GHT CONSULTING SCIENTISTS

HOTAZEL MANGANESE MINES

MAMATWAN MINE (2021): REGIONAL HYDROCENSUS OF FARM WATER SUPPLY BOREHOLES

for

SOUTH32

SOUTH32 LIMITED

by

GHT CONSULTING

PROJECT TEAM

J.J.H. Hough

D.C. Rudolph

Project No.:	153-30-HYD.898	Start Date:	May 2021
Report No.:	RVN898.1/2097	Report Date:	June 2021

3 June 2021

HOTAZEL MANGANESE MINES
SAMANCOR LIMITED
1 Peperboom Ave Hotazel
P.O. Box 1
Hotazel
8490
Republic of South Africa
Tel No:. +27(0)53 742-2000
Fax No.: +27(0)53 242-2805

FOR ATTENTION: MRS. MASE RANTSIENG

Dear Sir,

MAMATWAN MINE (2021): REGIONAL HYDROCENSUS OF FARM WATER SUPPLY BOREHOLES

It is our pleasure to enclose three copies of report RVN898.1/2097: "MAMATWAN MINE (2021): REGIONAL HYDROCENSUS OF FARM WATER SUPPLY BOREHOLES".

We trust that the report will fulfil in the expectations of Hotazel Manganese Mines and we will supply any additional information if needed.

Regards,

D.C. RUDOLPH *(M.Sc. / Pr. Sci. Nat.)*	J.J.H. HOUGH *(M.Sc. / Pr. Sci. Nat.)*
Director	*Principal Geohydrologist*

Copies: Three copies to Mamatwan Mine (South32).

- TABLE OF CONTENTS -

- TABLE OF FIGURES -

- LIST OF TABLES -

- GLOSSARY OF GEOHYDROLOGICAL TERMS & ABBREVIATIONS -

GEOHYDROLOGICAL	DEFINITION
Aquifer	A water-bearing geological formation.
Aquitard	An aquitard is a geological unit that is permeable enough to transmit water in significant quantities when viewed over large and long periods, but its permeability is not sufficient to justify production boreholes being placed in it. Clays, loams and shale are typical aquitards.
Confined Aquifer	A confined aquifer is bounded above and below by an aquiclude. In a confined Aquifer, the pressure of the water is usually higher than that of the atmosphere. So that if a borehole taps the aquifer, the water in it stands above the top of the aquifer, or even above the ground surface. We then speak of a free-flowing or artesian borehole.
Contamination	The introduction of any substance into the environment by the action of man.
Diffusivity (KD/S)	The hydraulic diffusivity is the ratio of the transmissivity and the storativity of a saturated aquifer, it governs the propagation of the chances a hydraulic head in the aquifer. Diffusivity has the dimension of $lenght^2/Time$.
Fractured-rock aquifer	Groundwater occurring in within fractures and fissures in hard-rock formations. Groundwater: Refers to water filling the pores and voids in geological formations below the water table.
Groundwater Flow	The movement of water though openings and pore spaces in rock below the water table i.e. in the saturated zone. Groundwater naturally drains from higher lying areas to low lying areas such as river, lakes and oceans. The rate of flow depends on the slope of the water table and the stransmissivity of the geological formations.
Groundwater Recharge	Refers to the portion of rainfall that infiltrates the soil, percolates under gravity through the unsaturated zone (also called the Vadose zone) down to the saturated zone below the water table (also called the Phreatic zone).
Groundwater Resource	All ground water available for the beneficial use, including by man, aquatic ecosystems and the grater environment.
Groundwater Resource Units (GRU's)	Represent provisional zones defined for the purpose of assessing and managing the groundwater resources of a region, in terms of large-scale abstraction from relatively shallow (depth<300m) production boreholes. They represent areas where the broad geohydrological characteristics (i.e. water occurrence and quality, hydraulic properties, flow regime, aquifer boundary conditions etc.) are anticipated to be similar. Sometimes also called ground water management units (GMU's).
Hydraulic Conductivity (K)	The hydraulic conductivity is the constant of proportionality in Darcy's law. It is defined as the volume of water that will move through a porous medium in a unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow
Hydrocensus	A field survey by which all relevant information regarding groundwater is amassed. This typically includes yields, borehole equipment, groundwater levels, casing height / diameter, WGS84 coordinates, potential pollution risks, photos etc.
Intergranular Aquifer	Groundwater contained intergranular interstices of sedimentary and weathered formations.
Leaky Aquifer	A leaky aquifer, also known as a semi-confined aquifer, is an aquifer who's upper and lower boundaries is aquitards, or one boundary is an aquitard and the other is an aquiclude. Water is free to move through the aquitards, either upwards or downwards. If a leaky aquifer is in hydrological equilibrium, the water level in a borehole tapping it may coincide with the water table.
Major Aquifer System	Highly permeable formations, usually with a known or probable presence pf significant fracturing and/or intergranular porosity; may be highly productive and able to support large abstractions for public supply and other purposes; water quality is generally very good.
Minor Aquifer System	Fractured or potentially fractured rocks that do not have a high primary permeability , or other formations of variable permeability; aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important for local supplies and in supplying base flow of rivers.
Non-Aquifer	A groundwater body that is essentially impermeable, does not readily transmit water and/or has water quality that renders it unfit for use.
Non-Aquifer System	Formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities; water quality may also be such that it renders the aquifer unusable; groundwater flow through such rocks does take place and needs to be considered when assessing the risk associated with persistent pollutants.
Permeability	The ease with which a fluid can pass through a porous medium and is defined as the volume of fluid discharged from a unit area of a aquifer under unit hydraulic gradient in unit time (expressed as $m^3/m^2.d$ or m/d). It is an intrinsic property of the porous medium and is independent of the properties of the saturating fluid; not to be confused with hydraulic conductivity, which relates specifically to the movement of water.
Pollution	The introduction into the environment of any substance by the action of man that is, or results in, significant harmful effects to man or the environment.
Porosity	The porosity of a rock is its property of containing pores or voids. With consolidated rocks and hard rocks, a distinction is usually made between primary porosity, which is present when the rock is formed and secondary porosity, which develops later as a result of solution or fracturing.
Recharge	Groundwater recharge or deep drainage or deep percolation is a hydrologic process where water moves downward from surface water to groundwater. This process usually occurs in the vadose zone below plant roots and is often expressed as a flux to the water table surface. Recharge occurs both naturally (through the water cycle) and anthropologically (i.e. "artificial ground water recharge"), where rainwater and or reclaimed water is touted to the subsurface.
Saline Water	Water that is generally considered unsuitable for human consumption or for irrigation because of it's high content of dissolved solids.
Saturated Zone	The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.
Specific Yield (S_y)	The specific yield is the volume of water that an unconfined aquifer releases from storage per unit surface area of aquifer per unit decline of the water table. The values of the specific yield range from 0.01 to 0.3 and are much higher that the storativities of confined aquifers.
Storativity Ratio	The storativity ratio is a parameter that controls the flow from the aquifer matrix blocks into the fractures of a confined fractured aquifer of the double-porosity type. Sustainable Yield: This usually refers to a yield calculated from aquifer test pumping by a professional geohydrologist. The yield refers to the recommended abstraction rate and pumping schedule for continued use.

GEOHYDROLOGICAL	DEFINITION
Storativity (S)	The storativity of a saturated confined aquifer of thickness D is the volume of water released from storage per unit are of the aquifer per unit decline in the component of hydraulic head normal to that surface.
Transmissivity (KD & T)	Transmissivity is the product of the average hydraulic conductivity K and the saturated thickness of the aquifer D. Consequently, transmissivity is the rate of flow under a unit hydraulic gradient through a cross-section of unit width over the whole saturated thickness of the aquifer.
Unconfined Aquifer	An unconfined aquifer, also known as a water table aquifer, is bounded below by an aquiclude, but is not restricted by any confining layer above it. Its upper boundary is the water table and is free to rise and fall.
Unsaturated Zone	That part of the geological stratum above the water table where interstices and voids contain a combination of air and water; synonymous with zone of aeration or vadose zone.
Water Table	The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is at atmospheric pressure, the depth to which may fluctuate seasonally.
Advection	Advection is the process by which solutes are transported by the bulk motion of the flowing groundwater.
Anisotropy	Anisotropy is an indication of some physical property varying with direction.
Cone of Depression	Cone of depression is a depression in the groundwater table or potentiometric surface that has the shape of an inverted cone and develops around a borehole from which water is being withdrawn. It defines the area of influence of a borehole.
Darcy Flux	The ***darcy flux*** , is the flow rate per unit area (m/d) in the aquifer and is controlled by the hydraulic conductivity and the piezometric gradient.
Dispersion	Dispersion is the measure of spreading and mixing of chemical constituents in groundwater caused by diffusion and mixing due to microscopic variations in velocities within and between pores.
Drawdown	Drawdown is the distance between the static water level and the surface of the cone of depression. Effective porosity is the percentage of the bulk volume of a rock or soil that is occupied by interstices that are connected.
Groundwater Resource Unit (GRU)	Groundwater Resource Unit (GRU) A groundwater body that has been delineated or grouped into a single significant water resource based on one or more characteristics that are similar across that unit.
Geosite	A naturally occurring or artificially excavated or constructed or improved underground cavity which can be used for the purpose of a) intercepting, collection or storing of water in, or removing water from an aquifer, b) observing and collecting data and information on water in an aquifer, or c) recharging an aquifer‖ (Xu et al., 2003).
Groundwater Table	Groundwater table is the surface between the zone of saturation and the zone of aeration; the surface of an unconfined aquifer.
Fault	A **fault** is a fracture or a zone of fractures along which there has been displacement. Hydrodynamic dispersion comprises of processes namely mechanical dispersion and molecular diffusion.
Hydraulic Gradient	Hydraulic gradient is the rate of change in the total head per unit distance of flow in a given direction.
Heterogeneous	Heterogeneous indicates non-uniformity in a structure.
Karstic Topography	Karstic topography is a type of topography that is formed on limestone, gypsum, and other rocks by dissolution, an is characterised by sinkholes, caves and underground drainage.
Mechanical Dispersion	Mechanical dispersion is the process whereby the initially close group of pollutants are spread in a longitudinal as well as a transverse direction because of velocity distributions.
Molecular Diffusion	Molecular diffusion is the dispersion of a chemical caused by the kinetic activity of the ionic or molecular constituents.
Observation Borehole	Observation borehole is a borehole drilled in a selected location for the purpose of observing parameters such as water levels.
Permeability	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.
Piezometric Head	Piezometric head 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	Porosity is the percentage of the bulk volume of a rock or soil that is occupied by interstices, whether isolated or connected.
Aquifer Test Pumping	Aquifer Test Pumping are conducted to determine aquifer and borehole characteristics.
Recharge	Recharge is the addition of water to the zone of saturation; also, the amount of water added.
Reserve	Reserve, means the quantity and quality of water required to:
Reserve (a)	to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No 108 of 1997), for people who are now or who will, in the reasonably near future, be:
i.	relying upon;
ii.	taking water from; or
iii.	being supplied from, the relevant water resource; an
Reserve (b)	to protect aquatic ecosystems in order to secure ecologically sustainable development and use the relevant water resource. ‖ [Source: National Water Act (Act No. 36 of 1998)].
Specific Storage (Ss)	Specific storage (Ss), 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, watertable) aquifer, specific yield is the water that is released or drained from storage per unit decline in the watertable.
Static Water Level	Static water level is the level of water in a borehole that is not being affected by withdrawal of groundwater. Also known as a ―rest water level‖
Storativity	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)	Total dissolved solids (TDS) is a term that expresses the quantity of dissolved material in a sample of water.
Transmissivity (T)	Transmissivity (T) is the two-dimensional form of hydraulic conductivity and is defined as the hydraulic conductivity multiplied by the saturated thickness.
Unconfined, Water Table or Phreatic Aquifer	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.
Vadose Zone	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 by the land surface and below by the surface of the zone of saturation, that is, the water table.
Water Table	Water table is the surface between the vadose zone and the saturated zone (i.e. groundwater). The water table is the surface of an unconfined aquifer at which the pressure is equal to that of the atmosphere.

