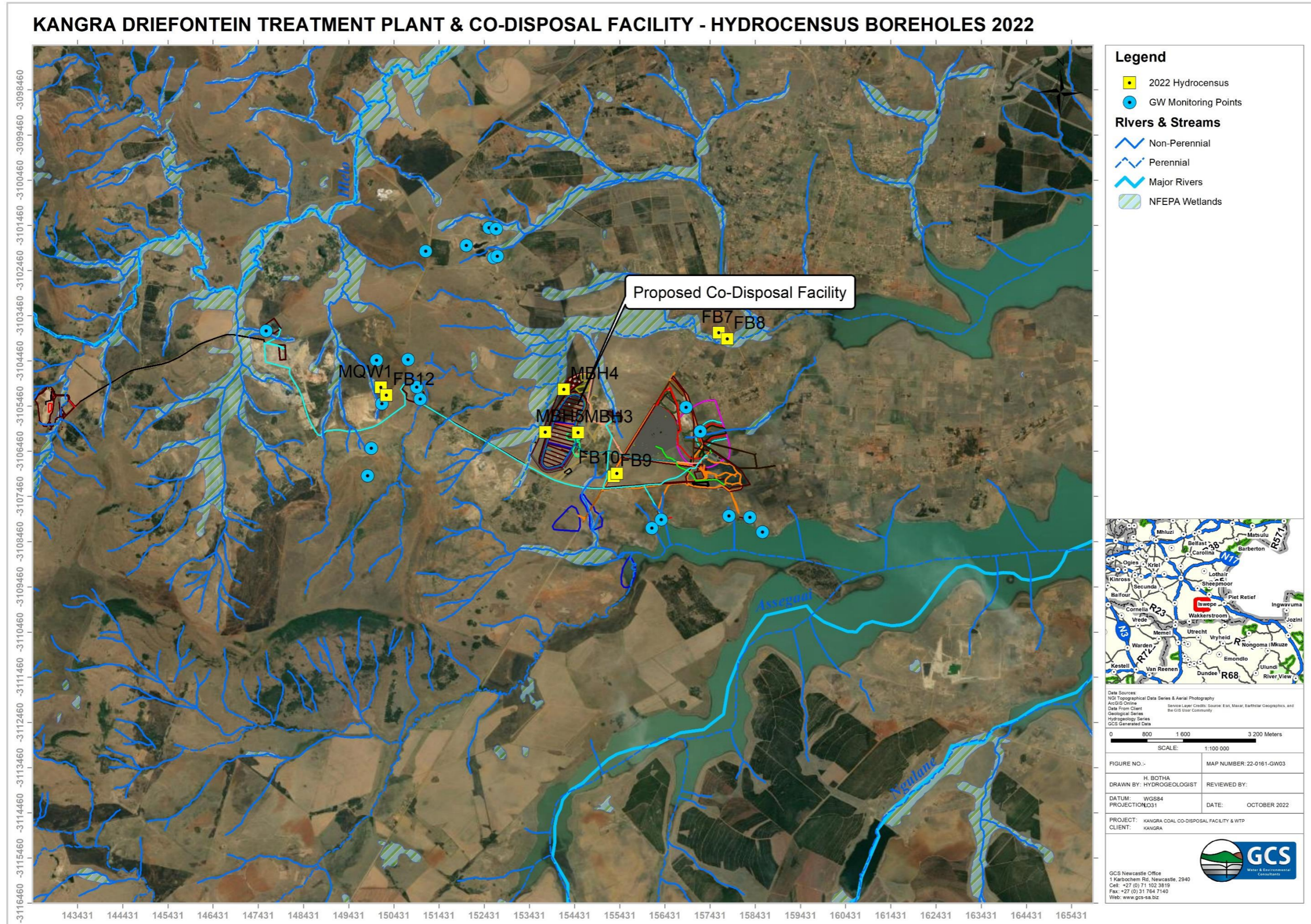


Figure 4-1: Hydrocensus borehole locations

4.4.2 Geophysical assessment findings

The geophysical investigation aimed to identify any subterranean structures which promote/limit groundwater movement through the area. The detailed geophysical investigation methodology and data interpretation are available in **Appendix B**. The findings are briefly summarised as follows:

- Seven (7) Magnetic (Mag) profiles were completed (refer to Table 4-4). The Mag traverse varied from approximately 500 m to 2.4 km lengths. Mag readings were taken at 10 m intervals. The spatial orientation of the survey and resulting profile lines are indicated in Figure 4-9.
- Based on the geophysical investigation undertaken, and the geophysical method applied, no evidence of contact zones could be identified. Hence, the area investigated is highly likely void of these preferential flow path structures. Groundwater movement is therefore expected to be via the bulk aquifer rock, in connected fractures or intergranular sedimentary occurrences.
- It is important to calibrate the magnetic data generated, by drilling boreholes in the anomalies identified. The proposed drilling positions are captured in Section 9 as part of the proposed groundwater monitoring improvements for the site.

Table 4-4: Geophysical Survey Record Summary

Traverse Number	Traverse Direction	Coordinates				Traverse Length [m]	Geological Target
		Line Start		Line End			
		Latitude [DD]	Longitude [DD]	Latitude [DD]	Longitude [DD]		
Line 1	SSW-NNE	-27.023740	30.379095	-27.004351	30.387018	-2360	Lineament (dyke) and geological formations boundaries
Line 2	NE-SW	-27.023053	30.381174	-27.005158	30.391205	-2430	Lineament (dyke) and geological formations boundaries
Line 3	SE-NW	-27.023727	30.383178	-27.021526	30.378342	-560	Lineament (dyke) and geological formations boundaries
Line 4	NNE-SSW	-27.021670	30.378498	-27.014713	30.380873	-850	Lineament (dyke) and geological formations boundaries
Line 5	NNE-SSW	-27.014962	30.381219	-27.006637	30.385266	-1080	Lineament (dyke) and geological formations boundaries
Line 6	W-E	-27.005931	30.385603	-27.004662	30.390827	-590	Lineament (dyke) and geological formations boundaries
Line 7	SW-NE	-27.023803	30.382935	-27.019889	30.389451	-880	Lineament (dyke) and geological formations boundaries

Note/s:

Unit and coordinate system description:

- [DD] - decimal degrees
- [m] - metres

Datum: WGS84

4.4.2.1 Magnetic Line 1

Line 1 was conducted from the south-southwest to the north-northeast over the length of the proposed discard dump footprint. The total length of the line was approx. 2360 m. The magnetic anomalies observed, suggest the presence of a shallow dolerite sill from $x \approx 690$ m to $x \approx 1140$, followed by several magnetic anomalies with the most prominent observed at $x \approx 1800$ m and $x \approx 2100$ m. The anomalies suggest that there are likely several contact areas between thin dolerite dykes, as well as dolerite dykes nearing the northern portion of the site (refer to Figure 4-2). The presence of these structures needs to be confirmed by drilling.

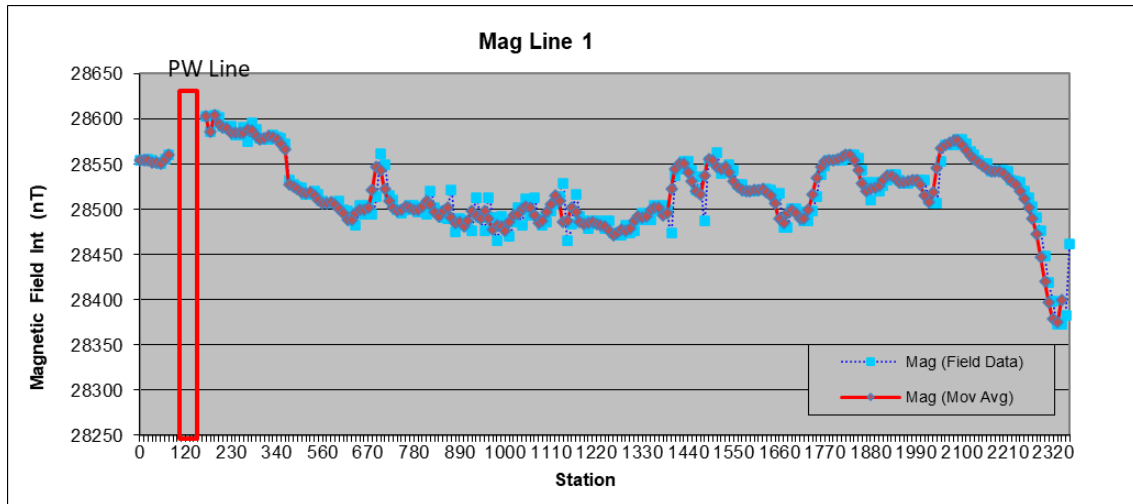


Figure 4-2: Mag line 1

4.4.2.2 Magnetic Line 2

Line 2 was conducted from the northeast to the southwest direction over the length of the proposed discard dump footprint. The total length of the line was approx. 2430 m. The result from the survey indicates a magnetic spike at 1040 m, which could represent the contact between the previously rehabilitated dump and the natural ground. A magnetic spike (and then drop) exists at station 2270. This could indicate the presence of a geological contact (refer to Figure 4-3).

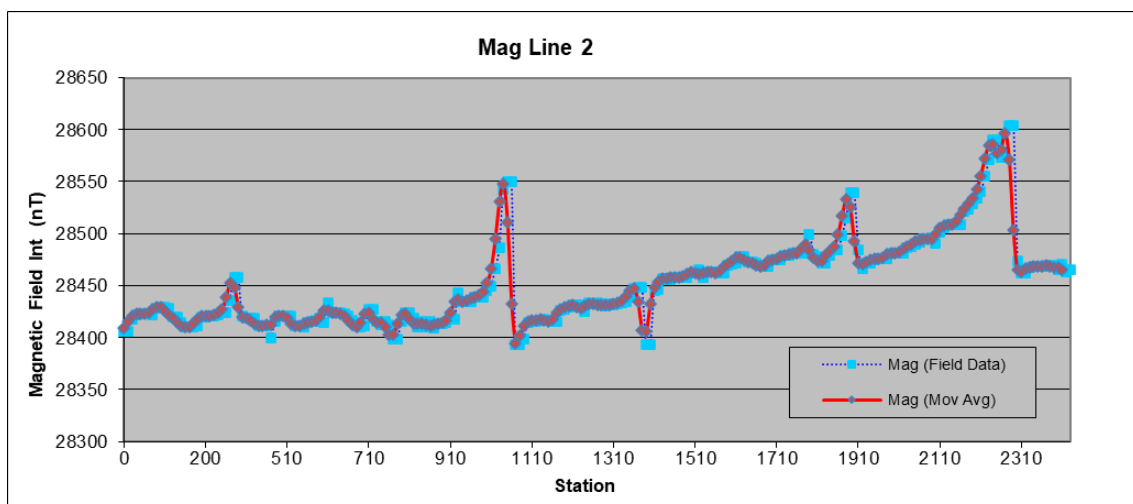


Figure 4-3: Mag line 2

4.4.2.3 Magnetic Line 3

Line 3 was conducted from the southeast to the northwest direction across the southern boundary of the proposed discard dump footprint. The total length of the line was approx. 560 m. The result from the magnetic survey suggests the presence of a thin dolerite dyke, at position $x \approx 220$ to 290 m (refer to Figure 4-4).

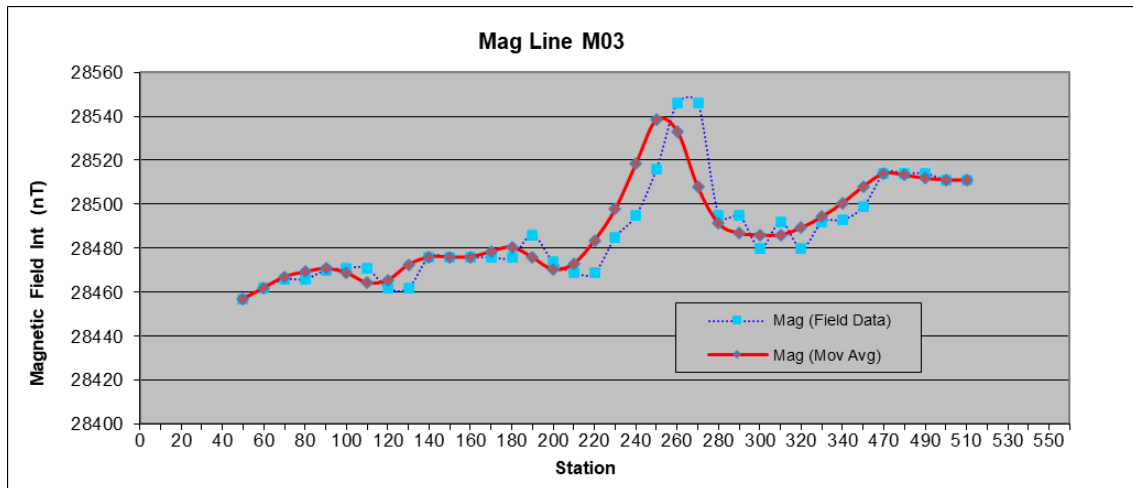


Figure 4-4: Mag line 3

4.4.2.4 Magnetic Line 4

Line 4 was conducted from the southwest to the northeast direction along the lower western boundary of the proposed discard dump footprint. The total length of the line was approx. 850 m. There was a lot of noise on this line, as a result of shallow Ferricrete outcrops. However, after refining the data, the presence of a likely dolerite dyke is noted from $x \approx 500$ m to $x \approx 620$ m (refer to Figure 4-5). The data correspond well to Line 1.

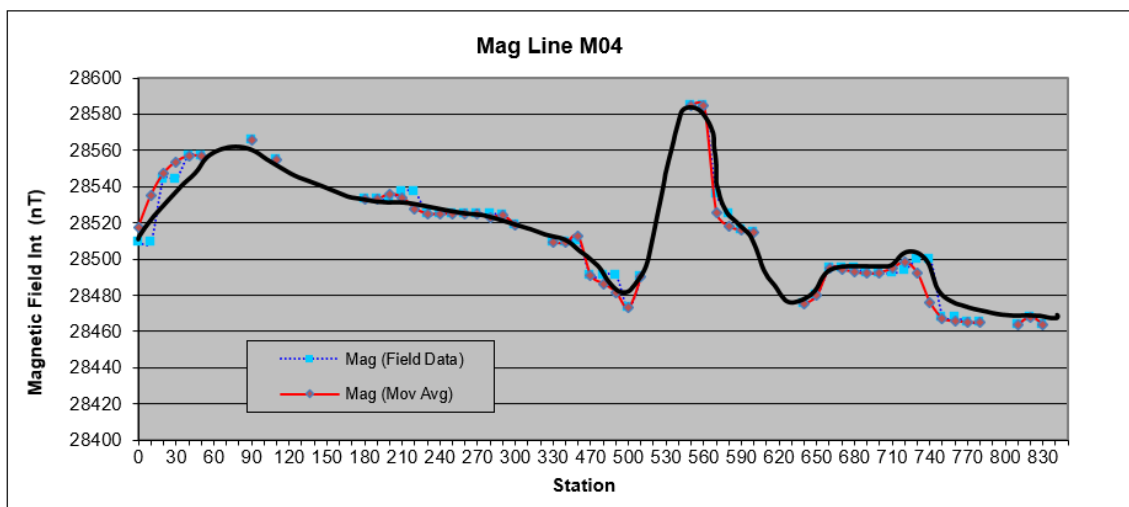


Figure 4-5: Mag line 4

4.4.2.5 *Magnetic Line 5*

Line 5 was conducted from the north-northeast to the south-southwest direction along the upper western boundary of the proposed discard dump footprint. The total length of the line was approx. 1080 m. The result from the survey indicates two distinct parabola anomalies at $x \approx 710$ m and $x \approx 960$ m (refer to Figure 4-6). The data suggest the presence of two (2) shallow thin dolerite dykes. The data correspond well to Line 1.

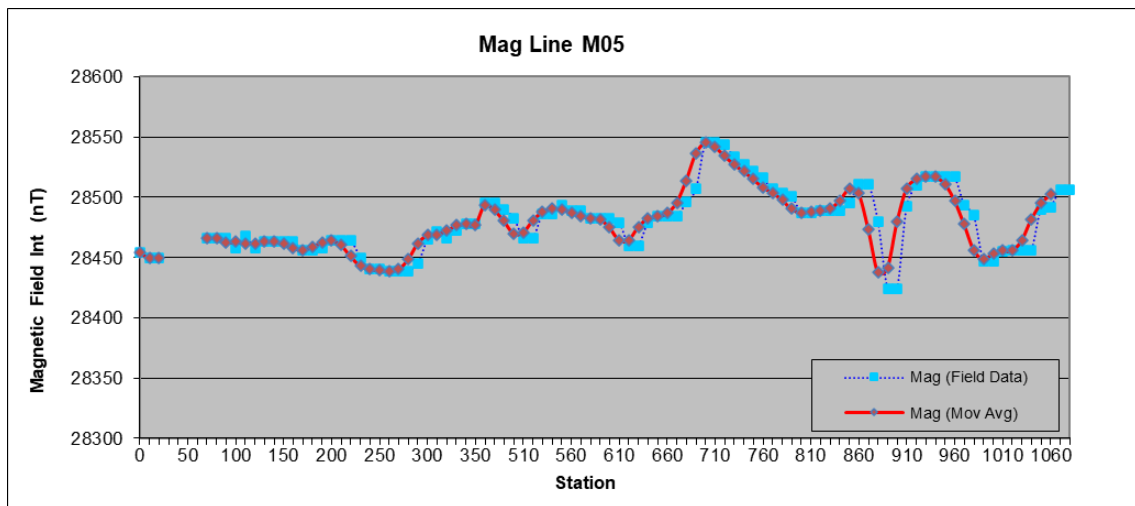


Figure 4-6: Mag line 5

4.4.2.6 *Magnetic Line 6*

Line 6 was conducted from the west to the east direction along the northern boundary of the proposed discard dump footprint. The total length of the line was approx. 590 m. The result from the survey shows the presence of a shallow weathered dolerite sill (refer to Figure 4-7). Ferricrete was also observed in this area, with the outcrop of the Ferricrete relating well to the observed peak anomalies.

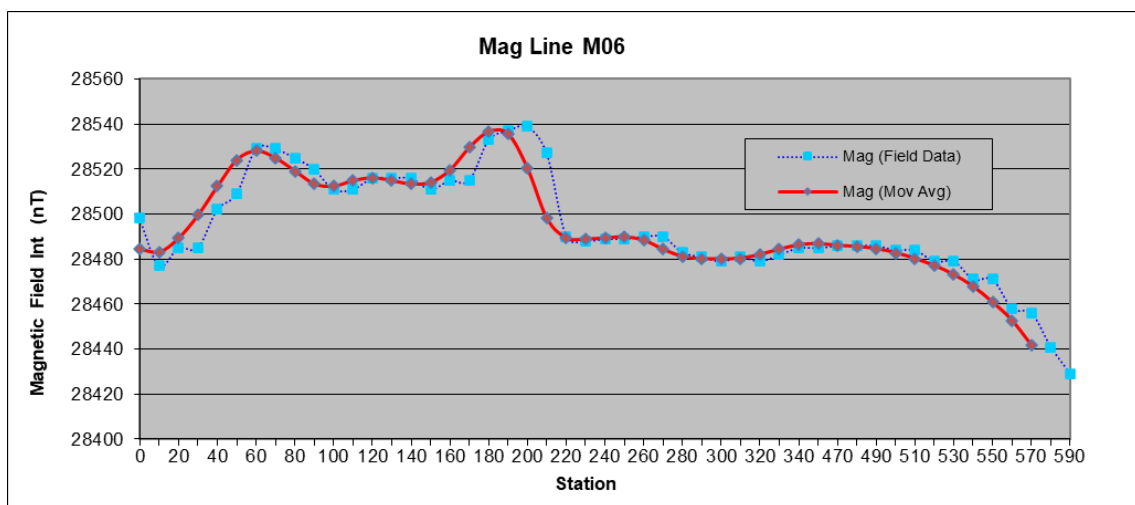


Figure 4-7: Mag line 6

4.4.2.7 Magnetic Line 7

Line 7 was conducted from the southwest to the northeast direction along the southeastern boundary of the proposed discard dump footprint. The total length of the line was approx. 880 m. The result from the survey suggests the presence of a dolerite dyke nearing $x \approx 530$ m.

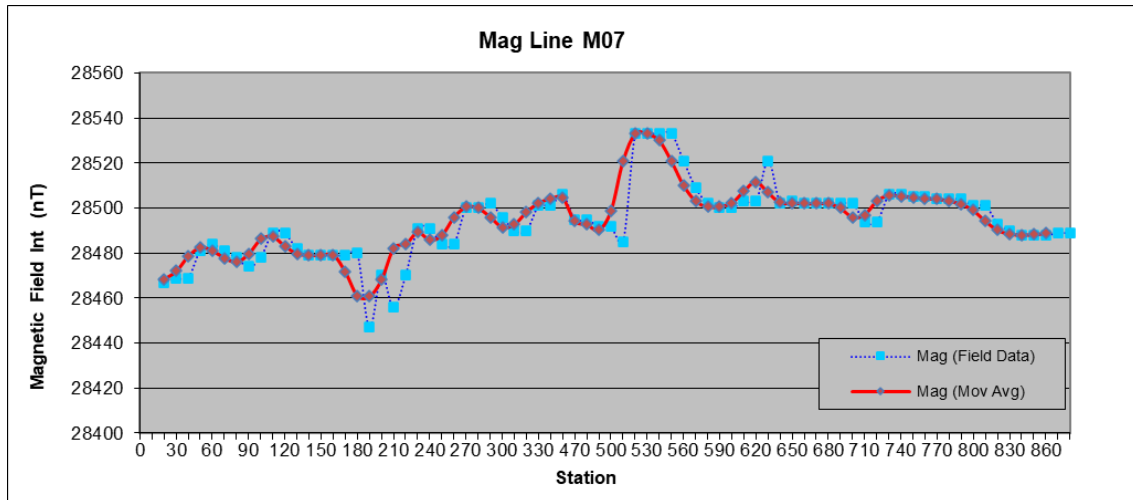


Figure 4-8: Mag line 7

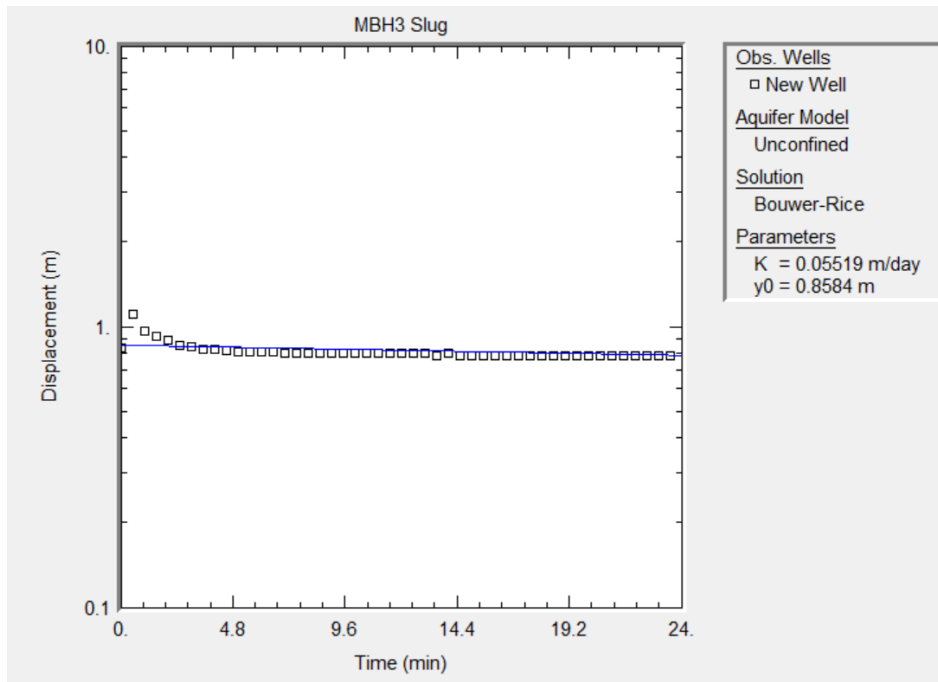
4.4.3 Aquifer slug testing

As mentioned above, two (2) slug tests were conducted. A slug test is a controlled field experiment performed by groundwater hydrologists to estimate the hydraulic properties of aquifers in which the water level in a control well is caused to change suddenly (rise or fall) and the subsequent water-level response (displacement or change from static) is measured through time in the control well and one or more surrounding observation wells. Slug tests are frequently designated as rising-head or falling-head tests to describe the direction of water-level recovery in the control well following test initiation. Other terms sometimes used instead of slug test include bail-down test, slug-in test and slug-out test (AQTESOLV, 2022)

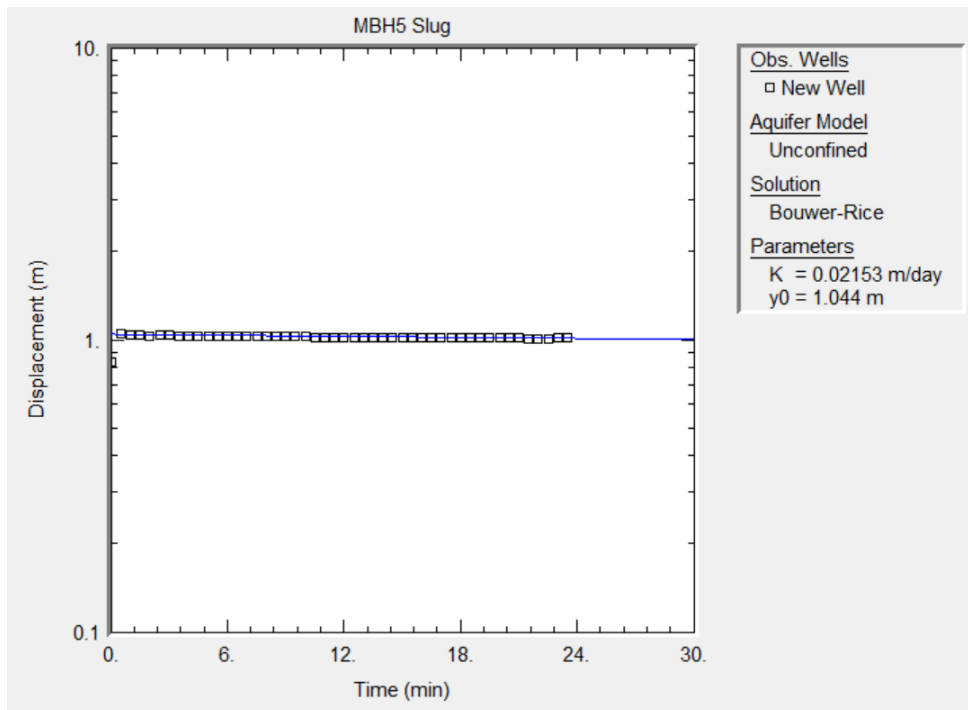
The goal of a slug test, as in any aquifer test, is to estimate the hydraulic properties of an aquifer system such as hydraulic conductivity. The aquifer test results are summarized in Table 4-5, and the diagnostic analyses plot using the Bower-Rice (1976). A saturated hydraulic thickness of 30 m is assumed, and the K-values estimated are for the weathered zone.

Table 4-5: Summary of slug test results

Borehole ID	Est. K (m/day)
MBH3	0.06
MBH5	0.02



MBH3



MBH5

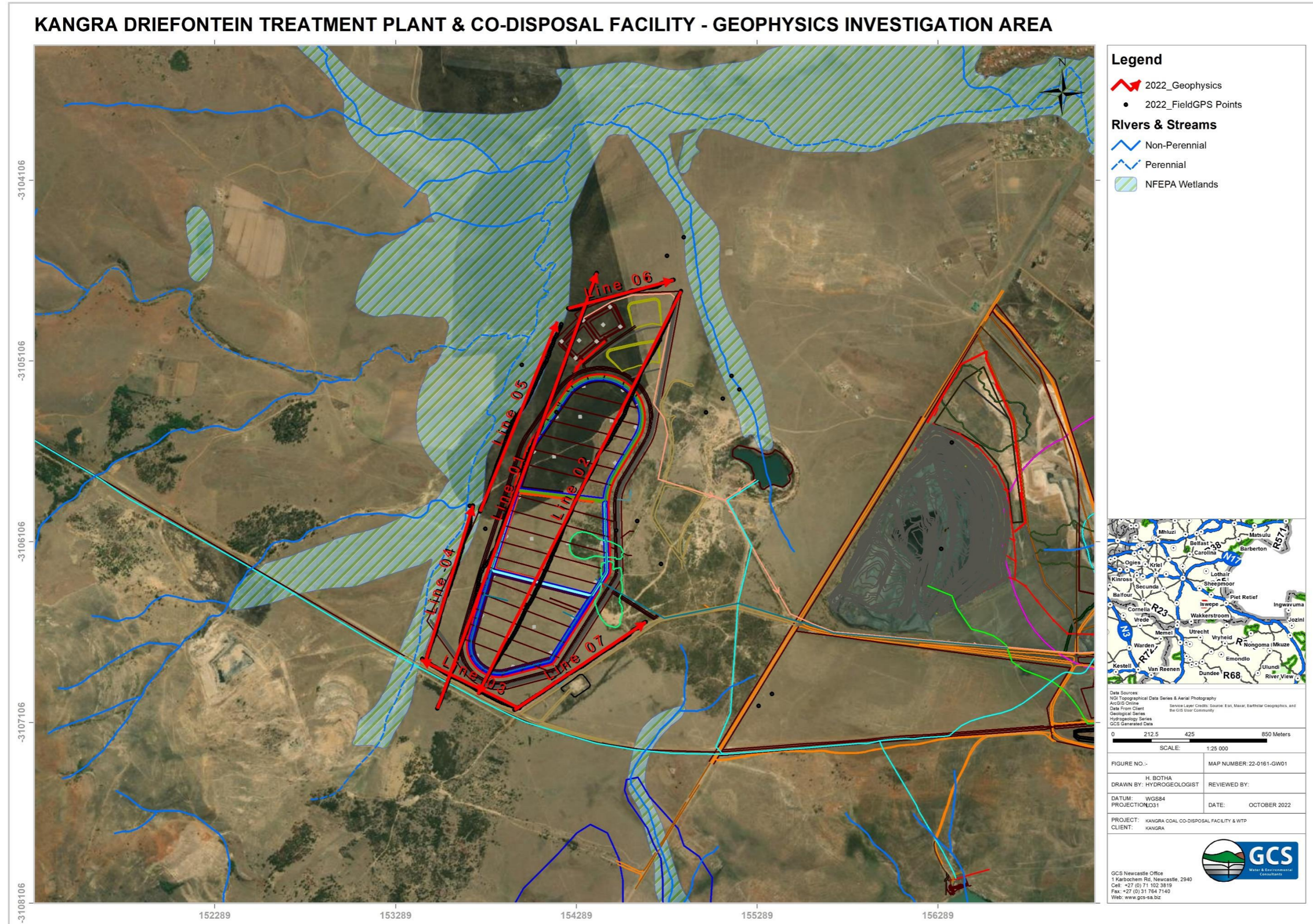


Figure 4-9: Geophysical investigation area

4.5 Geochemical assessment

Two (2) rock/material samples were subjected to static geochemical testing. The samples were obtained from the slurry (refer to Figure 4-10) and dry (refer to Figure 4-11) material from the existing discard dump at MQE.

Two (2) types of static testing were used to assess the acid (short & long-term) and neutralisation potential of the rock at the mine, namely Acid-Base Accounting (ABA) and Net Acid Generation (NAG).



Figure 4-10: Slurry deposit at discard dump



Figure 4-11: Dry discard deposit

4.5.1 ABA

ABA is a static test where the net potential of the rock to produce acidic drainage is determined. The percentage sulfur (%S), the AP (acid potential), the NP (neutralisation potential) and the Net Neutralization Potential (NNP) of the rock material are determined in this test, as an important first-order assessment of the potential leachate that could be expected from the rock material. The ABA screening criteria as described by (Price, 1997) are listed in Table 4-6. The components of an ABA analysis are further explained below:

- If pyrite is the only sulphide in the rock the AP is determined by multiplying the %S with a factor of 31.25. The unit of AP is kg CaCO₃/t rock and indicates the theoretical amount of calcite neutralized by the acid produced.
- The NP is determined by treating a sample with a known excess of standardized hydrochloric or sulfuric acid (the sample and acid are heated to ensure a complete reaction). The paste is then back titrated with standardized sodium hydroxide to determine the amount of unconsumed acid. NP is also expressed as kg CaCO₃/t rock to represent the amount of calcite theoretically available to neutralize the acidic drainage; and
- NNP is determined by subtracting AP from NP (EPA, 1994).

For the material to be classified in terms of its AD potential, the ABA results could be screened in terms of its NNP, %S and NP: AP ratio as follows:

- A rock with $NNP < 0 \text{ kg CaCO}_3/\text{t}$ will theoretically have a net potential for acidic drainage. A rock with $NNP > 0 \text{ kg CaCO}_3/\text{t}$ rock will have a net potential for the neutralization of acidic drainage. Because of the uncertainty related to the exposure of the carbonate minerals or the pyrite for reaction, the interpretation of whether a rock will be net acid generating or neutralizing is more complex. Research has shown that a range from $-20 \text{ kg CaCO}_3/\text{t}$ to $20 \text{ kg CaCO}_3/\text{t}$ exists which is defined as a “grey” area in determining the net acid generation or neutralization potential of rock. Material with an NNP above this range is classified as Rock Type IV - No Potential for Acid Generation and material with an NNP below this range as Rock Type I - Likely Acid Generating; and
- (Soregaroli & Lawrence, 1998) further states that samples with less than 0.3% sulphide sulphur are regarded as having insufficient oxidisable sulphides to sustain long-term acid generation. Material with a %S below 0.3% is therefore classified as Rock Type IV - No Potential for Acid Generation, and material with a %S of above 0.3%, as Rock Type I - Likely Acid Generating.

Table 4-6: ABA and NAG screening criteria (adapted from (Price, 1997) and (Fourie, 2014))

ABA: NPR Screening Criteria			ABA: %S Screening Criteria			ABA: NNP Screening Criteria		
Potential Acid Generation	NP: AP (NPR)	Comments	Potential Acid Generation	% S	Comments	Potential Acid Generation	NP: AP (NPR)	Comments
Rock Type I: Likely Acid Generating.	< 1	Likely AMD generating.	Rock Type IV: No Potential for Long-Term Acid Generation	< 0.3%	The sample may produce AMD bit will be short term.	Rock Type IV: No potential Acid Generation.	> 20	No AMD potential
Rock Type II: Possibly Acid Generating.	1-2	Possibly AMD generates if NP is insufficiently reactive or is depleted at a faster rate than sulphides.				Rock Type I: Likely Acid Generation.	< -20	Likely AMD potential
Rock Type III: Low Potential for Acid Generation.	2-4	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficient reactive NP.	Rock Type I: Likely Long-Term Acid Generation	> 0.3%	Potential for long-term AMD.	Uncertain	20 to -20	The sample may become acidic or remain neutral. Use the conjunction of the other criteria to resolve this uncertainty.
Rock Type IV: No Potential for Acid Generation.	> 4	No further AMD testing is required unless materials are to be used as a source of alkalinity.						

4.5.2 NAG

In the NAG test hydrogen peroxide (H_2O_2) is used to oxidize sulphide minerals to predict the acid generation potential of the sample.

The NAG test provides a direct assessment of the potential for a material to produce acid after a period of exposure (to a strong oxidant) and weathering. The test can be used to refine the results of the ABA predictions (refer to Table 4-7).

In general, the static NAG test involves the addition of 25 ml of 30% H_2O_2 to 0.25 g of sample in a 250 ml wide-mouth conical flask, or equivalent. The sample is covered with a watch glass and placed in a fume hood or well-ventilated area. Once "boiling" or effervescing ceases, the solution can cool to room temperature and the final pH (NAG pH) is determined. A quantitative estimation of the amount of net acidity remaining (the NAG capacity) in the sample is determined by titrating it with NaOH to pH 4.5 (and/or pH 7.0) to obtain the NAG Value (Lapakko & Lawrence, 1993).

Table 4-7: NAG screening methods used (Edited from (Miller, et al., 1997)

Rock Type	NAG pH	NAG Value (H_2SO_4 kg/t)	NNP ($CaCO_3$ kg/t)
Rock Type Ia. High Capacity Acid Forming.	< 4	> 10	Negative
Rock Type Ib. Lower Capacity Acid Forming.	< 4	≤ 10	-
Uncertain, possibly Ib.	< 4	> 10	Positive
Uncertain.	≥ 4	0	Negative
Rock Type IV. Non-acid Forming.	≥ 4	0	Positive

4.6 Mineralogy and total element analyses

The mineralogical composition of the solid rock samples was determined using X-ray diffraction (XRD). The XRD results and a simplified classification of the identified minerals are listed in Table 4-8. The results are summarised as follows:

- Boromuscovite (32.3%) is the dominant mineral in the dry sample whereas Quartz (45.7%) is by far the dominant mineral in the slurry sample;
- Quartz (26.4%), Orthoclase (18.7%) and Calcite (14.7%) are the other dominant minerals in the dry sample;
- Diapose (14.9%), Enstatite (13.1%), Orthoclase (8.9%) and Muscovite (7.9%) are the other major minerals found in the slurry sample;

No sulphide-bearing minerals were identified however, Calcite and Aragonite (5.1%) were identified in the dry sample. These are carbonate-bearing minerals which are typically associated with acid generation/neutralisation reactions.

Table 4-8: XRD results and mineral classification

Sample ID	K-DISCARD	K-SLURRY
Rock Type > Mineralogy	Dry Discard	Slurry
Aragonite	5.1	
Calcite	14.7	
Diapose		14.9
Enstatite		13.1
Franklinite	2	0.7
Magnesite		7.6
Muscovite	32.3	7.9
Orthoclase	18.7	8.9
Phlogopite		1.3
Portlandite	0.8	
Quartz	26.4	45.7
Totals	100	100.1

4.7 Acid potential

The Acid-Base Accounting (ABA) and Net Acid Generation (NAG) screening results are presented in Table 4-9. Figure 4-12 presents the acid potential of the samples, based on NP/AP and %S. Based on the screening results, the following is noted:

- The net acid potential (NNP) and nag screening suggest no long-term acid potential (AP). However, the ABA and %S paint a different picture in terms of the material AP.
- Samples are potentially acid generating (PAG) and long-term acid drainage is associated with the samples analysed; and

- NAG results suggest that samples are PAG.