ABBREVIATION	DEFINITION
AGEP	Average Groundwater Exploitation Potential
BHN	Basic Human Needs
BID	Basic Information Document
CD: RDM	Chief Directorate: Resource Directed Measures
CD: WE	Chief Directorate: Water Ecosystems (Name change from CD: RDM)
CFB	Cape Fold Belt
CMA	Catchment Management Agency
CMB	Chloride Mass Balance
CRD	Cumulative Rainfall Departure
CSIR	Council for Scientific and Industrial Research
DM	District Municipality
DMR	Department of Mineral Resources
DTM	Digital Terrain Model
DWA	Department of Water Affairs
DWA	Department of Water Affairs (Name change from DWAF applicable after April 2009)
DWAE	Department of Water Affairs and Environment
DWAF	Department of Water Affairs and Forestry
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation (Name change from DWA applicable after May 2014)
EC	Electric Conductivity
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
GA	General Authorisation
GDE	Groundwater Dependent Ecosystem
GHT	GHT Consulting
GIS	Geographical Information System
GRDM	Groundwater Reserve Determination Methodology
GRUs	Groundwater Resource Units
GW	Groundwater
GYMR	Groundwater Yield Model for the Reserve
HGM	Hydrogeomorphic
IFR	Instream Flow Requirement
IWRM	Integrated Water Resource Management
K	Hydraulic Conductivity (m/d)
KGEG	Karoo Groundwater Expert Group
KKRWSS	Klein Karoo Rural Water Supply Scheme
L/T	Unit with dimensions of Length(L)/Time(T)
L^2	Unit with dimensions of Length(L) squared
m	Metres
m^3/a	Cubic Metres per Annum
m^3/d	Cubic Metres per Day
Ma	Mega-Annum or Million Annums
MAE	Mean Annual Evaporation
magl	Metres Above Ground Level
mamsl	Metres Above Mean Sea Level
MAP	Mean Annual Precipitation
mbgl	Metres Below Ground Level
mm	Millimetres
MPA	Marine Protected Area
mS/cm	Milli-Siemens per Centimetre
mS/m	Milli-Siemens per Metre
NEMA	National Environmental Management Act

ABBREVIATION	DEFINITION
NGA	National Groundwater Archive
NGDB	National Groundwater Database
NGI	National Geospatial Information: Department of Rural Development and Land Reform
NSBA	National Spatial Biodiversity Assessment
NWA	National Water Act
PES	Present Ecological State
PSP	Professional Service Provider
RBIG	Regional Bulk Infrastructure Grant
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RQO	Resource Quality Objective
RU	Resource Unit
SANBI	South African National Biodiversity Institute
SANS	South African National Standard
SVF	Saturated Volume Fluctuation
T	Transmissivity (m^2/d)
TDS	Total Dissolved Solids
TOR	Terms of Reference
UGEP	Utilisable Groundwater Exploitation Potential
WAAS	Water Availability Assessment Study
WARMS	Water Authorisation and Management System
WMA	Water Management Area
WRC	Water Research Commission
WULA	Water Use Licence Application

1 INTRODUCTION

GHT Consulting was commissioned to perform a hydrocensus study of the farm boreholes in the vicinity of the Mamatwan Mine operations.

Previous hydrocensus studies were done in 2002, 2005, 2016, 2018 and 2019. The groundwater elevation data collected is to be utilised to analyse potential how the dewatering at the Mamatwan Mine Opencast Pit has potentially impact the surrounding water users. The collected groundwater quality data will be utilised to establish the groundwater baseline conditions around the Mamatwan mine operations as required by the DWS (Department of Water and Sanitation).

The scope and objectives of the Hydrocensus are as follows:

- Hydrocensus fieldwork and conducting of groundwater level measurement and groundwater sampling of the farm boreholes on privately owned farms in the vicinity Mamatwan Mine operations. The water samples will be analyses at a SANS accredited laboratory.
- Investigation of possible dewatering effects on the local aquifers of the farms in the vicinity of the Mamatwan Mine operations.
- The collected groundwater quality data will also be utilised to establish the groundwater baseline conditions around the Mamatwan Mine operations as required by the DWS WUL requirements.
- Impact analyses on surrounding groundwater users in terms of potential impacts regarding groundwater elevations (dewatering) and groundwater quality (contaminant impacts).
- Drafting of a Mamatwan Mine Hydrocensus Report.

The locality map of the study area can be viewed in Figure 1 on page 2.

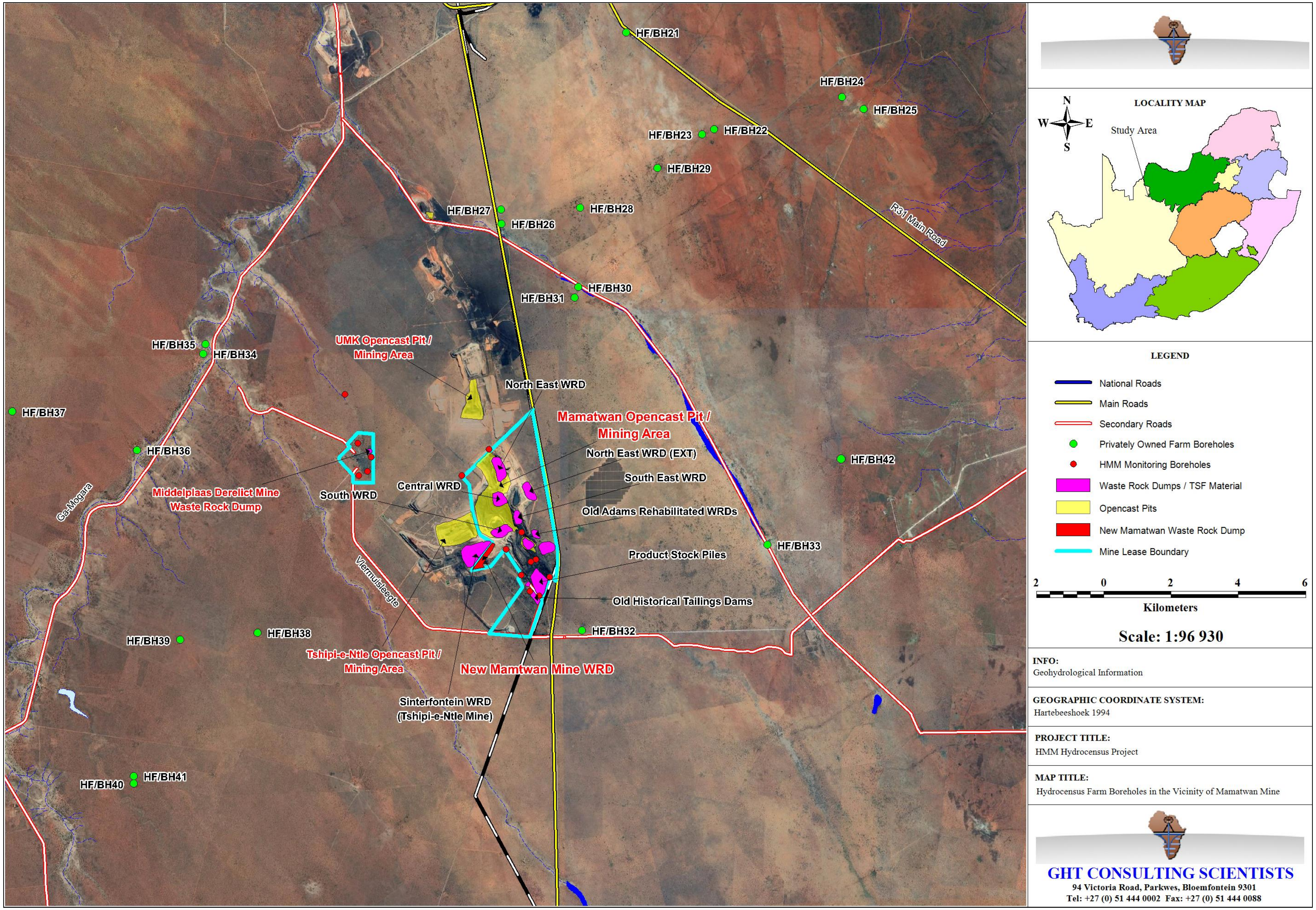


Figure 1. Locality map of the hydrocensus study area for Mamatwan Mine.

2 BACKGROUND INFORMATION OF THE STUDY AREA

2.1 LOCATION

Mamatwan Mine are located in the Northern Cape Province. The hydrocensus area is located about 17 km south of Hotazel, 44 km northwest of Kuruman and approximately 35 km north east of Kathu (refer to Figure 1 on page 2).

2.2 CLIMATE

Rainfall in the area, while summer dominant, is sporadic and varies significantly from year to year, with most rain falling in heavy downpours (refer to Figure 2 on page 4). Annual rainfall data for Hotazel does suggest, however, that droughts are cyclical (once every five to eight years), and probably a response to El Nino-La Nina weather patterns. Available Intensity Frequency Duration (IFD) data indicates that the most intense rainfall events occur in May, with 35.9 and 101 mm falling in 60 minute and 24-hour rainfall events, respectively. The Mean Annual Precipitation (MAP) for Kuruman, the nearest official recording station to the site, is approximately 350 mm/year (refer to Figure 3 on page 4) although this figure is somewhat misleading given the significant variations that can occur from year to year.

The semi-arid conditions and the sites position on the fringes of the Kalahari Desert can result in extreme daily and seasonal temperature variations, with average daily temperatures ranging from 30 to 15 C in January to about 17 and 0 C in July (refer to Figure 4 on page 5). 70 to 80% of possible sunshine hours can be expected year-round, which when considered with other climatic data, results in relatively high average monthly evaporation rates, 2276 mm of evaporation occurring on average annually. Of most significance, however, is the degree to which monthly evaporation exceeds monthly precipitation. Based on average monthly results, the ratio of evaporation to precipitation is about 2.7:1 in February, increasing to approximately 46:1 in July. Such significant evaporation excesses are not conducive for the direct recharge of site aquifers (i.e. the infiltration of rainwater through the seasonal moisture variation zone, the surficial portion of the unsaturated zone that becomes drier and wetter according to seasonal climatic variations), particularly where site groundwater tables are deeper than about ±4 m. Thus, any recharge that does occur is likely to be episodic and confined to those years where above average rainfall is received.

2.3 DRAINAGE

The site is located within the D41K quaternary catchment which has a total catchment area of 4 216 km^2 and a net Mean Annual Runoff of 6.53 million m^2. The entire Moloto catchment which includes D41K is classified as a catchment with large areas that do not contribute to runoff. The nearest watercourse to the Mamatwan Mine is the Vlermuisleegte, a non-perennial tributary of the Ga-Mogara, which flows from south-east to north-west approximately 1.6 km west of the site. Given the large distance between the mine and these watercourses, flood lines have not been mapped for the site.

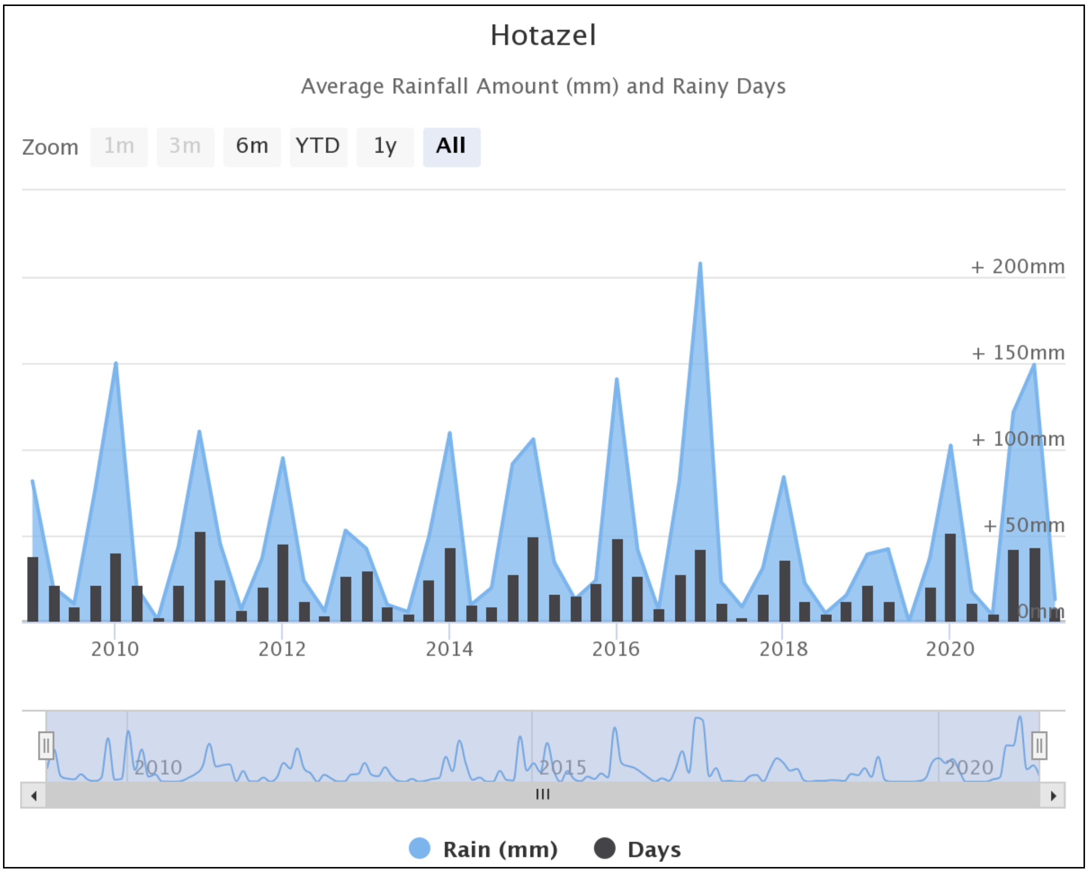


Figure 2. Average rainfall for the Hotazel area (Period: 2009 to 2021).

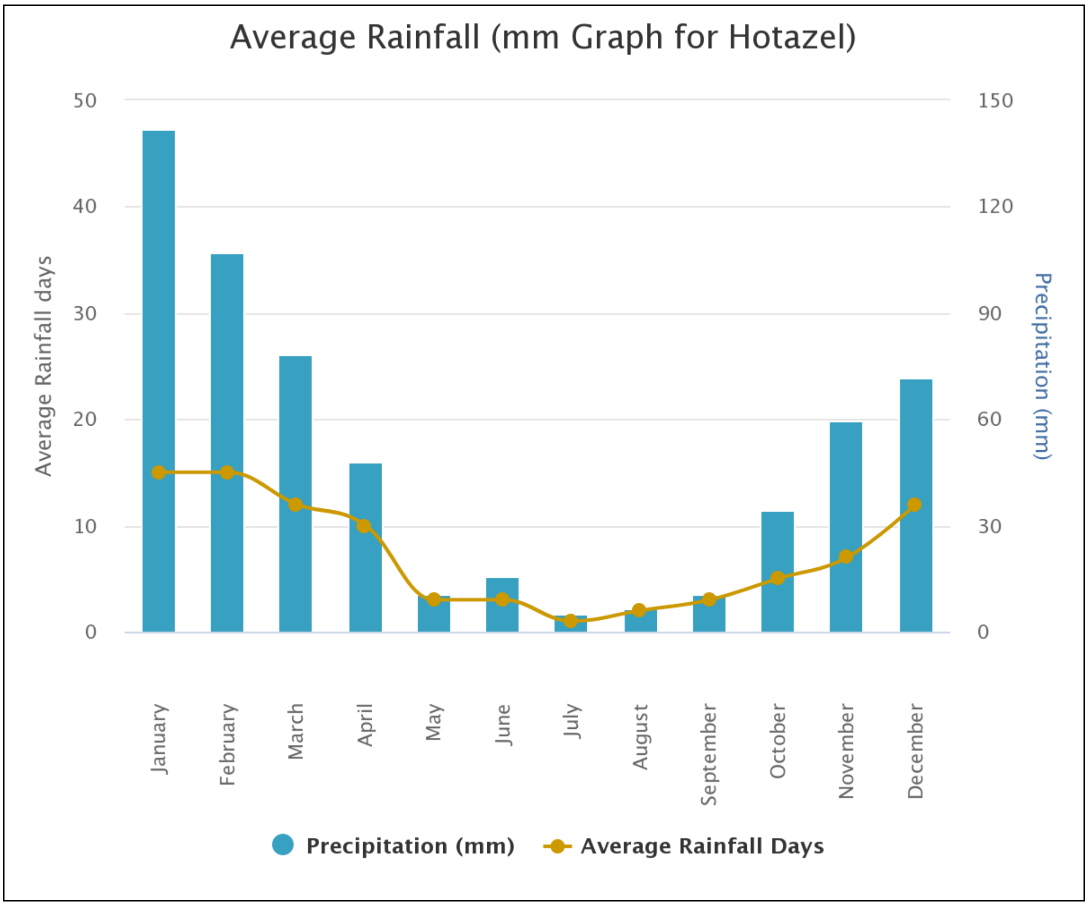


Figure 3. Average annual monthly rainfall for the Hotazel area.

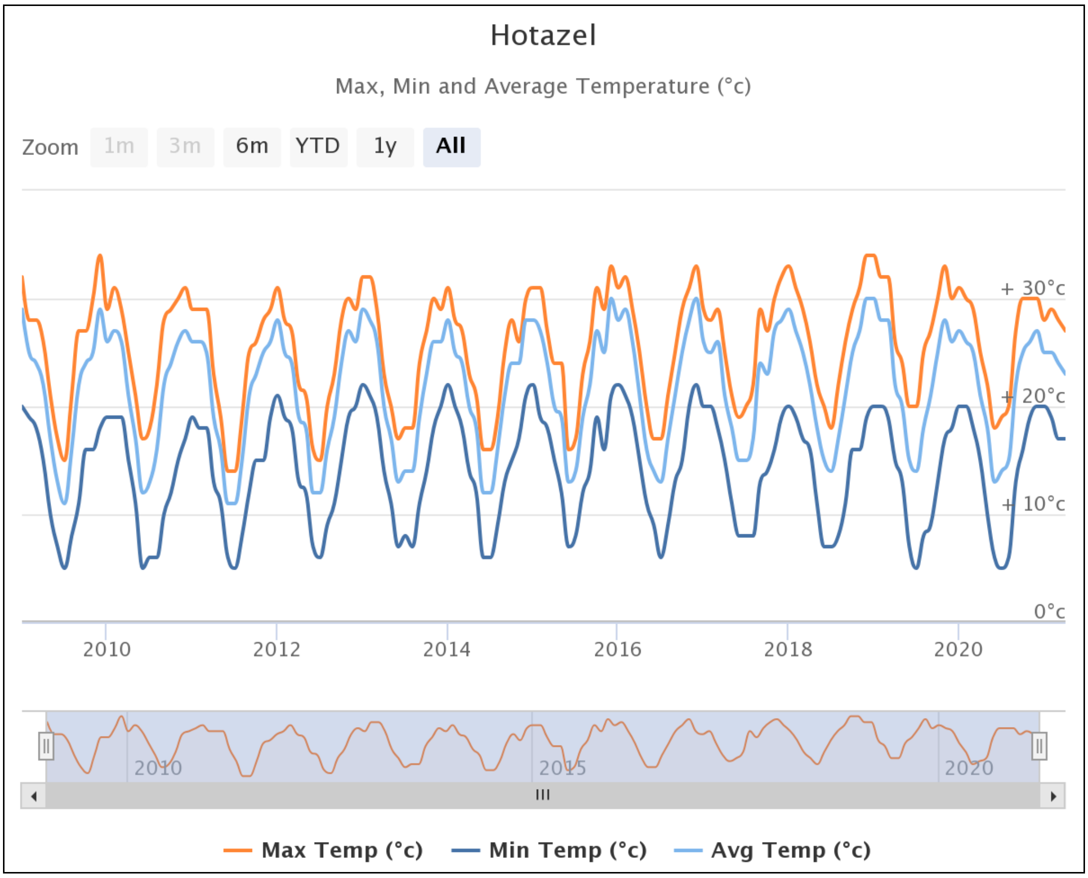


Figure 4. Average temperatures for the Hotazel area (Period: 2009 to 2021).

2.4 GENERAL DESCRIPTION OF THE GEOLOGY

The following summary of site geology was developed following reference to Hotazel Manganese Mines, Cairncross et al. (1997) and Van der Merwe (2002). The following sections were adapted from GHT Consulting report titled, Geohydrology of the Kalahari Manganese Field (2003) as well as the Groundwater Investigation for Mamatwan Mine, Northern Cape Report, Project No.: SOU6754, 2020.

2.4.1 Regional Geology

The project area is located within the Kalahari Manganese Field (KMF) hosted by the early Proterozoic Transvaal Supergroup, in the Griqualand West Basin along the western margin of the Kaapvaal Craton (refer to Figure 5 on page 6).

The rocks of the Transvaal Supergroup within the Griqualand Basin are gently folded. The folds are truncated by the Olifantshoek unconformity at the base of the Olifantshoek Group. The Griqualand West is divided into two groups (refer to Figure 5 on page 6):

- The basal Ghaap Group; and
- The Postmasburg Group.