Table 4-9: Summary of ABA and NAG screening results

Sample ID	K-DISCARD	K-SLURRY
Description	Coal Discard	Coal Slurry
Paste pH	7.36	8.01
Total %S	2.01	3.24
Sulphide %S	0.854	0.846
AP CaCO3 kg/t	62.8	101
NP CaCO3 kg/t	56.3	56.3
NNP CaCO3 kg/t	29.9	29.6
NP/AP	0.896	0.556
NAG pH: (H2O2)	7.38	3.07
NAG (kg H2SO4/t)	0	16.6
Rock Type NNP	IV - AMD not likely	IV - AMD not likely
Rock Type %S	I - long-term AMD	I - long-term AMD
Rock Type NP/AP	I - long-term AMD	I - long-term AMD

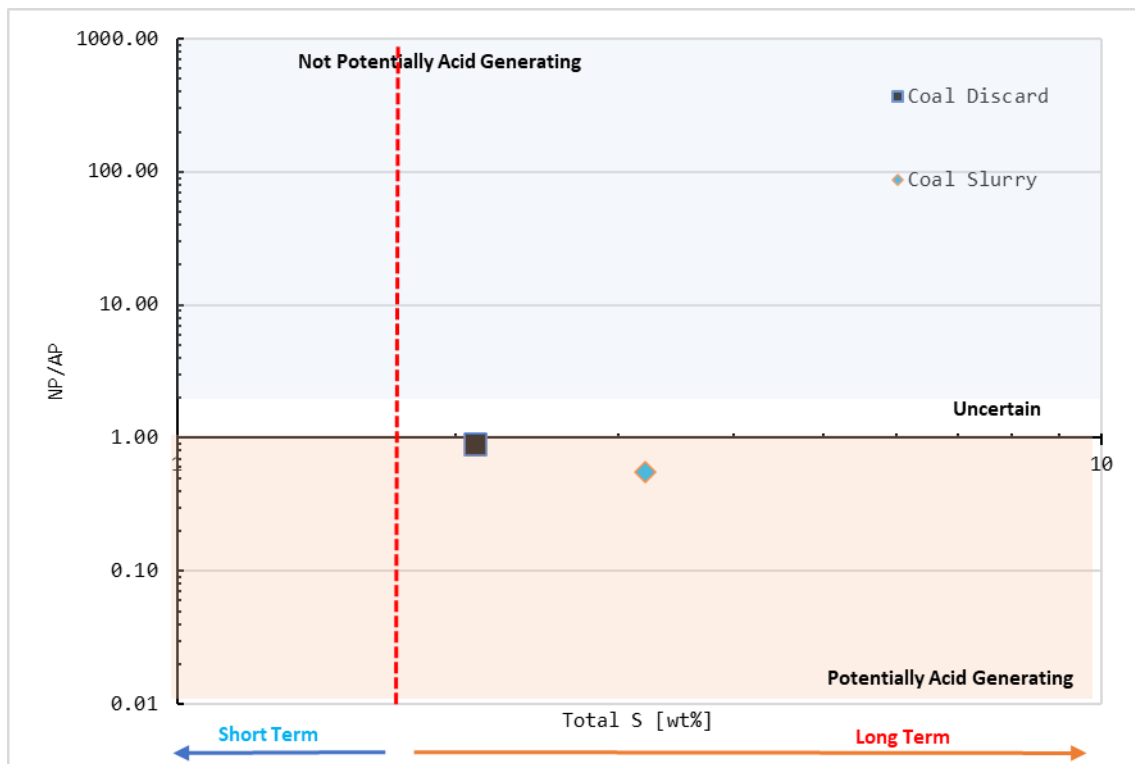


Figure 4-12: Acid Potential - based on sample AP/NP and %S

4.8 Static leach testing

1-20 (rock to water ratio) distilled water (DW) tests were conducted on the samples obtained. The leachate analytical results are summarised in Table 4-10, below. The following is noted from the static leach testing results:

- All samples exhibit near-neutral pH conditions;
- Sulphate (SO₄) and calcium (Ca) concentrations are observed to be high, compared to DWAD ideal water limits for potable water use.
- Several metals are observed to be present in the leachate.

Table 4-10: Summary of 1:20 DW Leachate Analytical Results

Locality		K-DISCARD	K-SLURRY1	DWAf 1996 Domestic Use WQO
Sample type		Geochem	Geochem	
Sampled date		10-Oct-2022	10-Oct-2022	
Geo - Reagent water Leach 1:20				
20 - pH	pH	8.1	8.11	4-9
20 - EC	mS/m	55.4	91.5	0 - 70
01 - Alk	mg CaCO ₃ /l	41.9	44.8	ns
02 - Cl	mg/l	2.3	6.38	0 - 100
03 - SO ₄	mg/l	220	421	0 - 200
04 - PO ₄	mg/l	-0.005	-0.005	ns
06 - NO ₃	mg/l	-0.194	-0.194	0 - 6
30 - Ca	mg/l	90	106	0 - 32
30 - Mg	mg/l	7.91	17.4	0 - 30
30 - Na	mg/l	6.19	57.3	0 - 100
30 - K	mg/l	6.58	8.28	0 - 50
31 - Al	mg/l	-0.002	-0.002	0 - 0.1
31 - Fe	mg/l	-0.004	-0.004	0 - 0.1
31 - Mn	mg/l	0.043	0.095	0 - 0.05
31 - Cd	mg/l	-0.002	-0.002	
31 - Co	mg/l	-0.003	-0.003	
31 - Cr	mg/l	-0.003	-0.003	
31 - Cu	mg/l	0.005	0.01	
31 - Ni	mg/l	-0.002	-0.002	
31 - Pb	mg/l	-0.004	-0.004	
31 - Zn	mg/l	-0.002	-0.002	
33 - B	mg/l	-0.013	-0.013	
33 - Ba	mg/l	0.066	0.054	
33 - Be	mg/l	-0.005	-0.005	
33 - V	mg/l	-0.001	-0.001	
32 - Bi	mg/l	0.011	0.015	
32 - Ag	mg/l	-0.001	-0.001	
32 - Ga	mg/l	0.002	0.002	
32 - Li	mg/l	0.006	0.009	
33 - Mo	mg/l	0.039	0.052	
32 - Rb	mg/l	0.01	0.011	
33 - Sr	mg/l	1.35	2.65	
32 - Te	mg/l	-0.001	-0.001	
32 - Tl	mg/l	-0.037	-0.037	
Below Detection limits				

4.9 Numerical model development

The modelling processes followed are indicated in Figure 4-13.

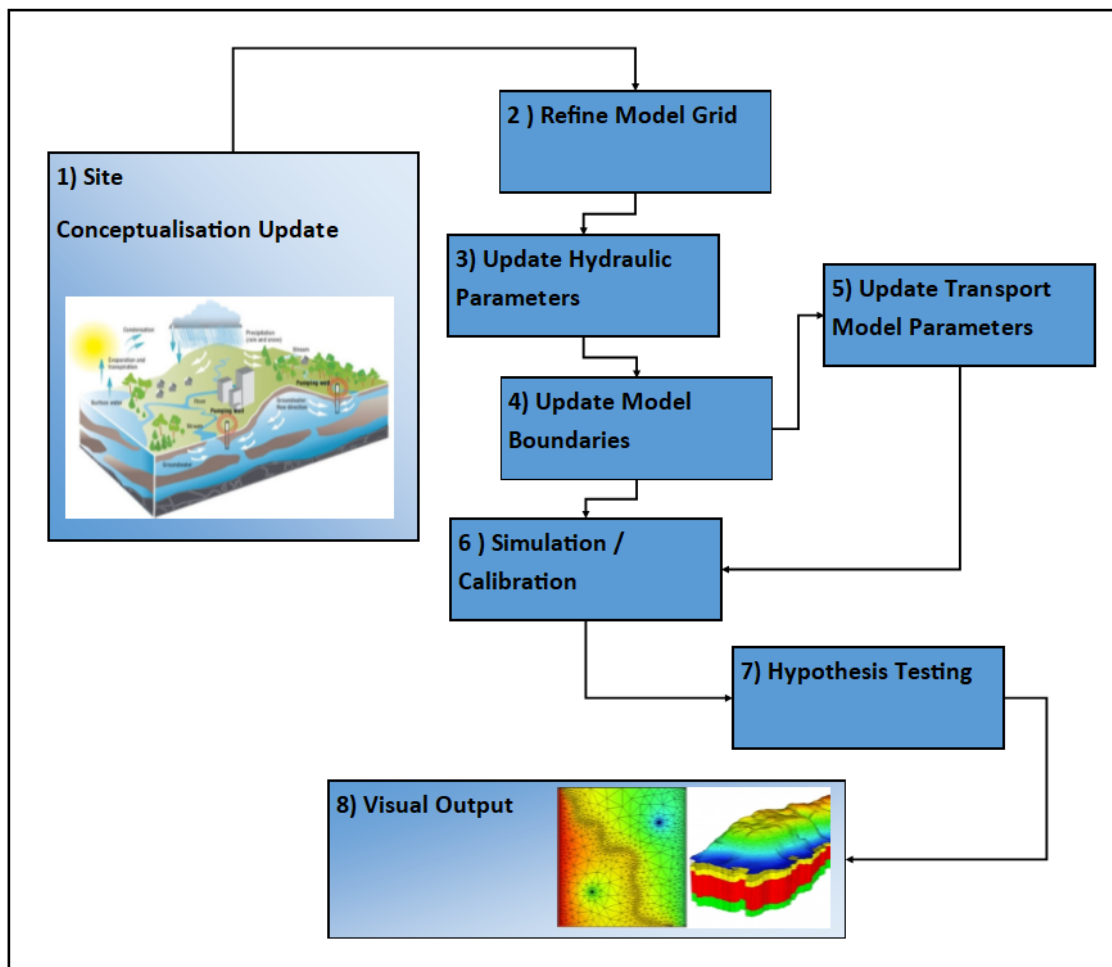


Figure 4-13: Numerical groundwater modelling process

4.9.1 Model software package

The numerical model for the project was constructed using Visual Modflow 6.1 Pro, Build 7088.31257, a pre-and post-processing package for the modelling code MODFLOW. MODFLOW is a modular three-dimensional groundwater flow model developed by the United States Geological Survey (Harbaugh, et al., 2000). MODFLOW uses 3D finite-difference discretisation and flow codes to solve the governing equations of groundwater flow.

4.9.2 Governing Equations

The numerical model used in this modelling study was based on the conceptual model developed from the findings of the desktop and the baseline investigations. The simulation model simulates groundwater flow based on a three-dimensional cell-centred grid and may be described by the following partial differential equation:

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

where:

- K_{xx} , K_{yy} , and K_{zz} are values of hydraulic conductivity along the x , y , and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity (L/T).
- h is the potentiometric head (L).
- W is a volumetric flux per unit volume representing sources and/or sinks of water,

with:

- $W < 0.0$ for flow out of the ground-water system, and $W > 0.0$ for flow in (T-1).
- S_s is the specific storage of the porous material (L-1), and
- t is time (T).

Equation 1, when combined with boundary and initial conditions, describes transient three-dimensional groundwater flow in a heterogeneous and anisotropic medium, provided that the principal axes of hydraulic conductivity are aligned with the coordinate directions (Harbaugh, et al., 2000).

4.9.3 Model confidence level classification

The Australian Groundwater Modelling Guidelines (Barnett, et al., 2012) refer to the following two principles that were considered in the numerical calibration process (refer to Appendix B):

- **Guiding Principle 2.3:**
 - A target model confidence level classification should be agreed upon and documented at an early stage of the project to help clarify expectations. The classification can be estimated from a semi-quantitative assessment of the available data on which the model is based (both for conceptualisation and calibration), the way the model is calibrated and how the predictions are formulated.
 - GCS aimed to construct a Class 2 flow and transport model. Class 2 models are founded on sufficient hydrogeological data (i.e. water level data and aquifer hydraulic parameters) and can be used to predict the future behaviour of a groundwater aquifer system.
- **Guiding Principle 2.4:**
 - The initial assessment of the confidence level classification should be revisited at later stages of the project, as many of the issues that influence the classification may not be known at the model planning stage.

4.10 Geohydrological risk assessment

As per GNR 982 of the EIA Regulations (2014), the significance of potential hydrological impacts was assessed. The risk assessment methodology and ratings applied to the study area and proposed activities are available in **Appendix C**.

4.11 Water monitoring plan

The monitoring network is based on the principles of a monitoring network design as described by the DWAF Best Practice Guidelines: G3 Monitoring (DWAF, 2007). The methodological approach that the monitoring plan follows is represented in Figure 4-14, below.

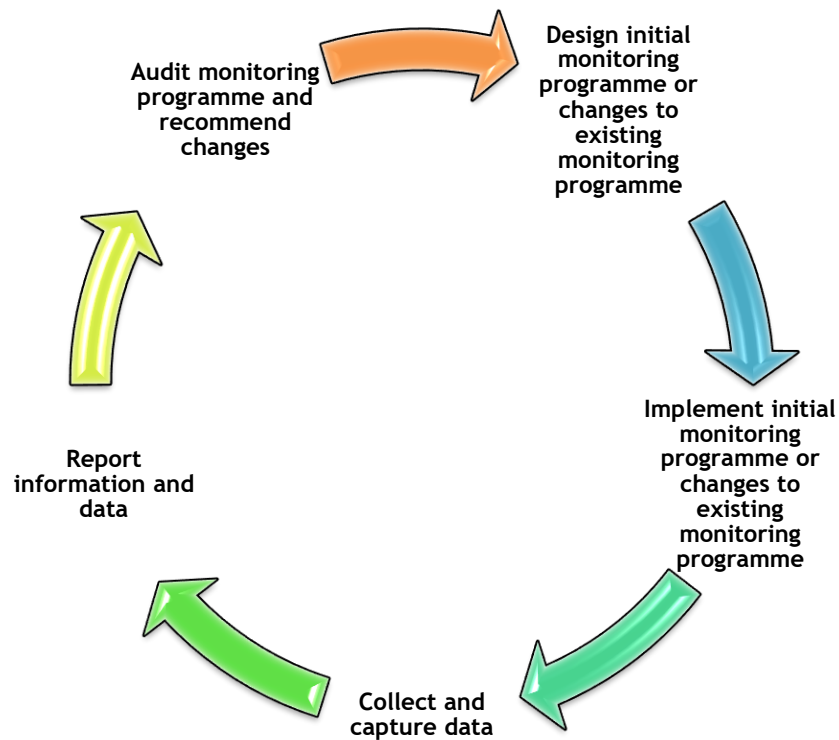


Figure 4-14: Monitoring Process

A groundwater monitoring plan was drafted and is based on the existing monitoring points, the site's conceptual model and risk assessment.

5 PREVAILING GROUNDWATER CONDITIONS

The following section supplies an overview of the prevailing geohydrological conditions encountered in the area for the proposed redevelopment. The data were derived from available literature sources and completed fieldwork.

5.1 Aquifer characteristics, classification, and groundwater recharge

The general aquifer characteristics and aquifer classification are summarised in Table 5-1.

Table 5-1: Aquifer characteristics and classification

Characteristics	Aquifer Classification
<p>The aquifer can be referred to as being primarily both intergranular (nearing alluvium areas) and intergranular & fractured (King, et al., 1998).</p> <p>Groundwater is typically encountered in:</p> <ul style="list-style-type: none"> • Fractures and bedrock contacts are recharged through overlying saturated sands; • Contacts between lithologies or unconformities; and • Dolerite dyke contacts (King, et al., 1998) <p>The weathered rock aquifer hosted within the Vryheid Formation Sediments is classified as the uppermost weathered rock. Exploratory drilling at the site shows an average depth of weathering of less than ~12 mbgl with borehole yields generally less than 2 L/s. Discrete and localised variations in hydraulic parameters may exist due to geological structural features (e.g. fractures, fault zones) refer to Figure 5-1.</p> <p>The fractured rock aquifer is classified as a thick sequence of sediments (i.e. sandstone, shale, siltstone, carbonaceous shale and coal). The matrix of the Vryheid Formation Sediments has a very low primary porosity; therefore, groundwater storage and movement are predominantly confined and are associated with geological structures and associated fracturing throughout the unit.</p> <p>Water strikes with discrete fracture zones generally range between ~20 and ~50 mbgl with moderate to high borehole yields (>3 L/s). Higher yields (~5 to >10 L/s) are largely associated with dolerite intrusion contact zones.</p> <p>Transmissivity values (GCS, 2012), analysed using several analytical (Cooper-Jacob, Theis) methods, range from ~0.4 to ~30 m²/d.</p>	<p>Based on a review of available data, it is evident that the key aquifer host media within the regional Project area can be generalised as follows:</p> <ol style="list-style-type: none"> 1. Unconsolidated aquifer - Alluvial material; 2. Semi-confined aquifer - weathered rock; and 3. Fractured rock aquifer. The aquifer present is classified as a Minor Aquifer system (Parsons, 1995) <p>minor aquifer region which is a moderately-yielding aquifer system of variable water quality, with reported yields ranging from 0.5 to 2 l/sec -Class D3 aquifer.</p>

Characteristics	Aquifer Classification
<p>The aquifer is an important contributor to groundwater baseflow to streams and rivers (King, et al., 1998). Groundwater contribution to baseflow (BF) on a quaternary scale is estimated to range from 4.91 mm/yr [Pitman Model] to 25.7 mm/yr [Hughes Estimate].</p>	

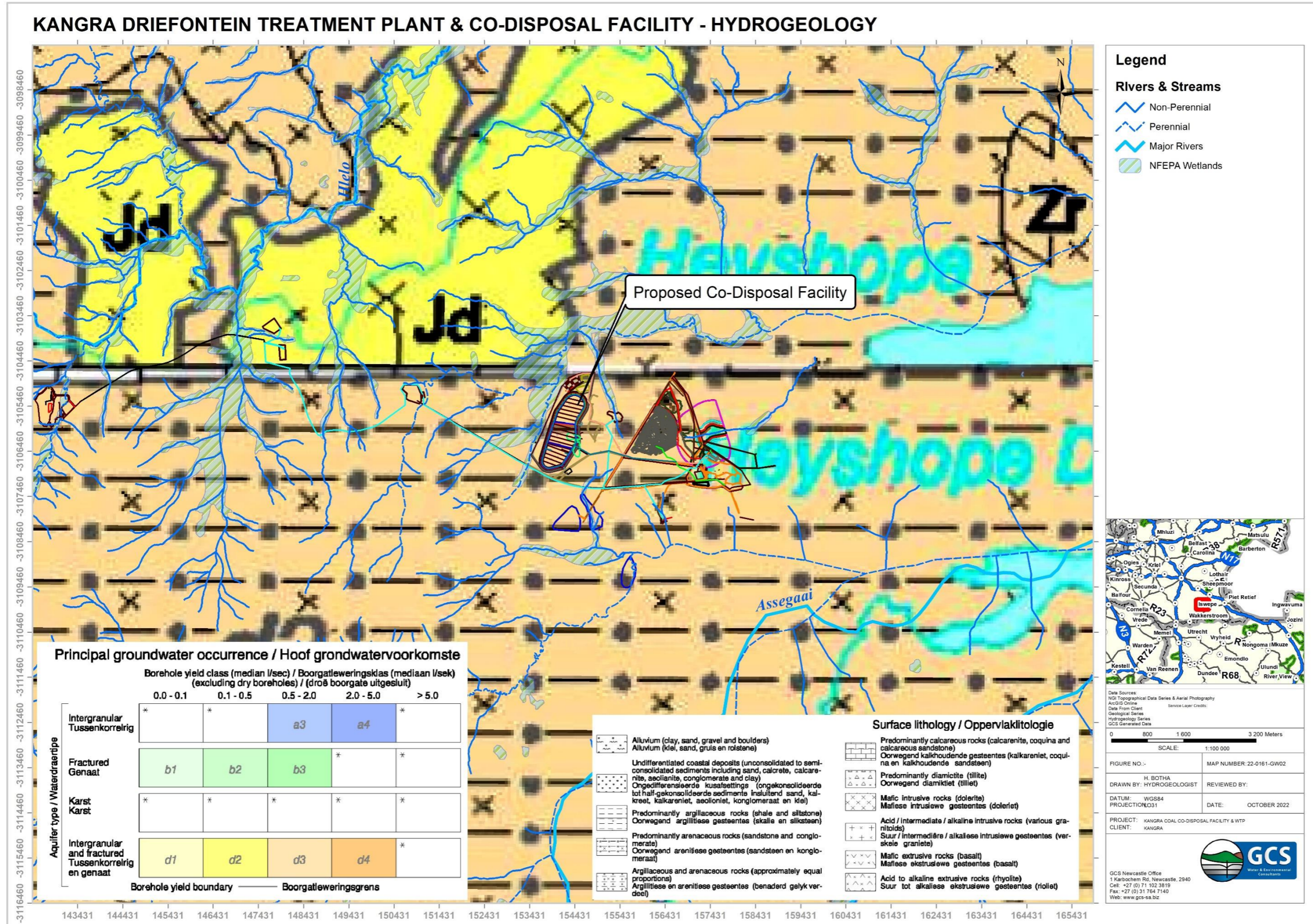


Figure 5-1: Local hydrogeology

5.2 Aquifer transmissivity

Available aquifer transmissivity values (T-values) for Maquasa East, West and Nooitgesien are summarised in Table 5-2. The T values were used to parameterise analytical and numerical flow models for the site.

Table 5-2: Summary of aquifer transmissivity

BH ID	SWL	Abstraction Rate	Duration of Test (Constant Drawdown and Recovery)	Maximum Drawdown	Transmissivity (m ² /d)	
	(mbgl)				(l/s)	(min)
GCS 11	11.44	0.8	215	31.42	1	0.5
GCS 12	2.87	1.09	185	34.29	1.76	1.58
GCS 13	6.98	1.08	183	23.24	0.67	0.9
GCS 14	13.88	1	183	35.69	0.89	0.9
GCS 15	1.61	1.51	540	8.87	6.2	7.5
GCS 16	8.71	1.1	189	34.73	1.6	1.6
GCS 17	9.71	1.2	245	34.44	2.5	1.78
GCS 18	4.25	0.9	185	29.76	0.8	0.6
GCS 19	3.98	0.3	140	26.52	0.76	0.88
GCS 20	4.26	0.63	360	32.69	1.9	1.3
GCS 21	4.39	0.75	360	11.84	2.6	2.6
GCS 22	5.29	1.4	110	32.94	1.6	1
GCS 23	13.96	1.09	245	33.22	1.4	1.25
GCS 24	3.93	0.75	480	5.21	11.6	14.2
GCS 25	12.32	0.39	187	31.82	0.6	0.4
GCS 26	6.84	0.42	360	28.21	4	1.2
GCS 27	13.57	1.26	360	23.67	3.5	7.7
GCS 28	15.71	1.48	290	17.09	28.2	13.9
GCS 29	21.87	0.9	185	35.13	0.8	0.7
GCS 30	7.08	1.22	75	30.05	1.8	1.5
MBH3	12.18	NA	Slug. Bower-Rice (1976).	Slug	0.006	
MBH5	5.15	NA	Slug. Bower-Rice (1976).	Slug	0.2	
Average					3.71	3.10
Geomean					1.96	1.65

5.3 Groundwater recharge

Recharge processes are using direct and indirect infiltration of precipitation. Based on values sourced from the scientific literature (i.e. Hodgson et al, 2007), a recharge of 1 to 5% of the annual precipitation is estimated for the fractured rock aquifer unit.

5.4 Aquifer storage

According to King *et al.* (1998) and DWAF (2006), the aquifer storage/storage coefficient is in the order of magnitude of $< 3.1 \times 10^{-3}$ (unitless) - supported by available pump test data. The porosity of the aquifer is expected to range from 15 to 20%. Literature data suggest that aquifer storage coefficients range from 5 to 10%.

5.5 Depth to groundwater

According to (Vegter, 1995) and (DWAF, 2006), the groundwater levels within the region are expected to range from 15 to 30 mbgl (meters below ground level). Available monitoring boreholes data for Kangra suggest a water level range from 1.28 to 131 mbgl (nearing the MQW underground workings in the mountains), with an average water level in the order of 12.4 mbgl for the MQE area.

Available water level data for boreholes in the area suggest there is a good correlation between the surface topography and the groundwater table (refer to Figure 5-2, $R \sim 90\%$). The groundwater table is expected to mimic the topography and be shallower closer to perennial streams (i.e. these are prominent groundwater contributions to base-flow areas or areas where groundwater seepage from the resource into the aquifer units may take place).

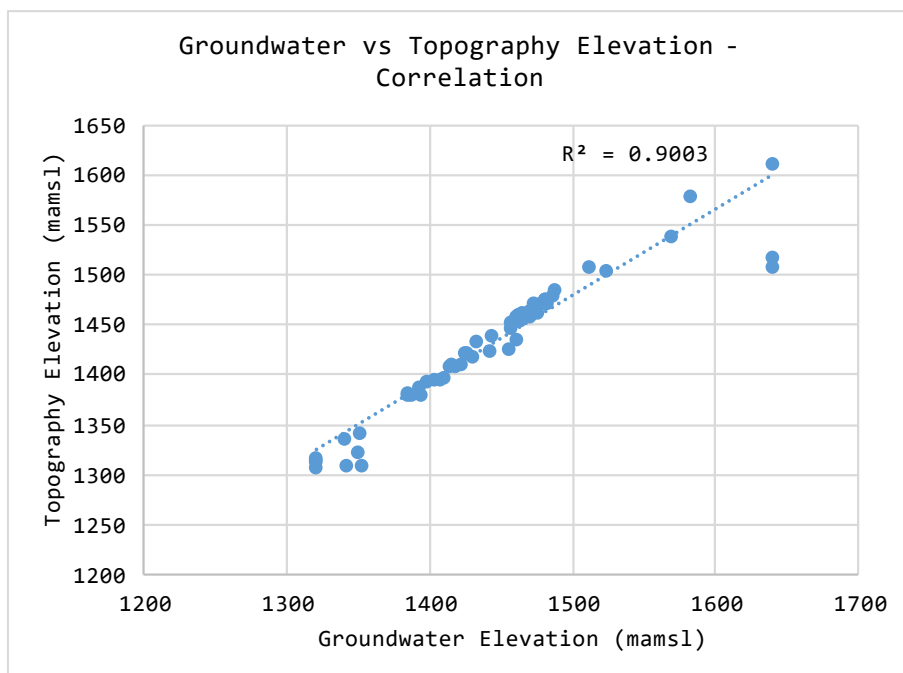


Figure 5-2: Groundwater elevation vs topography elevation - correlation (Kangra Monitoring Holes)

5.6 Wetland areas

Based on available National Wetland Freshwater Ecosystem Priority Areas (NFEPA) (Van Deventer, 2018) the non-perennial and perennial drainage areas situated downstream of the proposed co-disposal facility are classified as channelled valley bottom (CVB) wetland areas of the Mesic Highveld Grassland Bioregion (refer to Figure 1-3).

In terms of wetland geo-hydrology, base flow is considered the most important contributor to wetland health. Base flow (refer to Figure 5-3) is a non-process-related term to signify low amplitude high-frequency flow in a river during dry or fair-weather periods. Base flow is not a measure of the volume of groundwater discharged into a river or wetland, but it is recognised that groundwater contributes to the base-flow component of river or wetland flow.

Available literature (WRC, 2015; DWAF, 2006) suggests groundwater contribution to baseflow ranges from 9.8 mm/yr (PITMAN MODEL) to 43.45 mm/yr (HUGHES MODEL). This relates to approximately 2% to 6% of rainfall.

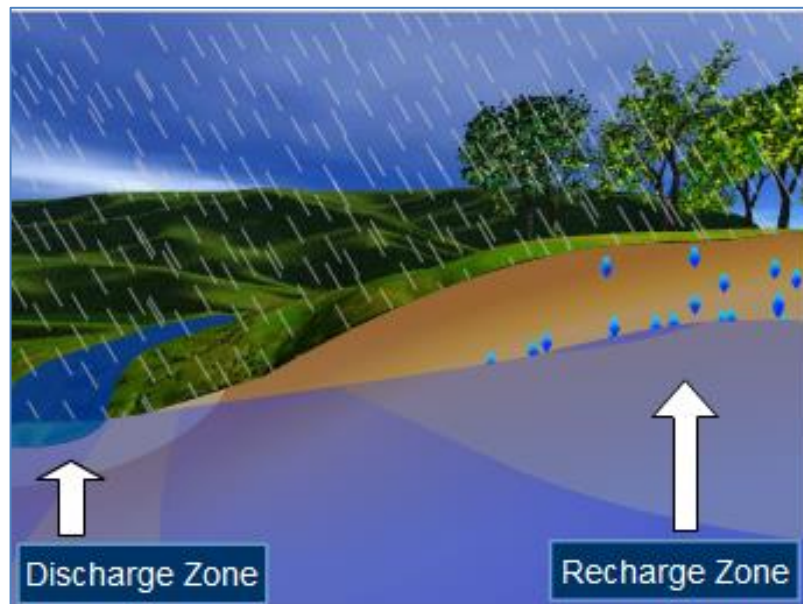


Figure 5-3: Groundwater base-flow concept (DWS, 2011)

5.7 Present ecological state (PES) and environmental sensitivity and ecological importance (EIS) - quaternary scale

Table 5-3 provides a summary of the PES and EIS for the quaternary catchment associated with the project area (WRC, 2015). It is recommended that the resource management objectives (RMO) for wetlands in the project area need to maintain the current PES and EIS post development

Table 5-3: Summary of PES and EIS for the Quaternary Catchment

Quat	PES	EIS
W51B	Class B: Largely Natural	High

5.8 Aquifer contextualization and extent

As groundwater flow behaviour is aligned to surface water flow conditions, it was assumed that the aquifer extent for the work conducted by GCS coincides with the surface water catchment boundaries.

5.9 Groundwater quantity

Intermediate groundwater (GW) Reserve Determination (IGRD) was conducted for the study area to establish the GW reserve. The IGRD aims to quantify the likely impact of the proposed development on the GW reserve.

It is necessary, from a GW point of view, to quantify the GW quantity and likely impact on the groundwater reserve as a result of rainfall, and an interception. Moreover, the GW balance gives an estimate of how much GW can safely be abstracted from the aquifer if an abstraction borehole is drilled.

The IGRD considers the following parameters:

- Effective recharge from rainfall and specific geological conditions.
- Basic human needs for the sub-catchment.
- GW contribution to surface water (baseflow).
- Existing and proposed abstraction; and
- Surplus reserve.

The data used for the calculation was derived from the WRC 90 Water Resources of South Africa 2012 Study (WR2012) and GW Resource Assessment Ver. 2 (GRAII) datasets.

5.9.1 Quaternary catchment

Data were obtained from the Groundwater Resource Directed Measures (GRDM). The site falls within the quaternary catchment W51B as indicated in Table 5-4.

Table 5-4: Summarised Quaternary Catchment Information

Quaternary Catchment	Total Area (km ²)	Recharge (mm/a)	Rainfall (mm/a)	Baseflow (mm/a)
W51B	496.5	7.4	864.3	4.9 [PITMAN MODEL]

5.9.2 Sub-catchment delineation

Seven (7) hydrological response unit (HRUs) describes the natural drainage for the study area (using a 1:1 000 stream count and 30 m DTM fill) - refer to **Figure 1-3**. The sub-catchment relates well to desktop-delineated drainage lines for the project area, as well as verified streams associated with the project area.

Primary drainage from the position of the proposed co-disposal site, and much of the MQE area is towards the northeast, to the perennial Egude River, which makes up the bottom inflow of the Heyshope Dam. Drainage from the southern portions of the MQE area, and Maquassa West (MQW) is towards the south, via several perennial and non-perennial drainage lines, towards the southern inflow of the Heyshope Dam. The Heyshope Dam is therefore the end received of any surface water-related pollution that may take place at the MQE operations. The sub-catchments that are associated with the proposed co-disposal facility are HRU1 to 3, and HRU6. The sub-catchment associated with the proposed treatment area is HRU5.

5.9.3 Groundwater balance

The groundwater balance and hence the reserve determination on a sub-catchment scale is summarised in Table 5-5. It can be seen that there is a surplus amount of 521 895 m³/a available on a sub-catchment scale. As no groundwater abstraction is propped, the impact on the reserve is estimated to be zero.

Table 5-5: Groundwater reserve determination

Description	MQE Co-disposal Discard Site Delineated Sub-catchment
Recharge through Precipitation	837 268 [m ³ /a]
Basic Human Need	46 [m ³ /a]
Existing Abstraction	28 [m ³ /a]
Proposed Abstraction	54750 [m ³ /a]
Baseflow	260548 [m ³ /a]
Surplus Amount	521 895 [m ³ /a]

Note/s:

[m³/a] - cubic metres per annum

5.10 Hydrochemistry

The following section supplies an overview of the groundwater hydrochemistry for the project area. Data were derived from field sampling and analyses done by GCS in 2022 as part of an ongoing monitoring program. A total of nineteen groundwater sites and twenty-three surface water sites have been identified in MQE. The spatial representation of these monitoring points can be seen in Figure 5-8.

5.10.1 Groundwater Levels

Shallow groundwater levels (< 8.0 mbgl) characterise the majority of the project area. Boreholes GCS14 and BCBH02 (non-operational) are characterised by deeper groundwater levels (> 10.0 mbgl); refer to Figure 5-4.

- Fluctuating water levels have been observed at most sites over time, although most boreholes indicate predominantly stable trends. All boreholes indicated a decrease in water levels during the July 2022 measurement event.
 - The most notable decrease observed in July 2022 was recorded at KGA2 (a decrease of 11.2 mbgl).

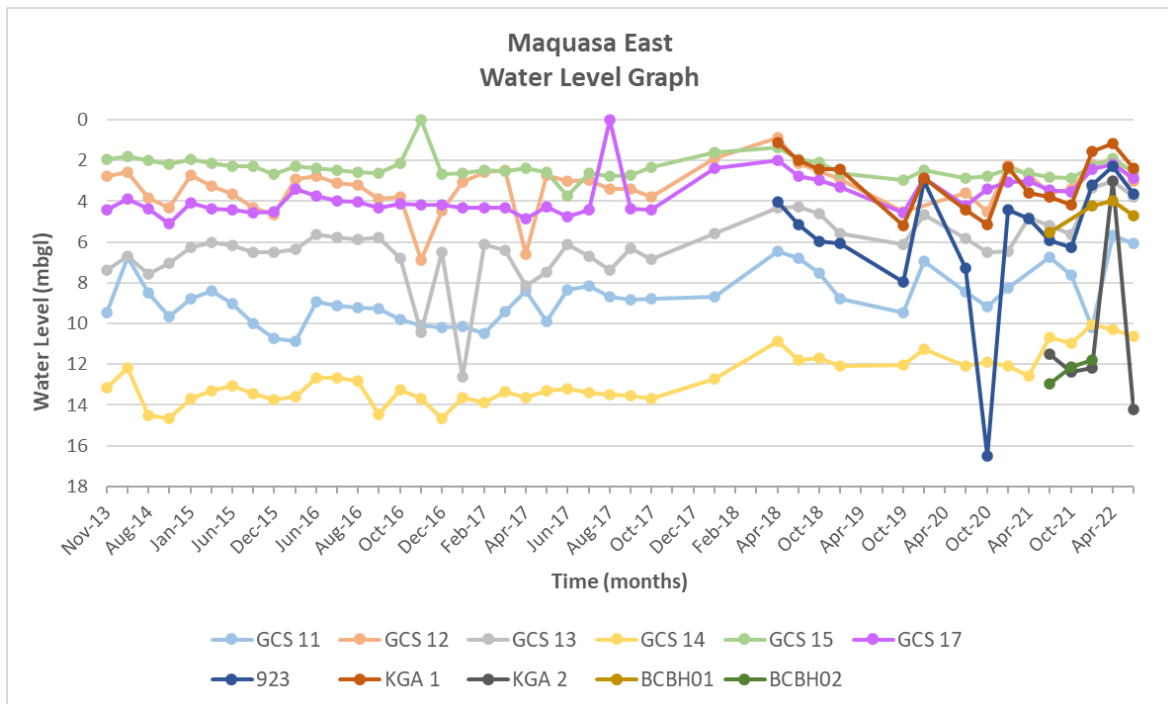


Figure 5-4: Groundwater level time trend graph for Maquasa East

5.10.2 Groundwater Quality

The following observations were made during the 2022 second-quarter monitoring event:

- All groundwater monitoring points exhibited relatively neutral to slightly alkaline pH conditions, ranging between 6.5 and 7.6.
- BH 923, BCBH01, GCS11, GCS12, GCS13, GCS14 and GCS15 showed low to no significant impact from the site in July 2022.
 - Only nitrate concentrations slightly exceeded the WUL limit at GCS11, GCS12, GCS14 and GCS15, ranging between 0.3 and 3.2 mg/l, which is considered to be low to moderately low.
- The water quality at Well Yende, KGA1, KGA2, GCS16 and GCS17 was non-compliant when compared to the WUL limits.
 - Several parameter concentrations exceeded the WUL Limits in July 2022:
 - Chloride and/or sodium were elevated at Well Yende and GCS17.
 - KGA2 indicated elevated EC and TDS concentrations during the July 2022 sampling event.
 - EC, TDS, total hardness, magnesium, sodium, potassium and chloride concentrations were elevated at KGA1.
 - EC, TDS, total alkalinity, total hardness, calcium, magnesium, sodium, potassium and chloride were significantly elevated at GCS16.
 - Sulphate concentrations varied at the site; refer to Figure 5-5.
 - Sulphate at GCS16 has displayed a stable trend over time, consistently exceeding the WUL limit, recorded as 819 mg/l in July 2022. GCS16 is decanting directly from the underground workings at Maquasa East into a pollution control dam which is situated near the Heyshope Dam.
 - Sulphate at KGA1 has displayed an increasing trend over time and currently exceeds the WUL limit. A notable increase was observed in July 2022, recorded as 585 mg/l. KGA1 is situated downgradient of the Discard Plant.
 - Sulphates at KGA2 indicated an increasing trend over time, exceeding the WUL limits since October 2021. A decrease was observed in July 2022, recorded as 72 mg/l.
 - The remaining points displayed low sulphate concentrations (< 16 mg/l).
 - Additionally, nitrate concentrations exceeded the WUL limit at KGA1 and GCS16 ranging between 1.1 and 3.2 mg/l.

- In terms of metal concentrations, manganese exceeded the WUL limits at GCS16 (0.48 mg/l) and KGA1 (0.48 mg/l).