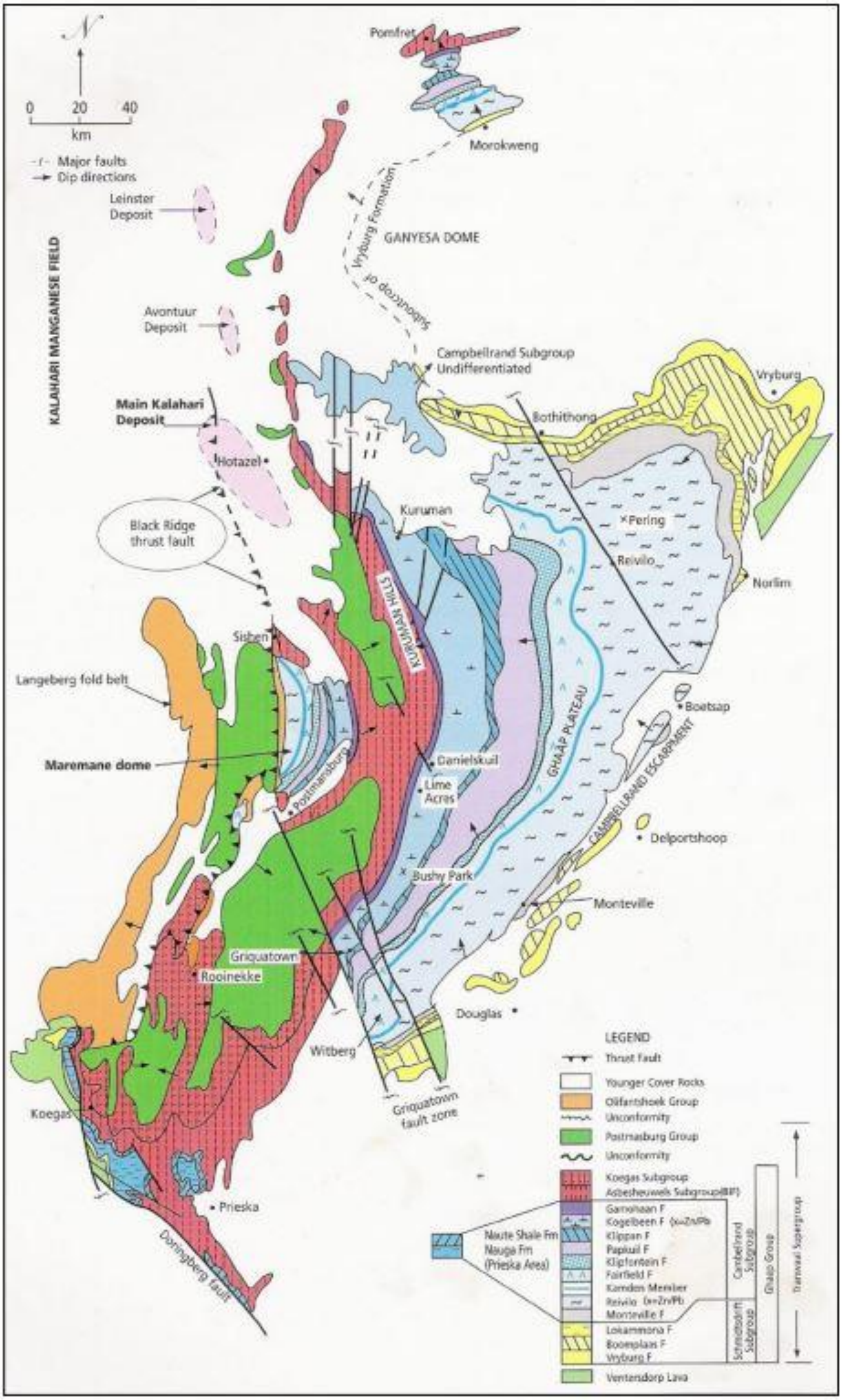


Figure 5. Distribution of the Major Stratigraphic Units and Ore Deposits of the Transvaal Supergroup within the Griqualand West (source: Hotazel Manganese Mines, 2001)

2.4.2 Local Geology

Mamatwan Mine is located within the south-western outer rim of the Kalahari Manganese Field. The KMF is dived into two ore types based on the geochemical characteristics of the manganese ore (Evans et al., 2001):

- The low grade, sedimentary, Mamatwan-type ore found in the south-east; and
- The high grade, hydrothermally altered, Wessels-type ore in the north-west.

The high-grade Wessels-type ore makes up to 3% of the total manganese resource while the low-grade Mamatwan-type ore makes up the remaining 97% (Gutzmer and Cairncross, 2002).

The Hotazel Formation was deposited between 2 200 and 2 300 million years ago and the formation is structurally confined within the Dimoten Syncline, a north-westerly plunging basin containing more than 80% of global land-based manganese reserves within an area of approximately 525 km2.

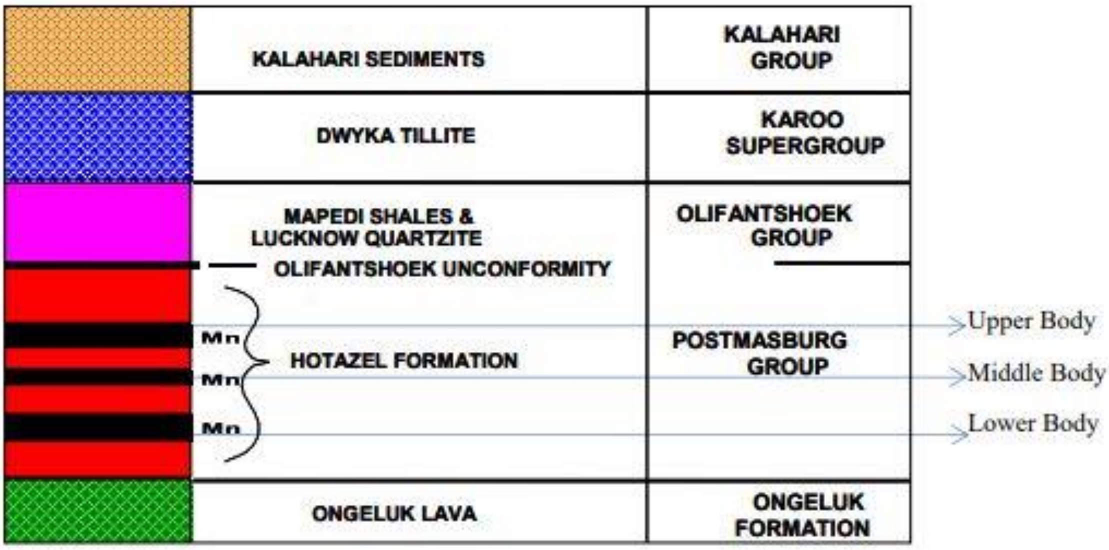
The Hotazel Formation includes the Banded Iron Form (BIF). The ore is contained within a 30 40 metres thick mineralised zone which occurs across the entire area and is made up of three manganese-rich zones as follows:

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

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

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

Table 1. Hotazel Manganese Mines Stratigraphic Units Within the Project Area (source: Zulu, 2019)



2.4.3 Structural History

Structural deformation varies across the field, with available data suggesting that it was more intense in the vicinity of Wessels Mine in the north. Here, fault orientations are typically orientated northeast-to-southwest, north-to-south, and west/northwest-to-east/southeast. The north-south orientated normal structures are thought to have developed during the initial deposition of the Oliphantshoek Group sediments some 1800 to 2150 million years ago in response to extensional stresses, these post-dating the northeast-to-southwesterly orientated structures that have, in part, been infilled with bostonite. While the timing of the west/northwesterly-to-east/southeasterly shear events appears unknown, it seems plausible that associated structures are conjugate features that developed in response to the extensional episode.

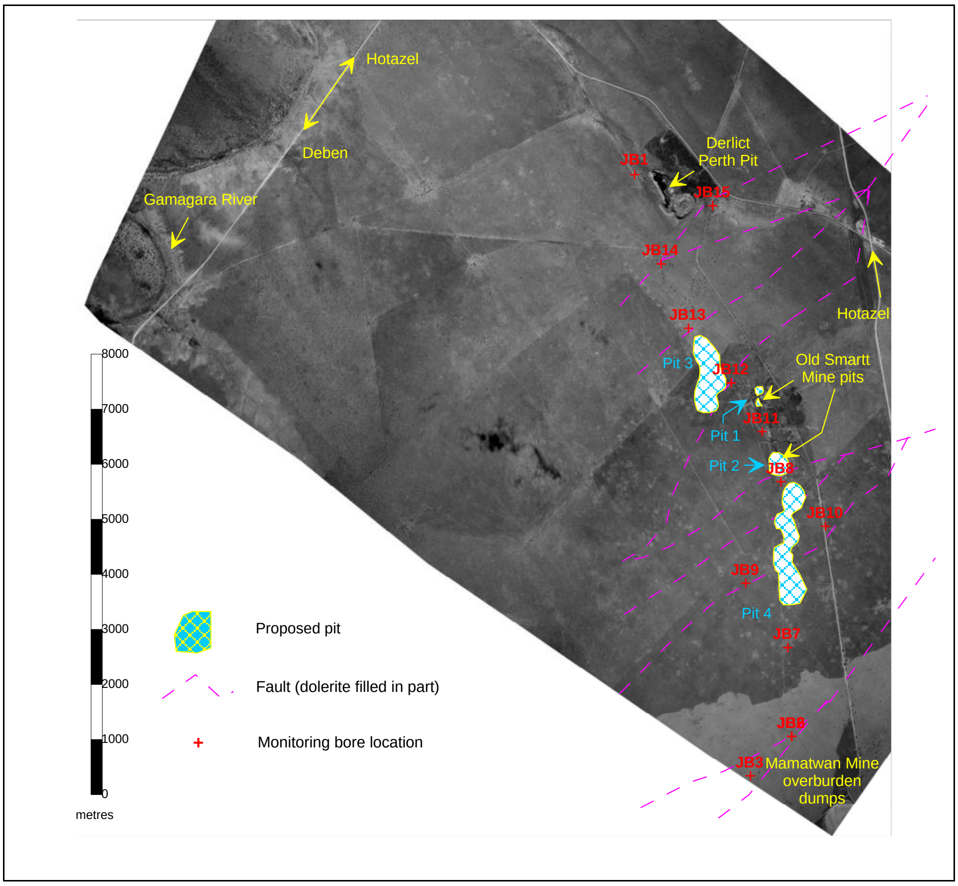


Figure 6. Location of Smartt Rissik prospect monitoring boreholes in relation to sub-cropping dykes and proposed mine pits. Note the topography falls gently (about 1V:200H) towards the Ga-Mogara River in the northeast.

Figure 7. Structure in Hotazel Formation, Hotazel Mine pit. While resembling a parasitic nappe, the virtual absence of similar structures elsewhere in the pit suggests the structure represents either the most easterly expression of thrusting, or localized deformation due to sill and dyke emplacement.

Nappe and recumbent fold structures that developed along the strike of the regionally extensive Black Ridge Thrust Fault in response to thrusting approximately 1800 million years ago are represented at Wessels Mine, and the western boundary of the Smartt-Rissik prospect. The suggestion has also been made that small-scale thrust-related structures occur in the old Hotazel Mine pit (refer Figure 7), although given their sporadic distribution it seems likely that these represent either,

- The most easterly expression of thrusting;
- Localized deformation in response to sill and dyke emplacement.

Localized structures are also of significance in the Hotazel area, as these appear to control the highest-grade manganese deposits yet discovered at this, and any other for that matter, mineral field. Here, ore mined from the now abandoned Hotazel, and adjacent Assmang-owned Devon, and Langdon Annex Mines, is thought to have been restricted to structurally isolated, north-south orientated, down-faulted grabens, although supporting evidence for the presence of the faults appears somewhat lacking.

2.1 HYDROGEOLOGY

The following section is containing a summary of the general geohydrological conditions of the study area. The following sections were adapted from GHT Consulting report titled, Geohydrology of the Kalahari Manganese Field (2003).

2.1.1 Regional Recharge Characteristics

The sites semi-arid climate and a relatively thick unsaturated zone (>25 m deep on average) are not conducive to active recharge, which has been calculated to be between 1 and 4% of average annual rainfall. Indeed, groundwater is up to 25000 years old in deeper, confined aquifers, although surficial unconfined/semi-confined aquifers have been recharged in relatively recent time. Site aquifers are recharged directly from rainfall, though stable isotope results suggest that infiltration of standing surface water contained in topographical depressions may be of importance regionally. Indeed, standing water contained within the derelict Smartt and Perth pits has infiltrated into site aquifers, resulting in localized increases in SWL.