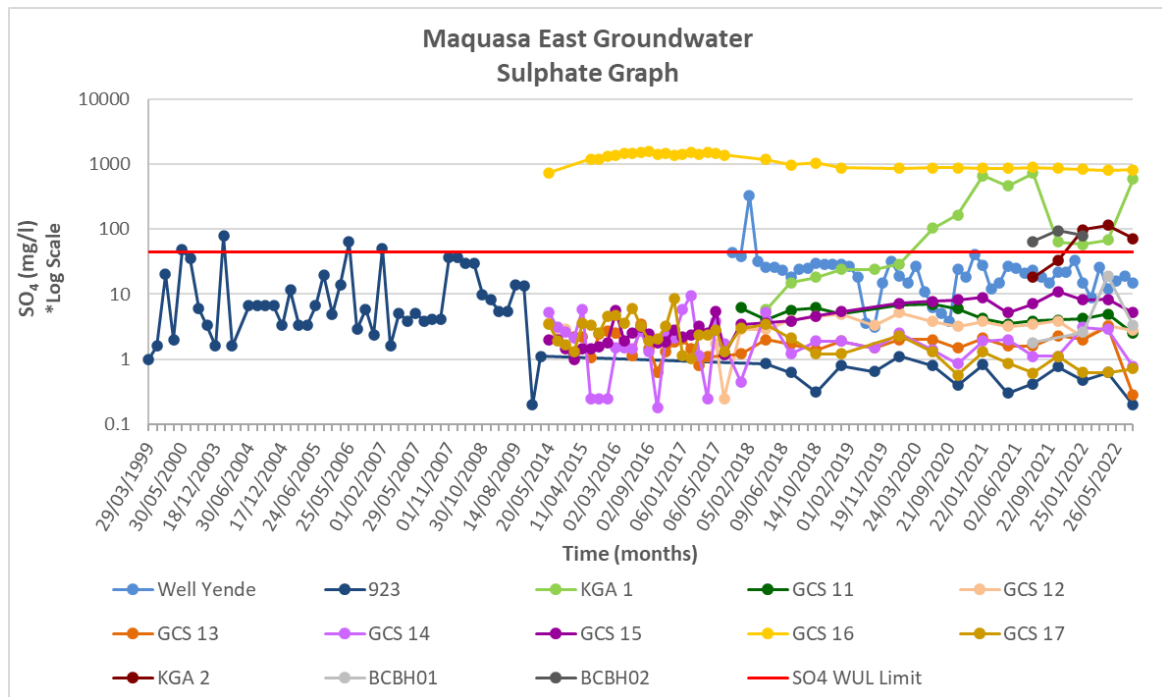


Figure 5-5: Maquasa East logarithmic groundwater sulphate graph

5.10.3 Surface Water Quality

The following observations were made during the 2022 second quarter:

- All surface water monitoring points exhibited neutral to slightly alkaline pH conditions throughout the second quarter, ranging between 6.8 and 8.3.
- Surface water points Below Highwall Seepage, Highwall Seepage, D/S of Natural Seepage, East Heyshope, Heyshope Dam Abstraction, West Heyshope and SW 932 displayed low to no significant impact from the site.
 - In terms of metal concentrations, manganese (< 0.65 mg/l) was elevated at Below Highwall Seepage, Highwall Seepage and SW 932 during the second quarter of 2022. Iron (< 0.15 mg/l) was elevated at East Heyshope, Heyshope Dam Abstraction and West Heyshope during the second quarter of 2022.
 - Aluminium concentrations were elevated at Heyshope Dam Abstraction and West Heyshope during the second quarter of 2022. The source is most likely the upstream discard dump. Aluminium is commonly associated with burnt clinker material generated by discard dumps.
 - Ammonia concentrations were elevated at Below Highwall Seepage, Highwall Seepage, D/S of Natural Seepage, East Heyshope, Heyshope Dam Abstraction, West Heyshope and SW 932 during the June 2022 sampling event, ranging between 7.3 and 7.9 mg/l.

- CSW04 and SW 933 indicated an impact from the site during the 2022 second quarter period. CSW04 was compliant with the Usuthu River Catchment TWQG during the May 2022 sampling event and could not be sampled during the July 2022 sampling event due to low water levels.
 - EC, TDS, calcium and sodium concentrations exceeded the Usuthu River Catchment TWQGs at SW 933 throughout the second quarter. TDS ranged between 2 00 mg/l and 3 300 mg/l; refer to Figure 5-6.
 - During the June 2022 sampling event, CSW04 indicated elevated EC, TDS, calcium and sodium concentrations exceeding the Usuthu River Catchment TWQGs. Elevated salt concentrations at CSW04 are likely due to evaporation at this locality causing the water to become more concentrated.

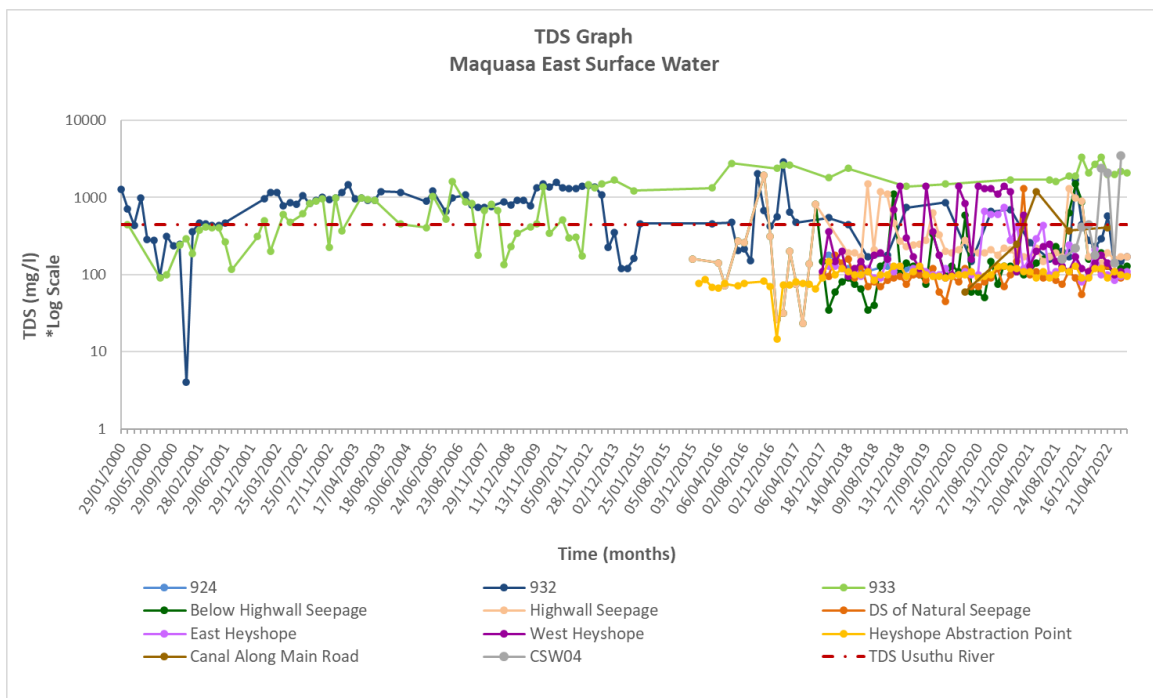


Figure 5-6: Maquasa East logarithmic surface water TDS graph

- Sulphate concentrations predominantly exceeded the Usuthu River Catchment TWQG at CSW04 and SW 933; refer to Figure 5-7.
 - Sulphate at SW 933, located downstream of the underground workings, has historically fluctuated however, a relatively stable trend has been observed since 2013. Sulphate ranged between 1 840 and 2 260 mg/l in the second quarter.
 - Sulphate at most localities indicated slight decreases in concentrations during the second quarter.

- Sulphate exceeded the Usuthu River Catchment TWQG at CSW04 (3 230 mg/l) during the June 2022 sampling event.
- Additionally, ammonia (8 mg/l) and nitrate (30 mg/l) were elevated at CSW04 during the June 2022 sampling event. SW 933 indicated elevated ammonia (7.8 mg/l) concentrations during the June 2022 sampling event.
- In terms of metal concentrations, manganese was in exceedance at SW 933 and CSW04, ranging between 3 and 10.0 mg/l.

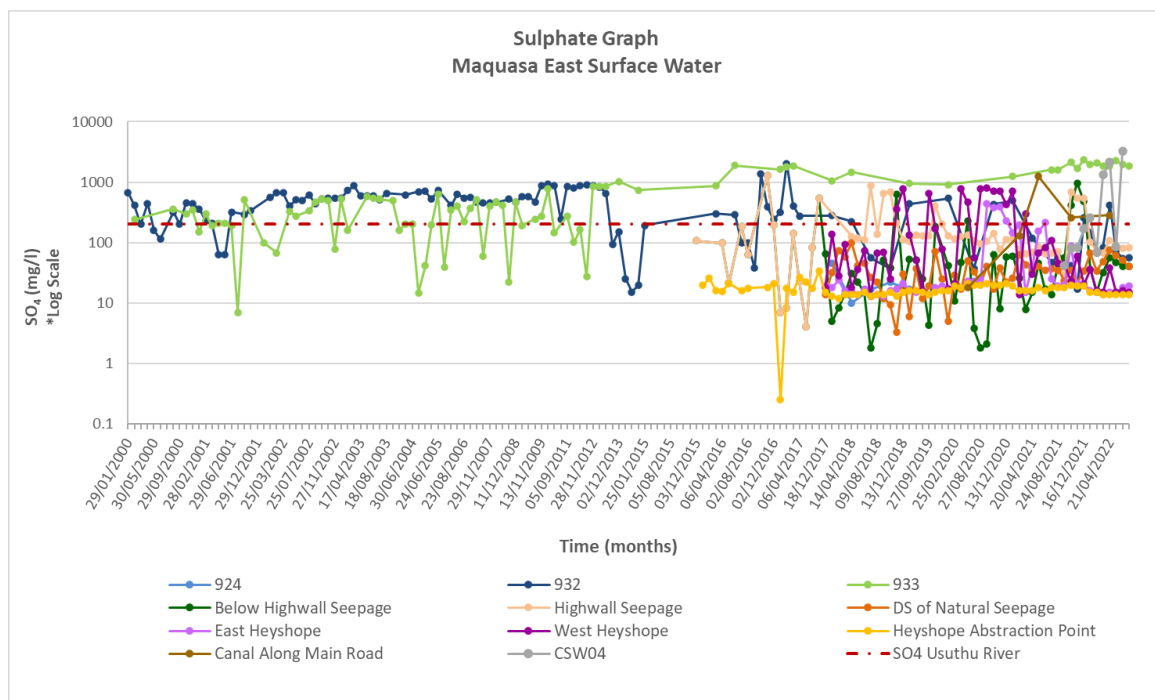


Figure 5-7: Maquasa East logarithmic surface water sulphate graph

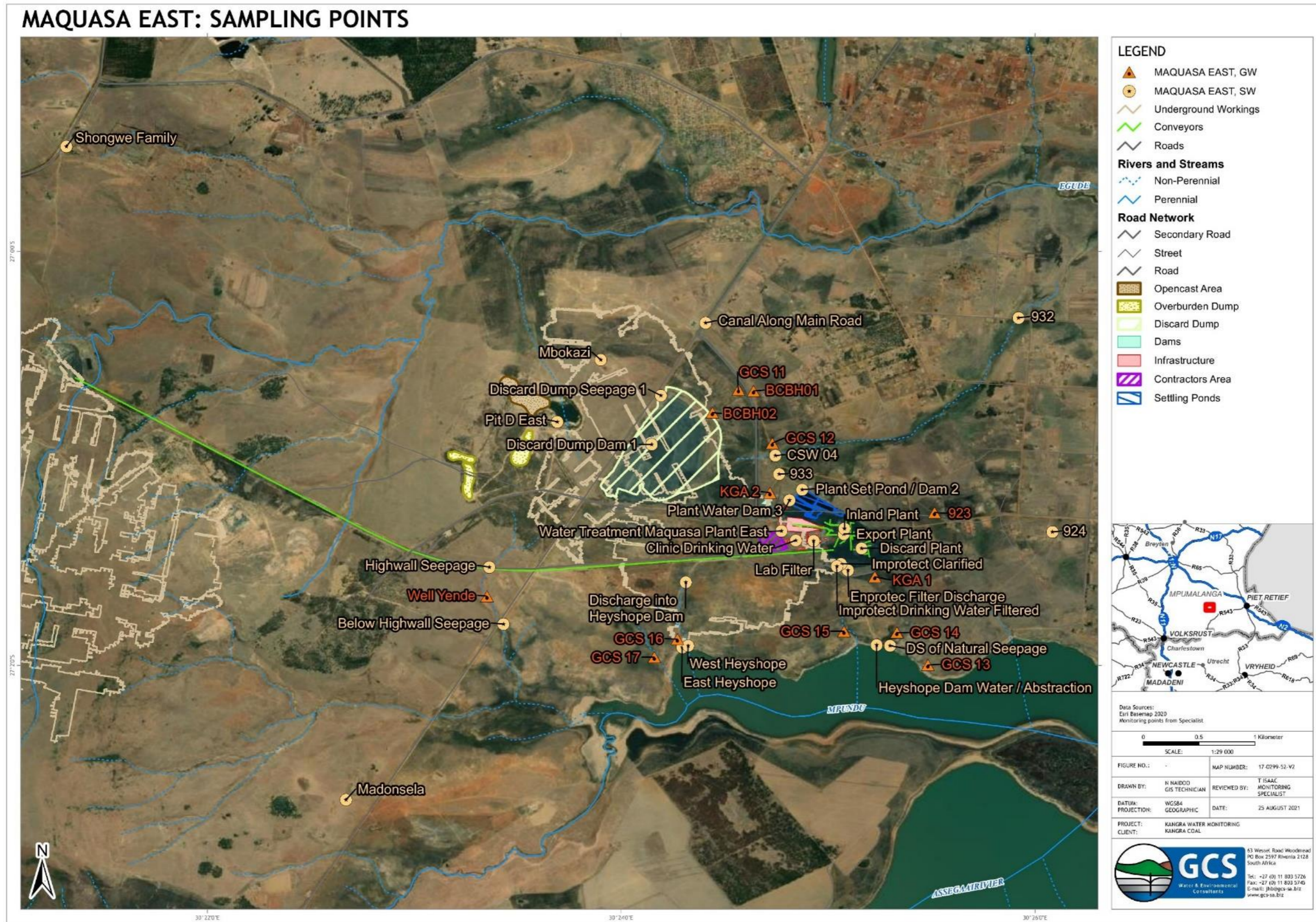


Figure 5-8: Monitoring Network for Maquasa East

6 SITE CONCEPTUAL MODEL

The hydrogeological conceptualisation describes the Project's hydrogeological environment and is based on the source-pathway-receptor principle. The site conceptual model developed for the site is shown in Figure 6-1.

Based on the groundwater data collected, it is confirmed that two (2) aquifers exist in the area:

- A shallow unconfined aquifer system associated with weathered Ecca sediments; and
- A deeper confined intergranular and fractured aquifer network is associated with the argillaceous and arenaceous rocks associated with the Vyheid Formation. The aquifer units may be intercepted and compartmented by intrusive dolerite sills and sykes.

6.1 Sources

The geochemical characterisation of the discarded material indicated that the material is likely to act as a source of contamination. Based on the geochemical analysis of the discarded material, the sulphate concentrations range between ~220 and ~420 mg/L (TDDS 800 to 1200 mg/l), as a result of pyrite oxidation. Aluminium, iron and manganese will be present at elevated concentrations in acid mine drainage.

The co-disposal facility and the brine treatment pond will be lined by a comprehensively engineered barrier liner system consisting inter alia of a combination of clay and geosynthetic membranes, with leakage detection and collection system/s in place. This is to ensure full containment and to minimise the risk of contaminating the underlying aquifer system/s.

Therefore, the proposed discard storage facility and associated infrastructure are unlikely to act as a significant contaminant source provided the liner system/s is not compromised during construction, operation and post-closure.

6.2 Pathways

Based on the aquifer characteristics (e.g. weathering depth, groundwater strike and static water levels), the hydrogeological system at the Project site can be categorised into two aquifers: shallow weathered rock/material aquifer and deeper fractured rock aquifer hosted within the Vryheid Formation sediments.

Shallow weathered rock/material aquifer - Vryheid Formation sediments comprise highly weathered material and have an average thickness of between ~5 and ~12 m. Due to the limited depth extent and average depth to groundwater (between ~9 and ~12 m), it is unlikely that this system will comprise a significant groundwater potential. However; in terms of seepage emanating contaminant transport, this aquifer is considered important. No site-specific aquifer hydraulic characteristics are available for this aquifer unit.

Deeper fractured rock aquifer - Vryheid Formation sediments comprise a thick sequence of interlayered sediments with limited primary porosity. Secondary structures are likely to result in the development of discrete zones of high hydraulic conductivity. Limited structural information is available due to the localised Project extent, relative to the extent of the Vryheid Formation and available data. Although specific differences in the lithological units of this formation are observed (e.g. degree of weathering and alteration etc.), the lithology of this formation can be considered similar across the Project site. No site-specific aquifer hydraulic characteristics are available for this aquifer unit.

Groundwater across the Project site flow towards the northwest (a subdued reflection of the surface topography), with groundwater levels varying from the surface (seepage) to -12 mbgl. The variation in groundwater levels is most likely a result of localised structural features (i.e. barrier) traversing the Project site. Recharge processes are using direct and indirect infiltration of precipitation. Project-specific recharge values are not known. Based on values sourced from the scientific literature (i.e. Hodgson *et al*, 2007), a recharge of 1 to 3% of the annual precipitation is estimated for the fractured rock aquifer unit. Recharge within the footprint of the proposed discard storage facility is considered insignificant due to the proposed liner system.

The ephemeral alluvial aquifer system located down-gradient of the Project site is regarded as a potential discharge zone.

6.3 Receptors

Although there are no groundwater-dependent receptors within the immediacy of the Project site, the ephemeral flow system is considered sensitive due to its locality concerning the Project site. Provided the integrity of the liner system/s is not compromised during the construction, operation and closure and post-closure phases of the Project, no impacts are expected.

With regards to the proposed brine storage pond, the weathered aquifer zone and the Heyshope dam are the receptors of potential pollution.

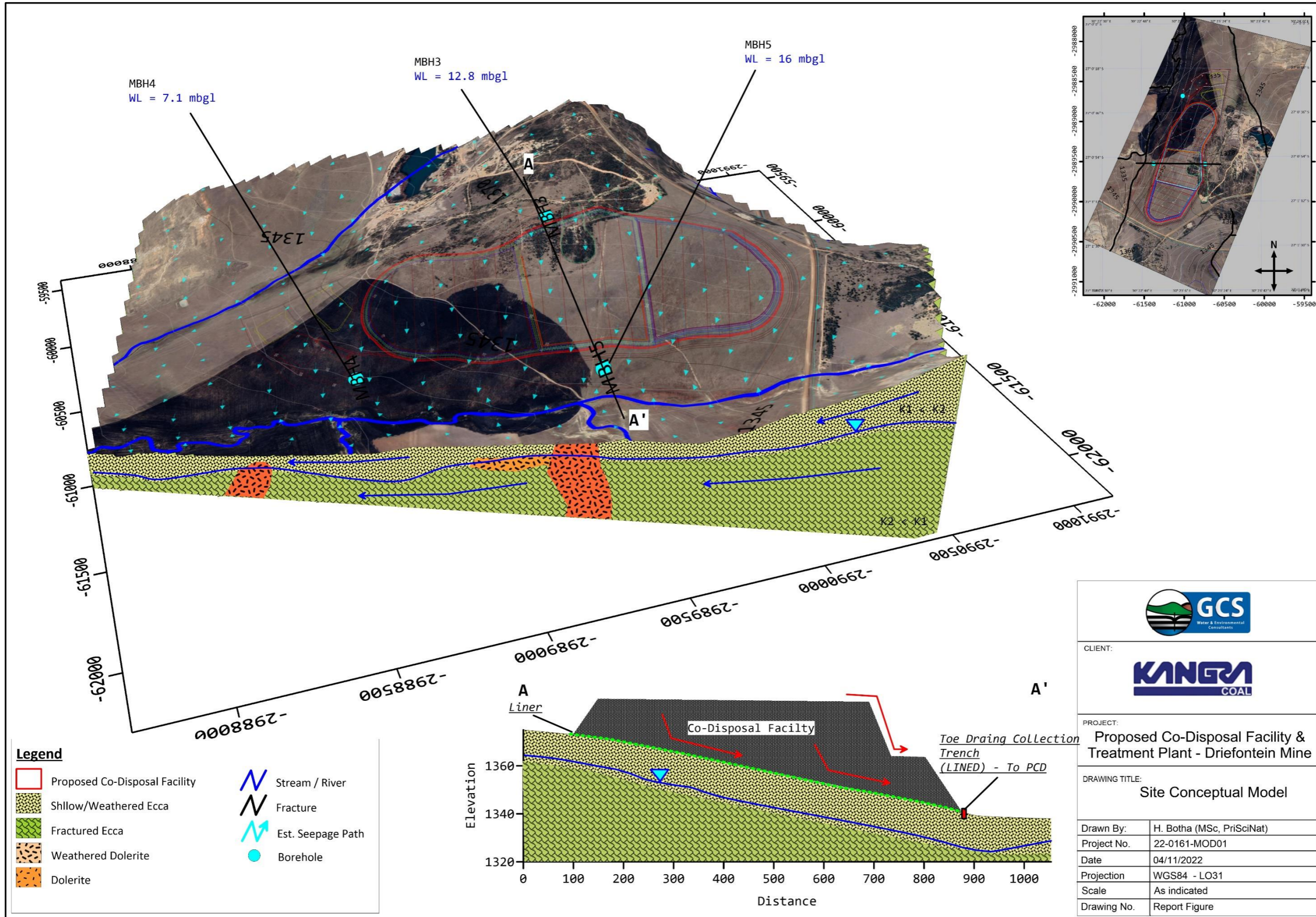


Figure 6-1: Site conceptual model

7 NUMERICAL GROUNDWATER MODEL

The following section supplies an overview of the numerical flow and transport model developed to assess the likely impacts associated with the proposed co-disposal facility and the treatment plant (and brine storage pond). The conceptual model was used to develop the numerical groundwater flow and transport model.

7.1 Model objective

The groundwater flow and transport models were developed to:

1. Understand the operational groundwater flow system.
2. Simulate the existing Zone of Impacts (ZOIp) associated with the Maquasa East operations, and
3. simulate the potential cumulate impacts associated with the development of the proposed infrastructure.
 - a) A worst-case scenario was simulated, where the facilities are not lined (Please Note: The engineering designs propose lining the facilities with impermeable barriers).
 - b) Simulate preferential flow paths from the proposed co-disposal facility and the WTP & brine storage pond.
 - c) Simulate potential plume movement from unlined facilities and calibrate the plume with the existing monitoring boreholes. SO_4 was used to illustrate plume movement. SO_4 is a well-known pollution tracer for SA mined (INAP, 2022).
4. Incorporate findings into the groundwater monitoring and management plan to assess hydrogeological risk and impacts in the area.

7.2 Assumptions and limitations

There are uncertainties in the groundwater flow simulated by a numerical model. These uncertainties are due to:

- Simplifications and assumptions in the design of the model.
- Uncertainty in the boundary conditions and input parameters; and
- Limited data is available to calibrate the model to the observed groundwater flow systems.

The model uncertainties and assumptions are as follows:

- Recharge for rehabilitated opencast areas is estimated at 15% of the MAP, while the regional aquifer recharge is estimated in the order of 5% of the MAP (Hughes, 2004).

- Available water levels were averaged and assumed to have been constant for one (1) hydrological year. No time-series water level data were made available for the Maquasa East boreholes. This is a best-case scenario applied, due to limited data.
- Transmissivity, storage and porosity values for similar rock types in the area are assumed to be in the same order as available data (refer to Section 5.3).
- The plume presentation indicates a 250 mg/l and 1000 mg/l sulphate plume contour line (also referred to as the Zone of Impact “ZOIp”):
 - The above-mentioned was applied to demarcate contaminated groundwater zones.
 - The 200 mg/l and 1000 mg/l zones represent the 1996 DWAF Target Water Quality Range for Domestic Use (DWAF, 1996b) and Livestock Watering (DWAF, 1996c), respectively.
 - These guidelines are not intended to be used for environmental compliance and are used only as a benchmark value, as a means of contextualising the results. Table 7-1 lists the target water quality range for sulphate as per the DWAF 1996 guideline document.
- The numerical model was updated with the latest hydrochemistry and hydrogeological information available for the Maquasa Operations (2022).

Table 7-1: Summary of the target water quality range as per DWAF guidelines

System	Target Water Quality Range - S04 (mg/l)			
Aquatic Ecosystems (DWAF, 1996d)	N/A			
Domestic (DWAF, 1996b)	Human Consumption			
	0-200			
Recreation (DWAF, 1996e)	Full Contact		Intermediate Contact	
	NA		NA	
Industry (DWAF, 1996f)	Category 1	Category 2	Category 3	Category 4
	0-30	0-80	0-200	0-500
Agriculture (DWAF, 1996c)	Livestock Watering	Irrigation	Agriculture	
	0-1000	N/A	N/A	

7.3 Conceptualisation and Model Grid

Based on the available data, a conceptual model of the study area was formulated. The conceptual model explains the aquifers that occur in the area, the spatial relationship between the aquifers, aquifer thickness, general geology, groundwater levels and flow directions.

7.3.1 Boundary Conditions

Boundary conditions express how the considered domain interacts with its environment. In other words, they express the conditions of known water flux, or known variables, such as the hydraulic head. Different boundary conditions result in different solutions, hence the importance of stating the correct boundary conditions. Boundary condition options in MODFLOW can be specified either as:

- Specified head or Dirichlet; or
- Specified flux or Neumann; or
- Mixed or Cauchy boundary conditions.

From the conceptual point of view, it was essential to meet two criteria to the maximum extent possible:

- The modelled area should be defined by natural geological and hydrogeological boundary conditions, i.e. the model domain should preferably encompass entire hydrogeological structures; and
- The mesh size of the model grid has to correspond to the nature of the problem being addressed with the model.

Local hydraulic boundaries were identified for model boundaries. They are represented by:

- Local watershed boundaries;
- Topographical highs;
- Constant head and general head boundaries; and
- The delineated area of the entire model domain.

These hydraulic boundaries were selected far enough from the area of investigation to not influence the numerical model behaviour artificially.

The model boundaries and model grid are shown in Figure 7-1 and Figure 7-2. Table 7-2 provides a summary of the boundaries, boundary descriptions and boundary conditions specified in the hydrogeological model.

Table 7-2: Identification of the real-world boundaries and the adopted model boundary conditions

Boundary	Boundary Description	Boundary Condition
Top	The top surface of the water table	Mixed type: Drain cells for main rivers and non-perennial drainage streams. Constant head and general head boundaries for dams (i.e. Heyshope Dam) Recharge is constant for the model area. Recharge flux is applied to the highest active cell. Artificial recharge is not considered for unknown values.
North	No-flow boundary and stream/river	Topographical high/low/stream
East	No-flow boundary and stream/river	Topographical low, streams/drain, and constant head boundary for Heyshope Dam
South	No-flow boundary and stream/river	Topographical highs/lows and streams
West	No-flow boundary and river	Topographical high /stream

7.3.2 Construction of the Finite Difference Grid

Compilation of the finite difference grid using the Visual MODFLOW graphic user interface facilitated the construction of a rectangular horizontal grid, as well as vertical geometry provided for each of the layers. The flow model was set up as a three-layer, confined / semi-confined aquifer.

The positions of the different geological boundaries are incorporated into the modelling grid. A grid refinement of 5-40 m x 5-40 m cells for the MQE and MQW areas which gradually coarsens away from the site was applied. This is standard practice and does not influence the accuracy of the results obtained.

7.3.3 Vertical Discretization

Along the vertical direction, the steady-state hydrogeological model is structured in 5 model layers. The layer positions were selected to best incorporate the conceptual model and to allow for accurate horizontal and vertical groundwater flow in the model. The following layers were defined:

- Layer 1 - Topographic elevation and combination of the dolerite sill intrusion of the mountain area up to a maximum depth of 110 mbgl; and weathered and partly-weathered Ecca formation sediments up to a maximum depth of 25 mbgl.

- Layer 2- Lower weathered and main coal seam occurrence in the area. The layer corresponds to the approximate underground working depth and generally dips in the direction of the coal seam. The layer thickness was set to 5 m to ensure that the MODFLOW numerical engines properly simulate the underground flow and transport regimes.
- Layer 3 - Lower weathered and main coal seam occurrence in the area. Follows the dip and direction of layer 2. The layer thickness was set to 10 m to ensure that the MODFLOW numerical engines properly simulate the underground flow and transport regimes.
- Layer 4 - Lower weathered (transition zone) and partly fractured aquifer (Ecca group) > 30-60 mbgl.
- Layer 5 - Deeply fractured basement aquifer > 60 mbgl.

7.3.4 Time Discretization

Time parameters are relevant when modelling transient (time-dependent) conditions. They include time units, the length and number of periods and the number of time steps within each period. All model parameters associated with boundary conditions and various stresses remain constant during one time period. Having more periods allows these parameters to change in time more often (Kresic, 2007).

The steady-state groundwater flow model was used for sensitivity analysis. For the simulation of pollution plume migration and dewatering, the transient simulation was discretized into stress periods of 4 months.

7.3.5 Transient State Model Simulation Time

The model simulation time runs from the year 1998 to the year 2163. The model simulation time takes into consideration the chronological order of events (i.e. start and end of underground mining, opencast mining etc.) which occurred/occur in the Maquasa and Nooitgesien operations.

Table 7-3 lists the model simulation time. The timeline was simplified to construct the groundwater model. The simulation time was compiled from available reports and satellite imagery for the mining area.

Table 7-3: Model Simulation Time

Model Phase	Year	Model Time	Event
Calibration	1995	-	No Mining
	1996	-	MQE Adit Start. No water level or quality data is available.
	1996	-	MQE Discard Dump Start. No water level or quality data is available.
	1998	0	First water level and quality data available. Model Start
	2002	1460	Opencast (Pit G) at MQE commences.
	2003	1825	MQW 1st Adit started.
	2006	2920	Opencast north of MQE (ROMA) commences.
	2007	3285	MQW 2nd Adit started.
	2009	4015	MQW Opencast started.
	2012	5110	MQE South opencast started.
	2013	5475	MQW opencast extension started. NZ Opencast started.
	2014	5840	MQE + MQW pit rehabilitation / backfilling started.
	2015	6205	NZ opencast mining and MQW underground mining. Calibrated Flow and Transport Model Time
	2016	6570	
	2017	6935	
	2018	7300	
2019	7665		
2020	8030		
2021	8395		
2022	8760	Calibration 2022	
Prediction	2023	9125	Co-Disposal Discard Dump Constructed
	2043	16425	Co-Disposal Discard Dump
	2093	34675	50Y Plume (No Mitigation) - Based on the calibrated model.
	2143	52925	100Y Plume (No Mitigation) - Based on the calibrated model.
	2163	60225	Simulation End

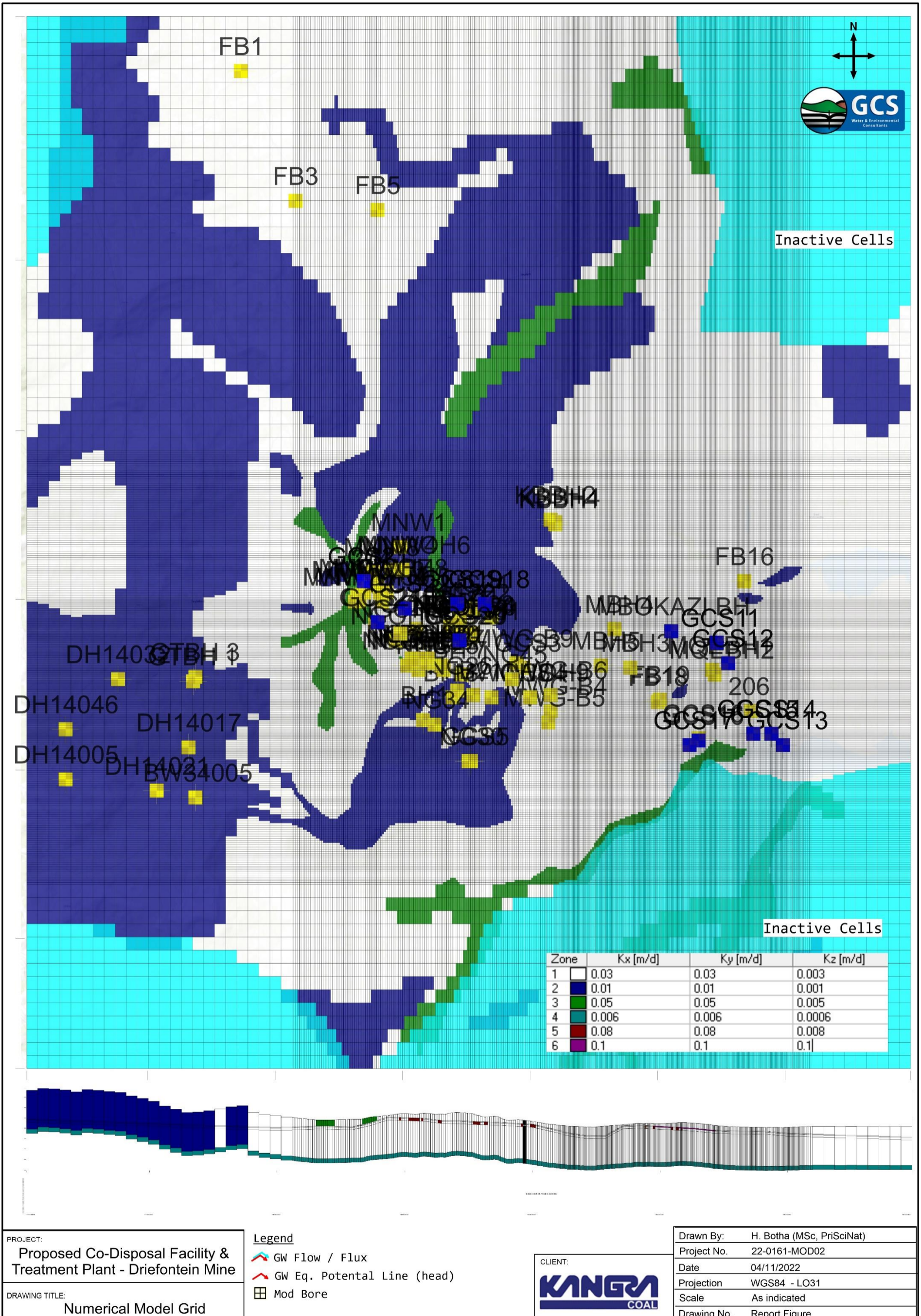
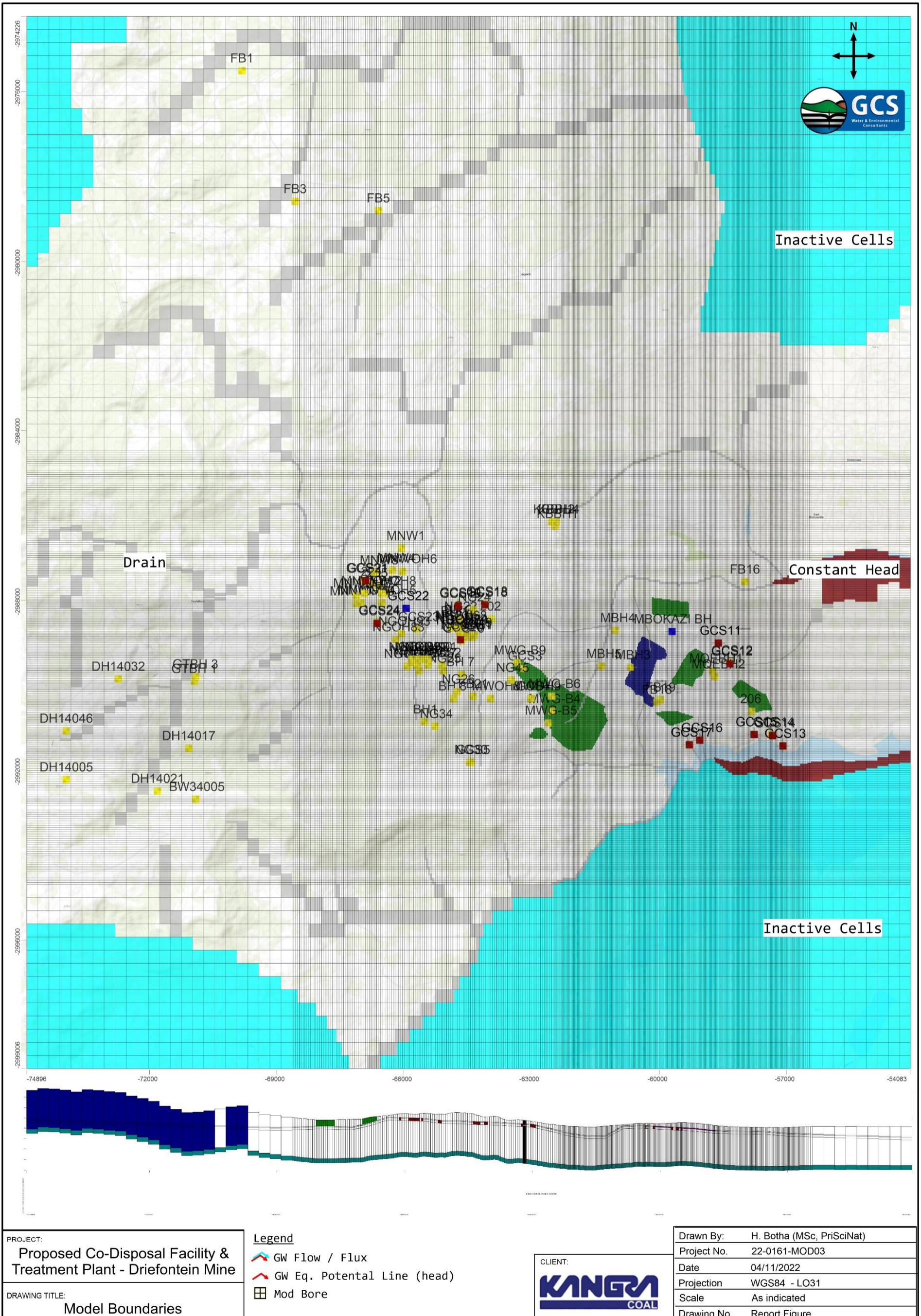


Figure 7-1: Model grid & conductivity



<p>PROJECT: Proposed Co-Disposal Facility & Treatment Plant - Driefontein Mine</p> <p>DRAWING TITLE: Model Boundaries</p>	<p>Legend</p> <ul style="list-style-type: none"> ↔ GW Flow / Flux — GW Eq. Potential Line (head) Mod Bore 	<p>CLIENT:</p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td>Drawn By:</td><td>H. Botha (MSc, PriSciNat)</td></tr> <tr><td>Project No.</td><td>22-0161-MOD03</td></tr> <tr><td>Date</td><td>04/11/2022</td></tr> <tr><td>Projection</td><td>WGS84 - LO31</td></tr> <tr><td>Scale</td><td>As indicated</td></tr> <tr><td>Drawing No.</td><td>Report Figure</td></tr> </table>	Drawn By:	H. Botha (MSc, PriSciNat)	Project No.	22-0161-MOD03	Date	04/11/2022	Projection	WGS84 - LO31	Scale	As indicated	Drawing No.	Report Figure
Drawn By:	H. Botha (MSc, PriSciNat)														
Project No.	22-0161-MOD03														
Date	04/11/2022														
Projection	WGS84 - LO31														
Scale	As indicated														
Drawing No.	Report Figure														

Figure 7-2: Model boundary conditions

7.3.6 Input Parameters/Initial Model Conditions

Model input parameters for this flow model are divided into two groups:

1. Hydrogeological parameters (hydraulic conductivity, recharge and aquifer storage);
and
2. Initial conditions.

The initial estimates for the hydraulic properties were assigned based on the aquifer test results for the 2013 test work conducted for Maquasa East and West. These hydraulic conductivity values were assigned to geological layers in the model area. The initial estimates were used for a combination of Parameter Estimation Simulation (PEST)¹ and manual calibration.

The initial head conditions, specified in the steady-state model, were estimated from topography. Initial transient model heads were derived from the steady-state model results.

Five per cent (5%) recharge of average annual rainfall was applied, which is approximately 48 mm/a. Due to the anticipated homogeneous nature of the geology in the study area, similar parameter values were assigned to the entire model domain.

Table 7-4 summarises the input parameters used in the steady state and transient state flow models.

Table 7-4: Input parameters to the flow model

Parameter	Value used
Horizontal Hydraulic conductivity (Kxy)	0.001 to 0.08 m/day
Vertical Hydraulic conductivity (Kz)	0.0001 to 0.008 m/day
Specific storage coefficient (Ss)	In the order of 1×10^{-5}
Specific yield (Sy)	0.2 - 0.3
Recharge (Re)	48 mm/yr
Porosity (n) (total)	0.1 - 0.5
Top elevation	Corresponded to surface topography.
Bottom elevation of the 1 st layer - extrapolated for rest of model grid	Corresponded to elevation 5 metres above the interpolated coal floor. Describes the weathered and partly weathered Ecca and dolerite aquifer rock in the area. Follows the curvature of the coal seam with a > thickness at the mountain area and < thickness further away from the mountainous area (110 m to 25 m)
Bottom fixed elevation of the 2 nd layer	Corresponds to the elevation of the coal floor.

¹ PEST (Parameter Estimation Simulation): automated parameter estimation tool, which provides a sensitivity and uncertainty analysis of the model, and much more.

Parameter	Value used
Bottom fixed elevation of the 3 rd layer	Approx. 10 m below the coal floor.
Bottom fixed elevation of the 4 th layer	Approx. 50-150 m below the bottom of layer 3. This layer represents the transition area between younger and deeper basement aquifer rock. Follows the curvature of the coal seam.
Bottom fixed elevation of the 5 th layers	Approx. 50 m below the bottom of layer 4. This layer represents older Ecca and Karoo rock.

7.3.7 Model Calibration

Calibration is the process of finding a set of boundary conditions, stresses and hydrogeological parameters that produce results which most closely match field measurements of hydraulic heads and flows.

In a catchment scale groundwater flow model, a difference between calculated and measured heads of up to several meters can be tolerated and is usually expressed as a function of the total range of observations. A scaled absolute mean value of below 10% is generally regarded as acceptable for a regional model (Tiedeman and Hills, 2005).

This calibration was done under steady state and transient state conditions. When calibrated, the model can be used to predict the influence of various management scenarios.

7.3.7.1 Calibration Targets

The groundwater levels and sulphate concentrations of on-site monitoring boreholes for 2002 - 2022 and 1998 - 2022 hydrocensus data were made available for calibration.

The model was calibrated according to average 2022 sulphate and water level data. The steady state, transient state and transport model calibration achieved are shown in Figure 7-3 to Figure 7-5.

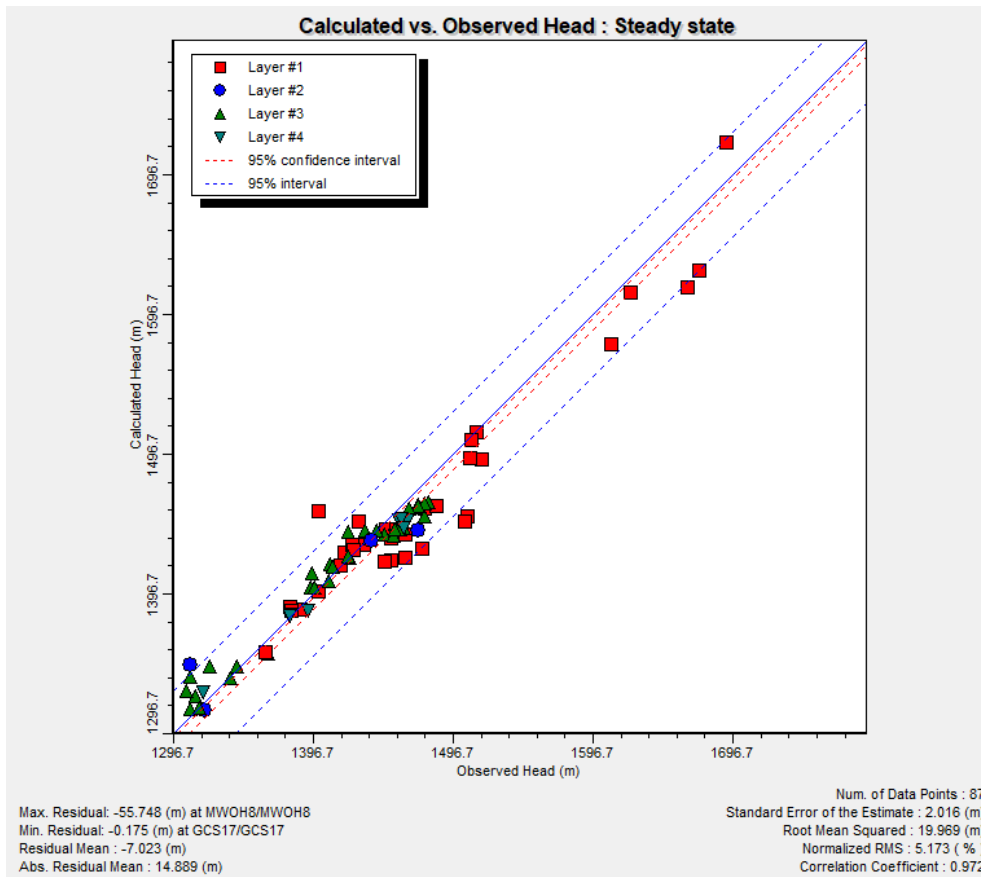


Figure 7-3: Steady-state model calibration achieved

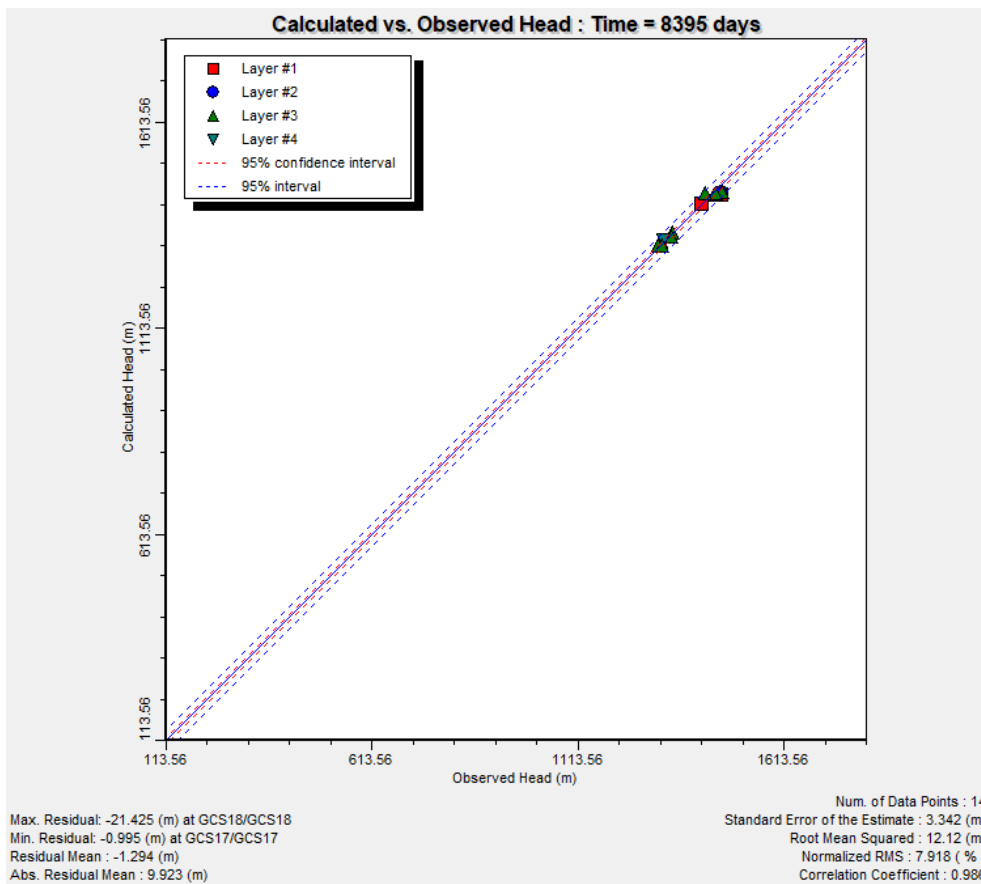


Figure 7-4: Flow model calibration achieved (2022)

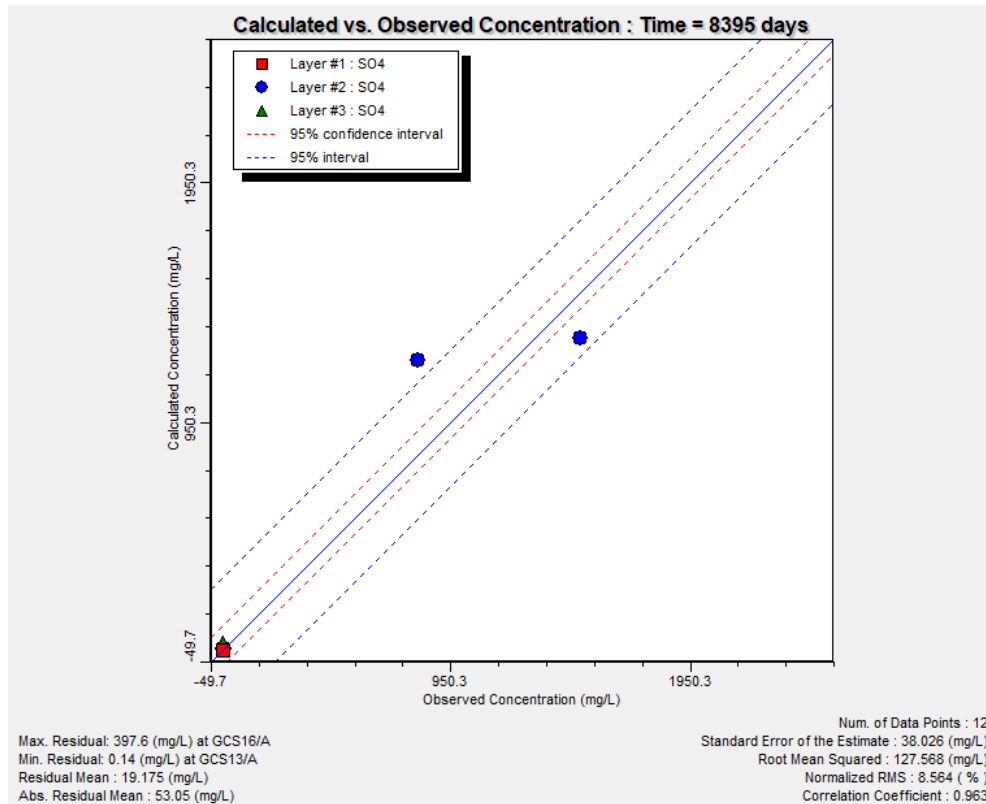


Figure 7-5: Sulphate plume calibration achieved (2017-2018 period)

7.3.7.2 Model sensitivity

A sensitivity analysis was carried out on the calibrated steady-state model using zones to assess the influence on groundwater level and flow dimensions by running the model in the *PEST* and sensitivity mode.

It can be seen from Figure 7-6 that the calibrated residuals (calculated heads vs observed heads) are slightly skewed towards the right. However, most of the data plots within the normalised distribution of the dataset are used for calibration.

The following parameters were observed to be sensitive (refer to Figure 7-7):

- Changes in horizontal hydraulic conductivity values (K_x and K_y);
- Recharge (indicated as par001); and
- Storage (SS) within layer 2.

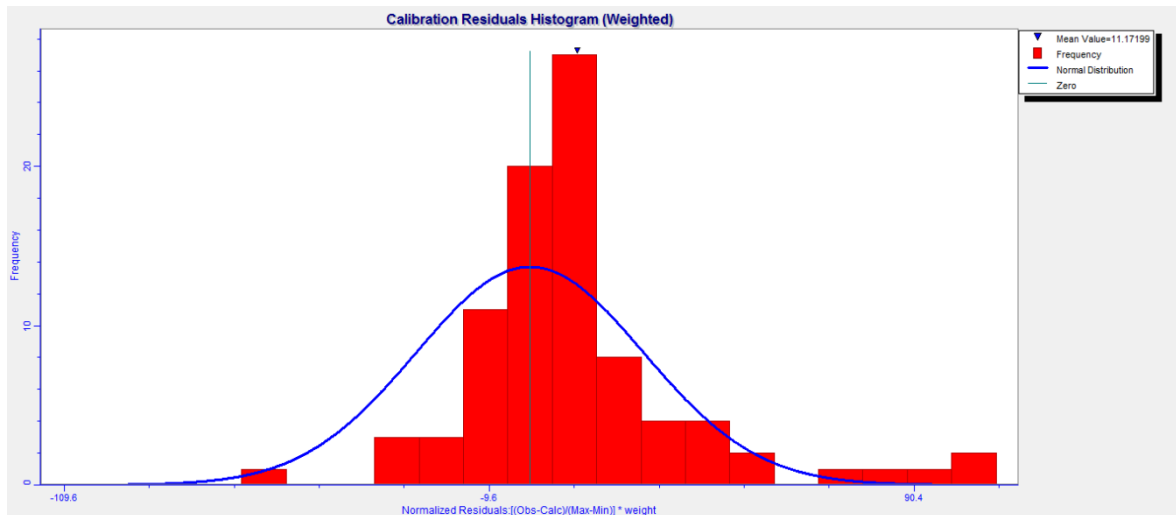


Figure 7-6: PEST Sensitivity Analysis - Histogram

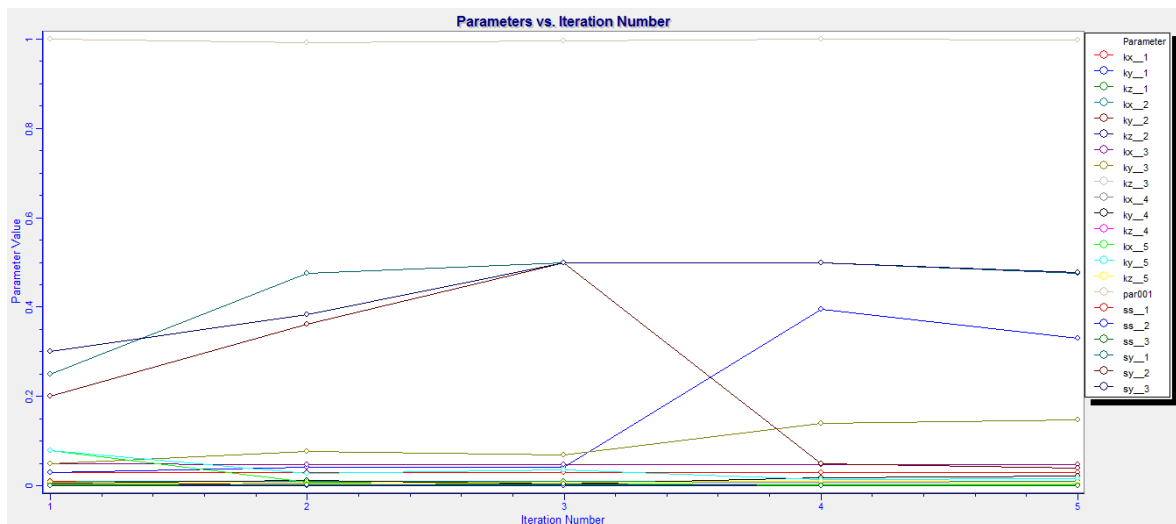


Figure 7-7: PEST Sensitivity Analysis - Weighted Parameter Sensitivity

7.4 Calibrated flow models

The calibrated flow model with simulated groundwater elevations is shown in Figure 7-8. The following is noted when evaluating the flow model (*with a focus on the proposed co-disposal facility, WTP and brine storage facility*):

- The groundwater table mimics the topography.
- Groundwater flow from the co-disposal facility is towards the northwest, towards the stream.
- Groundwater flow from the proposed brine pond is towards the south, towards the Heyshope dam.
- Groundwater flow for the Maquasa East and the proposed WTP area is towards the northeast.
- The flow model indicates groundwater flow velocities ranging from 0.01 (min) to 1.75 (max) m/day (or 638 m/yr). Groundwater movement in the weathered zone is greater than that of the deeper aquifer zones, as well as several orders greater in the alluvium zones when compared to the host rock.

7.5 Simulated 2022 plume and 20-year plumes

The calibrated TDS for the Maquasa East well as the predicted 50-year and 100-year sulphate plume movement from the proposed co-disposal facility and WTP brine pond is shown in Figure 7-9.

It can be seen that there is an existing mining impact in the Maquasa East area, primarily as a result of the old rehabilitated opencast operations, partially flooded underground workings and the coal processing and beneficiation area.

The 50-year and 100-year predictions are based on a 'no mitigation' scenario, where the proposed facilities are not lined. It can be seen from the 50-year and 100-year predictions, that the proposed co-disposal facility and the WTP may add to the existing impact footprint. The 250 mg/l plume front does not intercept the surrounding water courses and remains close to the proposed facilities.

If the facilities are lined, as is proposed by the engineering designs for Type C waste streams, then no poor-quality seepage is expected. There may then only be a slight risk of contaminant runoff during storm events.

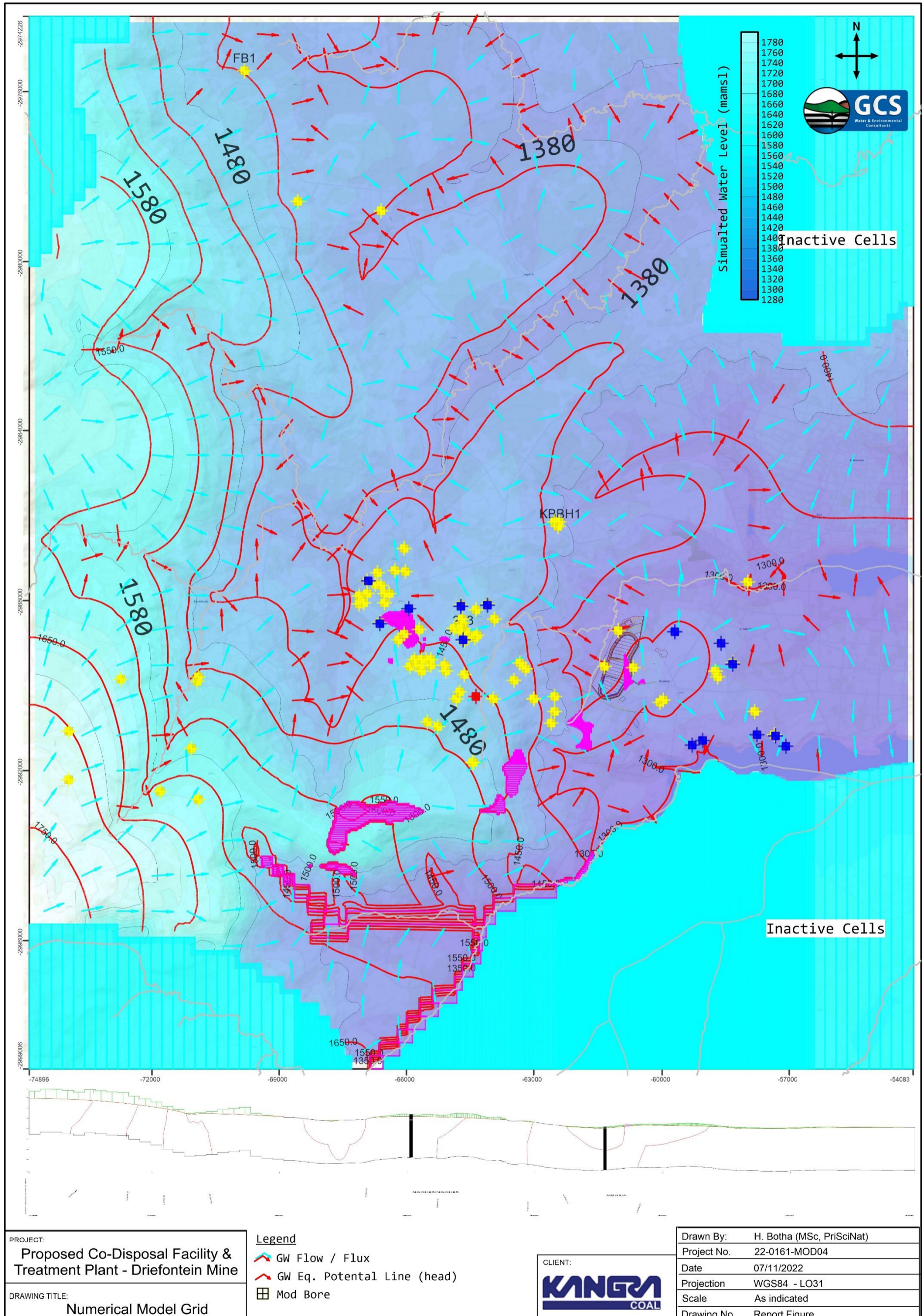


Figure 7-8: Calibrated flow model

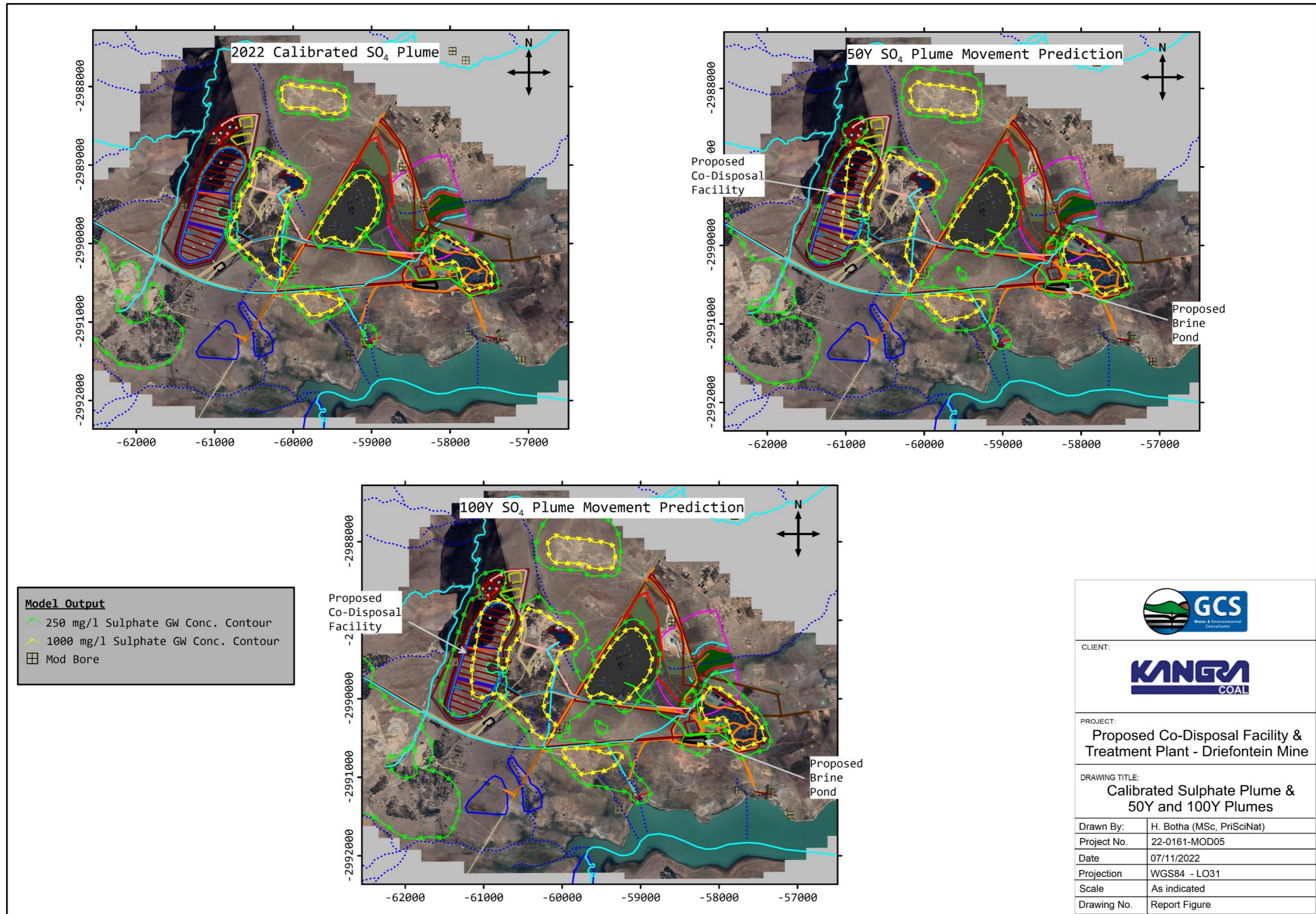


Figure 7-9: Calibrated 2022 SO₄ plumes, 50Y and 100Y unmitigated plumes from proposed developments

8 GEOHYDROLOGICAL RISKS ASSESSMENT & MITIGATION MEASURES

Risk assessment entails the understanding of the generation of a hazard, the probability that the hazard will occur, and the consequences should it occur. The risk assessment is based on the conceptual site model and the numerical model outputs, and further incorporates a worst-case scenario approach.

The anticipated geohydrological risks identified are discussed in Sections 8.1 to 8.3. The net consequence of geohydrological risk was established by the following equation:

$$\text{Consequence} = (\text{Duration} + \text{Extent} + \text{Irreplaceability of resource}) \times \text{Severity}$$

The environmental significance of an impact was determined by multiplying the consequence by probability. The risk significance rating is summarised in Table 8-1.

Table 8-1: Risk rating scale

Criteria	Rating Scales
Significance	Very high - negative (-49 to -66)
	High - negative (-37 to -48)
	Moderate - negative (-25 to -36)
	Low - negative (-13 to -24)
	Neutral - Very low (0 to -12)
	Low-positive (0 to 12)
	Moderate-positive (13 to 24)
	High-positive (37 to 48)
	Very high - positive (49 to 66)

In terms of the proposed developments, several hydrological risks were identified. The potential impacts identified and environmental significance for the construction, operational and closure phases are listed in Table 8-2, Table 8-3 and Table 8-4.

8.1 Pre-mining/development phase

The activities during the pre-development phase will generally include the following:

- vegetation clearance;
- topsoil and sub-soil stripping and stockpiling; and
- construction and introduction of infrastructure (i.e. roads, discard storage facility), including the risk of spillage of oils/fuel.

The identified risks for the construction/development phase include (Table 8-2):

- Typical earthworks are required to start construction of the disposal facility and WTP. This includes the destruction of the localised geological units during excavations. This impact is permanent and is therefore not included in the impact table as no mitigation measures can be recommended.

- Clearing topsoil from footprint areas will influence the rate of infiltration of water to the shallow groundwater system and/or base-flow component to shallow streams. The establishment of compacted areas during infrastructure and haul road construction reduces the recharge to the underlying aquifers due to increased runoff.
- The potential spillage of hydrocarbons from construction equipment during the construction of infrastructure, topsoil and overburden stripping as well as haul road construction which has the potential to cause the pollution of groundwater and surface water resources.

The continuation of the existing monitoring plan during construction is critical. This will ensure that water quality is continuously monitored. The collected information should be used as part of an active water management system and act as an early warning system for the application of mitigation measures. Except for the destruction of the geology, the other identified impacts during the construction phase are rated low after mitigation and management measures are applied. The identified impacts are therefore not likely to negatively affect the commencement of the proposed project.

8.2 Operational Phase

During the operational phase, minimal impact on the groundwater system/s is expected, due to Kangra's commitment to design the facility to mitigate all adverse environmental impacts on groundwater resources (i.e. liner system, concurrent rehabilitation methodology).

The key activities that could have a potential impact on groundwater in this phase include:

- Deposition of coal slurry and coal discard on one footprint. There is a possibility of the addition of brine to the discard dump; and
- Seepage and runoff from the proposed discard storage facility and associated infrastructure (e.g. PCD/s).

The identified risks for the operational phase include (refer to Table 8-3).

- Analyses showed that acid mine drainage (AMD) formation is expected and poor-quality leachate can occur based on the leaching potential of the material. This can influence runoff, soil, and groundwater quality. Containment systems are proposed and need to be regularly checked to ensure no seepage to the environment takes place;
- Liner system (i.e. storage facility and PCDs) - deterioration/damage to the liner system (during construction and operational phases) will cause contaminated seepage to migrate from the site (both vertically and laterally);

- Uncontrolled or emergency release - uncontrolled and/or emergency release of effluent from the PCD/s will cause contaminated seepage to migrate from the site (both vertically and laterally).

The installation of a comprehensively engineered barrier liner system reduces the recharge of aquifers due to containment. This is considered a LOW impact, localised and of long duration.

8.3 Closure and Post-Closure Phase

The closure and decommissioning phases will be per an agreed and approved closure plan for the WTP (if decant ceases) and co-disposal facility. This will entail:

- Termination of landfill/ co-disposal activities onto the co-disposal footprint area and rehabilitation; and
- Installation of long-term stormwater systems or upgrades to the operational stormwater system.

The identified risks for these phases include (refer to Table 8-4):

- Poor quality seepage and runoff from the co-disposal facility; and
- Poor quality seepage from vehicles accessing the site to do rehabilitation work.

Apart from continuous monitoring, engineering and managerial mitigation measures, including the evaluation of newly identified impacts during the construction and operational phases, the key closure and post-closure objective would be to minimise infiltration of precipitation.

To achieve this objective, it is proposed that a regulating authority-approved engineered designed capping is constructed to limit precipitation and oxygen infiltration and to enhance run-off and evaporation. This will assist in the management of potential high seepage at the facility toe after closure. The impacts are expected to have a HIGH positive significance rating due to Kangra's proposed facility and associated infrastructure design criteria.

8.4 Cumulative impacts and impacts on the hydrological cycle

As all activities will take place on the same property, there will be cumulative impacts. The proposed discard dump is zoned in an area where existing mine impacts are noted. The construction and operational phase risk table includes cumulative risks about the site, and activities thereon. Considering the sub-catchment and the activities associated with the site and surroundings, no impacts are expected in terms of the site hydrogeology. This is due to the proposed dump being lined, negating the risk of contamination reaching the groundwater system.

Treated water will be discharged into the Heyshope dam at the existing decant rate at pristine water quality (in line with GA limits for treated effluent discharge), and therefore will likely not have a negative impact on water quantity or quality. Compared to the active decant water quality, the proposed activity is predicted to improve the Heyshope water quality. Proposed discharge will take place at an existing abstraction point west of Driefontein, that is no longer in use.

Table 8-2: Pre-mining/construction phase hydrogeological risk

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation							Confidence
			Duration	Extent	Potential for impact on irreplaceable resources	Severity	Consequence	Probability	Significance		Duration	Extent	Severity	Potential for impact on irreplaceable resources	Consequence	Probability	Significance	
Vadose zone soils	Disturbing vadose zone during soil excavations/activities.	Earthworks	Long-Term (4)	Site (2)	Yes (1)	High (-3)	Highly detrimental (-19 to -24) (-21)	Definite (2)	High - negative (-37 to -48) (-42)	<ul style="list-style-type: none"> Only excavate areas applicable to the project area. Keep the site clean of all general and domestic waste. All development footprint areas to remain as small as possible and vegetation clearing to be limited to what is essential. Retain as much indigenous vegetation as possible. Exposed soils to be protected using a suitable covering. Existing roads should be used as far as practical to gain access to the site, and crossing the streams in areas where no existing crossing is apparent should be unnecessary, but if it is essential crossings should be made at right angles. 	Long-Term (4)	Site (2)	Yes (1)	Probable (-2)	Low - negative (-13 to -24) (-14)	Definite (2)	Moderate - negative (-25 to -36) (-28)	Medium
Groundwater quality	Topsoil and sub-soil stripping and stockpiling	Stockpiling	Long-Term (4)	Site (2)	Yes (1)	Probable (-2)	Moderately detrimental (-13 to -18) (-14)	Definite (2)	Moderate - negative (-25 to -36) (-28)	<ul style="list-style-type: none"> Install a temporary cut-off trench (if required) to contain poor-quality runoff. Cover soil stockpiles with a temporary liner to prevent contamination (where required and visually determined). Park vehicles in designated areas. 	Long-Term (4)	Site (2)	Yes (1)	Probable (-1)	Slightly detrimental (-7 to -12) (-7)	Probable (1)	Neutral - Very low (0 to -12) (-7)	Medium
Perched Water Table Dewatering	Temporary dewatering of perched groundwater (only expected during intense storm events and shortly thereafter).	Earthworks	Long-Term (4)	Site (2)	Yes (1)	Low (-1)	Slightly detrimental (-7 to -12) (-7)	Definite (2)	Low (12 to -25) (-14)	<ul style="list-style-type: none"> Water quality monitoring and routine visual assessment for contamination. Discharge dewatered / rainwater collected into the nearby stream. May require authorisation. If water is contaminated, discharge to the closest greywater system (depending on the extent of contamination) 	Long-Term (4)	Site (2)	Yes (1)	Negligible (0 to -6) (-0)	Probable (1)	Neutral - Very low (0 to -12) (0)	Medium	

Table 8-3: Operational phase hydrogeological risk

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation							Confidence
			Duration	Extent	Potential for impact on irreplaceable resources	Severity	Consequence	Probability	Significance		Duration	Extent	Severity	Potential for impact on irreplaceable resources	Consequence	Probability	Significance	
Shallow Aquifer System	Seepage from the co-disposal facility (landfill), PCDs and brine effluent pond • Poor quality seepage and runoff from vehicles parked at the site.	Site activities	Long-Term (4)	Site (2)	Yes (1)	Low (-1)	Slightly detrimental (-7 to -12) (-7)	Probable (1)	Neutral - Very low (0 to -12) (-7)	<ul style="list-style-type: none"> Keep the site clean of all general and domestic waste. Water quality monitoring of the groundwater system. 	Long-Term (4)	Site (2)	Yes (1)	Probable (-1)	Slightly detrimental (-7 to -12) (-7)	Probable (1)	Neutral - Very low (0 to -12) (-7)	Medium
Groundwater Quality and Quantity	Deposition of coal slurry and coal discard on one footprint.	Mine activities	Long-Term (4)	Site (2)	Yes (1)	High (-3)	Highly detrimental (-19 to -24) (-21)	Definite (2)	High - negative (-37 to -48) (-42)	<ul style="list-style-type: none"> Groundwater quality monitoring and visual assessments. Stick to the designated operational footprint as far as possible. 	Long-Term (4)	Site (2)	Yes (1)	Low (-1)	Slightly detrimental (-7 to -12) (-7)	Definite (2)	Low (12 to -25) (-14)	Medium
	Seepage and runoff from the proposed discard storage facility and associated infrastructure (e.g. PCD/s)	Mine activities	Long-Term (4)	Site (2)	Yes (1)	High (-3)	Highly detrimental (-19 to -24) (-21)	Definite (2)	High - negative (-37 to -48) (-42)	<ul style="list-style-type: none"> Water quality monitoring and visual assessments. Routine inspections of all stormwater systems. Ensure the facility is lined. 	Long-Term (4)	Site (2)	Yes (1)	Low (-1)	Slightly detrimental (-7 to -12) (-7)	Definite (2)	Low (12 to -25) (-14)	Medium

Table 8-4: Closure Phase Hydrogeological Risks

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation							Confidence
			Duration	Extent	Potential for impact on irreplaceable resources	Severity	Consequence	Probability	Significance		Duration	Extent	Severity	Potential for impact on irreplaceable resources	Consequence	Probability	Significance	
Shallow Aquifer System	The reshaping and rehabilitation of the co-disposal facility will be beneficial to the environment. Capping and reducing infiltration into the dump will help mitigate any poor-quality seepage.	Earthworks	Long-Term (4)	Site (2)	Yes (1)	Probable (-2)	Moderately detrimental (-13 to -18) (-14)	Definite (2)	Moderate - negative (-25 to -36) (-28)	<ul style="list-style-type: none"> Only excavate areas applicable to the project area. Keep the site clean of all general and domestic waste. Revegetate the co-disposal facility. Cover the co-disposal facility with a suitable impermeable capping layer or compact t reduce recharge into the landfill. 	Medium Term (4)	Site (2)	Yes (1)	High (3)	Highly beneficial (19 to 24) (21)	Definite (2)	High-positive (37 to 48) (42)	Medium
Groundwater Quality	<p><i>Seepage from the co-disposal facility</i></p> <ul style="list-style-type: none"> Poor quality seepage into the subsoils from landfill may impact soil quality, and eventually lead to poor quality seepage into the groundwater system. 	The net result of facilities constructed and rehabilitation thereof	Long-Term (4)	Footprint (1)	Yes (1)	Probable (-1)	Negligible (-6 to 0) (-6)	Probable (1))	Neutral - Very low (0 to -12) (-6)	<ul style="list-style-type: none"> After rehabilitation takes place, there should be limited seepage from the dump. Routine inspections and water quality monitoring of the boreholes should be sufficient to determine closure objectives. 								Medium

9 GROUNDWATER MONITORING

Kangra coal has an existing groundwater monitoring system in place. The monitoring network is considered sufficient however, a potential monitoring gap may exist towards the south of the proposed co-disposal facility. The WTP is considered a lower-risk infrastructure when compared to the co-disposal facility and hence will not require dedicated monitoring.