Recharge occurs via the relatively permeable Kalahari Formation, the recharge front mobilizing soil nitrates, particularly at sites that have been overgrazed or stripped of vegetation. This has resulted in dangerously high nitrate concentrations (i.e. Class 4) in groundwater throughout the investigation area. This is of significance as the resource is now only of importance to stock and industrial users, although the reported death of cattle watered from some boreholes suggests it may even have limited agricultural application in some instances.

It is now known that groundwater is derived from aquifers within the Ongeluk, Hotazel, Mooidraai, and Kalahari in the region, although sediments of the Olifantshoek Group may also be of significance in the vicinity of Wessels Mine. Ongeluk Formation aquifers appear to be primarily associated with weathered horizons and zones adjacent to regional scale structures, although the unit is generally not favoured as a potential water supply source because of its low yield characteristics. Aquifers within the Hotazel Formation typically have higher yields when compared to those in the older Ongeluk Formation, the groundwater stored in voids that developed following bed separation, within faults and periphery fractures, and along the dolerite dykes that have partially filled regional faults. The high number of dykes and fractures interpreted for the site suggest vertical hydraulic connection throughout much of the formation above the sill, with horizontal interconnection provided along bedding planes. The formation can therefore be regarded as semi-confined on the Smartt-Rissik and Mamatwan prospects where it sub-crops at shallow depth, the better aquifer yields generally being associated with the preferentially fractured, brittle BIF's adjacent to regional faults. With increasing depth, however, Hotazel Formation aquifers can be confined, particularly when the overlying Kalahari Formation contains thick inter-beds of highly plastic red clay as observed across the Wessels and Middelplaas leases, and along on the southern edge of the Mamatwan Mine property.

The dolomitic aquifers of the Mooidraai Formation are only of significance in the southwest of the study area in the vicinity of the now-derelict Middelplaats Mine. Available data suggests that aquifers comprising broken dolomites, have been subsequently confined by clay bearing units inter-bedded within the younger sediments of the Dwyka and Kalahari Formations. In terms of potential groundwater use, the aquifer is of significance locally due to its high yielding characteristics (>10 L/s), and indeed is currently exploited by Mamatwan Mine as an emergency supply. Of significance, however, is that there is no evidence to suggests that these aquifers have been recharged in recent time

On a regional scale the Kalahari Formation behaves as a semi-confined aquifer, which is hydraulically connected with aquifers in underlying formations at those sites where extensive red clay or clay-bearing Dwyka Formation beds are absent. While the aquifer is generally more porous than other site aquifers, it is heterogeneous; that is, like other aquifers discussed here, the characteristics of the aquifer vary from site to site. Thus, yields vary significantly spatially, although blow yields in excess of 5 L/s are possible, particularly where palaeochannel deposits have developed along regionally extensive structures that dissect the underlying lithologies. These palaeochannel deposits, one of which has been identified to the north of the Mamatwan Mine pit, contain significant quantities of groundwater, although the high nitrate concentrations in groundwater regionally prevent them from being classed as important groundwater resources. Of significance, however, is that inferred tributaries, which developed parallel to the contact between the older Ongeluk and Hotazel Formations, appear to have higher yields than the palaeochannel itself.

The dolerite sill and dykes that have intruded the Hotazel Formation are relatively impermeable, the dykes compartmentalizing groundwater regionally. This has resulted in an increase in groundwater levels and flattening off of the water table in the northern portion of the Smartt-Rissik prospect. The groundwater table does reflect topography when it occurs within the Kalahari Formation, however, although the dykes continue to act as a barrier to flow within older, underlying formations. If the compartmentalizing effects of the dykes are ignored, the hydraulic gradient across the site is about 1V: 200H towards the northwest. Site aquifers do not contribute to stream baseflow, although short-term contributions (i.e. < 1 month) may occur elsewhere in the investigation area during wetter-than-average years.

2.1.2 Aquifer Classification

The Aquifer Classification Map of South Africa (DWS, 1999) indicated that the local aquifer of Mamatwan Mine is classified as poor to minor (refer to Figure 8 on page 12). The aquifer vulnerability of Mamatwan Mine is rated as least to moderate by the Aquifer Vulnerability Classification Map of South Africa (refer to Figure 9 on page 13), (DWS, 2013).

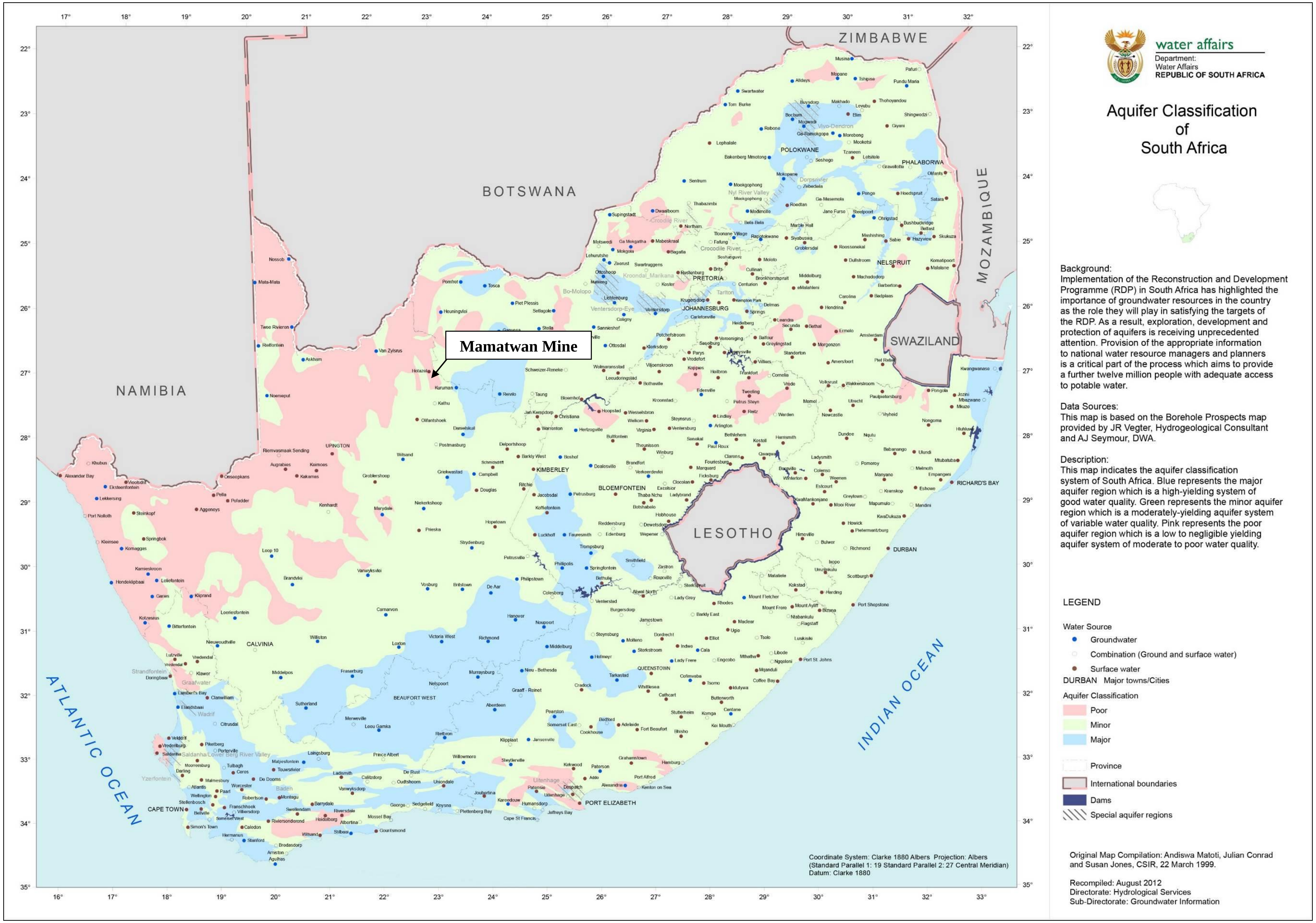


Figure 8. Map of the Aquifer Classification of South Africa. Note that the aquifer of Mamatwan Mine is classified as poor.

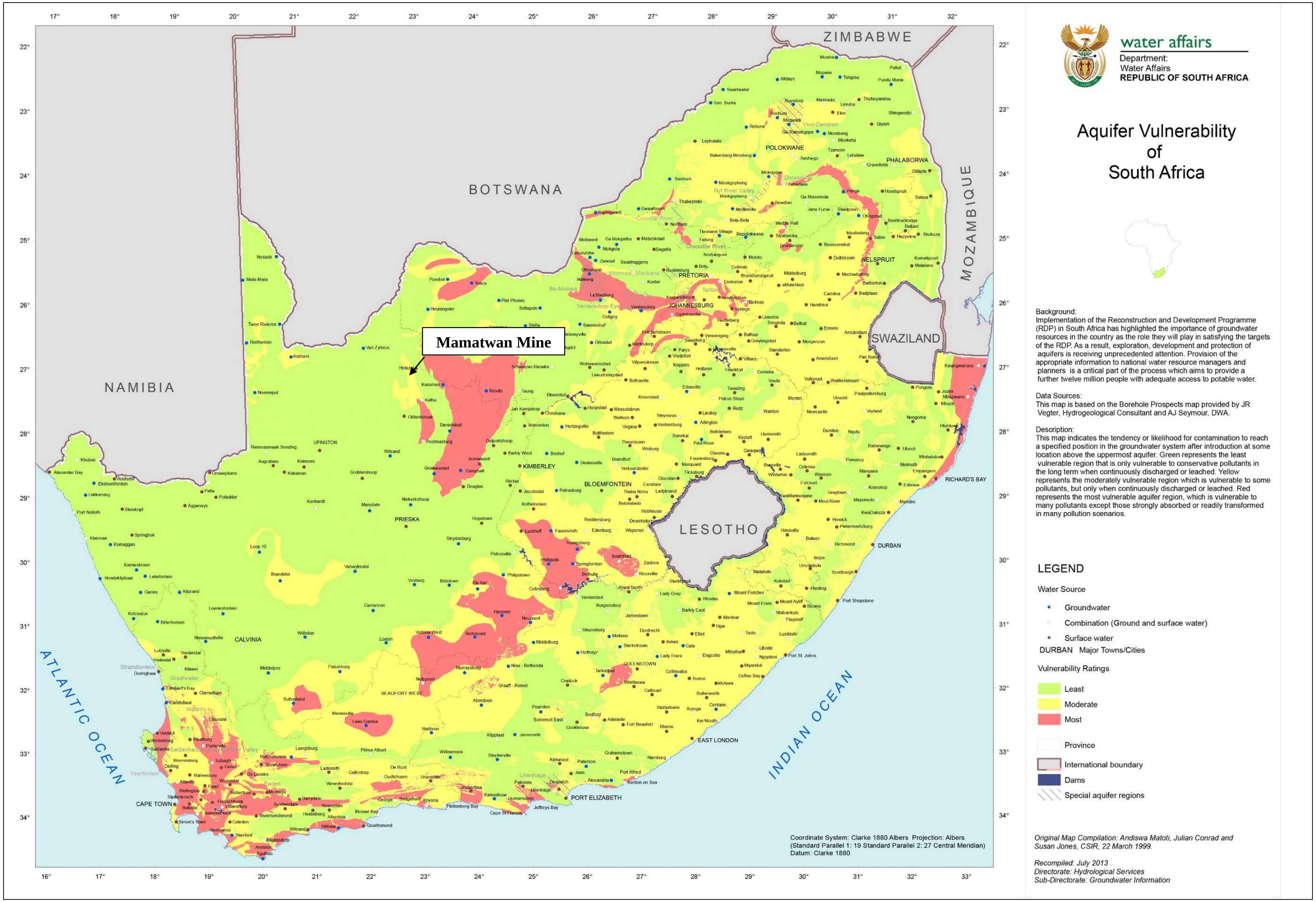


Figure 9. Map of the Aquifer Vulnerability Classification of South Africa (DWS, 2013). Note that the aquifer vulnerability of Wessels Mine is classified as moderate.

2.1.3 Aquifer Description

The aquifer type of the hydrocensus area can be described as an intergranular and fractured. The aquifer yield of the is in the order of 0.1 – 0.5 L/s for most of the area and 0.5 – 2.0 L/s for the western and north eastern parts of the hydrocensus area (1:1 000 000 Hydrogeological Map series of South Africa), (refer to Figure 10 on page 15). The aquifer recharge volumes are between 4.6 – 8.2 mm/a or 1 – 4% of MAP [Groundwater Resource Assessment Phase 2 (GRA2, 2005)].

Four aquifers are present in the Ongeluk, Hotazel, Mooidraai, and Kalahari Formations. The aquifers are described as follows:

- **Kalahari Formation:** On a regional scale the Kalahari Formation behaves as a semi-confined aquifer, which is hydraulically connected with aquifers in underlying formations at those sites where extensive red clay or clay-bearing Dwyka Formation beds are absent. While the aquifer is generally more porous than other site aquifers, the characteristics of the aquifer vary from site to site. Yields vary significantly spatially. A paleo-channel deposit has been identified to the north of the Mamatwan pit, containing significant quantities of groundwater, however, this aquifer contains high nitrate concentrations and therefore it cannot be classed as an important groundwater resource. Of significance, however, is that the inferred tributaries, which developed parallel to the contact between the older Ongeluk and Hotazel Formations, appear to have higher yields than the paleo-channel itself.
- **Hotazel Formation:** This aquifer typically has a higher yield, with the groundwater stored in voids that developed following bed separation, within faults and periphery fractures, and along the dolerite dykes that have partially filled regional faults. The high number of dykes and fractures interpreted for the site suggest vertical hydraulic connection throughout much of the formation above an intrusive sill, with horizontal interconnection provided along bedding planes. The formation is regarded as semi-confined on the Smartt-Rissik and Mamatwan prospects where its sub-crops at shallow depth. The higher aquifer yields are associated with the preferentially fractured, brittle BIF's adjacent to regional faults. With increasing depth, however, the Hotazel Formation aquifer can be confined, particularly when the overlying Kalahari Formation contains thick inter-beds of highly plastic red clay as observed along the southern edge of the Mamatwan Mine property.
- **Mooidraai Formation:** A dolomitic aquifer occurring in the southwest of the study area in the vicinity of the now-derelict Middelplaas Mine. This aquifer is of significance locally due to its high yielding characteristics (>10 L/s) and is currently exploited by Mamatwan Mine as an emergency supply source. It is noted that there is no evidence to suggest that these aquifers have been recharged in recent times.
- **The Ongeluk Formation:** Being an older geological formation, the aquifer is primarily associated with weathered horizons and zones adjacent to regional-scale structures. This aquifer is generally not favoured as a source of water supply due to its general low yield.

Various intrusive dolerite sill and dykes have intruded the Hotazel Formation which is relatively impermeable and creates groundwater compartments regionally. The groundwater table does reflect the topography when it occurs within the Kalahari Formation; however, the dykes continue to act as a barrier to flow within older, underlying formations.

The simplified local stratigraphy at Mamatwan mine includes sand, calcrete, gravel and clay (Kalahari formation) underlain by the Hotazel Formation. Although the water-bearing part of the aquifer occurs within the gravel contact zone between the calcrete and clay, GHT views the main exploitable aquifer (as well as receiving part of the aquifer) as the top three geological formations. The clay together with the Hotazel Formation forms a relatively impermeable aquifer bottom.

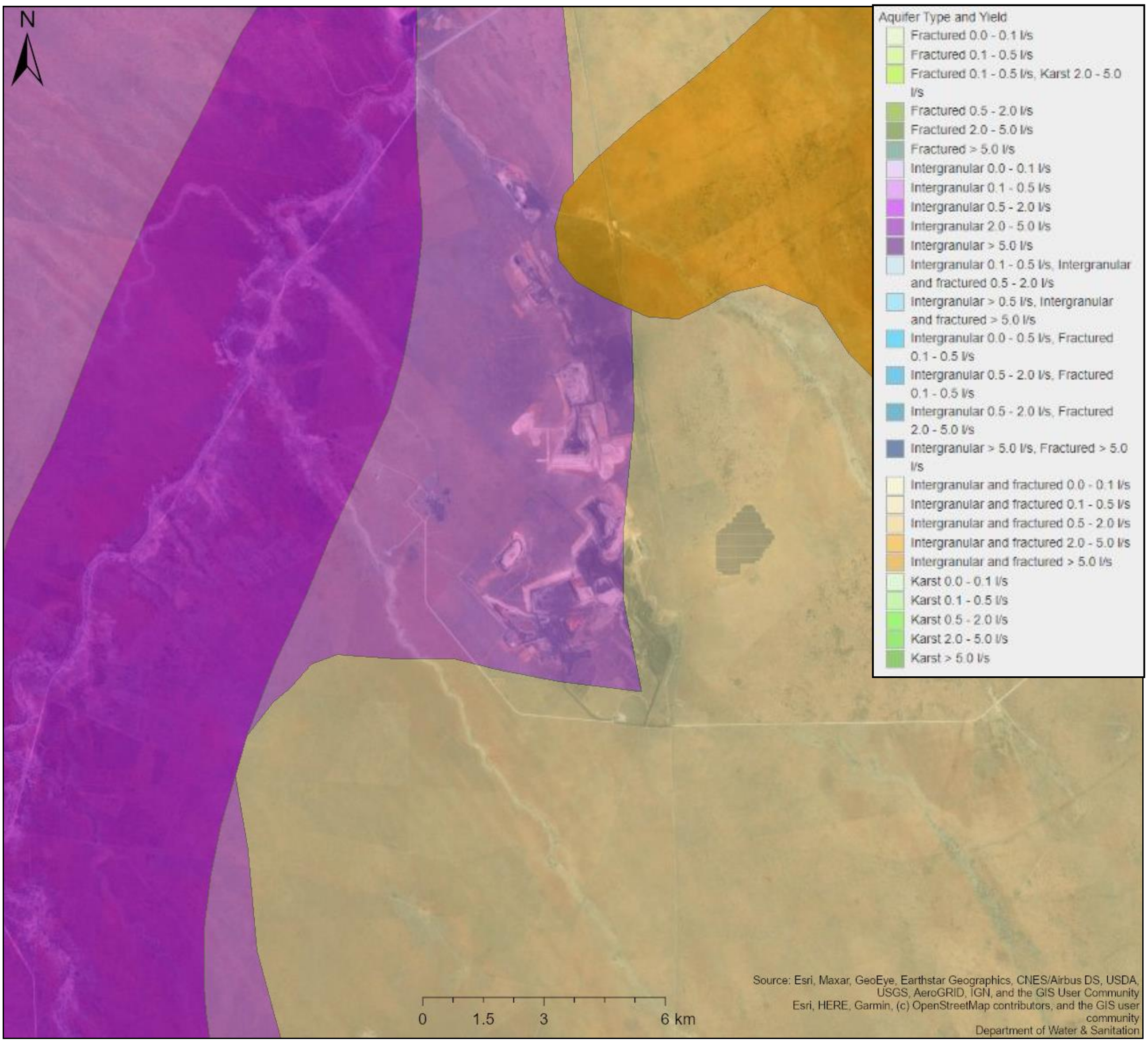


Figure 10. Mamatwan hydrocensus area aquifer type and yield (1:1 000 000 Hydrogeological Map series of South Africa).

2.1.4 Presence of Boreholes and Springs

No springs or permanent surface water bodies are known to occur within the study area, while the main drainage features, the Kuruman and Ga-Mogara Rivers, flow rarely and only after periods of prolonged wet weather during wetter than average years.

To determine the location of pre-existing boreholes and springs in the vicinity of the respective HMM mines, surrounding properties were visited and landholders and tenants consulted. A total of 48 boreholes were located in 2002, none of which were within 1 km of current or proposed mine mining operations. While no logs or yield information was available for any of the located bores, the owner of Perth, a farm adjacent to the Smartt-Rissik prospect, was able to confirm that boreholes on his property tap weathered Ongeluk Lava aquifers. Perth BH3 is apparently a relatively high yielding borehole that was used as the sole water supply for the farms Botha, Perth, Rissik, and Smartt in the past, although this was stopped once bores were subsequently constructed on the respective properties. This approach is, however, still used to overcome water supply problems on other properties in the region.

Within the area of investigation, the bore from which most water has the potential to be extracted annually is MB(MID)24 (M24), a production borehole located to the north of the abandoned Middelplaats Mine shaft. Constructed in 1977 as an emergency water supply bore for the nearby Mamatwan Mine (the main water supply is derived from the Vaal-Gamagara system), available usage data suggests that the bore was not used as a water supply source for most of 2002. Thus, in terms of the current mine water management strategy, the borehole is not an operational necessity for the site.

2.1.5 Groundwater Use and Water Supply

This section was adapted from GHT Consulting report titled, Geohydrology of the Kalahari Manganese Field (2003) as well as the Groundwater Investigation for Mamatwan Mine, Northern Cape Report, Project No.: SOU6754, 2020.

The mine predates 1963, however, the first recorded hydrocensus was performed and reported in 2002/2003 in the "The Regional Geohydrology of the Kalahari Manganese Field: Study conducted at Wessels Mine, Hotazel Mine, Mamatwan and Middelplaats Mine" report. The report indicates that no springs or permanent surface water bodies were known to occur in the study area. The main drainage features are the Kuruman and Ga-MogaraRivers which rarely flow apart from prolonged periods of increased rainfall.

A total of 48 boreholes were identified, with the boreholes being at least 1 km away from the current or proposed mining operations. The average hydrochemistry results from the hydrocensus study were assumed to representative as baseline/background values, while keeping in mind that these average values do not necessarily reflect pre-mining conditions as there have been almost thirty years of mining activities before the hydrocensus was carried out. In 2019, a hydrocensus survey update was carried out for the 48 identified boreholes. The following groundwater usage was identified from the boreholes:

- Nine (9) boreholes used for domestic use,
- One (1) used for domestic use and gardening (irrigation),
- Eighteen (18) boreholes used for livestock watering, a
- Fourteen (14) boreholes were not in use.

3 HYDROCENSUS FIELDWORK ACTIVITIES

The field investigation was performed in May 2021, these activities involved the location, surveying, water level measurement, sampling, and collection of all relevant general borehole information of privately owned boreholes in the vicinity of the operations of Mamatwan Mine.

3.1 DETERMINATION SAMPLE LOCALITIES

The sampling localities were determined by consulting each private landowner in regard to the boreholes in use on each of the farms.