It is proposed that at least 2 additional groundwater monitoring points be added to the existing water monitoring network. The proposed additional groundwater monitoring points are listed in Table 9-1 and the positions are shown in Figure 9-1. The proposed depth of the boreholes is 45m.

Table 9-1: Proposed monitoring points

Site	Type	Latitude	Longitude
GCS-GW1	Groundwater	-27.02106	30.37900
GCS-GW2	Groundwater	-27.00522	30.386902

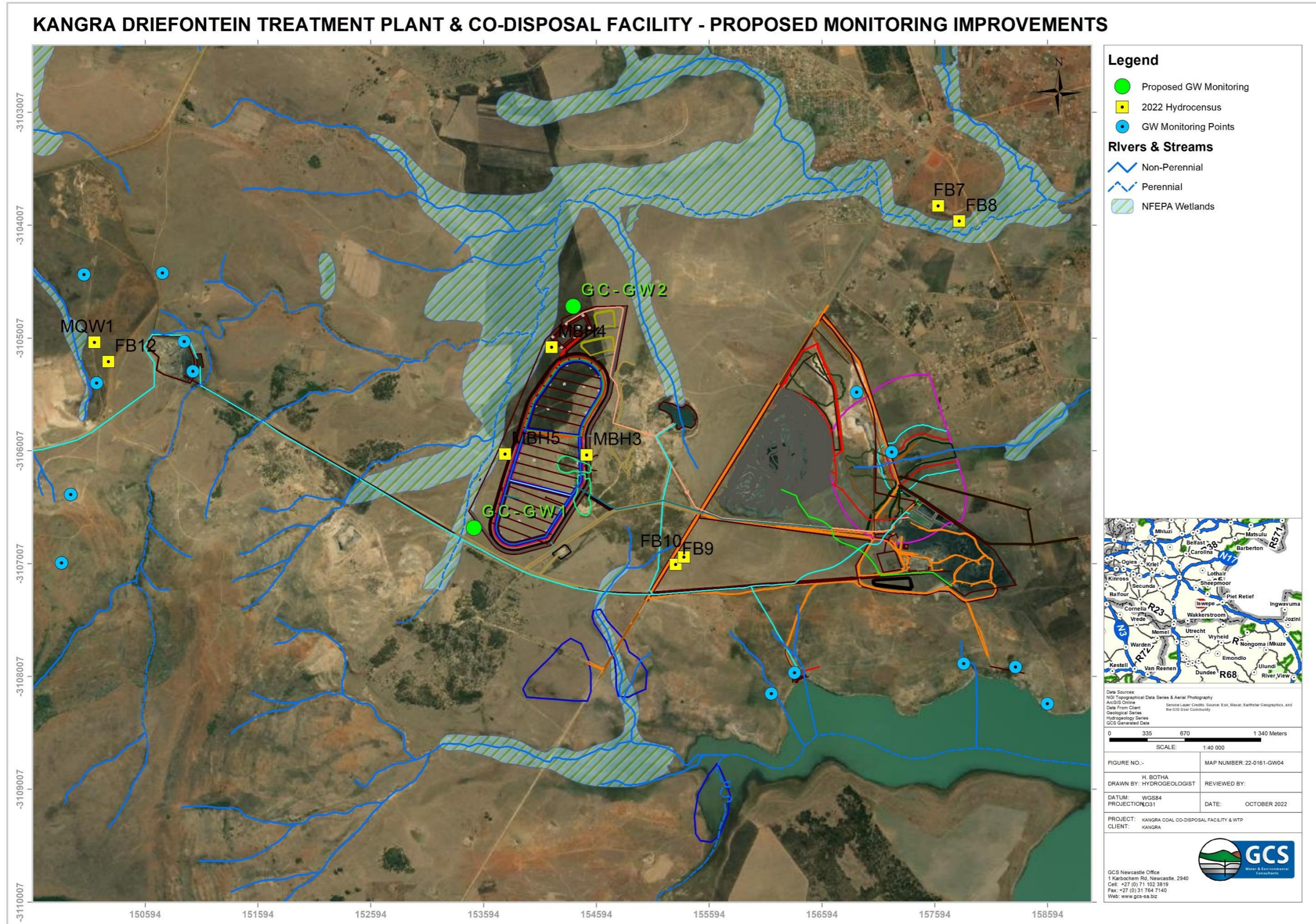


Figure 9-1: Proposed groundwater monitoring points

10 CONCLUSIONS

Based on the findings of the investigation, the following conclusion is drawn:

- This specialist study focused on the predicted groundwater impact for the proposed co-disposal facility, WTP and brine pond, that Kangra wants to construct at the existing Maquasa East operations.
- The study found that there is an existing impact on the groundwater regime at Maquasa East and that the proposed facilities will be situated in already impacted areas. The facilities will be lined and there is a marginal probability that there will be poor-quality seepage generation via the liner. As such, the geohydrological risks were found to be very low (refer to Section 8). There may still be some risk in the construction phase of the facilities, as well as the probability of poor-quality runoff generation (i.e. during storm events) onto the surrounding soils, which could lead to secondary poor-quality seepage and direct runoff into the perennial streams downstream of the sites.
- According to Guiding Principles 2.3 and 2.4 in the Australian groundwater modelling guidelines (Barnett *et al.*, 2012) the degree of confidence in the groundwater flow and transport model was evaluated:
 - The flow model is assigned a Class 2 confidence level due to the numerous groundwater heads available for calibration. Class 2 models are suitable for assessing higher-risk developments in higher-value aquifers (i.e. major aquifers for groundwater supply or an aquifer highly susceptible to pollution).
 - The transport model is assigned a Class 2 confidence as a sufficient amount of groundwater concentration calibration points are available.

10.1 Proposed Groundwater Management Aspects

The following section supplies a brief groundwater management plan which could help to improve the groundwater conditions during the construction, operational and closure phases of the co-disposal facility and WTP facilities at Kangra, and can be considered as commitments in the EMPr.

10.1.1 Operational/Decommission

To restrict the local groundwater and surface water impact the following actions are proposed:

- Re-use groundwater seepage collected in soak ways, stormwater trenches, and cut-off trenches and adequately size pollution control facilities.
- Keep dirty areas like workshops and oil and diesel storage areas as small as possible.
- Contain poor quality runoff from dirty areas and divert this water to pollution control dam for re-use.
- Have oil/diesel spill kits on site.
- Confirm groundwater and surface water monitoring protocol and plans.

10.1.2 Groundwater closure objectives

The following groundwater closure objectives are proposed:

- To cap the co-disposal facility (and other discard dumps) with an impermeable barrier, to eliminate rainfall infiltration.
- Use the results of the existing monitoring programme to confirm/validate the predicted impacts on groundwater availability and quality after closure;
- Update existing predictive tools to verify long-term impacts on groundwater, if required;
- Present the results to the competent authority on an annual basis to determine compliance with the closure objectives set during the Decommissioning Phase;
- Negotiate and get the groundwater closure objectives approved by the competent authority during the Decommissioning Phase of Kangra Maquasa East Operations, based on the results of the monitoring information obtained during the Operational Phases of the project, and through verification of the numerical model constructed for the project;

- To continue the groundwater quality and groundwater level monitoring for a period of at least two to four years after the plant and waste facilities are decommissioned to establish post-closure groundwater level and quality trends. The monitoring information must be used to update, verify and recalibrate the predictive tools used during the study to increase confidence in the closure objectives and management plans;
- To present the results of the monitoring programme to the competent authority on an annual basis. The post-closure monitoring programme will be re-evaluated on an annual basis in consultation with competent authority;
- To negotiate closure with competent authority based on the results of the groundwater monitoring undertaken, after the two to four-year post-closure monitoring periods.

10.2 Recommendations

The following recommendations are made:

- It is recommended that several groundwater monitoring boreholes be drilled at the sited locations (refer to Section 9).
- Rock/waste samples should be collected bi-annually from all waste streams (specifically waste stockpiles), to maintain a clear understanding of the ARD and leachate potential of the waste streams. The samples should be submitted for geochemical testing which includes Acid-Base Accounting (ABA), Net Acid Generation (NAG), and Static and kinetic leach testing. The geochemical test work will help to determine the chemical composition of the leachate produced by the various waste facilities. This will assist with understating ways to reduce seepage from these waste streams and assist in closure assessments.
- The following can be done to improve the assumptions and understanding of the groundwater aquifer and hence improve the numerical groundwater model confidence:
 - Based on available aquifer data, is recommended that 24-hour pump tests be performed on three (3) different boreholes situated within each proposed groundwater management area (so 9 in total). Aquifer pump test data will help to determine and confirm invaluable aquifer parameter data (aquifer storage, aquifer specific yield and aquifer transmissivity) which cannot be determined by slug testing.

-
- All monitoring boreholes drilled in the area should note groundwater occurrences as well as strike depths. The data can be used to update the conceptual hydrogeological model which is incorporated into the numerical flow model.
 - Water levels of dedicated monitoring boreholes that will be drilled, as well as any new boreholes which are discovered in the area during routine hydrocensus updates, should be monitored (quarterly dedicated holes, bi-annual hydrocensus).
 - It is recommended that the numerical groundwater model and transport model be updated annually, to:
 - Recalibrate the flow system based on the dedicated monitoring boreholes drilled and routine water level monitoring data gathered for the site.
 - Confirm preferential flow paths and groundwater migration velocities as new geological data is attained via mining.
 - Evaluate the spatial impact (i.e. SO₄ plume) calibrated with the proposed monitoring borehole data.
 - Confirm long-term liabilities associated with the workings (i.e. predict likely changes in flow fields etc.); and
 - Ensure no monitoring network gaps exist (i.e. check if the monitoring network is representative of the site).
 - The numerical groundwater model should be updated when changes to the site plan occur, and at least 5 years before decommissioning and site closure. It is important to verify groundwater quality objectives for the closure phase, and predict what the lingering impact will be if Kangra Maquasa East Operations are closed.
 - Ensure that all dams and leachate ponds are operated to capacities to prevent overflow during 1:50 and 1:100yr storm events.

10.3 Identification of any areas that should be avoided

No dedicated groundwater buffer areas are recommended. Operations should however be kept within the earmarked footprint.

10.4 Reasoned opinion on whether WULA should not be granted



This assessment cannot find any grounds or identify high geohydrological that could potentially not enable the approval of the construction of the co-disposal facility and the WTP and the authorization of these activities. This is grounded on the assumption that the proposed mitigation measures (Section 8) and monitoring improvements (Section 9) will be implemented, with routine numerical groundwater model updates.



11 BIBLIOGRAPHY



- AQTESOLV, 2022. *Slug Testing*. [Online]
Available at: <http://www.aqtesolv.com/slug-tests/slug-tests.htm>
[Accessed 29 07 2022].
- ARC, 2006. *Lan Types of South Africa*, s.l.: Pretoria: Agricultural Research Council.
- Bailey, A. & Pitman, W., 2015. *Water Resources of South Africa 2012 Study (WR2012): Executive Summary Version 1*. WRC Report No. K5/2143/1, Gezina, South Africa: Water Research Commission Report.
- Bailey, A. & Pitman, W., 2015. *Water Resources of South Africa 2012 Study (WR2012): Executive Summary Version 1*. WRC Report No. K5/2143/1., Gezina, South Africa: Water Research Commission Report: s.n.
- Barnett, B. et al., 2012. *Australian groundwater modelling guidelines*. ISBN- 978-1-921853-91-3, s.l.: s.n.
- Botha, J. et al., 1998. *Karoo Aquifers: Their Geology, Geometry and Physical Properties*, s.l.: WRC Report No: 457/1/98.
- DEA, 2019. *South African National Land Cover (SANLC) 2018*, South Africa: DEA on 1st October 2019.
- DMEA, 1998g. *1:250 000 Geological Series - 2730 Vryheid*, s.l.: s.n.
- DWA, 2012. *Aquifer Classification of South Africa map*, s.l.: Hydrological Services - Groundwater Information.
- DWAF, 1996b. *Water Quality Guidelines - Volume 1: Domestic Use*, s.l.: s.n.
- DWAF, 1996c. *South African Water Quality Guidelines (2nd Edition). Volume 5: Livestock Watering*, s.l.: s.n.
- DWAF, 1996d. *Water Quality Guidelines Volume 7: Aquatic Ecosystems*, s.l.: DWAF.
- DWAF, 1996e. *Water Quality Guidelines Volume 2: Recreational Use*, s.l.: DWAF.
- DWAF, 1996f. *Water Quality Guidelines Volume 3: Industrial Use*, s.l.: DWAF.
- DWAF, 2006. *Groundwater Resource Assessment II*, s.l.: s.n.
- DWAF, 2007. *Best Practice Guidelines - G3: Water Monitoring Systems*, s.l.: DWS.
- DWAF, 2008. *Best Practice Guidelines: Impact Prediction (G4)*, s.l.: DWS.
- DWS, 2011. *The Groundwater Dictionary - A Comprehensive Reference of Groundwater Related Terminology. 2nd Edition.*, s.l.: s.n.
- DWS, 2016. *New Water Management Areas*, South Africa: Government Gazette No. 40279.
- EPA, 1994. *U.S. Technical Document: Acid Mine Drainage Prediction. Environmental Protection Agency. EPA530-R-94-036. Retrieved from: <http://water.epa.gov/polwaste/nps/upload/amd.pdf>*, s.l.: s.n.
- Eyring, V. B. S. M. G. A. S. C. A. S. B. S. R. J. a. T. K. E., 2016. *Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization*, *Geosci. Model Dev.*, 9, 1937-1958, doi:10.5194/gmd-9-1937-2016. s.l.:s.n.
- Fourie, J., 2014. *Graphical representation of ABA and NAG screening results [telephonic correspondence]*. 11 September 2014., s.l.: s.n.
- GRIP, 2016. *Groundwater Resource Information Project*, s.l.: s.n.
- Harbaugh, A., B. E., Hill, M. & McDonald, M., 2000. *Modflow-200, the U.S. Geological Survey Modular Ground-Water Model - User Guide to Modularization Concepts and the Ground-Water Flow Process*. Open-File Report 00-92, s.l.: s.n.
- Hill, M. & Tiedeman, C., 2005. *Effective Groundwater Model Calibration: With analysis of Data, Sensitivities, and Uncertainty*. Wiley Press. ISBN-13: 978-0-471-77636-9, s.l.: s.n.
- Hughes, D., 2004. *Three decades of hydrological modelling research in South Africa*. *South African journal of science*, 100(11 & 12):638-642.. s.l.:s.n.



- INAP, 2022. *International Network for Acid Prevention. GARD guide: Chapter 2 Acid Rock Drainage Process.* c http://www.gardguide.com/index.php?title=Chapter_2., s.l.: s.n.
- King, G., Maritz, E. & Jonck, F., 1998. 2730 Vryheid - 1:500 000 Hydrogeological map series of the Republic of South Africa., s.l.: s.n.
- King, G., Maritz, E. & Jonck, F., 1998. 2829 Durban - 1:500 000 Hydrological Map Series of the Republic of South Africa, s.l.: s.n.
- Kottek, M. et al., 2006. *World Map of the Köppen-Geiger climate classification updated.* *Meteorol. Z.* 15, 259-263. doi:10.1127/0941-2948/2006/0130. s.l.:s.n.
- Kresic, N., 2007. *Hydrogeology and Groundwater Modeling. 2nd Edition.* CRC Press. ISBN - 978 084 966 3484, s.l.: s.n.
- Lapakko, K. & Lawrence, R. W., 1993. *Modification of the net acid production (NAP) test. Proceedings of the 17th Annual British Columbia Mine Reclamation Symposium in Port Hardy, BC, 1993. The Technical and Research Committee on Reclamation,* s.l.: s.n.
- Lourens, P., 2013. *The relationship between South African geology and geohydrology,* s.l.: IGS, University of the Free State, Bloemfontein. Masters Dissertation.
- Lynch, S., 2004. *Development of a Raster Database of Annual, Monthly and Daily Rainfall for Southern Africa, WRC Report No. 1156/1/04,* Pretoria: Water Research Commission.
- Meteoblue, 2022. *Climate Data.* s.l.:<https://www.meteoblue.com>.
- Meteoblue, 2022. *Climate Data.* s.l.:<https://www.meteoblue.com>.
- Miller, S., Robertson, A. & Donahue, T., 1997. *Advances in Acid Drainage Prediction using the Net Acid Generation (NAG) Test. Proc. 4th International Conference on Acid Rock Drainage, Vancouver, BC, 0533-549,* s.l.: s.n.
- NGA, 2019. *National Groundwater Archive.* [Online]
Available at: <https://www3.dwa.gov.za/NGANet/Security/WebLoginForm.aspx>
- NWA, 1999. *National Water Act, Government Gazette No. 20526, 8 October 1999. Wastewater limit values applicable to discharge of wastewater into a water resource,* s.l.: s.n.
- Parsons, R., 1995. *A South African Aquifer System Management Classification,* s.l.: Water Research Commission Report No. KV 7795.
- Price, W., 1997. *Guidelines and Recommended Methods for the prediction of metal leaching and Acid Rock Drainage at Minesites in British Columbia. British Columbia Ministry of Employment and Investment, Energy and Minerals Division, Smithers, BC, p.143,* s.l.: s.n.
- SADC GIP, 2022. *SADC Groundwater Information Portal (SADC GIP).* s.l.:s.n.
- Schulze, R., 1997. *South African Atlas of Agrohydrology and Climatology. WRC Report No. TT85/96,* Pretoria: Water Research Commission.
- Soregaroli, B. A. & Lawrence, R. W., 1998. *Update on waste characterization studies. In Mine Design, Operations and Closure Conference. Polson, Montana.,* s.l.: s.n.
- Van Deventer, H. S.-A. L. M. N. P. C. S. A. C. N. G. M. J. N. L. M. O. D. S. P. S. E. & S. K., 2018. *NBA2018 National Wetland Map 5.* s.l.:s.n.
- Vegter, J., 1995. *An explanation of a set of National Groundwater Maps. Water Research Commission. Report No TT 74/95..* s.l.:s.n.
- Woodford, A. V. T. G. T. A. T. G. R. P. G. M. O. R. V. D. a. E. C., 2013. *Karoo Groundwater Atlas Volume 2,* s.l.: Karoo Groundwater Expert Group (KGE).
WRC, 2015. <http://www.waterresourceswr2012.co.za/resource-centre/>. [Online].


APPENDIX A: PHOTOGRAPHIC LOG

<p>FB7</p>	<p>Date: 19-10-2022</p>	
<p>Direction Photo Taken: North</p>		
<p>Description</p> <p>The borehole is situated at Driefontein Community Health Centre.</p>		
<p>FB8</p>	<p>Date: 19-10-2022</p>	
<p>Direction Photo Taken: South</p>		
<p>Description</p> <p>The borehole is situated southwest of the Health Centre on the edge of the wetland.</p>		

<p>FB9</p>	<p>Date: 21-10-2022</p>	
<p>Direction Photo Taken: South</p>		
<p>Description The borehole is situated downstream of the existing discard dump. The borehole is excessively deep with no signs of water.</p>		
<p>FB10</p>	<p>Date: 21-10-2022</p>	
<p>Direction Photo Taken: South</p>		
<p>Description The borehole is situated downstream of the existing discard dump and approx. 85 m upstream of FB9.</p>		
<p>FB12</p>	<p>Date: 20-10-2022</p>	
<p>Direction Photo Taken:</p>		

<p>South</p>	
<p>Description</p> <p>The borehole is situated west and upgradient of Maqwasa West Shaft.</p>	
<p>MQW1</p>	<p>Date: 21-10-2022</p>
<p>Direction Photo Taken:</p> <p>North</p>	
<p>Description</p> <p>The borehole is situated west and upgradient of Maqwasa West Shaft.</p>	

<p>MBH3</p>	<p>Date: 20-10-2022</p>	
<p>Direction Photo Taken: West</p>		
<p>Description The borehole is situated on the eastern boundary upstream of the proposed co-disposal discard dump.</p>		
<p>MBH4</p>	<p>Date: 20-10-2022</p>	
<p>Direction Photo Taken: North</p>		
<p>Description The borehole is situated on the northern boundary upstream of the proposed co-disposal discard dump.</p>		
<p>MBH5</p>	<p>Date: 20-10-2022</p>	

<p>Direction Photo Taken: East</p>	 A photograph showing a yellow marker, likely a survey point or borehole location, situated in a field of tall, dry, golden-brown grass. The marker is a small, bright yellow object, possibly a cap or a small container, partially obscured by the grass. The background is a dense field of similar grass extending to the horizon.	
<p>Description The borehole is situated on the western boundary downstream of the proposed co-disposal discard dump.</p>		

APPENDIX B: GEOPHYSICAL INVESTIGATION

The geophysical system used in this investigation was a Geonics G5-proton precession magnetometer (Mag). The aim was to identify if there are dolerite intrusive rock or contact areas in the area, extrapolate the likely spatial spread of these structures, and site future monitoring boreholes.

The presence of magnetic minerals in rocks causes deviations in the earth's magnetic field. The proton precision magnetometer measures the remnant magnetic field strength of these rocks. The instrument measures the magnetic field strength in Nano Tesla (nT). Rock associated with magmatic intrusions, such as dolerite sills and dykes, have more magnetic minerals than the surrounding sedimentary rocks or metamorphic rocks. The zone between the intruding rocks is known as the baked zone (a zone that is weathered and cracked due to intruding magmatic rock heat and pressure) and is known to be associated with preferential flow paths of groundwater. It is these structures that are primarily targeted in Karoo aquifer systems for groundwater development and as potential pollution transmitters/boundaries. Hence, the purpose of the survey was to identify structures that may/may not promote groundwater flow.

1. Survey orientation and spacing length

Seven (7) Mag profiles were completed. The Mag traverse varied from approximately 200 m in length. Mag readings were taken at 5 m intervals. Moreover, each spacing was recorded with a handheld GPS.

2. Potential inference

Mag lines were shifted and oriented to best avoid and compensate for the interference sources identified in the project area (i.e., power lines and fences).

3. Data analyses

The data obtained from the magnetic survey was analysed as follows:

- All magnetic data was captured in Microsoft Excel®, and profile trend graphs for the profile lines walked were constructed. A 3-point average algorithm was applied to smooth the data. The magnetic anomalies observed were then interpreted based on the magnetic field strength observed along the profile lines.

LINE 1

Project:	Kangra Maquasa	Traverse Number:	Line1
Project Number:	22-0161	Traverse Direction:	NNE-SSW
Survey Area:	Maquasa East	Station Spacing:	10 m
Date of Survey:	06 October 2022	Operator:	Shuaib Dustay

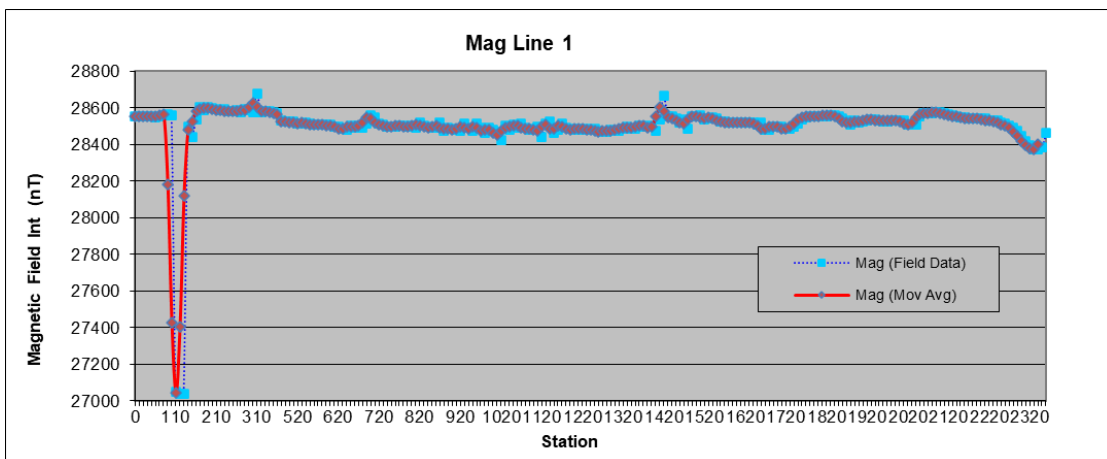
Station	Station Coordinates		Mag		Comments
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)	
0	30° 22' 44.7420" E	27° 01' 25.4640" S	28555	28555	
10	30° 22' 44.9076" E	27° 01' 25.1364" S	28554	28555	
20	30° 22' 45.0480" E	27° 01' 24.8592" S	28556	28554	
40	30° 22' 45.2064" E	27° 01' 24.5820" S	28554	28552	
50	30° 22' 45.3108" E	27° 01' 24.3012" S	28552	28553	
60	30° 22' 45.4440" E	27° 01' 24.0528" S	28551	28556	
70	30° 22' 45.5628" E	27° 01' 23.7324" S	28556	28562	
80	30° 22' 45.6564" E	27° 01' 23.4120" S	28561	28565	
90	30° 22' 45.7248" E	27° 01' 23.1348" S	28568	28185	
100	30° 22' 46.0344" E	27° 01' 22.7064" S	28561	27426	
110	30° 22' 46.2000" E	27° 01' 22.3032" S	27051	27043	Power line
120	30° 22' 46.3116" E	27° 01' 22.0152" S	27040	27405	Power line
130	30° 22' 46.4952" E	27° 01' 21.6840" S	27040	28121	Power line
140	30° 22' 46.5564" E	27° 01' 21.4104" S	28500	28480	
150	30° 22' 46.6860" E	27° 01' 21.1476" S	28442	28529	
160	30° 22' 46.7148" E	27° 01' 20.8740" S	28535	28582	
170	30° 22' 46.9200" E	27° 01' 20.5608" S	28603	28595	
180	30° 22' 47.0712" E	27° 01' 20.2368" S	28586	28599	
190	30° 22' 47.2368" E	27° 01' 19.8912" S	28604	28600	
200	30° 22' 47.3484" E	27° 01' 19.6104" S	28602	28594	
210	30° 22' 47.5104" E	27° 01' 19.3152" S	28592	28591	
220	30° 22' 47.5752" E	27° 01' 19.0308" S	28590	28589	
230	30° 22' 47.6976" E	27° 01' 18.7320" S	28592	28585	
240	30° 22' 47.8164" E	27° 01' 18.4404" S	28583	28585	
250	30° 22' 47.9496" E	27° 01' 18.1380" S	28583	28585	
260	30° 22' 48.0756" E	27° 01' 17.7996" S	28591	28584	
270	30° 22' 48.2304" E	27° 01' 17.5008" S	28575	28589	
280	30° 22' 48.3276" E	27° 01' 17.1768" S	28596	28588	
290	30° 22' 48.4680" E	27° 01' 16.8672" S	28588	28606	
300	30° 22' 48.5652" E	27° 01' 16.5720" S	28579	28629	
310	30° 22' 48.6696" E	27° 01' 16.2660" S	28679	28604	
320	30° 22' 48.7812" E	27° 01' 15.9600" S	28577	28581	
330	30° 22' 48.9036" E	27° 01' 15.6864" S	28583	28581	
340	30° 22' 49.0332" E	27° 01' 15.3624" S	28580	28578	
350	30° 22' 49.1664" E	27° 01' 15.0492" S	28579	28573	
360	30° 22' 49.2096" E	27° 01' 14.8188" S	28573	28567	
370	30° 22' 49.3680" E	27° 01' 14.5236" S	28565	28561	
380	30° 22' 49.4868" E	27° 01' 14.2716" S	28564	28555	
390	30° 22' 49.6056" E	27° 01' 13.9620" S	28551	28556	
400	30° 22' 49.7028" E	27° 01' 13.6956" S	28553	28570	
410	30° 22' 49.8864" E	27° 01' 13.4148" S	28568	28575	
420	30° 22' 49.9584" E	27° 01' 13.1556" S	28590	28560	
430	30° 22' 50.0448" E	27° 01' 12.8856" S	28553	28544	

440	30° 22' 50.1672" E	27° 01' 12.5652" S	28543	28539	
450	30° 22' 50.2752" E	27° 01' 12.2844" S	28538	28538	
460	30° 22' 50.3544" E	27° 01' 11.9676" S	28536	28537	
470	30° 22' 50.4444" E	27° 01' 11.6580" S	28540	28533	
480	30° 22' 50.5452" E	27° 01' 11.3268" S	28532	28528	
490	30° 22' 50.6316" E	27° 01' 11.0568" S	28527	28525	
500	30° 22' 50.7432" E	27° 01' 10.7328" S	28525	28523	
510	30° 22' 50.8548" E	27° 01' 10.4700" S	28524	28519	
520	30° 22' 50.9160" E	27° 01' 10.1604" S	28517	28518	
530	30° 22' 51.0276" E	27° 01' 09.8580" S	28517	28519	
540	30° 22' 51.0924" E	27° 01' 09.5556" S	28520	28516	
550	30° 22' 51.2076" E	27° 01' 09.2244" S	28517	28511	
560	30° 22' 51.2940" E	27° 01' 08.9436" S	28509	28508	
570	30° 22' 51.4020" E	27° 01' 08.6304" S	28507	28507	
580	30° 22' 51.4776" E	27° 01' 08.3568" S	28507	28508	
590	30° 22' 51.5892" E	27° 01' 08.0400" S	28508	28506	
600	30° 22' 51.6648" E	27° 01' 07.7520" S	28509	28501	
610	30° 22' 51.7620" E	27° 01' 07.4208" S	28499	28496	
620	30° 22' 51.8520" E	27° 01' 07.1328" S	28498	28489	
630	30° 22' 51.8988" E	27° 01' 06.8160" S	28488	28489	
640	30° 22' 51.9816" E	27° 01' 06.4668" S	28482	28496	
650	30° 22' 52.0320" E	27° 01' 06.1896" S	28504	28500	
660	30° 22' 52.0860" E	27° 01' 05.8728" S	28495	28500	
670	30° 22' 52.1004" E	27° 01' 05.5380" S	28504	28502	
680	30° 22' 52.0896" E	27° 01' 05.2392" S	28495	28521	
690	30° 22' 52.1472" E	27° 01' 04.9404" S	28514	28547	
700	30° 22' 52.2768" E	27° 01' 04.6092" S	28562	28544	
710	30° 22' 52.3632" E	27° 01' 04.3032" S	28549	28523	
720	30° 22' 52.4208" E	27° 01' 03.9864" S	28516	28510	
730	30° 22' 52.5108" E	27° 01' 03.6948" S	28511	28502	
740	30° 22' 52.7304" E	27° 01' 03.4464" S	28500	28498	
750	30° 22' 52.8600" E	27° 01' 03.1116" S	28496	28500	
760	30° 22' 53.0724" E	27° 01' 02.7984" S	28500	28503	
770	30° 22' 53.3064" E	27° 01' 02.5860" S	28504	28502	
780	30° 22' 53.5908" E	27° 01' 02.2908" S	28504	28500	
790	30° 22' 53.8284" E	27° 01' 02.0244" S	28497	28499	
800	30° 22' 54.0120" E	27° 01' 01.7364" S	28502	28503	
810	30° 22' 54.1920" E	27° 01' 01.4376" S	28495	28509	
820	30° 22' 54.3360" E	27° 01' 01.0884" S	28520	28506	
830	30° 22' 54.4728" E	27° 01' 00.8040" S	28502	28497	
840	30° 22' 54.6168" E	27° 01' 00.4980" S	28498	28493	
850	30° 22' 54.8364" E	27° 01' 00.2568" S	28491	28498	
860	30° 22' 55.0416" E	27° 01' 00.0048" S	28490	28502	
870	30° 22' 55.2288" E	27° 00' 59.7348" S	28522	28491	
880	30° 22' 55.3548" E	27° 00' 59.4396" S	28475	28486	
890	30° 22' 55.4232" E	27° 00' 59.1336" S	28490	28486	
900	30° 22' 55.5024" E	27° 00' 58.8204" S	28487	28482	
910	30° 22' 55.5780" E	27° 00' 58.5216" S	28481	28487	
920	30° 22' 55.6824" E	27° 00' 58.2336" S	28477	28499	
930	30° 22' 55.7904" E	27° 00' 57.9384" S	28513	28493	
940	30° 22' 55.9200" E	27° 00' 57.6468" S	28491	28490	
950	30° 22' 56.0028" E	27° 00' 57.3516" S	28477	28499	
960	30° 22' 56.1288" E	27° 00' 57.0168" S	28513	28490	

970	30° 22' 56.2728" E	27° 00' 56.7036" S	28491	28478	
980	30° 22' 56.3736" E	27° 00' 56.4264" S	28465	28483	
990	30° 22' 56.5140" E	27° 00' 56.2032" S	28492	28482	
1000	30° 22' 56.6040" E	27° 00' 55.9044" S	28482	28462	
1010	30° 22' 56.6868" E	27° 00' 55.6488" S	28470	28456	
1020	30° 22' 56.7732" E	27° 00' 55.3824" S	28425	28478	
1030	30° 22' 56.8740" E	27° 00' 55.1232" S	28502	28495	
1040	30° 22' 56.9892" E	27° 00' 54.8244" S	28483	28500	
1050	30° 22' 57.1080" E	27° 00' 54.5616" S	28512	28503	
1060	30° 22' 57.2232" E	27° 00' 54.2664" S	28494	28503	
1070	30° 22' 57.3456" E	27° 00' 53.9892" S	28513	28494	
1080	30° 22' 57.4464" E	27° 00' 53.7120" S	28490	28485	
1090	30° 22' 57.6012" E	27° 00' 53.4348" S	28482	28488	
1100	30° 22' 57.7452" E	27° 00' 53.1468" S	28486	28481	
1110	30° 22' 57.9000" E	27° 00' 52.9092" S	28498	28474	
1120	30° 22' 58.0476" E	27° 00' 52.6896" S	28442	28500	
1130	30° 22' 58.1988" E	27° 00' 52.3656" S	28514	28509	
1140	30° 22' 58.3356" E	27° 00' 52.0848" S	28529	28486	
1150	30° 22' 58.3968" E	27° 00' 51.8184" S	28465	28488	
1160	30° 22' 58.5048" E	27° 00' 51.5484" S	28484	28503	
1170	30° 22' 58.6272" E	27° 00' 51.2784" S	28517	28497	
1180	30° 22' 58.7208" E	27° 00' 51.0120" S	28492	28486	
1190	30° 22' 58.9116" E	27° 00' 50.7096" S	28487	28483	
1200	30° 22' 58.9980" E	27° 00' 50.4216" S	28479	28485	
1210	30° 22' 59.0880" E	27° 00' 50.1480" S	28488	28486	
1220	30° 22' 59.1996" E	27° 00' 49.8960" S	28484	28484	
1230	30° 22' 59.3112" E	27° 00' 49.6332" S	28487	28483	
1240	30° 22' 59.4300" E	27° 00' 49.2984" S	28479	28482	
1250	30° 22' 59.5524" E	27° 00' 49.0212" S	28487	28477	
1260	30° 22' 59.6532" E	27° 00' 48.7440" S	28474	28472	
1270	30° 22' 59.7900" E	27° 00' 48.4812" S	28471	28474	
1280	30° 22' 59.9016" E	27° 00' 48.1860" S	28471	28477	
1290	30° 22' 59.9700" E	27° 00' 47.8980" S	28482	28477	
1300	30° 23' 00.0420" E	27° 00' 47.5992" S	28474	28479	
1310	30° 23' 00.0852" E	27° 00' 47.3004" S	28476	28488	
1320	30° 23' 00.1572" E	27° 00' 47.0124" S	28489	28493	
1330	30° 23' 00.2292" E	27° 00' 46.6992" S	28496	28491	
1340	30° 23' 00.3804" E	27° 00' 46.3968" S	28489	28493	
1350	30° 23' 00.4272" E	27° 00' 46.1268" S	28489	28499	
1360	30° 23' 00.7008" E	27° 00' 45.5724" S	28504	28502	
1370	30° 23' 00.8196" E	27° 00' 45.2880" S	28500	28502	
1380	30° 23' 00.9456" E	27° 00' 44.9928" S	28504	28494	
1390	30° 23' 01.0392" E	27° 00' 44.7300" S	28499	28496	
1400	30° 23' 01.2408" E	27° 00' 44.4420" S	28474	28553	
1410	30° 23' 01.3128" E	27° 00' 44.1036" S	28537	28605	
1420	30° 23' 01.4172" E	27° 00' 43.8012" S	28665	28581	
1430	30° 23' 01.6008" E	27° 00' 43.5744" S	28553	28551	
1440	30° 23' 01.8060" E	27° 00' 43.3368" S	28553	28541	
1450	30° 23' 01.9032" E	27° 00' 43.0812" S	28544	28531	
1460	30° 23' 02.0220" E	27° 00' 42.8148" S	28522	28521	
1470	30° 23' 02.1552" E	27° 00' 42.5160" S	28536	28516	
1480	30° 23' 02.3280" E	27° 00' 42.2892" S	28488	28537	
1490	30° 23' 02.4540" E	27° 00' 41.9724" S	28553	28556	