3.2 SURVEYING

Hydrocensus boreholes were surveyed by means of a Garmin GPS (Global Positioning System) to obtained accurate coordinates. The coordinates will be utilised for the following:

- The construction of a GIS Map (Geographical information System);
- The creation of data point sites in a GIS capable electronic database;
- Construction of hydro-chemical contour maps; and
- To facilitate in the location of hydrocensus boreholes during future sampling events.

3.3 WATER LEVEL MEASUREMENT

The groundwater levels of the hydrocensus boreholes were measure by means of a dipmeter where possible to determine the depth of the regional and local aquifers surrounding the HMM mining operations.

3.4 SAMPLING METHODS

The hydrocensus boreholes sampled were predominantly equipped with mono or submersible pumps or with wind driven pumps. Therefore, the boreholes were sampled at pump outlets or in dams located next to the borehole. Where possible the unequipped boreholes were sampled by means of a specific depth bailer.

4 GENERAL HYDROCENSUS BOREHOLE INFORMATION

This section contains the general borehole information of the farm boreholes of the 2021 hydrocensus study for Mamatwan Mine. The general hydrocensus borehole information can be viewed in Table 2 below. The locality map of the hydrocensus borehole localities area can be viewed in Figure 11 on page 20. The hydrocensus study included site visits and gathering of all relevant geohydrological data from twenty farm boreholes in the vicinity of Mamatwan Mine (investigation radius: 15.60 km). The farms investigated included of London, Kameelaar, Aarpan, Perth 276, Eldoret, Rissik, Moab, Milner, Heunning Draai, Smuts, Cobham and Sutton. The groundwater resource is utilised in the study area and represents the sole source of water for the farmers. The groundwater use is mainly for livestock watering, although some farmers also utilise the groundwater resource for domestic purposes. Borehole equipment used to abstract the groundwater from boreholes ranges from submersible pumps, solar pumps and windmills.

Table 2. General borehole information of the Mamatwan Mine Hydrocensus Study.

	Borehole Name	Topographic Map Reference	Quaternary Sub-Catchment	Locality Discription	Farm Name	Owner	Mobile Number	Date	Coordinates (WGS84) Longitude (East)	Latitude (South)	Elevation (mamsl)	General Borhole Information Casing Height (m)	Casing Diameter (mm)	Borehole Depth (m)	Borehole Equipment [Pump Outlet Diammeter (mm)]	Rest Water Level (mbgl)	Water Use	Comments
1.)	**HF/BH22**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	London / Kameelaar	Mr. Dawid Venter	(082) 507-7716	2021/05/10	23.04815	-27.26684	1098.93	0.40	160	n/a	Submersible Pump.	n/a	* LS & * DD	Borehole top is closed. No WL.
2.)	**HF/BH23**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	London / Kameelaar	Mr. Hendrik Venter	(082) 507-7716	2021/05/10	23.04455	-27.26819	1099.20	0.00	160	n/a	Windpomp / Wind Powered Pump (50 mm).	13.63	* LS	~
3.)	**HF/BH24**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Aarpan	Ms. Ansie Venter	(082) 873-4856	2021/05/10	23.08828	-27.25825	1122.31	0.36	160	n/a	Solar Powered Pump (40 mm).	16.57	Not utilised	Not utilised, Pump broken
4.)	**HF/BH25**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Aarpan	Ms. Ansie Venter	(082) 873-4856	2021/05/10	23.09512	-27.26161	1128.70	0.80	160	n/a	Submersible Pump (40 mm).	n/a	* LS	Borehole top is closed. No WL.
5.)	**HF/BH26**	2722BD	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Perth 276	Mr.Eben Anthonissen	(073) 163-4665	2021/05/10	22.98135	-27.29251	1070.13	0.04	160	n/a	Mono Pump (40 mm).	n/a	* LS	~
6.)	**HF/BH27**	2722BD	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Perth 276	Mr.Eben Anthonissen	(073) 163-4665	2021/05/10	22.98135	-27.28864	1070.75	0.40	160	n/a	Borehole Is Blocked.	21.97	Not Utilised.	~
7.)	**HF/BH28**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Eldoret	Mr. Piet Swanepoel	(072) 758-3331	2021/05/10	23.00597	-27.28831	1083.63	0.60	160	n/a	Windpomp / Wind Powered Pump (50 mm).	34.88	Not Utilised.	~
8.)	**HF/BH29**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Eldoret	Mr. Piet Swanepoel	(072) 758-3331	2021/05/10	23.03036	-27.27744	1095.45	0.60	160	n/a	Windpomp / Wind Powered Pump (50 mm).	27.00	* LS	~
9.)	**HF/BH30**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Rissik	Mr. Gideon Poolman	(082) 805-4280	2021/05/14	23.00516	-27.31032	1080.00	0.45	160	n/a	Submersible Pump (40 mm).	n/a	* LS	Farmers not responding to calls. Owner not available.
10.)	**HF/BH31**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Rissik	Mr. Gideon Poolman	(082) 805-4280	2021/05/14	23.00407	-27.31317	1080.00	0.40	200	n/a	Borehole Is Blocked.	n/a	Not Utilised.	Farmers not responding to calls. Owner not available.
11.)	**HF/BH32**	2723AC	D41K	Mamatwan Mine District	Moab	Mr. Niekie Kruger	(082) 879-7451	2021/05/11	23.00551	-27.40557	1110.03	0.50	180	n/a	Windpomp / Wind Powered Pump (50 mm).	n/a	* LS	~
12.)	**HF/BH33**	2723AC	D41K	Mamatwan Mine District	Milner	Mr. Niekie Kruger	(082) 879-7451	2021/05/11	23.06380	-27.38234	1119.05	0.40	160	n/a	Windpomp / Wind Powered Pump (25 mm).	23.59	* LS	~
13.)	**HF/BH34**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Heunning Draai	Mr. Ampie Coetzee	(082) 559-8161	2021/05/10	22.88761	-27.32795	1060.00	0.60	130	n/a	Submersible Pump (40 mm).	n/a	* LS & * DD	~
14.)	**HF/BH35**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Heunning Draai	Mr. Ampie Coetzee	(082) 559-8161	2021/05/10	22.88844	-27.32523	1060.00	0.70	166	n/a	Submersible Pump (40 mm).	n/a	* LS & * DD	~
15.)	**HF/BH36**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Smuts	Mr. Nico Smith	(072) 323-3060	2021/05/10	22.86649	-27.35455	1060.00	0.27	200	n/a	Submersible Pump (50 mm).	29.13	* LS & * DD	~
16.)	**HF/BH37**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Smuts	Mr. Nico Smith	(072) 323-3060	2021/05/10	22.82764	-27.34351	1074.26	0.32	170	n/a	Solar Powered Pump (40 mm).	n/a	* LS	~
17.)	**HF/BH38**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Cobham	Mr. Phillip van der Merwe	(083) 379-7547	2021/05/10	22.90379	-27.40549	1080.00	0.60	200	n/a	Windpomp / Wind Powered Pump (50 mm).	n/a	* LS	Owner not available.
18.)	**HF/BH39**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Cobham	Mr. Phillip van der Merwe	(083) 379-7547	2021/05/10	22.87963	-27.40732	1080.69	0.17	160	n/a	Windpomp / Wind Powered Pump (50 mm).	n/a	* LS	Owner not available.
19.)	**HF/BH40**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Sutton	Mr. Philip Markram	(073) 228-9555	2021/05/14	22.86471	-27.44708	1081.88	0.14	150	n/a	No Equipment.	n/a	Not Utilised.	Farmers not responding to calls. Owner not available.
20.)	**HF/BH41**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Sutton	Mr. Philip Markram	(073) 228-9555	2021/05/14	22.86471	-27.44505	1081.79	0.28	160	n/a	No Equipment.	n/a	Not Utilised.	Farmers not responding to calls. Owner not available.

* DD - Domestic Water/Drinking Water
* LS - Livestock Watering
** New Boreholes / Replacement Boreholes

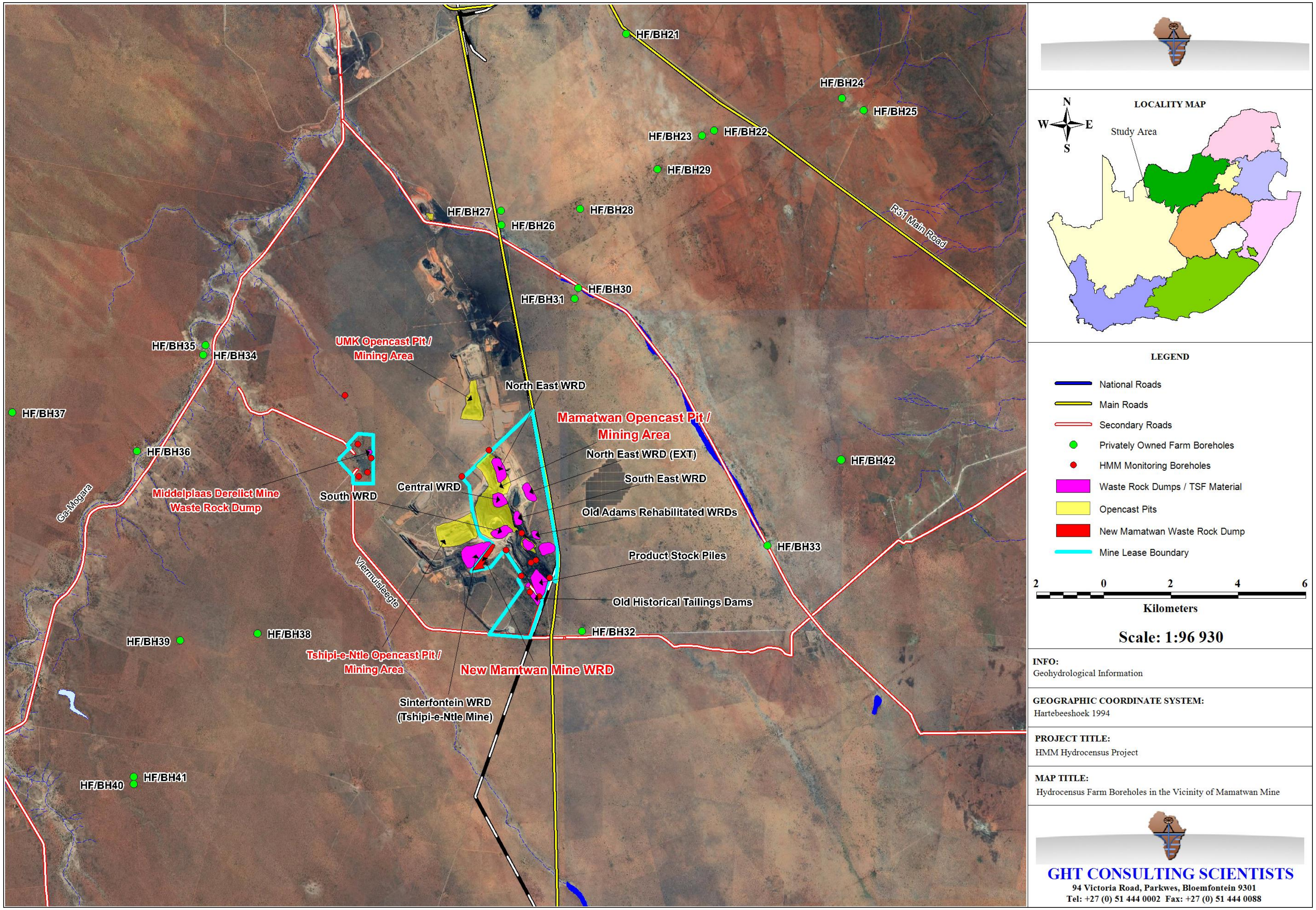


Figure 11. Locality map of the hydrocensus study area for Mamatwan Mine.