1500	30° 23' 02.5800" E	27° 00' 41.6736" S	28553	28555	
1510	30° 23' 02.7276" E	27° 00' 41.3856" S	28563	28547	
1520	30° 23' 02.9292" E	27° 00' 41.1696" S	28540	28545	
1530	30° 23' 03.0912" E	27° 00' 40.8564" S	28546	28547	
1540	30° 23' 03.2352" E	27° 00' 40.5576" S	28549	28541	
1550	30° 23' 03.3972" E	27° 00' 40.2732" S	28543	28532	
1560	30° 23' 03.4908" E	27° 00' 39.9312" S	28528	28526	
1570	30° 23' 03.5880" E	27° 00' 39.6216" S	28527	28522	
1580	30° 23' 03.6672" E	27° 00' 39.3552" S	28520	28520	
1590	30° 23' 03.7428" E	27° 00' 39.1176" S	28520	28520	
1600	30° 23' 03.8328" E	27° 00' 38.8404" S	28520	28521	
1610	30° 23' 03.9408" E	27° 00' 38.5668" S	28521	28522	
1620	30° 23' 04.0524" E	27° 00' 38.2752" S	28522	28523	
1630	30° 23' 04.1640" E	27° 00' 38.0160" S	28523	28519	
1640	30° 23' 04.2576" E	27° 00' 37.7280" S	28522	28515	
1650	30° 23' 04.3224" E	27° 00' 37.4328" S	28510	28507	
1660	30° 23' 04.3908" E	27° 00' 37.1556" S	28518	28490	
1670	30° 23' 04.4844" E	27° 00' 36.8496" S	28480	28485	
1680	30° 23' 04.5708" E	27° 00' 36.5904" S	28480	28496	
1690	30° 23' 04.7400" E	27° 00' 36.3024" S	28501	28500	
1700	30° 23' 04.9092" E	27° 00' 36.0000" S	28501	28496	
1710	30° 23' 05.0496" E	27° 00' 35.7408" S	28497	28490	
1720	30° 23' 05.1612" E	27° 00' 35.4312" S	28487	28490	
1730	30° 23' 05.3196" E	27° 00' 35.1468" S	28487	28499	
1740	30° 23' 05.4672" E	27° 00' 34.8660" S	28498	28516	
1750	30° 23' 05.6364" E	27° 00' 34.5816" S	28514	28535	
1760	30° 23' 05.7912" E	27° 00' 34.2900" S	28539	28547	
1770	30° 23' 05.9532" E	27° 00' 34.0056" S	28548	28553	
1780	30° 23' 06.0864" E	27° 00' 33.7572" S	28554	28555	
1790	30° 23' 06.1980" E	27° 00' 33.4368" S	28555	28555	
1800	30° 23' 06.3204" E	27° 00' 33.1272" S	28554	28555	
1810	30° 23' 06.3996" E	27° 00' 32.8536" S	28555	28558	
1820	30° 23' 06.5184" E	27° 00' 32.5440" S	28557	28560	
1830	30° 23' 06.6552" E	27° 00' 32.2704" S	28561	28560	
1840	30° 23' 06.7596" E	27° 00' 32.0220" S	28561	28555	
1850	30° 23' 06.8568" E	27° 00' 31.7376" S	28557	28543	
1860	30° 23' 06.9612" E	27° 00' 31.4568" S	28543	28528	
1870	30° 23' 07.1268" E	27° 00' 31.1868" S	28530	28520	
1880	30° 23' 07.2492" E	27° 00' 30.9168" S	28510	28523	
1890	30° 23' 07.3284" E	27° 00' 30.6360" S	28530	28524	
1900	30° 23' 07.4580" E	27° 00' 30.3516" S	28520	28526	
1910	30° 23' 07.5840" E	27° 00' 29.9628" S	28526	28532	
1920	30° 23' 07.6488" E	27° 00' 29.7288" S	28532	28537	
1930	30° 23' 07.7460" E	27° 00' 29.4768" S	28539	28538	
1940	30° 23' 07.8252" E	27° 00' 29.1528" S	28539	28534	
1950	30° 23' 07.9260" E	27° 00' 28.8972" S	28533	28530	
1960	30° 23' 08.0520" E	27° 00' 28.6452" S	28529	28530	
1970	30° 23' 08.1816" E	27° 00' 28.3536" S	28529	28531	
1980	30° 23' 08.2860" E	27° 00' 28.0476" S	28531	28533	
1990	30° 23' 08.4048" E	27° 00' 27.7524" S	28533	28533	
2000	30° 23' 08.5092" E	27° 00' 27.4644" S	28533	28527	
2010	30° 23' 08.6496" E	27° 00' 27.1548" S	28533	28515	
2020	30° 23' 08.8116" E	27° 00' 26.8488" S	28510	28508	

2030	30° 23' 08.9340" E	27° 00' 26.5644" S	28507	28519	
2040	30° 23' 09.0456" E	27° 00' 26.2692" S	28507	28546	
2050	30° 23' 09.1932" E	27° 00' 25.9344" S	28553	28567	
2060	30° 23' 09.2976" E	27° 00' 25.6788" S	28572	28572	
2070	30° 23' 09.4164" E	27° 00' 25.3800" S	28572	28574	
2080	30° 23' 09.5244" E	27° 00' 25.1028" S	28572	28577	
2090	30° 23' 09.6936" E	27° 00' 24.8148" S	28578	28577	
2100	30° 23' 09.7872" E	27° 00' 24.5268" S	28578	28572	
2110	30° 23' 09.9204" E	27° 00' 24.2352" S	28573	28565	
2120	30° 23' 10.0464" E	27° 00' 23.9364" S	28564	28560	
2130	30° 23' 10.1364" E	27° 00' 23.6268" S	28560	28555	
2140	30° 23' 10.2660" E	27° 00' 23.3244" S	28555	28552	
2150	30° 23' 10.4352" E	27° 00' 23.0220" S	28551	28549	
2160	30° 23' 10.5324" E	27° 00' 22.7268" S	28551	28544	
2170	30° 23' 10.6512" E	27° 00' 22.3920" S	28542	28542	
2180	30° 23' 10.7772" E	27° 00' 22.0968" S	28542	28543	
2190	30° 23' 10.8960" E	27° 00' 21.8124" S	28543	28543	
2200	30° 23' 11.0400" E	27° 00' 21.4992" S	28543	28540	
2210	30° 23' 11.1588" E	27° 00' 21.1968" S	28542	28535	
2220	30° 23' 11.2848" E	27° 00' 20.8872" S	28533	28531	
2230	30° 23' 11.3820" E	27° 00' 20.5632" S	28531	28528	
2240	30° 23' 11.5260" E	27° 00' 20.2176" S	28530	28521	
2250	30° 23' 11.6556" E	27° 00' 19.9152" S	28520	28512	
2260	30° 23' 11.7672" E	27° 00' 19.6164" S	28513	28503	
2270	30° 23' 11.9112" E	27° 00' 19.3032" S	28503	28490	
2280	30° 23' 12.0516" E	27° 00' 18.9936" S	28491	28473	
2290	30° 23' 12.1272" E	27° 00' 18.6948" S	28476	28448	
2300	30° 23' 12.2748" E	27° 00' 18.3960" S	28448	28421	
2310	30° 23' 12.4296" E	27° 00' 18.0648" S	28419	28397	
2320	30° 23' 12.5124" E	27° 00' 17.7876" S	28398	28379	
2330	30° 23' 12.6168" E	27° 00' 17.4672" S	28373	28376	
2340	30° 23' 12.6816" E	27° 00' 17.1720" S	28373	28400	
2350	30° 23' 12.7752" E	27° 00' 16.8948" S	28383	21327	
2360	30° 23' 12.9192" E	27° 00' 16.5780" S	28462	7116	



LINE 2

Project:	Kangra Maquasa	Traverse Number:	Line2
Project Number:	22-0161	Traverse Direction:	NNE-SSW
Survey Area:	Maquasa East	Station Spacing:	10 m
Date of Survey:	10 October 2022	Operator:	Shuaib Dustay & Martin Ngubana

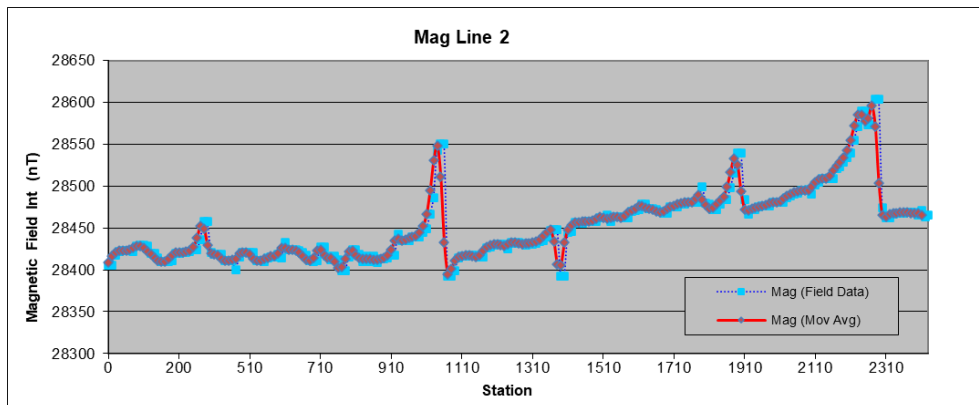
Station	Station Coordinates		Mag		Comments
	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)	
0	30° 23' 28.3380" E	27° 00' 18.5688" S	28406	28409	
10	30° 23' 28.2444" E	27° 00' 18.8028" S	28406	28416	
20	30° 23' 28.0932" E	27° 00' 19.0620" S	28418	28421.25	
30	30° 23' 27.8916" E	27° 00' 19.2996" S	28422	28422.75	
40	30° 23' 27.7008" E	27° 00' 19.5624" S	28423	28423	
50	30° 23' 27.5568" E	27° 00' 19.8396" S	28423	28422.75	
60	30° 23' 27.4272" E	27° 00' 20.0952" S	28423	28423.75	
70	30° 23' 27.2976" E	27° 00' 20.3940" S	28422	28426.75	
80	30° 23' 27.1536" E	27° 00' 20.6928" S	28428	28428.75	
90	30° 23' 27.0348" E	27° 00' 20.9952" S	28429	28428.75	
100	30° 23' 26.9124" E	27° 00' 21.2868" S	28429	28426.25	
110	30° 23' 26.7972" E	27° 00' 21.5784" S	28428	28422	
120	30° 23' 26.6820" E	27° 00' 21.8952" S	28420	28418.5	
130	30° 23' 26.5452" E	27° 00' 22.1364" S	28420	28414.5	
140	30° 23' 26.4084" E	27° 00' 22.4424" S	28414	28411	
150	30° 23' 26.2932" E	27° 00' 22.7088" S	28410	28410	
160	30° 23' 26.1888" E	27° 00' 22.9608" S	28410	28410.25	
170	30° 23' 26.0772" E	27° 00' 23.2488" S	28410	28413	
180	30° 23' 25.9116" E	27° 00' 23.5440" S	28411	28417.75	
190	30° 23' 25.7352" E	27° 00' 23.8284" S	28420	28420.25	
200	30° 23' 25.5876" E	27° 00' 24.1020" S	28420	28420.75	
210	30° 23' 25.4436" E	27° 00' 24.3936" S	28421	28421.25	
220	30° 23' 25.2852" E	27° 00' 24.6708" S	28421	28422.25	
230	30° 23' 25.1448" E	27° 00' 24.9408" S	28422	28423.5	
240	30° 23' 24.9936" E	27° 00' 25.2252" S	28424	28427	
250	30° 23' 24.8316" E	27° 00' 25.5060" S	28424	28438.5	
260	30° 23' 24.7128" E	27° 00' 25.8120" S	28436	28452.5	
270	30° 23' 24.6120" E	27° 00' 26.0928" S	28458	28448.75	
280	30° 23' 24.5508" E	27° 00' 26.4024" S	28458	28429.75	
290	30° 23' 24.3852" E	27° 00' 26.6940" S	28421	28419.5	
300	30° 23' 24.2160" E	27° 00' 26.9532" S	28419	28419	
310	30° 23' 24.0576" E	27° 00' 27.2052" S	28419	28417	
320	30° 23' 23.8956" E	27° 00' 27.4824" S	28419	28413	
330	30° 23' 23.7012" E	27° 00' 27.7488" S	28411	28411	
340	30° 23' 23.5500" E	27° 00' 28.0296" S	28411	28411.5	
350	30° 23' 23.3700" E	27° 00' 28.2888" S	28411	28412.5	
360	30° 23' 23.1972" E	27° 00' 28.5372" S	28413	28413.25	
370	30° 23' 22.9920" E	27° 00' 28.8288" S	28413	28413.75	
380	30° 23' 22.8156" E	27° 00' 29.0988" S	28414	28414	
390	30° 23' 22.6752" E	27° 00' 29.3472" S	28414	28414.25	
400	30° 23' 22.4880" E	27° 00' 29.6424" S	28414	28414	
410	30° 23' 22.3224" E	27° 00' 29.9340" S	28415	28414.5	
420	30° 23' 22.1172" E	27° 00' 30.2040" S	28412	28415.5	

430	30° 23' 21.9084" E	27° 00' 30.4560" S	28419	28413	
440	30° 23' 21.7140" E	27° 00' 30.7368" S	28412	28407.5	
450	30° 23' 21.5376" E	27° 00' 31.0392" S	28409	28402.25	
460	30° 23' 21.3540" E	27° 00' 31.3128" S	28400	28403.75	
470	30° 23' 21.2172" E	27° 00' 31.5864" S	28400	28412.75	
480	30° 23' 21.0768" E	27° 00' 31.8744" S	28415	28419.5	
490	30° 23' 20.9508" E	27° 00' 32.1732" S	28421	28421	
500	30° 23' 20.8176" E	27° 00' 32.4756" S	28421	28421	
510	30° 23' 20.7528" E	27° 00' 32.8140" S	28421	28418.5	
520	30° 23' 20.6052" E	27° 00' 33.1128" S	28421	28413.5	
530	30° 23' 20.4900" E	27° 00' 33.3612" S	28411	28410.75	
540	30° 23' 20.3352" E	27° 00' 33.6924" S	28411	28411.25	
550	30° 23' 20.2200" E	27° 00' 33.9516" S	28410	28413.25	
560	30° 23' 20.0832" E	27° 00' 34.2252" S	28414	28414.75	
570	30° 23' 19.9428" E	27° 00' 34.4880" S	28415	28416	
580	30° 23' 19.8024" E	27° 00' 34.7724" S	28415	28416.75	
590	30° 23' 19.6440" E	27° 00' 35.0676" S	28419	28420	
600	30° 23' 19.5576" E	27° 00' 35.3736" S	28414	28426	
610	30° 23' 19.4100" E	27° 00' 35.6796" S	28433	28426.25	
620	30° 23' 19.2156" E	27° 00' 35.9244" S	28424	28424	
630	30° 23' 19.0680" E	27° 00' 36.1836" S	28424	28423.75	
640	30° 23' 18.9420" E	27° 00' 36.4860" S	28424	28422.75	
650	30° 23' 18.8448" E	27° 00' 36.7524" S	28423	28420.5	
660	30° 23' 18.7440" E	27° 00' 37.0260" S	28421	28416.5	
670	30° 23' 18.6144" E	27° 00' 37.3212" S	28417	28412.25	
680	30° 23' 18.4812" E	27° 00' 37.6164" S	28411	28410.5	
690	30° 23' 18.3588" E	27° 00' 37.9008" S	28410	28414.75	
700	30° 23' 18.2724" E	27° 00' 38.1924" S	28411	28423	
710	30° 23' 18.0816" E	27° 00' 38.5164" S	28427	28424.25	
720	30° 23' 17.9340" E	27° 00' 38.8008" S	28427	28417.75	
730	30° 23' 17.7072" E	27° 00' 39.0312" S	28416	28414	
740	30° 23' 17.5236" E	27° 00' 39.3084" S	28412	28414	
750	30° 23' 17.3652" E	27° 00' 39.5892" S	28416	28409.75	
760	30° 23' 17.1996" E	27° 00' 39.8772" S	28412	28402.25	
770	30° 23' 17.0196" E	27° 00' 40.1436" S	28399	28403	
780	30° 23' 16.8072" E	27° 00' 40.4388" S	28399	28413.25	
790	30° 23' 16.6452" E	27° 00' 40.7268" S	28415	28421.75	
800	30° 23' 16.4832" E	27° 00' 41.0256" S	28424	28422.75	
810	30° 23' 16.2816" E	27° 00' 41.3100" S	28424	28418	
820	30° 23' 16.1160" E	27° 00' 41.6052" S	28419	28413.75	
830	30° 23' 15.9180" E	27° 00' 41.8896" S	28410	28413	
840	30° 23' 15.7668" E	27° 00' 42.2172" S	28416	28413	
850	30° 23' 15.5724" E	27° 00' 42.4836" S	28410	28412.75	
860	30° 23' 15.3816" E	27° 00' 42.7320" S	28416	28411.75	
870	30° 23' 15.1548" E	27° 00' 43.0236" S	28409	28412	
880	30° 23' 14.8704" E	27° 00' 43.2648" S	28413	28413.25	
890	30° 23' 14.6508" E	27° 00' 43.5312" S	28413	28414.75	
900	30° 23' 14.4348" E	27° 00' 43.8012" S	28414	28417	
910	30° 23' 14.1864" E	27° 00' 44.0496" S	28418	28424.25	
920	30° 23' 13.9560" E	27° 00' 44.2548" S	28418	28434.75	
930	30° 23' 13.7472" E	27° 00' 44.4888" S	28443	28437	
940	30° 23' 13.5600" E	27° 00' 44.7372" S	28435	28435	
950	30° 23' 13.4232" E	27° 00' 44.9928" S	28435	28436	

960	30° 23' 13.3584" E	27° 00' 45.2916" S	28435	28438	
970	30° 23' 13.3116" E	27° 00' 45.5148" S	28439	28439	
980	30° 23' 13.1712" E	27° 00' 45.8316" S	28439	28440.5	
990	30° 23' 13.0344" E	27° 00' 46.1484" S	28439	28444.5	
1000	30° 23' 12.9156" E	27° 00' 46.3896" S	28445	28452.25	
1010	30° 23' 12.7752" E	27° 00' 46.6344" S	28449	28466.75	
1020	30° 23' 12.6492" E	27° 00' 46.8828" S	28466	28495.25	
1030	30° 23' 12.5124" E	27° 00' 47.1240" S	28486	28530.5	
1040	30° 23' 12.3720" E	27° 00' 47.4228" S	28543	28548.25	
1050	30° 23' 12.1884" E	27° 00' 47.6640" S	28550	28510.75	
1060	30° 23' 12.0768" E	27° 00' 47.8944" S	28550	28432.25	
1070	30° 23' 11.8860" E	27° 00' 48.1212" S	28393	28394.5	
1080	30° 23' 11.7456" E	27° 00' 48.3840" S	28393	28401.25	
1090	30° 23' 11.5908" E	27° 00' 48.6360" S	28399	28410.75	
1100	30° 23' 11.4288" E	27° 00' 48.8916" S	28414	28415.5	
1110	30° 23' 11.2236" E	27° 00' 49.1544" S	28416	28416.25	
1120	30° 23' 11.0616" E	27° 00' 49.3884" S	28416	28417	
1130	30° 23' 10.8960" E	27° 00' 49.6620" S	28417	28417.5	
1140	30° 23' 10.7340" E	27° 00' 49.9752" S	28418	28416.75	
1150	30° 23' 10.6296" E	27° 00' 50.2272" S	28417	28415.5	
1160	30° 23' 10.4604" E	27° 00' 50.4864" S	28415	28417.75	
1170	30° 23' 10.2768" E	27° 00' 50.7456" S	28415	28423.5	
1180	30° 23' 10.1220" E	27° 00' 51.0192" S	28426	28427.25	
1190	30° 23' 09.9744" E	27° 00' 51.2964" S	28427	28429	
1200	30° 23' 09.8160" E	27° 00' 51.5556" S	28429	28430.5	
1210	30° 23' 09.6396" E	27° 00' 51.8328" S	28431	28431	
1220	30° 23' 09.5208" E	27° 00' 52.1100" S	28431	28429.5	
1230	30° 23' 09.3552" E	27° 00' 52.3980" S	28431	28428.5	
1240	30° 23' 09.2364" E	27° 00' 52.6644" S	28425	28430.75	
1250	30° 23' 09.0924" E	27° 00' 52.9416" S	28433	28432.5	
1260	30° 23' 08.9664" E	27° 00' 53.2224" S	28432	28432.5	
1270	30° 23' 08.8800" E	27° 00' 53.4600" S	28433	28431.75	
1280	30° 23' 08.7792" E	27° 00' 53.7156" S	28432	28431	
1290	30° 23' 08.7180" E	27° 00' 53.9676" S	28430	28431.25	
1300	30° 23' 08.5344" E	27° 00' 54.2304" S	28432	28431.5	
1310	30° 23' 08.3724" E	27° 00' 54.4752" S	28431	28432.25	
1320	30° 23' 08.2860" E	27° 00' 54.6480" S	28432	28433.75	
1330	30° 23' 08.1636" E	27° 00' 54.9468" S	28434	28435.75	
1340	30° 23' 08.0124" E	27° 00' 55.2312" S	28435	28440	
1350	30° 23' 07.8684" E	27° 00' 55.4652" S	28439	28445.25	
1360	30° 23' 07.6956" E	27° 00' 55.7352" S	28447	28447.75	
1370	30° 23' 07.5372" E	27° 00' 56.0196" S	28448	28434.25	
1380	30° 23' 07.4256" E	27° 00' 56.2248" S	28448	28406.75	
1390	30° 23' 07.3284" E	27° 00' 56.5416" S	28393	28406	
1400	30° 23' 07.1916" E	27° 00' 56.8188" S	28393	28432.25	
1410	30° 23' 07.0944" E	27° 00' 57.0960" S	28445	28448.5	
1420	30° 23' 06.9792" E	27° 00' 57.3804" S	28446	28454	
1430	30° 23' 06.8532" E	27° 00' 57.6468" S	28457	28456.25	
1440	30° 23' 06.7344" E	27° 00' 57.9312" S	28456	28456.5	
1450	30° 23' 06.6336" E	27° 00' 58.2156" S	28456	28457.5	
1460	30° 23' 06.4716" E	27° 00' 58.4928" S	28458	28458	
1470	30° 23' 06.3420" E	27° 00' 58.7268" S	28458	28458	
1480	30° 23' 06.1944" E	27° 00' 59.0148" S	28458	28459	

1490	30° 23' 06.0720" E	27° 00' 59.2920" S	28458	28461	
1500	30° 23' 05.9676" E	27° 00' 59.5548" S	28462	28462.75	
1510	30° 23' 05.8128" E	27° 00' 59.8392" S	28462	28462.5	
1520	30° 23' 05.6904" E	27° 01' 00.0912" S	28465	28461	
1530	30° 23' 05.5428" E	27° 01' 00.3576" S	28458	28461.75	
1540	30° 23' 05.4096" E	27° 01' 00.6492" S	28463	28463	
1550	30° 23' 05.2440" E	27° 01' 00.8832" S	28463	28462.75	
1560	30° 23' 05.1720" E	27° 01' 01.1604" S	28463	28462.25	
1570	30° 23' 05.1072" E	27° 01' 01.4232" S	28462	28464	
1580	30° 23' 04.9632" E	27° 01' 01.6824" S	28462	28468.25	
1590	30° 23' 04.7976" E	27° 01' 01.9452" S	28470	28471	
1600	30° 23' 04.6860" E	27° 01' 02.2008" S	28471	28473.25	
1610	30° 23' 04.5456" E	27° 01' 02.4960" S	28472	28476.5	
1620	30° 23' 04.4232" E	27° 01' 02.7660" S	28478	28476.75	
1630	30° 23' 04.2936" E	27° 01' 03.0288" S	28478	28474.25	
1640	30° 23' 04.1496" E	27° 01' 03.3060" S	28473	28472.75	
1650	30° 23' 03.9840" E	27° 01' 03.5544" S	28473	28471.75	
1660	30° 23' 03.8508" E	27° 01' 03.8244" S	28472	28470	
1670	30° 23' 03.7284" E	27° 01' 04.0980" S	28470	28468.5	
1680	30° 23' 03.6024" E	27° 01' 04.3608" S	28468	28469.75	
1690	30° 23' 03.4620" E	27° 01' 04.6344" S	28468	28473.25	
1700	30° 23' 03.3108" E	27° 01' 04.8936" S	28475	28475	
1710	30° 23' 03.1920" E	27° 01' 05.1636" S	28475	28476	
1720	30° 23' 03.0840" E	27° 01' 05.4228" S	28475	28478	
1730	30° 23' 02.9364" E	27° 01' 05.6856" S	28479	28479.5	
1740	30° 23' 02.8104" E	27° 01' 05.9664" S	28479	28480.5	
1750	30° 23' 02.6664" E	27° 01' 06.2184" S	28481	28481	
1760	30° 23' 02.4900" E	27° 01' 06.4344" S	28481	28481	
1770	30° 23' 02.3460" E	27° 01' 06.7116" S	28481	28485.5	
1780	30° 23' 02.2308" E	27° 01' 06.9780" S	28481	28489.75	
1790	30° 23' 02.1084" E	27° 01' 07.2300" S	28499	28484.25	
1800	30° 23' 01.9860" E	27° 01' 07.4892" S	28480	28477	
1810	30° 23' 01.8132" E	27° 01' 07.7592" S	28478	28473.5	
1820	30° 23' 01.6476" E	27° 01' 08.0220" S	28472	28473.75	
1830	30° 23' 01.4784" E	27° 01' 08.2776" S	28472	28478.5	
1840	30° 23' 01.3272" E	27° 01' 08.5224" S	28479	28482.75	
1850	30° 23' 01.1400" E	27° 01' 08.7636" S	28484	28487.5	
1860	30° 23' 00.9492" E	27° 01' 08.9976" S	28484	28498.75	
1870	30° 23' 00.8088" E	27° 01' 09.2712" S	28498	28516.75	
1880	30° 23' 00.6180" E	27° 01' 09.5232" S	28515	28533	
1890	30° 23' 00.4884" E	27° 01' 09.7680" S	28539	28525.25	
1900	30° 23' 00.3408" E	27° 01' 10.0596" S	28539	28493.25	
1910	30° 23' 00.2076" E	27° 01' 10.3188" S	28484	28472	
1920	30° 23' 00.0852" E	27° 01' 10.5348" S	28466	28470.5	
1930	30° 22' 59.9736" E	27° 01' 10.7904" S	28472	28472.75	
1940	30° 22' 59.8332" E	27° 01' 11.0496" S	28472	28474.5	
1950	30° 22' 59.6820" E	27° 01' 11.3088" S	28475	28475.75	
1960	30° 22' 59.5452" E	27° 01' 11.5608" S	28476	28476	
1970	30° 22' 59.4264" E	27° 01' 11.8164" S	28476	28477.25	
1980	30° 22' 59.3148" E	27° 01' 12.0648" S	28476	28479.75	
1990	30° 22' 59.1672" E	27° 01' 12.3240" S	28481	28481	
2000	30° 22' 59.0124" E	27° 01' 12.5760" S	28481	28481	
2010	30° 22' 58.8684" E	27° 01' 12.8352" S	28481	28482.25	

2020	30° 22' 58.7172" E	27° 01' 13.0908" S	28481	28485.25	
2030	30° 22' 58.5552" E	27° 01' 13.3464" S	28486	28488	
2040	30° 22' 58.4004" E	27° 01' 13.5948" S	28488	28490	
2050	30° 22' 58.2384" E	27° 01' 13.8396" S	28490	28492.25	
2060	30° 22' 58.0656" E	27° 01' 14.0844" S	28492	28494.25	
2070	30° 22' 57.8892" E	27° 01' 14.2932" S	28495	28495.25	
2080	30° 22' 57.6984" E	27° 01' 14.5416" S	28495	28494.5	
2090	30° 22' 57.5652" E	27° 01' 14.7864" S	28496	28494.75	
2100	30° 22' 57.3852" E	27° 01' 15.0132" S	28491	28499.5	
2110	30° 22' 57.2052" E	27° 01' 15.2508" S	28501	28505	
2120	30° 22' 57.0504" E	27° 01' 15.4920" S	28505	28508	
2130	30° 22' 56.9172" E	27° 01' 15.7440" S	28509	28509	
2140	30° 22' 56.7084" E	27° 01' 15.9744" S	28509	28509	
2150	30° 22' 56.5140" E	27° 01' 16.2048" S	28509	28512	
2160	30° 22' 56.3160" E	27° 01' 16.4568" S	28509	28518.5	
2170	30° 22' 56.1684" E	27° 01' 16.7268" S	28521	28524	
2180	30° 22' 55.9848" E	27° 01' 16.9680" S	28523	28528.75	
2190	30° 22' 55.8228" E	27° 01' 17.2236" S	28529	28534.25	
2200	30° 22' 55.6824" E	27° 01' 17.4828" S	28534	28542.25	
2210	30° 22' 55.5024" E	27° 01' 17.7312" S	28540	28555.25	
2220	30° 22' 55.3260" E	27° 01' 17.9724" S	28555	28571.75	
2230	30° 22' 55.1460" E	27° 01' 18.1992" S	28571	28585.25	
2240	30° 22' 54.9804" E	27° 01' 18.4404" S	28590	28585.75	
2250	30° 22' 54.8328" E	27° 01' 18.6852" S	28590	28577.25	
2260	30° 22' 54.6744" E	27° 01' 18.8976" S	28573	28580.75	
2270	30° 22' 54.5088" E	27° 01' 19.1496" S	28573	28596.25	
2280	30° 22' 54.3360" E	27° 01' 19.4016" S	28604	28571.5	
2290	30° 22' 54.1704" E	27° 01' 19.6536" S	28604	28503.5	
2300	30° 22' 53.9616" E	27° 01' 19.9308" S	28474	28465	
2310	30° 22' 53.8140" E	27° 01' 20.1720" S	28462	28463.25	
2320	30° 22' 53.6592" E	27° 01' 20.4240" S	28462	28466	
2330	30° 22' 53.5224" E	27° 01' 20.6652" S	28467	28467.75	
2340	30° 22' 53.3244" E	27° 01' 20.9028" S	28468	28468	
2350	30° 22' 53.1444" E	27° 01' 21.1440" S	28468	28468.25	
2360	30° 22' 52.9644" E	27° 01' 21.3888" S	28468	28468.75	
2370	30° 22' 52.8744" E	27° 01' 21.6480" S	28469	28469	
2380	30° 22' 52.7448" E	27° 01' 21.9216" S	28469	28468	
2390	30° 22' 52.6332" E	27° 01' 22.2024" S	28469	28467.5	
2400	30° 22' 52.4928" E	27° 01' 22.4616" S	28465	28467.5	
2410	30° 22' 52.3596" E	27° 01' 22.7532" S	28471	28465.5	
2420	30° 22' 52.2264" E	27° 01' 22.9908" S	28463	21348.25	

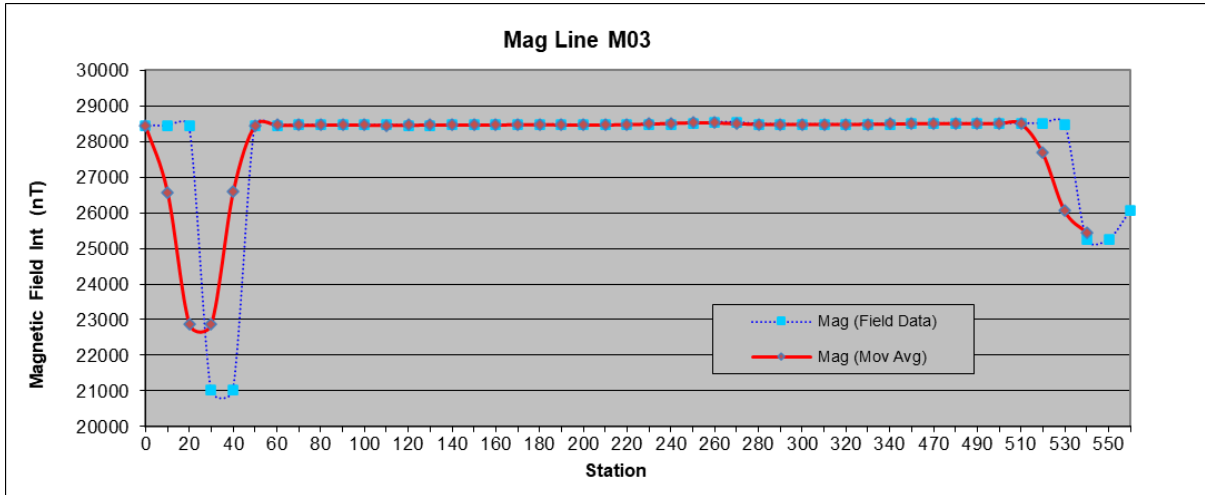


LINE 3

Project:	Kangra Maquasa	Traverse Number:	Line3
Project Number:	22-0161	Traverse Direction:	SE-NW
Survey Area:	Maquasa East	Station Spacing:	10 m
Date of Survey:	10 October 2022	Operator:	Shuaib Dustay & Martin Ngubana

Station	Station Coordinates		Mag		Comments
	Latitude (y)	Longitude (x)	Mag	Mag (Moving Average)	
0	30° 22' 59.4408" E	27° 01' 25.4172" S	28463	28442	
10	30° 22' 59.1420" E	27° 01' 25.3452" S	28436	26578.25	
20	30° 22' 58.7604" E	27° 01' 25.2444" S	28433	22866.5	
30	30° 22' 58.4256" E	27° 01' 25.1436" S	21011	22872.5	
40	30° 22' 58.0656" E	27° 01' 25.0428" S	21011	26596.75	
50	30° 22' 57.7164" E	27° 01' 24.9528" S	28457	28461.75	
60	30° 22' 57.3636" E	27° 01' 24.8484" S	28462	28465	
70	30° 22' 57.0324" E	27° 01' 24.7296" S	28466	28467	
80	30° 22' 56.7012" E	27° 01' 24.6288" S	28466	28469.25	
90	30° 22' 56.3484" E	27° 01' 24.5208" S	28470	28470.75	
100	30° 22' 55.9992" E	27° 01' 24.3840" S	28471	28468.75	
110	30° 22' 55.6788" E	27° 01' 24.2436" S	28471	28464.25	
120	30° 22' 55.3800" E	27° 01' 24.1356" S	28462	28465.5	
130	30° 22' 55.0416" E	27° 01' 23.9484" S	28462	28472.5	
140	30° 22' 54.7140" E	27° 01' 23.7972" S	28476	28476	
150	30° 22' 54.4224" E	27° 01' 23.6640" S	28476	28476	
160	30° 22' 54.0840" E	27° 01' 23.5020" S	28476	28476	
170	30° 22' 53.7780" E	27° 01' 23.3832" S	28476	28478.5	
180	30° 22' 53.4396" E	27° 01' 23.2140" S	28476	28480.5	
190	30° 22' 53.1264" E	27° 01' 23.0340" S	28486	28475.75	
200	30° 22' 52.8024" E	27° 01' 22.8792" S	28474	28470.25	
210	30° 22' 52.4640" E	27° 01' 22.7676" S	28469	28473	
220	30° 22' 52.1328" E	27° 01' 22.6272" S	28469	28483.5	
230	30° 22' 51.8160" E	27° 01' 22.4796" S	28485	28497.75	
240	30° 22' 51.5316" E	27° 01' 22.3032" S	28495	28518.25	
250	30° 22' 51.2472" E	27° 01' 22.1232" S	28516	28538.5	
260	30° 22' 50.9484" E	27° 01' 21.9468" S	28546	28533.25	
270	30° 22' 50.6136" E	27° 01' 21.7920" S	28546	28507.75	
280	30° 22' 50.3220" E	27° 01' 21.6660" S	28495	28491.25	
290	30° 22' 49.9620" E	27° 01' 21.5148" S	28495	28486.75	
300	30° 22' 49.6884" E	27° 01' 21.3492" S	28480	28486	
310	30° 22' 49.4076" E	27° 01' 21.2340" S	28492	28486	
320	30° 22' 49.0800" E	27° 01' 21.0684" S	28480	28489.25	
330	30° 22' 48.7848" E	27° 01' 20.9172" S	28492	28494.25	
340	30° 22' 48.4752" E	27° 01' 20.8308" S	28493	28500.5	
350	30° 22' 48.1584" E	27° 01' 20.7192" S	28499	28508	
360	30° 22' 47.8488" E	27° 01' 20.5644" S	28511	28513.5	
370	30° 22' 47.5356" E	27° 01' 20.4204" S	28511	28521.5	
380	30° 22' 47.2080" E	27° 01' 20.2692" S	28521	28530.25	
390	30° 22' 46.8984" E	27° 01' 20.1540" S	28533	28533.75	
400	30° 22' 46.5672" E	27° 01' 20.0100" S	28534	28536	
410	30° 22' 46.2720" E	27° 01' 19.8552" S	28534	28541.5	
420	30° 22' 45.9696" E	27° 01' 19.6968" S	28542	28545	
430	30° 22' 45.7032" E	27° 01' 19.5456" S	28548	28541.75	
440	30° 22' 45.4008" E	27° 01' 19.3836" S	28542	28532.5	
450	30° 22' 45.1128" E	27° 01' 19.2036" S	28535	28521.25	
460	30° 22' 44.8572" E	27° 01' 19.0740" S	28518	28515	

470	30° 22' 44.5368" E	27° 01' 18.9012" S	28514	28514	
480	30° 22' 44.2452" E	27° 01' 18.7500" S	28514	28513.25	
490	30° 22' 43.9680" E	27° 01' 18.6312" S	28514	28511.75	
500	30° 22' 43.6944" E	27° 01' 18.4728" S	28511	28511	
510	30° 22' 43.4316" E	27° 01' 18.2928" S	28511	28506.75	
520	30° 22' 43.1148" E	27° 01' 18.1092" S	28511	27686.25	
530	30° 22' 42.8628" E	27° 01' 17.9472" S	28494	26058	
540	30° 22' 42.5604" E	27° 01' 17.8176" S	25246	25449	
550	30° 22' 42.3012" E	27° 01' 17.6736" S	25246	19340.5	
560	30° 22' 42.0312" E	27° 01' 17.4936" S	26058	6514.5	

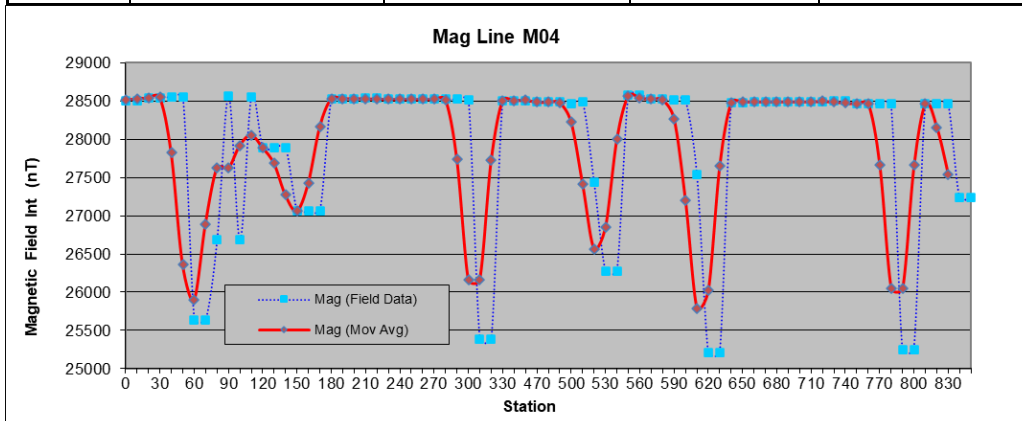


LINE 4

Project:	Kangra Maquasa	Traverse Number:	Line4
Project Number:	22-0161	Traverse Direction:	SSW-NNE
Survey Area:	Maquasa East	Station Spacing:	10 m
Date of Survey:	11 October 2022	Operator:	Shuaib Dustay & Martin Ngubana

Station	Station Coordinates		Mag		Comments
Station	Latitude (y)	Longitude (x)	Mag	Mag (Moving Average)	
0	30° 22' 42.5928" E	27° 01' 18.0120" S	28509	28517.75	
10	30° 22' 42.7872" E	27° 01' 17.7096" S	28509	28535.25	
20	30° 22' 42.8988" E	27° 01' 17.3676" S	28544	28547.25	
30	30° 22' 42.9888" E	27° 01' 17.0940" S	28544	28553.75	
40	30° 22' 43.0572" E	27° 01' 16.7700" S	28557	27826	
50	30° 22' 43.1904" E	27° 01' 16.4892" S	28557	26364	
60	30° 22' 43.3092" E	27° 01' 16.1868" S	25633	25895.75	
70	30° 22' 43.3956" E	27° 01' 15.8808" S	25633	26891.75	
80	30° 22' 43.4856" E	27° 01' 15.5784" S	26684	27625	
90	30° 22' 43.6044" E	27° 01' 15.2904" S	28566	27622.25	
100	30° 22' 43.7376" E	27° 01' 14.9988" S	26684	27921.75	
110	30° 22' 43.8780" E	27° 01' 14.7036" S	28555	28058.5	
120	30° 22' 43.9824" E	27° 01' 14.4408" S	27893	27893	
130	30° 22' 44.0724" E	27° 01' 14.1168" S	27893	27686	
140	30° 22' 44.2020" E	27° 01' 13.8468" S	27893	27272	
150	30° 22' 44.3388" E	27° 01' 13.5552" S	27065	27065	
160	30° 22' 44.4468" E	27° 01' 13.2636" S	27065	27432	
170	30° 22' 44.5404" E	27° 01' 12.9756" S	27065	28166	
180	30° 22' 44.6052" E	27° 01' 12.7344" S	28533	28533	
190	30° 22' 44.7240" E	27° 01' 12.4356" S	28533	28534	
200	30° 22' 44.8356" E	27° 01' 12.1296" S	28533	28536	
210	30° 22' 44.9328" E	27° 01' 11.8524" S	28537	28534	
220	30° 22' 45.0048" E	27° 01' 11.5788" S	28537	28528	
230	30° 22' 45.0876" E	27° 01' 11.3160" S	28525	28525	
240	30° 22' 45.1668" E	27° 01' 11.0208" S	28525	28525	
250	30° 22' 45.2280" E	27° 01' 10.6968" S	28525	28525	
260	30° 22' 45.2964" E	27° 01' 10.3836" S	28525	28525	
270	30° 22' 45.4188" E	27° 01' 10.0740" S	28525	28524.75	
280	30° 22' 45.5160" E	27° 01' 09.7932" S	28525	28523	
290	30° 22' 45.6240" E	27° 01' 09.4764" S	28524	27736.25	
300	30° 22' 45.7140" E	27° 01' 09.1668" S	28519	26167	
310	30° 22' 45.8364" E	27° 01' 08.8176" S	25383	26164.5	
320	30° 22' 45.9372" E	27° 01' 08.5008" S	25383	27727.5	
330	30° 22' 46.0164" E	27° 01' 08.1912" S	28509	28509.25	
340	30° 22' 46.1208" E	27° 01' 07.9176" S	28509	28510.5	
350	30° 22' 46.3656" E	27° 01' 07.4568" S	28510	28512.5	
360	30° 22' 46.5492" E	27° 01' 07.1616" S	28513	28513.5	
370	30° 22' 46.6284" E	27° 01' 06.8736" S	28514	28513.25	
380	30° 22' 46.7364" E	27° 01' 06.6036" S	28513	28511.75	
390	30° 22' 46.8660" E	27° 01' 06.2796" S	28513	28506.5	
400	30° 22' 46.9848" E	27° 01' 05.9952" S	28508	28498.75	
410	30° 22' 47.0892" E	27° 01' 05.7144" S	28497	28493.75	
420	30° 22' 47.2116" E	27° 01' 05.4192" S	28493	27964	
430	30° 22' 47.2584" E	27° 01' 05.1384" S	28492	26907.25	

440	30° 22' 47.3844" E	27° 01' 04.8540" S	26379	26904.25	
450	30° 22' 47.4888" E	27° 01' 04.5696" S	26379	27957.5	
460	30° 22' 47.6076" E	27° 01' 04.2852" S	28480	28488.25	
470	30° 22' 47.6940" E	27° 01' 03.9756" S	28491	28491	
480	30° 22' 47.8200" E	27° 01' 03.6876" S	28491	28486.5	
490	30° 22' 47.9208" E	27° 01' 03.4104" S	28491	28481.75	
500	30° 22' 48.0324" E	27° 01' 03.1260" S	28473	28224.5	
510	30° 22' 48.1188" E	27° 01' 02.8668" S	28490	27413.75	
520	30° 22' 48.2592" E	27° 01' 02.5572" S	27445	26567.5	
530	30° 22' 48.3600" E	27° 01' 02.3124" S	26275	26852.5	
540	30° 22' 48.4284" E	27° 01' 01.9956" S	26275	28007.5	
550	30° 22' 48.4932" E	27° 01' 01.7220" S	28585	28572.75	
560	30° 22' 48.6012" E	27° 01' 01.4268" S	28585	28545.5	
570	30° 22' 48.7056" E	27° 01' 01.1568" S	28536	28525.5	
580	30° 22' 48.7920" E	27° 01' 00.8580" S	28525	28518	
590	30° 22' 48.9144" E	27° 01' 00.5448" S	28516	28272.75	
600	30° 22' 49.0296" E	27° 01' 00.2676" S	28515	27202.25	
610	30° 22' 49.1268" E	27° 00' 59.9544" S	27545	25789.25	
620	30° 22' 49.2132" E	27° 00' 59.6844" S	25204	26021.75	
630	30° 22' 49.2708" E	27° 00' 59.3820" S	25204	27658.5	
640	30° 22' 49.3248" E	27° 00' 59.0832" S	28475	28482.5	
650	30° 22' 49.4292" E	27° 00' 58.7664" S	28480	28491.25	
660	30° 22' 49.5012" E	27° 00' 58.4928" S	28495	28495	
670	30° 22' 49.5804" E	27° 00' 58.2048" S	28495	28494.25	
680	30° 22' 49.6884" E	27° 00' 57.9456" S	28495	28492.75	
690	30° 22' 49.8432" E	27° 00' 57.7008" S	28492	28492	
700	30° 22' 50.0088" E	27° 00' 57.4452" S	28492	28492.5	
710	30° 22' 50.1636" E	27° 00' 57.1824" S	28492	28495	
720	30° 22' 50.2968" E	27° 00' 56.8800" S	28494	28498.5	
730	30° 22' 50.4372" E	27° 00' 56.5884" S	28500	28492	
740	30° 22' 50.5272" E	27° 00' 56.2860" S	28500	28476	
750	30° 22' 50.6028" E	27° 00' 55.9800" S	28468	28467.25	
760	30° 22' 50.6640" E	27° 00' 55.6848" S	28468	28465.75	
770	30° 22' 50.6784" E	27° 00' 55.3464" S	28465	27661.25	
780	30° 22' 50.6820" E	27° 00' 55.0440" S	28465	26053.75	
790	30° 22' 50.6856" E	27° 00' 54.7524" S	25250	26053.5	
800	30° 22' 50.7288" E	27° 00' 54.4428" S	25250	27661.5	
810	30° 22' 50.7900" E	27° 00' 54.1404" S	28464	28466	
820	30° 22' 50.9232" E	27° 00' 53.8416" S	28468	28157.75	
830	30° 22' 50.9844" E	27° 00' 53.5716" S	28464	27542.25	
840	30° 22' 51.0780" E	27° 00' 53.2548" S	27235	20426.25	
850	30° 22' 51.1428" E	27° 00' 52.9668" S	27235	6808.75	

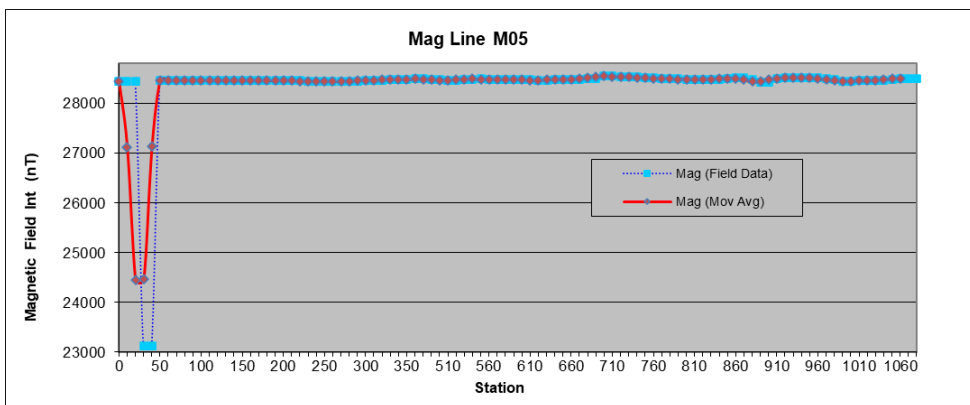


LINE 5

Project:	Kangra Maquasa	Traverse Number:	Line 5
Project Number:	22-0161	Traverse Direction:	NNE-SSW
Survey Area:	Maquasa East	Station Spacing:	10 m
Date of Survey:	11 October 2022	Operator:	Shuaib Dustay & Martin Ngubana

Station	Station Coordinates		Mag	Mag	Comments
	Latitude (y)	Longitude (x)		Mag (Moving Average)	
0	30° 22' 52.3884" E	27° 00' 53.8632" S	28454	28451	
10	30° 22' 52.4172" E	27° 00' 53.6220" S	28450	27118.25	
20	30° 22' 52.5576" E	27° 00' 53.3448" S	28450	24454.75	
30	30° 22' 52.7196" E	27° 00' 53.0640" S	23123	24458.25	
40	30° 22' 52.8996" E	27° 00' 52.8120" S	23123	27129.75	
50	30° 22' 53.0616" E	27° 00' 52.5636" S	28464	28466.5	
60	30° 22' 53.2560" E	27° 00' 52.2972" S	28468	28466.5	
70	30° 22' 53.3712" E	27° 00' 52.0092" S	28466	28466	
80	30° 22' 53.4864" E	27° 00' 51.7248" S	28466	28464	
90	30° 22' 53.6340" E	27° 00' 51.4296" S	28466	28462.5	
100	30° 22' 53.7132" E	27° 00' 51.1488" S	28458	28463	
110	30° 22' 53.8068" E	27° 00' 50.8788" S	28468	28461.75	
120	30° 22' 53.9040" E	27° 00' 50.5692" S	28458	28461.75	
130	30° 22' 54.0048" E	27° 00' 50.3280" S	28463	28463	
140	30° 22' 54.1056" E	27° 00' 49.9968" S	28463	28463	
150	30° 22' 54.1884" E	27° 00' 49.7340" S	28463	28461.25	
160	30° 22' 54.2892" E	27° 00' 49.4352" S	28463	28457.75	
170	30° 22' 54.3864" E	27° 00' 49.1544" S	28456	28456.5	
180	30° 22' 54.4872" E	27° 00' 48.8772" S	28456	28459	
190	30° 22' 54.6024" E	27° 00' 48.6072" S	28458	28462.5	
200	30° 22' 54.7428" E	27° 00' 48.3408" S	28464	28464	
210	30° 22' 54.8796" E	27° 00' 48.0708" S	28464	28460.5	
220	30° 22' 54.9336" E	27° 00' 47.7684" S	28464	28451.25	
230	30° 22' 55.0596" E	27° 00' 47.4804" S	28450	28443.25	
240	30° 22' 55.1748" E	27° 00' 47.2176" S	28441	28440.5	
250	30° 22' 55.2648" E	27° 00' 46.9008" S	28441	28439.5	
260	30° 22' 55.3620" E	27° 00' 46.6380" S	28439	28439	
270	30° 22' 55.4916" E	27° 00' 46.3392" S	28439	28440.5	
280	30° 22' 55.6032" E	27° 00' 46.0512" S	28439	28448.5	
290	30° 22' 55.7436" E	27° 00' 45.7560" S	28445	28461.75	
300	30° 22' 55.8408" E	27° 00' 45.5292" S	28465	28468.75	
310	30° 22' 55.9632" E	27° 00' 45.2160" S	28472	28469.25	
320	30° 22' 56.1216" E	27° 00' 44.9136" S	28466	28472.5	
330	30° 22' 56.2296" E	27° 00' 44.6436" S	28473	28476.75	
340	30° 22' 56.3592" E	27° 00' 44.3664" S	28478	28478	
350	30° 22' 56.4348" E	27° 00' 44.0820" S	28478	28477.25	
360	30° 22' 56.5572" E	27° 00' 43.7904" S	28478	28483	
370	30° 22' 56.6760" E	27° 00' 43.5132" S	28475	28485.25	
380	30° 22' 56.7732" E	27° 00' 43.2036" S	28504	28456.25	
390	30° 22' 56.8812" E	27° 00' 42.9300" S	28458	28418	
400	30° 22' 56.9640" E	27° 00' 42.6420" S	28405	28404.25	
410	30° 22' 57.0720" E	27° 00' 42.3216" S	28404	28420.75	
420	30° 22' 57.1836" E	27° 00' 42.0192" S	28404	28497	
430	30° 22' 57.2844" E	27° 00' 41.7312" S	28471	28599.25	
440	30° 22' 57.4032" E	27° 00' 41.4612" S	28642	28611.5	
450	30° 22' 57.4680" E	27° 00' 41.1588" S	28642	28544.25	
460	30° 22' 57.5796" E	27° 00' 40.8996" S	28520	28501.25	
470	30° 22' 57.7020" E	27° 00' 40.6440" S	28495	28493.75	
480	30° 22' 57.8136" E	27° 00' 40.3200" S	28495	28489.5	
490	30° 22' 57.9360" E	27° 00' 40.0536" S	28490	28480.5	
500	30° 22' 58.0404" E	27° 00' 39.7728" S	28483	28470.25	
510	30° 22' 58.1520" E	27° 00' 39.5388" S	28466	28471	
520	30° 22' 58.3788" E	27° 00' 39.3048" S	28466	28481	
530	30° 22' 58.5768" E	27° 00' 39.0780" S	28486	28488	
540	30° 22' 58.7496" E	27° 00' 38.8260" S	28486	28490.75	
550	30° 22' 58.9548" E	27° 00' 38.5992" S	28494	28490.25	
560	30° 22' 59.1852" E	27° 00' 38.3904" S	28489	28487.5	
570	30° 22' 59.3652" E	27° 00' 38.1780" S	28489	28484.5	
580	30° 22' 59.5488" E	27° 00' 37.9440" S	28483	28483	

590	30° 22' 59.7180" E	27° 00' 37.6884" S	28483	28482	
600	30° 22' 59.9196" E	27° 00' 37.4508" S	28483	28475.25	
610	30° 23' 00.1104" E	27° 00' 37.2564" S	28479	28464.75	
620	30° 23' 00.3012" E	27° 00' 37.0044" S	28460	28464.75	
630	30° 23' 00.4704" E	27° 00' 36.7164" S	28460	28475.5	
640	30° 23' 00.6216" E	27° 00' 36.4968" S	28479	28482.75	
650	30° 23' 00.7800" E	27° 00' 36.2592" S	28484	28484	
660	30° 23' 00.9312" E	27° 00' 35.9928" S	28484	28487	
670	30° 23' 01.0860" E	27° 00' 35.7120" S	28484	28495.75	
680	30° 23' 01.2480" E	27° 00' 35.4204" S	28496	28514	
690	30° 23' 01.3884" E	27° 00' 35.1576" S	28507	28536.25	
700	30° 23' 01.5504" E	27° 00' 34.8804" S	28546	28545.5	
710	30° 23' 01.7016" E	27° 00' 34.6176" S	28546	28542	
720	30° 23' 01.8240" E	27° 00' 34.3260" S	28544	28534.75	
730	30° 23' 01.9788" E	27° 00' 34.0524" S	28534	28527.5	
740	30° 23' 02.1120" E	27° 00' 33.7752" S	28527	28521.75	
750	30° 23' 02.2452" E	27° 00' 33.5196" S	28522	28515.25	
760	30° 23' 02.3640" E	27° 00' 33.2280" S	28516	28508.5	
770	30° 23' 02.4864" E	27° 00' 32.9328" S	28507	28504	
780	30° 23' 02.6772" E	27° 00' 32.6412" S	28504	28498.25	
790	30° 23' 02.7924" E	27° 00' 32.3568" S	28501	28490.5	
800	30° 23' 02.9220" E	27° 00' 32.0832" S	28487	28487.5	
810	30° 23' 03.0948" E	27° 00' 31.8312" S	28487	28488.5	
820	30° 23' 03.2496" E	27° 00' 31.5288" S	28489	28489	
830	30° 23' 03.3792" E	27° 00' 31.2408" S	28489	28490.5	
840	30° 23' 03.5232" E	27° 00' 30.9492" S	28489	28497.5	
850	30° 23' 03.7176" E	27° 00' 30.7008" S	28495	28507	
860	30° 23' 03.8940" E	27° 00' 30.4092" S	28511	28503.25	
870	30° 23' 04.0740" E	27° 00' 30.1068" S	28511	28473.75	
880	30° 23' 04.2360" E	27° 00' 29.8368" S	28480	28438	
890	30° 23' 04.3620" E	27° 00' 29.5812" S	28424	28441.25	
900	30° 23' 04.4952" E	27° 00' 29.2356" S	28424	28480	
910	30° 23' 04.6392" E	27° 00' 28.9728" S	28493	28507.5	
920	30° 23' 04.7544" E	27° 00' 28.6812" S	28510	28515.25	
930	30° 23' 04.8552" E	27° 00' 28.3428" S	28517	28517	
940	30° 23' 04.9308" E	27° 00' 28.0476" S	28517	28517	
950	30° 23' 05.0496" E	27° 00' 27.8028" S	28517	28511.25	
960	30° 23' 05.1936" E	27° 00' 27.5076" S	28517	28497.5	
970	30° 23' 05.3268" E	27° 00' 27.2520" S	28494	28477.75	
980	30° 23' 05.4564" E	27° 00' 26.9460" S	28485	28456.5	
990	30° 23' 05.5608" E	27° 00' 26.6580" S	28447	28449	
1000	30° 23' 05.6616" E	27° 00' 26.3628" S	28447	28453.25	
1010	30° 23' 05.8092" E	27° 00' 26.0748" S	28455	28455.75	
1020	30° 23' 05.9424" E	27° 00' 25.8300" S	28456	28456	
1030	30° 23' 06.1332" E	27° 00' 25.5492" S	28456	28464.5	
1040	30° 23' 06.2700" E	27° 00' 25.2468" S	28456	28482	
1050	30° 23' 06.4284" E	27° 00' 24.9516" S	28490	28495	
1060	30° 23' 06.5724" E	27° 00' 24.6672" S	28492	28502.5	
1070	30° 23' 06.7236" E	27° 00' 24.3900" S	28506	21379.5	
1080	30° 23' 06.8712" E	27° 00' 24.1380" S	28506	7126.5	

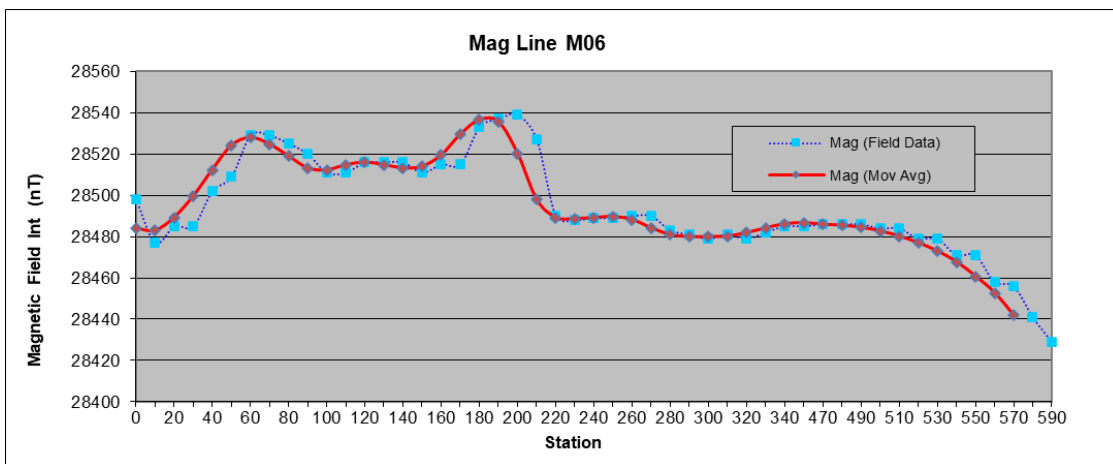


LINE 6

Project:	Kangra Maquasa	Traverse Number:	Line 6
Project Number:	22-0161	Traverse Direction:	W-E
Survey Area:	Maquasa East	Station Spacing:	10 m
Date of Survey:	11 October 2022	Operator:	Shuaib Dustay & Martin Ngubana

Station	Station Coordinates		Mag		Comments
Station	Latitude (y)	Longitude (x)	Mag	Mag (Moving Average)	
0	30° 23' 08.1708" E	27° 00' 21.3516" S	28498	28484.25	
10	30° 23' 08.4948" E	27° 00' 21.4776" S	28477	28483	
20	30° 23' 08.8584" E	27° 00' 21.5352" S	28485	28489.25	
30	30° 23' 09.2148" E	27° 00' 21.4740" S	28485	28499.5	
40	30° 23' 09.5568" E	27° 00' 21.4560" S	28502	28512.25	
50	30° 23' 09.8736" E	27° 00' 21.3804" S	28509	28524	
60	30° 23' 10.1904" E	27° 00' 21.2544" S	28529	28528	
70	30° 23' 10.5324" E	27° 00' 21.0960" S	28529	28524.75	
80	30° 23' 10.8312" E	27° 00' 20.9484" S	28525	28519	
90	30° 23' 11.1336" E	27° 00' 20.8224" S	28520	28513.25	
100	30° 23' 11.4648" E	27° 00' 20.7036" S	28511	28512.25	
110	30° 23' 11.7456" E	27° 00' 20.5092" S	28511	28514.75	
120	30° 23' 12.0696" E	27° 00' 20.3796" S	28516	28516	
130	30° 23' 12.3936" E	27° 00' 20.2608" S	28516	28514.75	
140	30° 23' 12.6960" E	27° 00' 20.1636" S	28516	28513.25	
150	30° 23' 13.0308" E	27° 00' 20.1456" S	28511	28514	
160	30° 23' 13.3404" E	27° 00' 20.0700" S	28515	28519.5	
170	30° 23' 13.6860" E	27° 00' 20.0340" S	28515	28529.5	
180	30° 23' 14.0496" E	27° 00' 19.9800" S	28533	28536.5	
190	30° 23' 14.3808" E	27° 00' 19.8756" S	28537	28535.5	
200	30° 23' 14.7264" E	27° 00' 19.7892" S	28539	28520.25	
210	30° 23' 15.0756" E	27° 00' 19.6956" S	28527	28498	
220	30° 23' 15.4320" E	27° 00' 19.6704" S	28490	28489.25	
230	30° 23' 15.7740" E	27° 00' 19.6128" S	28488	28488.75	
240	30° 23' 16.1088" E	27° 00' 19.5444" S	28489	28489.25	
250	30° 23' 16.4508" E	27° 00' 19.4760" S	28489	28489.75	
260	30° 23' 16.7676" E	27° 00' 19.3968" S	28490	28488.25	
270	30° 23' 17.1024" E	27° 00' 19.3068" S	28490	28484.25	
280	30° 23' 17.4516" E	27° 00' 19.2024" S	28483	28481	
290	30° 23' 17.7684" E	27° 00' 19.1268" S	28481	28480	
300	30° 23' 18.1032" E	27° 00' 19.0152" S	28479	28480	
310	30° 23' 18.4092" E	27° 00' 18.9648" S	28481	28480.25	
320	30° 23' 18.7800" E	27° 00' 18.8712" S	28479	28482	
330	30° 23' 19.0716" E	27° 00' 18.7488" S	28482	28484.25	
340	30° 23' 19.3380" E	27° 00' 18.6084" S	28485	28486.25	
350	30° 23' 19.6224" E	27° 00' 18.5112" S	28485	28486.75	
360	30° 23' 19.9248" E	27° 00' 18.4932" S	28490	28482.75	
370	30° 23' 20.2380" E	27° 00' 18.4572" S	28482	28477	
380	30° 23' 20.5656" E	27° 00' 18.4104" S	28477	28473.25	
390	30° 23' 20.9040" E	27° 00' 18.3636" S	28472	28474.25	
400	30° 23' 21.2208" E	27° 00' 18.2880" S	28472	28479.25	
410	30° 23' 21.5556" E	27° 00' 18.2592" S	28481	28482.5	
420	30° 23' 21.8328" E	27° 00' 18.1764" S	28483	28484.25	
430	30° 23' 22.1136" E	27° 00' 18.0612" S	28483	28486.75	
440	30° 23' 22.4340" E	27° 00' 18.0324" S	28488	28488	
450	30° 23' 22.7544" E	27° 00' 18.0108" S	28488	28487.5	

460	30° 23' 23.0820" E	27° 00' 18.0000" S	28488	28486.5	
470	30° 23' 23.3952" E	27° 00' 17.9604" S	28486	28486	
480	30° 23' 23.7228" E	27° 00' 17.8776" S	28486	28485.5	
490	30° 23' 24.0216" E	27° 00' 17.8416" S	28486	28484.5	
500	30° 23' 24.2952" E	27° 00' 17.6904" S	28484	28482.75	
510	30° 23' 24.5652" E	27° 00' 17.5752" S	28484	28480.25	
520	30° 23' 24.7524" E	27° 00' 17.4132" S	28479	28477	
530	30° 23' 25.0188" E	27° 00' 17.3088" S	28479	28473	
540	30° 23' 25.3572" E	27° 00' 17.2368" S	28471	28467.75	
550	30° 23' 25.6776" E	27° 00' 17.1648" S	28471	28460.75	
560	30° 23' 25.9908" E	27° 00' 17.0784" S	28458	28452.75	
570	30° 23' 26.3112" E	27° 00' 16.9776" S	28456	28441.75	
580	30° 23' 26.6892" E	27° 00' 16.8552" S	28441	21324.75	
590	30° 23' 26.9772" E	27° 00' 16.7832" S	28429	7107.25	

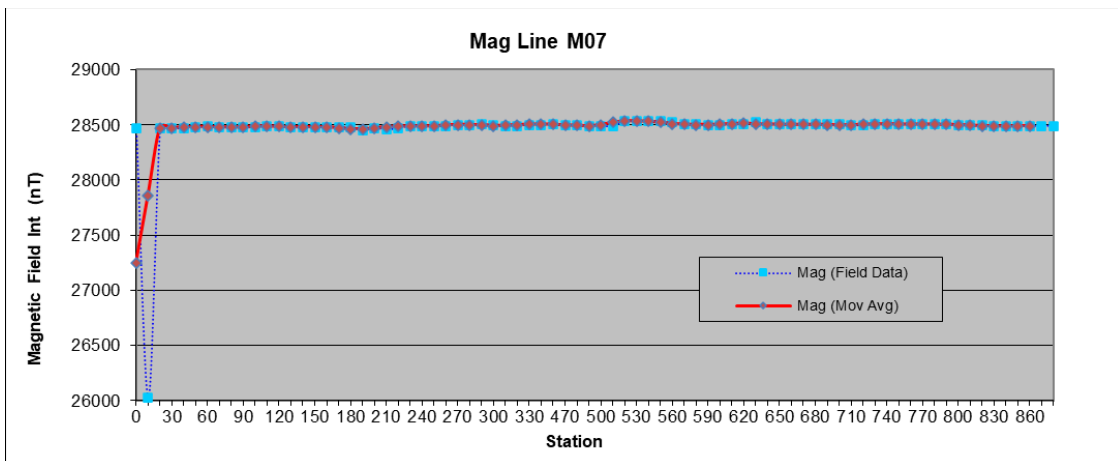


LINE 7

Project:	Kangra Maquasa	Traverse Number:	Line 6
Project Number:	22-0161	Traverse Direction:	SW-NE
Survey Area:	Maquasa East	Station Spacing:	10 m
Date of Survey:	11 October 2022	Operator:	Shuaib Dustay & Martin Ngubana

Station	Station Coordinates		Mag		Comments
	Latitude (y)	Longitude (x)	Mag	Mag (Moving Average)	
0	30° 22' 58.5660" E	27° 01' 25.6908" S	28467	27248.5	
10	30° 22' 58.8432" E	27° 01' 25.5684" S	26030	27858.25	
20	30° 22' 59.0772" E	27° 01' 25.4568" S	28467	28468.5	
30	30° 22' 59.3796" E	27° 01' 25.2300" S	28469	28472	
40	30° 22' 59.6100" E	27° 01' 25.1472" S	28469	28478.75	
50	30° 22' 59.8152" E	27° 01' 24.9636" S	28481	28482.5	
60	30° 23' 00.0528" E	27° 01' 24.8412" S	28484	28481	
70	30° 23' 00.3624" E	27° 01' 24.6648" S	28481	28477.75	
80	30° 23' 00.6288" E	27° 01' 24.4956" S	28478	28476	
90	30° 23' 00.9168" E	27° 01' 24.3444" S	28474	28479.75	
100	30° 23' 01.1616" E	27° 01' 24.1932" S	28478	28486.25	
110	30° 23' 01.4568" E	27° 01' 24.0276" S	28489	28487.25	
120	30° 23' 01.7304" E	27° 01' 23.8548" S	28489	28483	
130	30° 23' 01.9896" E	27° 01' 23.7036" S	28482	28479.75	
140	30° 23' 02.2884" E	27° 01' 23.5560" S	28479	28479	
150	30° 23' 02.5116" E	27° 01' 23.3796" S	28479	28479	
160	30° 23' 02.7312" E	27° 01' 23.2896" S	28479	28479.25	
170	30° 23' 02.9832" E	27° 01' 23.1600" S	28479	28471.5	
180	30° 23' 03.2244" E	27° 01' 23.0016" S	28480	28461	
190	30° 23' 03.4836" E	27° 01' 22.8720" S	28447	28460.75	
200	30° 23' 03.7392" E	27° 01' 22.7244" S	28470	28468.25	
210	30° 23' 03.9732" E	27° 01' 22.5516" S	28456	28482.25	
220	30° 23' 04.2900" E	27° 01' 22.3680" S	28470	28484	
230	30° 23' 04.5600" E	27° 01' 22.1952" S	28491	28489.25	
240	30° 23' 04.8516" E	27° 01' 22.0188" S	28491	28485.75	
250	30° 23' 05.1000" E	27° 01' 21.8712" S	28484	28488	
260	30° 23' 05.3772" E	27° 01' 21.7056" S	28484	28496	
270	30° 23' 05.6256" E	27° 01' 21.5328" S	28500	28500.5	
280	30° 23' 05.9064" E	27° 01' 21.3492" S	28500	28500	
290	30° 23' 06.2196" E	27° 01' 21.2052" S	28502	28496	
300	30° 23' 06.5292" E	27° 01' 21.0360" S	28496	28491.5	
310	30° 23' 06.8100" E	27° 01' 20.8704" S	28490	28492.75	
320	30° 23' 07.0656" E	27° 01' 20.7048" S	28490	28498.25	
330	30° 23' 07.3608" E	27° 01' 20.5392" S	28501	28502.25	
340	30° 23' 07.6128" E	27° 01' 20.3880" S	28501	28504.25	
350	30° 23' 07.8900" E	27° 01' 20.2044" S	28506	28504.5	
360	30° 23' 08.0880" E	27° 01' 19.9884" S	28504	28503.5	
370	30° 23' 08.3904" E	27° 01' 19.8696" S	28504	28502.25	
380	30° 23' 08.6676" E	27° 01' 19.7400" S	28502	28501.25	
390	30° 23' 08.9700" E	27° 01' 19.5708" S	28501	28498.5	
400	30° 23' 09.2724" E	27° 01' 19.4304" S	28501	28493.5	
410	30° 23' 09.5244" E	27° 01' 19.2576" S	28491	28491.25	
420	30° 23' 09.8376" E	27° 01' 19.0884" S	28491	28491.75	
430	30° 23' 10.1184" E	27° 01' 18.9552" S	28492	28491.5	
440	30° 23' 10.4136" E	27° 01' 18.8220" S	28492	28490.5	
450	30° 23' 10.7304" E	27° 01' 18.6708" S	28490	28491.25	
460	30° 23' 11.0040" E	27° 01' 18.4944" S	28490	28493.75	
470	30° 23' 11.2776" E	27° 01' 18.3000" S	28495	28494.25	
480	30° 23' 11.5800" E	27° 01' 18.1416" S	28495	28492.75	
490	30° 23' 11.8212" E	27° 01' 17.9580" S	28492	28490.25	
500	30° 23' 12.0624" E	27° 01' 17.7816" S	28492	28498.75	
510	30° 23' 12.3576" E	27° 01' 17.5800" S	28485	28521	
520	30° 23' 12.5952" E	27° 01' 17.4540" S	28533	28533	
530	30° 23' 12.8868" E	27° 01' 17.2776" S	28533	28533	
540	30° 23' 13.1532" E	27° 01' 17.1300" S	28533	28530	
550	30° 23' 13.4268" E	27° 01' 16.9428" S	28533	28521	
560	30° 23' 13.6860" E	27° 01' 16.7556" S	28521	28510.25	
570	30° 23' 13.9632" E	27° 01' 16.6116" S	28509	28503.25	

580	30° 23' 14.2548" E	27° 01' 16.4532" S	28502	28500.5	
590	30° 23' 14.5248" E	27° 01' 16.2768" S	28500	28500.75	
600	30° 23' 14.7768" E	27° 01' 16.1328" S	28500	28502.25	
610	30° 23' 15.0792" E	27° 01' 15.9708" S	28503	28507.5	
620	30° 23' 15.3564" E	27° 01' 15.8304" S	28503	28511.75	
630	30° 23' 15.6408" E	27° 01' 15.6900" S	28521	28507	
640	30° 23' 15.9288" E	27° 01' 15.5316" S	28502	28502.5	
650	30° 23' 16.1844" E	27° 01' 15.3696" S	28503	28502.25	
660	30° 23' 16.4292" E	27° 01' 15.1896" S	28502	28502	
670	30° 23' 16.6956" E	27° 01' 15.0132" S	28502	28502	
680	30° 23' 16.9656" E	27° 01' 14.8476" S	28502	28502	
690	30° 23' 17.2356" E	27° 01' 14.7108" S	28502	28500	
700	30° 23' 17.5632" E	27° 01' 14.5344" S	28502	28496	
710	30° 23' 17.8656" E	27° 01' 14.4444" S	28494	28497	
720	30° 23' 18.1536" E	27° 01' 14.2788" S	28494	28503	
730	30° 23' 18.3984" E	27° 01' 14.0916" S	28506	28505.75	
740	30° 23' 18.6324" E	27° 01' 13.9332" S	28506	28505.25	
750	30° 23' 18.8952" E	27° 01' 13.7496" S	28505	28504.75	
760	30° 23' 19.1616" E	27° 01' 13.5912" S	28505	28504.25	
770	30° 23' 19.2948" E	27° 01' 13.3464" S	28504	28504	
780	30° 23' 19.5576" E	27° 01' 13.1700" S	28504	28503.25	
790	30° 23' 19.7268" E	27° 01' 12.9612" S	28504	28501.75	
800	30° 23' 19.9752" E	27° 01' 12.7992" S	28501	28499	
810	30° 23' 20.2848" E	27° 01' 12.6876" S	28501	28494.25	
820	30° 23' 20.6340" E	27° 01' 12.6120" S	28493	28490.25	
830	30° 23' 20.7600" E	27° 01' 12.3744" S	28490	28488.5	
840	30° 23' 20.9904" E	27° 01' 12.1908" S	28488	28488	
850	30° 23' 21.2712" E	27° 01' 12.0432" S	28488	28488.25	
860	30° 23' 21.5376" E	27° 01' 11.8884" S	28488	28488.75	
870	30° 23' 21.7860" E	27° 01' 11.7192" S	28489	21366.75	
880	30° 23' 22.0236" E	27° 01' 11.6004" S	28489	7122.25	



APPENDIX C: LABORATORY CERTIFICATES



Test Report

Page 1 of 1

Client: Groundwater Consulting Services (GCS)
Address: 63 Wessel Road, Woodmead, 2191
Report no: 137167
Project: Kangra

Date of report: 19 October 2022
Date accepted: 10 October 2022
Date completed: 19 October 2022
Date received: 10 October 2022

Lab no:	185437	185438
Date sampled:	10-Oct-22	10-Oct-22
Aquatico sampled:	No	No
Sample type:	Geochem	Geochem
Locality description:	KSLURRY1	KDISCARD
Analyses		
	Unit	Method
N Paste pH (1:2)	pH	Geochem
N Net acid generation (NAG)	H2SO4 kg/t	Geochem
N NAGpH	pH	Geochem
N Total Sulphur	%	Geochem
N Sulphate Sulphur	%	Geochem
N Acid Potential based Total Sulphur	CaCO3 kg/t	Geochem
N Acid Potential based Sulphide Sulphur	CaCO3 kg/t	Geochem
N Neutralization Potential (NP)	CaCO3 kg/t	Geochem
N Net Neutralization Potential (NNP)	CaCO3 kg/t	Geochem
N NP / AP (TS)	-	Geochem
N NP / AP (SS)	-	Geochem
N Geo - Milling 75um	-	Geochem
N Sulphide Sulphur	%	Geochem

Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative test report
 Results relate only to the items sampled and tested ; Results reported against the limit of detection.
 The report shall not be reproduced except in full without approval of the laboratory
 The results apply to the sample received.

M. Swanepoel
 Technical Signatory



Test Report

Page 1 of 2

Client: Groundwater Consulting Services (GCS)
Address: 63 Wessel Road, Woodmead, 2191
Report no: 137169
Project: Kangra

Date of report: 17 October 2022
Date accepted: 10 October 2022
Date completed: 17 October 2022
Date received: 10 October 2022

Lab no:	185451	185452		
Date sampled:	10-Oct-22	10-Oct-22		
Aquatico sampled:	No	No		
Sample type:	Geochem	Geochem		
Locality description:	KDISCARD	KSLURRY1		
Analyses				
	Unit	Method		
N Geo - Reagent water Leach 1:20	-	Geochem	Yes	Yes
A pH @ 25°C	pH	ALM 20	8.10	8.11
A Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	55.4	91.5
A Total Alkalinity	mg CaCO ₃ /l	ALM 01	41.9	44.8
A Chloride (Cl)	mg/l	ALM 02	2.30	6.38
A Sulphate (SO ₄)	mg/l	ALM 03	220	421
A Orthophosphate (PO ₄) as P	mg/l	ALM 04	<0.005	<0.005
A Nitrate (NO ₃) as N	mg/l	ALM 06	<0.194	<0.194
A Calcium (Ca)	mg/l	ALM 30	90.0	106
A Magnesium (Mg)	mg/l	ALM 30	7.91	17.4
A Sodium (Na)	mg/l	ALM 30	6.19	57.3
A Potassium (K)	mg/l	ALM 30	6.58	8.28
A Aluminium (Al)	mg/l	ALM 31	<0.002	<0.002
A Iron (Fe)	mg/l	ALM 31	<0.004	<0.004
A Manganese (Mn)	mg/l	ALM 31	0.043	0.095
A Cadmium (Cd)	mg/l	ALM 31	<0.002	<0.002
A Cobalt (Co)	mg/l	ALM 31	<0.003	<0.003
A Chromium (Cr)	mg/l	ALM 31	<0.003	<0.003
A Copper (Cu)	mg/l	ALM 31	0.005	0.010
A Nickel (Ni)	mg/l	ALM 31	<0.002	<0.002
A Lead (Pb)	mg/l	ALM 31	<0.004	<0.004
A Zinc (Zn)	mg/l	ALM 31	<0.002	<0.002
A Boron (B)	mg/l	ALM 33	<0.013	<0.013
A Barium (Ba)	mg/l	ALM 33	0.066	0.054
A Beryllium (Be)	mg/l	ALM 33	<0.005	<0.005
A Vanadium (V)	mg/l	ALM 33	<0.001	<0.001
N Bismuth (Bi)	mg/l	ALM 32	0.011	0.015
N Silver (Ag)	mg/l	ALM 32	<0.001	<0.001

A = Accredited N = Non accredited Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative P = Pretoria K = K test report ; Results relate only to the items sampled and tested ; Results reported against the limit of detection; Results marked 'Non SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory; Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation; The report shall not be reproduced except in full without approval of the laboratory

M. Swanepoel
 Technical Signatory



Test Report

Client: Groundwater Consulting Services (GCS) **Date of report:** 17 October 2022
Address: 63 Wessel Road, Woodmead, 2191 **Date accepted:** 10 October 2022
Report no: 137169 **Date completed:** 17 October 2022
Project: Kangra **Date received:** 10 October 2022

Lab no:	185451	185452
Date sampled:	10-Oct-22	10-Oct-22
Aquatico sampled:	No	No
Sample type:	Geochem	Geochem
Locality description:	KDISCARD	KSLURRY1
Analyses		
	Unit	Method
N Gallium (Ga)	mg/l	ALM 32
N Lithium (Li)	mg/l	ALM 32
A Molybdenum (Mo)	mg/l	ALM 33
N Rubidium (Rb)	mg/l	ALM 32
A Strontium (Sr)	mg/l	ALM 33
N Tellurium (Te)	mg/l	ALM 32
N Thallium (Tl)	mg/l	ALM 32
A Total oxidised nitrogen as N	mg/l	ALM 06

A = Accredited N = Non accredited Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative P = Pretoria K = K test report ; Results relate only to the items sampled and tested ; Results reported against the limit of detection; Results marked 'Non SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory; Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation; The report shall not be reproduced except in full without approval of the laboratory

Authenticated signature on first page



leaders in environmental monitoring

address: 89 Regency drive, R21 Corporate Park, Centurion
postal: P.O. Box 905008, Garsfontein, 0042
web: www.aquatico.co.za
office: 012 450 3800 • fax: 012 450 3851

63 WESSEL ROAD
WOODMEAD
2191

ATTENTION: GROUNDWATER CONSULTING SERVICES (GCS)
17 OCTOBER 2022

Kangra
(TEST REPORT 137170)

Qualitative and quantitative XRD results

Geochem samples (2) were submitted to Aquatico Laboratories on **10 October 2022** for Rietveld analysis.

The material was milled and prepared for XRD analysis using a front-loading preparation method.

The samples were analysed with a PANalytical Empyrean diffractometer with X'Celerator detector and fixed slits with a Cu-K α radiation.

The phases were identified by using X'Pert Highscore plus software.

Comments:

- If the results in this report do not correspond to results of other analytical techniques, please contact us for further review of the XRD results.
- The mineral names in this report may not reflect the specific mineral identified, but rather the mineral group.
- Due to preferred orientation and crystallite size effects as well as small sample amounts, results may not be as accurate as shown.
- Small amounts of additional phases may be present.
- **It may be advisable to confirm results using alternative analytical techniques.**
- Amorphous phases, if present, were not taken into account during quantification.

If you have any further queries, please contact the laboratory.

Analyst
Paula Aucamp
BSc (Hons) Geology

Samples will be stored for 1 month after which it will be discarded



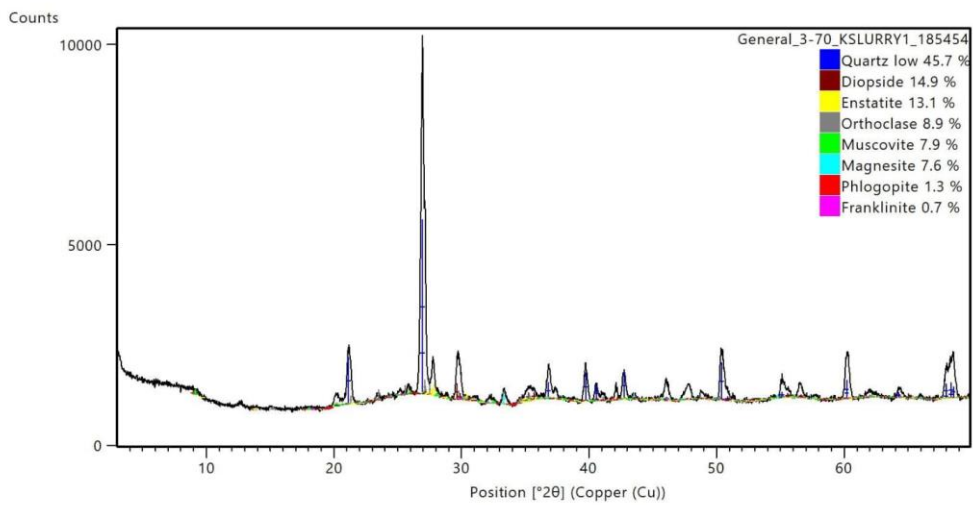
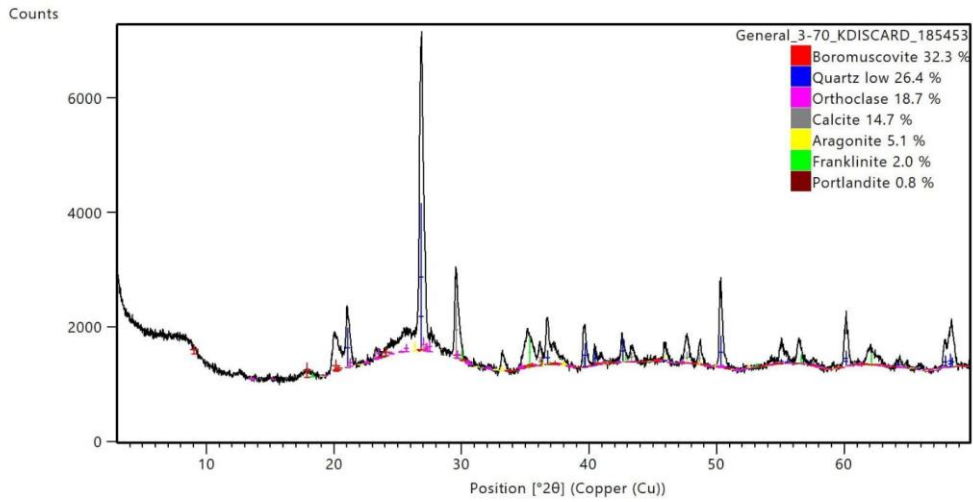
directors: R. Erdmann (CEO) • P.J. Noudé • T.B. Sefolo • L.E. Kolobe.
company registration number: 2006/028605/07. uat no: 4360195723.



leaders in environmental monitoring

address: 89 Regency drive, R21 Corporate Park, Centurion
 postal: P.O. Box 905008, Garsfontein, 0042
 web: www.aquatico.co.za
 office: 012 450 3800 • fax: 012 450 3851

Results:



directors: R. Erdmann (CEO) • P.J. Naudé • T.B. Sefolo • L.E. Kolobe.
 company registration number: 2006/028605/07. uat no: 4360195723.


leaders in environmental monitoring

address: 89 Regency drive, R21 Corporate Park, Centurion
 postal: P.O. Box 905008, Garsfontein, 0042
 web: www.aquatico.co.za
 office: 012 450 3800 • fax: 012 450 3851

Mineral description:

Mineral	Chemical formula	Description
Aragonite	CaCO ₃	Aragonite is a polymorph of the carbonate mineral calcite (i.e., the minerals have the same chemical formula but different crystal structures). Aragonite is stable under higher pressure conditions compared to calcite.
Calcite	CaCO ₃	Calcite is a carbonate mineral and one of the most common minerals in sedimentary, igneous and metamorphic rocks. Calcite is usually white in colour.
Diopside	MgCaSi ₂ O ₆	Diopside is a pyroxene mineral and belongs to the clinopyroxene sub-group. It is an important rock-forming mineral in mafic igneous rocks and can also be found in metamorphic rocks.
Enstatite	Mg ₂ Si ₂ O ₆	Enstatite is part of the pyroxene group of minerals and is a common rock forming mineral in ultramafic-mafic igneous rocks and metamorphic rocks. Enstatite belongs to the orthopyroxene subgroup and typically occurs as grey to greenish brown crystals.
Franklinite	ZnFe ₂ O ₄	Franklinite is a zinc iron oxide which is part of the spinel group of minerals. Similar to magnetite, franklinite can contain both ferric (Fe ³⁺) and ferrous (Fe ²⁺) iron with manganese commonly occurring together with zinc.
Magnesite	MgCO ₃	Magnesite is a whitish, brittle, magnesium carbonate mineral that is typically formed through the carbonation of ultramafic magnesium-rich rocks such as peridotite.
Muscovite	KAl ₂ (AlSi ₃ O ₁₀)(OH) ₂	Muscovite is a hydrated phyllosilicate mineral containing aluminium and potassium. It has a perfect basal cleavage yielding remarkably thin laminae (sheets) which are often highly elastic.
Orthoclase	KAlSi ₃ O ₈	Orthoclase is a potassium bearing feldspar. It has similar chemical composition to microcline. It commonly forms large well-shaped crystals in pegmatites, where it is associated with quartz, mica and other feldspars such as microcline and albite.
Phlogopite	KMg ₃ AlSi ₃ O ₁₀ (OH) ₂	Phlogopite is the magnesium-rich endmember of biotite. This micaceous mineral is typically found in ultra-mafic igneous rocks and metamorphosed clayey rocks like shale and mudstone.
Portlandite	Ca(OH) ₂	Portlandite is a calcium hydroxide mineral. This mineral is typically formed during the alteration of calcium silicate minerals in contact metamorphic zones and can also be found in burning coal measures.
Quartz	SiO ₂	Quartz is one of the most common minerals on Earth, and is present in many sedimentary, igneous and metamorphic rocks.



directors: R. Erdmann (CEO) • P.J. Naudé • T.B. Sefolo • L.E. Kolobe.
 company registration number: 2006/028605/07. uat no: 4360195723.



leaders in environmental monitoring

address: 89 Regency drive, R21 Corporate Park, Centurion
postal: P.O. Box 905008, Garsfontein, 0042
web: www.aquatico.co.za
office: 012 450 3800 • fax: 012 450 3851

References:

1. Cairncross, B., 2004. Field Guide to Rocks and Minerals of South Africa. South Africa, Struik Nature.
2. Dutrow, B., & Klein, C., 2007. The Manual of Minerals Science. 23rd Edition, United States of America, Jay O'Callaghan.



directors: R. Erdmann (CEO) • P.J. Naudé • T.B. Sefolo • L.E. Kolobe.
company registration number: 2006/028605/07. uat no: 4360195723.



Test Report

Page 1 of 1

Client: Groundwater Consulting Services (GCS)
Address: 63 Wessel Road, Woodmead, 2191
Report no: 137172
Project: Kangra

Date of report: 14 October 2022
Date accepted: 10 October 2022
Date completed: 14 October 2022
Date received: 10 October 2022

Lab no:	185457		
Date sampled:	10-Oct-22		
Aquatico sampled:	No		
Sample type:	Water		
Locality description:	EG1		
Analyses	Unit	Method	
A pH @ 25°C	pH	ALM 20	7.57
A Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	15.3
A Total dissolved solids (TDS)	mg/l	ALM 26	110
A Total Alkalinity	mg CaCO ₃ /l	ALM 01	63.4
A Chloride (Cl)	mg/l	ALM 02	11.2
A Sulphate (SO ₄)	mg/l	ALM 03	22.2
A Nitrate (NO ₃) as N	mg/l	ALM 06	<0.194
A Nitrite (NO ₂) as N	mg/l	ALM 07	0.075
A Fluoride (F)	mg/l	ALM 08	<0.263
A Calcium (Ca)	mg/l	ALM 30	9.90
A Magnesium (Mg)	mg/l	ALM 30	8.34
A Sodium (Na)	mg/l	ALM 30	12.1
A Potassium (K)	mg/l	ALM 30	7.47
A Aluminium (Al)	mg/l	ALM 31	0.034
A Iron (Fe)	mg/l	ALM 31	<0.004
A Manganese (Mn)	mg/l	ALM 31	<0.001
A Bicarbonate alkalinity	mg CaCO ₃ /l	ALM 26	63.2
A Total oxidised nitrogen as N	mg/l	ALM 06	<0.194

A = Accredited N = Non accredited Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative P = Pretoria K = K test report ; Results relate only to the items sampled and tested ; Results reported against the limit of detection; Results marked 'Non SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory; Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation; The report shall not be reproduced except in full without approval of the laboratory

M. Swanepoel
 Technical Signatory



Test Report

Page 1 of 1

Client: Groundwater Consulting Services (GCS)
Address: 63 Wessel Road, Woodmead, 2191
Report no: 137244
Project: Kangra

Date of report: 19 October 2022
Date accepted: 11 October 2022
Date completed: 19 October 2022
Date received: 11 October 2022

Lab no:	185786		
Date sampled:	11-Oct-22		
Aquatico sampled:	No		
Sample type:	Geochem		
Locality description:	KDISCARD 1		
Analyses	Unit	Method	
N Paste pH (1:2)	pH	Geochem	7.54
N Net acid generation (NAG)	H2SO4 kg/t	Geochem	53.3
N NAGpH	pH	Geochem	2.56
N Total Sulphur	%	Geochem	4.51
N Sulphate Sulphur	%	Geochem	3.00
N Acid Potential based Total Sulphur	CaCO3 kg/t	Geochem	141
N Acid Potential based Sulphide Sulphur	CaCO3 kg/t	Geochem	47.2
N Neutralization Potential (NP)	CaCO3 kg/t	Geochem	44.5
N Net Neutralization Potential (NNP)	CaCO3 kg/t	Geochem	0
N NP / AP (TS)	-	Geochem	0.316
N NP / AP (SS)	-	Geochem	0.943
N Geo - Milling 75um	-	Geochem	Yes
N Sulphide Sulphur	%	Geochem	1.51

Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative test report
 Results relate only to the items sampled and tested ; Results reported against the limit of detection.
 The report shall not be reproduced except in full without approval of the laboratory
 The results apply to the sample received.

M. Swanepoel
 Technical Signatory



Test Report

Page 1 of 2

Client: Groundwater Consulting Services (GCS)
Address: 63 Wessel Road, Woodmead, 2191
Report no: 137245
Project: Kangra

Date of report: 18 October 2022
Date accepted: 11 October 2022
Date completed: 18 October 2022
Date received: 11 October 2022

Lab no:	185787		
Date sampled:	11-Oct-22		
Aquatico sampled:	No		
Sample type:	Geochem		
Locality description:	KDISCARD 1		
Analyses	Unit	Method	
N Geo - Reagent water Leach 1:20	-	Geochem	Yes
A pH @ 25°C	pH	ALM 20	8.23
A Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	30.8
A Total Alkalinity	mg CaCO ₃ /l	ALM 01	42.3
A Chloride (Cl)	mg/l	ALM 02	1.79
A Sulphate (SO ₄)	mg/l	ALM 03	86.1
A Orthophosphate (PO ₄) as P	mg/l	ALM 04	<0.005
A Nitrate (NO ₃) as N	mg/l	ALM 06	<0.194
A Calcium (Ca)	mg/l	ALM 30	40.9
A Magnesium (Mg)	mg/l	ALM 30	5.39
A Sodium (Na)	mg/l	ALM 30	5.73
A Potassium (K)	mg/l	ALM 30	6.48
A Aluminium (Al)	mg/l	ALM 31	0.017
A Iron (Fe)	mg/l	ALM 31	0.006
A Manganese (Mn)	mg/l	ALM 31	0.022
A Cadmium (Cd)	mg/l	ALM 31	<0.002
A Cobalt (Co)	mg/l	ALM 31	<0.003
A Chromium (Cr)	mg/l	ALM 31	<0.003
A Copper (Cu)	mg/l	ALM 31	0.004
A Nickel (Ni)	mg/l	ALM 31	<0.002
A Lead (Pb)	mg/l	ALM 31	<0.004
A Zinc (Zn)	mg/l	ALM 31	<0.002
A Boron (B)	mg/l	ALM 33	<0.013
A Barium (Ba)	mg/l	ALM 33	0.095
A Beryllium (Be)	mg/l	ALM 33	<0.005
A Vanadium (V)	mg/l	ALM 33	<0.001
N Bismuth (Bi)	mg/l	ALM 32	<0.004
N Silver (Ag)	mg/l	ALM 32	<0.001

A = Accredited N = Non accredited Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative P = Pretoria K = K test report ; Results relate only to the items sampled and tested ; Results reported against the limit of detection; Results marked 'Non SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory; Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation; The report shall not be reproduced except in full without approval of the laboratory

M. Swanepoel
 Technical Signatory



Test Report

Page 2 of 2

Client: Groundwater Consulting Services (GCS)
Address: 63 Wessel Road, Woodmead, 2191
Report no: 137245
Project: Kangra

Date of report: 18 October 2022
Date accepted: 11 October 2022
Date completed: 18 October 2022
Date received: 11 October 2022

Lab no:	185787		
Date sampled:	11-Oct-22		
Aquatico sampled:	No		
Sample type:	Geochem		
Locality description:	KDISCARD 1		
Analyses	Unit	Method	
N Gallium (Ga)	mg/l	ALM 32	0.002
N Lithium (Li)	mg/l	ALM 32	0.005
A Molybdenum (Mo)	mg/l	ALM 33	0.029
N Rubidium (Rb)	mg/l	ALM 32	0.011
A Strontium (Sr)	mg/l	ALM 33	0.842
N Tellurium (Te)	mg/l	ALM 32	<0.001
N Thallium (Tl)	mg/l	ALM 32	<0.037
A Total oxidised nitrogen as N	mg/l	ALM 06	<0.194

A = Accredited N = Non accredited Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative P = Pretoria K = K test report ; Results relate only to the items sampled and tested ; Results reported against the limit of detection; Results marked 'Non SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory; Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation; The report shall not be reproduced except in full without approval of the laboratory

Authenticated signature on first page



Test Report

Page 1 of 1

Client: Groundwater Consulting Services (GCS) **Date of report:** 19 October 2022
Address: 63 Wessel Road, Woodmead, 2191 **Date accepted:** 11 October 2022
Report no: 137247 **Date completed:** 19 October 2022
Project: Kangra **Date received:** 11 October 2022

Lab no:	185791		
Date sampled:	11-Oct-22		
Aquatiko sampled:	No		
Sample type:	Geochem		
Locality description:	KDISCARD 1		
Analyses	Unit	Method	
N XRD Quantitative	%	XRD	Yes

Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative test report
 Results relate only to the items sampled and tested ; Results reported against the limit of detection.
 The report shall not be reproduced except in full without approval of the laboratory
 The results apply to the sample received.

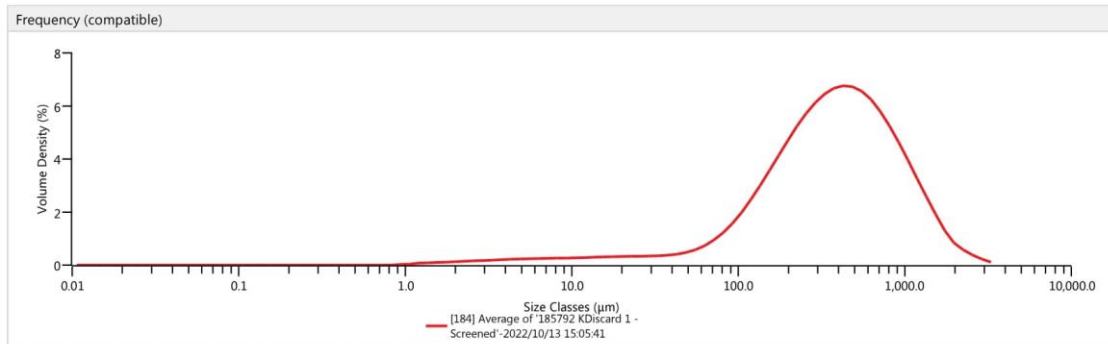
M. Swanepoel
 Technical Signatory

Particle size distribution

Malvern Instruments



Measurement Details Sample Name Average of '185792 KDiscard 1 - Screened' SDS 318 SOP File Name Default + 60us LV.msop	Measurement Details Measurement Date Time 2022/10/13 15:05:41 Analysis Date Time 2022/10/13 15:05:41 Original Record Number 184
Analysis Particle Name Default 1.0 Dispersant Name Water Particle Absorption Index 1.000 Weighted Residual 0.30 % Analysis Model General Purpose	Analysis Particle Refractive Index 1.520 Dispersant Refractive Index 1.330 Laser Obscuration 7.38 % Scattering Model Mie Analysis Sensitivity Normal
Result Concentration 0.0733 % Uniformity 0.818 Specific Surface Area 73.32 m ² /kg D [3,2] 77.9 μm D [4,3] 505 μm	Result Span 2.603 Result Units Volume Dv (10) 93.5 μm Dv (50) 379 μm Dv (90) 1080 μm



Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.11	12.7	3.09	111	12.09	1110	90.66
0.0114	0.00	0.146	0.00	1.45	0.18	14.5	3.35	127	14.25	1260	93.39
0.0129	0.00	0.166	0.00	1.65	0.27	16.4	3.59	144	16.71	1430	95.56
0.0147	0.00	0.188	0.00	1.88	0.36	18.7	3.86	163	19.58	1630	97.16
0.0189	0.00	0.214	0.00	2.13	0.47	21.2	4.13	186	23.14	1850	98.23
0.0215	0.00	0.243	0.00	2.50	0.62	24.1	4.40	211	27.01	2100	98.92
0.0278	0.00	0.276	0.00	2.75	0.72	27.4	4.68	240	31.42	2390	99.40
0.0315	0.00	0.314	0.00	3.12	0.86	31.1	4.97	272	36.11	2710	99.72
0.0358	0.00	0.357	0.00	3.55	1.02	35.3	5.25	310	41.35	3080	99.91
0.0407	0.00	0.405	0.00	4.03	1.19	40.1	5.56	352	46.72	3500	100.00
0.0463	0.00	0.460	0.00	4.58	1.37	44.0	5.81	400	52.30		
0.0526	0.00	0.523	0.00	5.21	1.57	45.0	5.87	454	57.91		
0.0597	0.00	0.594	0.00	5.92	1.76	51.8	6.30	516	63.55		
0.0679	0.00	0.675	0.00	6.72	1.97	58.9	6.79	586	69.01		
0.0771	0.00	0.767	0.00	7.64	2.18	66.9	7.39	666	74.25		
0.0876	0.00	0.872	0.00	8.68	2.40	76.0	8.18	756	79.07		
0.0995	0.00	1.00	0.02	10.0	2.65	86.4	9.19	859	83.47		
0.113	0.00	1.13	0.05	11.2	2.85	98.1	10.49	976	87.34		

APPENDIX D: RISK ASSESSMENT METHODOLOGY

Due to the hydrological assessment forming part of a larger risk assessment for the study area, the potential impacts and the determination of impact significance were assessed. The process of assessing the potential impacts of the project encompasses the following four activities:

1. Identification and assessment of potential impacts;
2. Prediction of the nature, magnitude, extent, and duration of potentially significant impacts;
3. Identification of mitigation measures that could be implemented to reduce the severity or significance of the impacts of the activity; and
4. Evaluation of the significance of the impact after the mitigation measures have been implemented i.e. the significance of the residual impact.

Per GNR 982 of the EIA Regulations (2014), the significance of potential impacts was assessed in terms of the following criteria:

- I. Cumulative impacts;
- II. Nature of the impact;
- III. The extent of the impact;
- IV. Probability of the impact occurring;
- V. The degree to which the impact can be reversed;
- VI. The degree to which the impact may cause irreplaceable loss of resources; and
- VII. The degree to which the impact can be mitigated.

Table 11-1 provides a summary of the criteria used to assess the significance of the potential impacts identified. An explanation of these impact criteria is provided in Table 11-2.

The net consequence is established by the following equation:

$$\text{Consequence} = (\text{Duration} + \text{Extent} + \text{Irreplaceability of resource}) \times \text{Severity}$$

And the environmental significance of an impact was determined by multiplying consequence by probability.

Table 11-1: Proposed Criteria and Rating Scales to be used in the Assessment of the Potential Impacts

Criteria	Rating Scales	Notes
Nature	Positive (+)	An evaluation of the effect of the impact related to the proposed development.
	Negative (-)	
Extent	Footprint (1)	The impact only affects the area in which the proposed activity will occur.

Criteria	Rating Scales	Notes
	Site (2)	The impact will affect only the development area.
	Local (3)	The impact affects the development area and adjacent properties.
	Regional (4)	The effect of the impact extends beyond municipal boundaries.
	National (5)	The effect of the impact extends beyond more than 2 regional/ provincial boundaries.
	International (6)	The effect of the impact extends beyond country borders.
Duration	Temporary (1)	The duration of the activity associated with the impact will last 0-6 months.
	Short-term (2)	The duration of the activity associated with the impact will last 6-18 months.
	Medium-term (3)	The duration of the activity associated with the impact will last 18 months-5 or years.
	Long-term (4)	The duration of the activity associated with the impact will last more than 5 years.
Severity	Low (1)	Where the impact affects the environment in such a way that natural, cultural and social functions and processes are minimally affected.
	Moderate (2)	Where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way; and valued, important, sensitive, or vulnerable systems or communities are negatively affected.
	High (3)	Where natural, cultural, or social functions and processes are altered to the extent that the natural process will temporarily or permanently cease; and valued, important, sensitive, or vulnerable systems or communities are substantially affected.
Potential for impact on irreplaceable resources	No (0)	No irreplaceable resources will be impacted.
	Yes (1)	Irreplaceable resources will be impacted.
Consequence	Extremely detrimental (-25 to -33)	A combination of extent, duration, intensity, and the potential for impact on irreplaceable resources.
	Highly detrimental (-19 to -24)	
	Moderately detrimental (-13 to -18)	
	Slightly detrimental (-7 to -12)	
	Negligible (-6 to 0)	
	Slightly beneficial (0 to 6)	

Criteria	Rating Scales	Notes
	Moderately beneficial (13 to 18)	
	Highly beneficial (19 to 24)	
	Extremely beneficial (25 to 33)	
Probability (the likelihood of the impact occurring)	Improbable (0)	It is highly unlikely or less than 50 % likely that an impact will occur.
	Probable (1)	It is between 50 and 70 % certain that the impact will occur.
	Definite (2)	It is more than 75 % certain that the impact will occur or it is definite that the impact will occur.
Significance	Very high - negative (-49 to -66)	A function of Consequence and Probability.
	High - negative (-37 to -48)	
	Moderate - negative (-25 to -36)	
	Low - negative (-13 to -24)	
	Very low (0 to -12)	
	Low-positive (0 to 12)	
	Moderate-positive (13 to 24)	
	High-positive (37 to 48)	
	Very high - positive (49 to 66)	

Table 11-2: Explanation of Assessment Criteria

Criteria	Explanation
Nature	This is an evaluation of the type of effect the construction, operation, and management of the proposed development would have on the affected environment. Will the impact of change on the environment be positive, negative, or neutral?
Extent or Scale	This refers to the spatial scale at which the impact will occur. The extent of the impact is described as footprint (affecting only the footprint of the development), site (limited to the site), and regional (limited to the immediate surroundings and closest towns to the site). The extent of scale refers to the actual physical footprint of the impact, not to the spatial significance. It is acknowledged that some impacts, even though they may be of a small extent, are of very high importance, e.g. impacts on species of very restricted range. To avoid “double counting, specialists have been requested to indicate spatial significance under “intensity” or “impact on irreplaceable resources” but not under “extent” as well.
Duration	The lifespan of the impact is indicated as temporary, short, medium, and long-term.
Severity	This is a relative evaluation within the context of all the activities and the other impacts within the framework of the project. Does the activity destroy the impacted environment, alter its functioning, or render it slightly altered?

Criteria	Explanation
Impact on irreplaceable resources	This refers to the potential for an environmental resource to be replaced, should it be impacted. A resource could be replaced by natural processes (e.g. by natural colonization from surrounding areas), through artificial means (e.g. by reseeding disturbed areas or replanting rescued species) or by providing a substitute resource, in certain cases. In natural systems, providing substitute resources is usually not possible, but in social systems, substitutes are often possible (e.g. by constructing new social facilities for those that are lost). Should it not be possible to replace a resource, the resource is essentially irreplaceable e.g. red data species that are restricted to a particular site or habitat to a very limited extent.
Consequence	The consequence of the potential impacts is a summation of the above criteria, namely the extent, duration, intensity, and impact on irreplaceable resources.
Probability of occurrence	The probability of the impact occurring is based on the professional experience of the specialist with environments of a similar nature to the site and/or with similar projects. It is important to distinguish between the probability of the impact occurring and the probability that the activity causing a potential impact will occur. Probability is defined as the probability of the impact occurring, not as the probability of the activities that may result in the impact.
Significance	Impact significance is defined to be a combination of the consequence (as described below) and the probability of the impact occurring. The relationship between consequence and probability highlights that the risk (or impact significance) must be evaluated in terms of the seriousness (consequence) of the impact, weighted by the probability of the impact occurring. In simple terms, if the consequence and probability of an impact are high, then the impact will have a high significance. The significance defines the level to which the impact will influence the proposed development and/or environment. It determines whether mitigation measures need to be identified and implemented and whether the impact is important for decision-making.
Degree of confidence in predictions	Specialists and the EIR team were required to indicate the degree of confidence (low, medium, or high) that there is in the predictions made for each impact, based on the available information and their level of knowledge and expertise. The degree of confidence is not taken into account in the determination of consequence or probability.
Mitigation measures	Mitigation measures are designed to reduce the consequence or probability of an impact or to reduce both consequence and probability. The significance of impacts has been assessed both with mitigation and without mitigation.

APPENDIX E: MODEL CONFIDENCE MATRIX

In the development of the numerical model, a detailed data review was conducted. Data confidence and data availability dictate model confidence. A summary of the required data versus the data available is outlined below; 3: indicates sufficient data availability, 2: indicates moderate availability, and 1: indicates limited or no availability.

As indicated in the table below, limited data required for the development of a medium-high confidence model is available. These data gaps will be required to be filled before updating the model and producing a higher confidence model suitable for defensible predictive modelling.

Table 1: Model Data Confidence (1: low, 2: moderate, 3: high)

Data types	Confidence
Spatial and temporal distribution of groundwater head observations is required to adequately define groundwater behaviour, especially in areas of greatest interest and where outcomes are to be reported.	3
The spatial distribution of bore logs and associated stratigraphic interpretations clearly define aquifer geometry.	3
Reliable metered groundwater extraction and injection data are available.	2
Rainfall and evaporation data is available.	2
Aquifer-testing data to define key parameters.	3
Streamflow and stage measurements are available with reliable base flow estimates at several points.	1
Reliable land-use and soil mapping data available.	2
Good quality and adequate spatial coverage of digital elevation model to define ground surface elevation.	3
The geometry of the existing mine workings.	2
Geometry and temporal plan of future mine workings/development activities.	3
The geometry of existing mine residue disposal/storage areas and proposed facilities.	3
Transport model calibration points and confidence of constant sampling data	2
Aquifer dewatering rates / verified estimates	2
<i>Model Data Confidence Rating</i>	<i>Class 2</i>
<i>Class 1: Low Confidence Model</i>	<i>Score <21 (50%)</i>
<i>Class 2: Intermediate Confidence Model</i>	<i>Score 21 - 31 (50-80%)</i>
<i>Class 3: High Confidence Model</i>	<i>Score >31 (80 - 100%)</i>

APPENDIX F: DISCLAIMER

The opinions expressed in this Report have been based on site /project information supplied to GCS (Pty) Ltd (GCS) by Kangra Coal and are based on public domain data, field data and data supplied to GCS by the client. GCS has acted and undertaken this assessment objectively and independently.

GCS has exercised all due care in reviewing the supplied information. Whilst GCS has compared key supplied data with expected values, the accuracy of the results and conclusions are entirely reliant on the accuracy and completeness of the supplied data. GCS does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them.

The boreholes that were sited in this investigation are sited according to scientific principles which relate to sub-surface hydrogeological signatures/structures which may act as preferential groundwater flow paths. It should be noted that in some cases (3 out of 10 boreholes) the hydrogeological signatures may indicate high water potential, however, during drilling low yields are observed. For this reason, GCS recommends that a hydrogeological specialist supervises the drilling to ensure that drilling is stopped, or the method is adapted if hydrogeology differs from desktop and sitting data. Even with such oversight and scientific recommendations, a high-yielding borehole is not guaranteed, and GCS cannot be held responsible or liable for dry or low-yielding boreholes or for any hydrogeological or any other condition which may affect the yield volume or yield water quality.

Opinions presented in this report, apply to the site conditions, and features as they existed at the time of GCS's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this report, about which GCS had no prior knowledge nor had the opportunity to evaluate.

APPENDIX G: DETAILS OF THE SPECIALIST, DECLARATION OF INTEREST AND UNDERTAKING UNDER OATH

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

PROJECT TITLE

Geohydrological Assessment, Numerical Flow & Transport Model Development for the Amatikulu Sugar Mill


SPECIALIST INFORMATION

Specialist Company Name:	GCS Water SA Pty Ltd		
B-BBEE	Contribution level (indicate 1 to 8 or non-compliant)	2	Percentage Procurement Recognition
Specialist name:	Hendrik Botha		
Specialist Qualifications:	MSc Environmental Sciences (Geohydrology & Geochemistry) BSc Hons. Environmental Sciences (Hydrology) BSc. Chemistry & Geology		
Professional affiliation/registration:	PR SCI NAT 400139/17		
Physical address:	1 Karbochem Road, Newcastle, KZN		
Postal address:			
Postal code:	2940	Cell:	
Telephone:	071 102 3819	Fax:	
E-mail:	hendrikb@gcs-sa.biz		

DECLARATION BY THE SPECIALIST

I, Hendrik Botha, declare that -

- I act as the independent specialist in this application.
- I will perform the work relating to the application objectively, 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 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 concerning 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 24F of the Act.



01/08/2022
3:14:46
Pr.Sci.Nat (400139/17)

Signature of the Specialist

GCS

Name of Company:

17 November 2023

Date

APPENDIX H: CV OF SPECIALIST



Hendrik Botha
Technical Director

LinkedIn:



CORE SKILLS

- Project management
- Analytical and numerical groundwater modelling
- Geochemical assessments and geochemical modelling
- Hydrogeology, hydrological assessments & yield assessments
- Hydrology, floodline modelling & storm water management
- Groundwater vulnerability, impact, and risk assessments
- Technical report writing
- GIS and mapping

DETAILS

Qualifications

- BSc Chemistry and Geology (Environmental Sciences) (2012)
- BSc Hons Hydrology (Environmental Sciences) (2013)
- MSc Geohydrology and Hydrology (Environmental Sciences) (2014-2016)

Membership

- Groundwater Division of GSSA
- Groundwater Association of KwaZulu Natal Member
- International Mine Water Association (IMWA)

Languages

- Afrikaans - Speak, read, write.
- English - Speak, read, write.

Projects undertaken in

- South Africa
- Nigeria
- Namibia
- Liberia

PROFILE

Hendrik (Henri) Botha is currently the manager of the GCS Newcastle Office and occupies the role of principal hydrogeologist. Groundwater, geochemistry and surface hydrology, as well as knowledge of water chemistry together with GIS, and analytical and numerical modelling skills, are some of his sought-after expertise. General and applied logical knowledge are his key elements in problem-solving.

Professional Affiliations:

SACNASP Professional Natural Scientist (400139/17)

Areas of Expertise:

- Waste classification and Impact Assessments
- Aquifer vulnerability assessments
- Geochemical sampling, data interpretation and modelling
- Geophysical surveys and data interpretation
- GIS
- Water quality sampling and data interpretation
- Groundwater impact and risk assessments
- Numerical and Conceptual Visual Modelling (Visual Modflow, ModflowFLEX, Voxler, RockWorks, Surfer and Excel)
- Hydrogeology (Hydrological Soil Types) & Soils Assessments
- Floodline Modelling (HEC-RAS)
- Stormwater Management Systems and Modelling
- Surface Water Yield Assessments
- Water and Salt Balances



Page 1 of 8