Photos of the hydrocensus boreholes of the Mamatwan Mine Hydrocensus Study.


Photo 1. Borehole HF/BH22.


Photo 2. Borehole HF/BH23.


Photo 3. Borehole HF/BH24.


Photo 4. Borehole HF/BH25.


Photo 5. Borehole HF/BH26.


Photo 6. Borehole HF/BH28.

Photo 7. Borehole HF/BH29.

Photo 8. Borehole HF/BH30.

Photo 9. Borehole HF/BH32.

Photo 10. Borehole HF/BH33.

Photo 11. Borehole HF/BH34.

Photo 12. Borehole HF/BH35.


Photo 13. Borehole HF/BH36.


Photo 14. Borehole HF/BH37.


Photo 15. Borehole HF/BH38.


Photo 16. Borehole HF/BH39.


Photo 17. Borehole HF/BH40.


Photo 18. Borehole HF/BH41.

5 HYDROCENSUS GROUNDWATER ELEVATIONS

The following section contain the results of the groundwater elevation measurements taken at the farm hydrocensus boreholes in the vicinity of Mamatwan Mine.

5.1 GROUNDWATER ELEVATION RESULTS

The detailed groundwater elevation results of Mamatwan Mine Hydrocensus of the farm boreholes as well as the Mamatwan Mine monitoring boreholes can be viewed in Table 3, Table 4 and Table 5 on pages 27 to 29. The graphs of the topographical elevation versus groundwater elevation for the hydrocensus farm boreholes and the Mamatwan Mine monitoring boreholes can be studied in Figure 12 and Figure 13 on page 25. The Mamatwan Mine numerical model topography can be viewed in Figure 14 on page 26. The groundwater elevation contour maps and flow vectors for the Mamatwan Hydrocensus as well as the numerically modelled groundwater elevations can be viewed in Figure 15, Figure 16, Figure 17 and Figure 18 on pages 30 to 33.

The lowering of the hydraulic head due to the Mamatwan Opencast Pit mining activities (dewatering) have resulted in drawdowns of up to 1039.60 to 1047.50 mamsl in close proximity (0.1 km) from the north and north western side of the Mamatwan Pit. The dewatering impact zone radius stretches laterally within 2.0 to 3.0 km from the pit. To the southern part of the Old Adams Pit and Mamatwan Pit, the mining activities mining have resulted in drawdowns of up to 1079.40 to 1085.94 mamsl.

The southern parts of Mamatwan Mine indicates no dewatering effects, which this is partly due to an artificial groundwater mound that has developed under the old, rehabilitated slimes dam. The artificial groundwater mound has caused the groundwater to flow up gradient of natural groundwater flow and topographical drainage in a south-eastern direction towards borehole HF/BH32 (Moab Farm).

The groundwater flow vectors indicated that the impacted area is more pronounce to the north and north west of the pit (1.5 to 3.0 km) than to the south where the impact may only be a 1.0 km or less due to the artificial groundwater mound of the old slimes dam. The R-Squared value is 0.67 for the Mamatwan Mine area, which value indicates that the natural groundwater table of the local mine aquifer has been dewatered by the Old Adams Pit and Mamatwan Opencast Pit mining activities as well as the newer the newer Tshipi-e-Ntle Opencast Pit.

The R-Squared value is 0.94 for the farm boreholes in the vicinity Mamatwan Mine, Tshipi-e-Ntle Mine as well as UMK Mine. This indicates that aquifer is mimicking the topographical elevations and that the dewatering cone at opencast pit operations have not impacted the farm hydrocensus boreholes of the farms of London, Kameelaar, Aarpan, Perth 276, Eldoret, Rissik, Moab, Milner, Heunning Draai, Smuts, Cobham and Sutton.

The new waste rock dump (WRD) in the southern side where Mamatwan and Tshipi-e-Ntle opencast pits meet, have no impact on the dewatering at the mine locally or regionally according to numerical modelling. All potential additional recharge generated by the New WRD will flow to the opencast pits directly to the north of the facility and will not contributed to any additional dewatering affects but might actually help to buffer the dewatering to some extend due to the potential additional recharge volume generated by rainfall.

It is important to note that the opencast pit operations of Mamatwan Mine, Tshipi-e-Ntle Mine and United Manganese of the Kalahari (UMK) must be viewed as a cumulative impact and that any potential future in pact on the farm hydrocensus boreholes, although shown by numerical modelling and current geohydrological data to be negligible, will be combined dewatering impact from the four opencast pits in the area (refer to Figure 11 on page 20 for the pit localities).

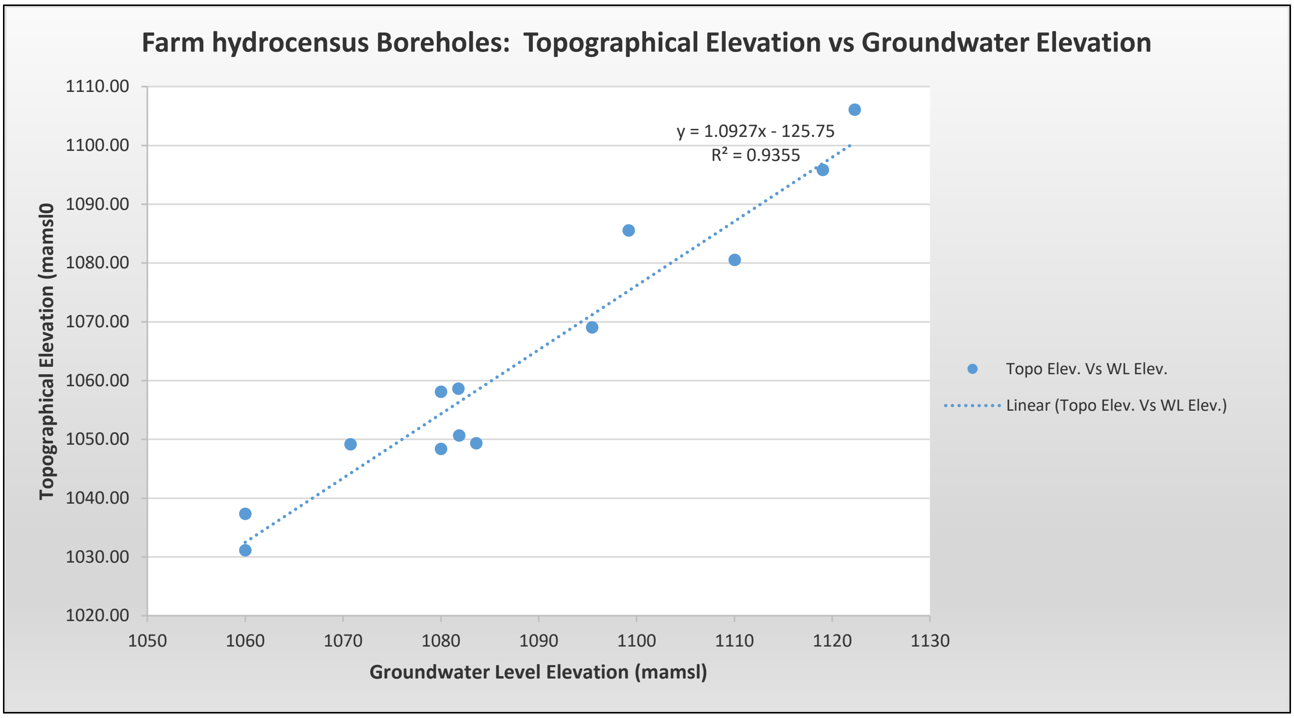


Figure 12. Graph of the topographical elevation versus groundwater elevation. Note that the R-Squared value is 0.94 for the farm boreholes in the vicinity of Mamatwan Mine as well as Tshipi-e-Ntle Mine and UMK Mine. The R-Squared value indicates that aquifer is mimicking the topographical elevations on these farms and that the dewatering cone at Mamatwan Opencast pits and Tshipi-e-Ntle Mine has not yet impacted these boreholes in terms of dewatering.

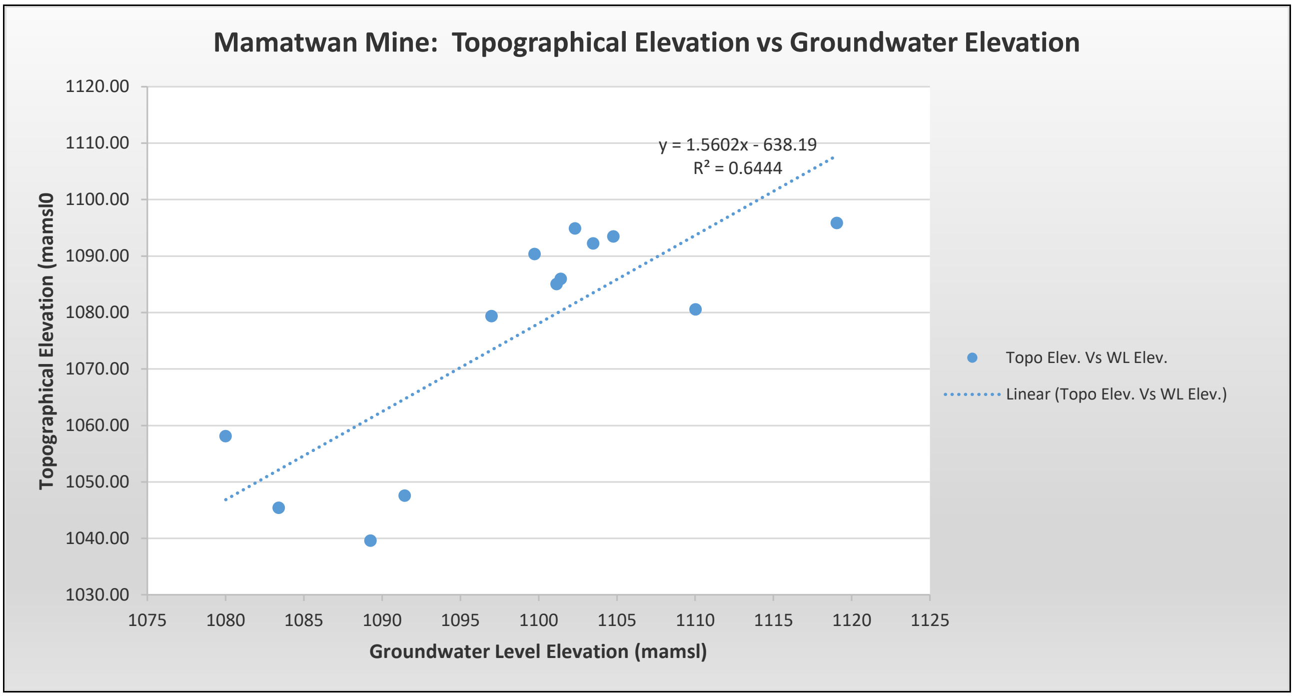


Figure 13. Graph of the topographical elevation versus groundwater elevation. Note that the R-Squared value is 0.64 for the Mamatwan Mine area. The R-Squared value indicates that the natural groundwater table elevation has been disturbed and that dewatering has occurred due to the opencast mining activities for the old Adams Pit as well as the Mamatwan Pit and the newer Tshipi-e-Ntle Pit.

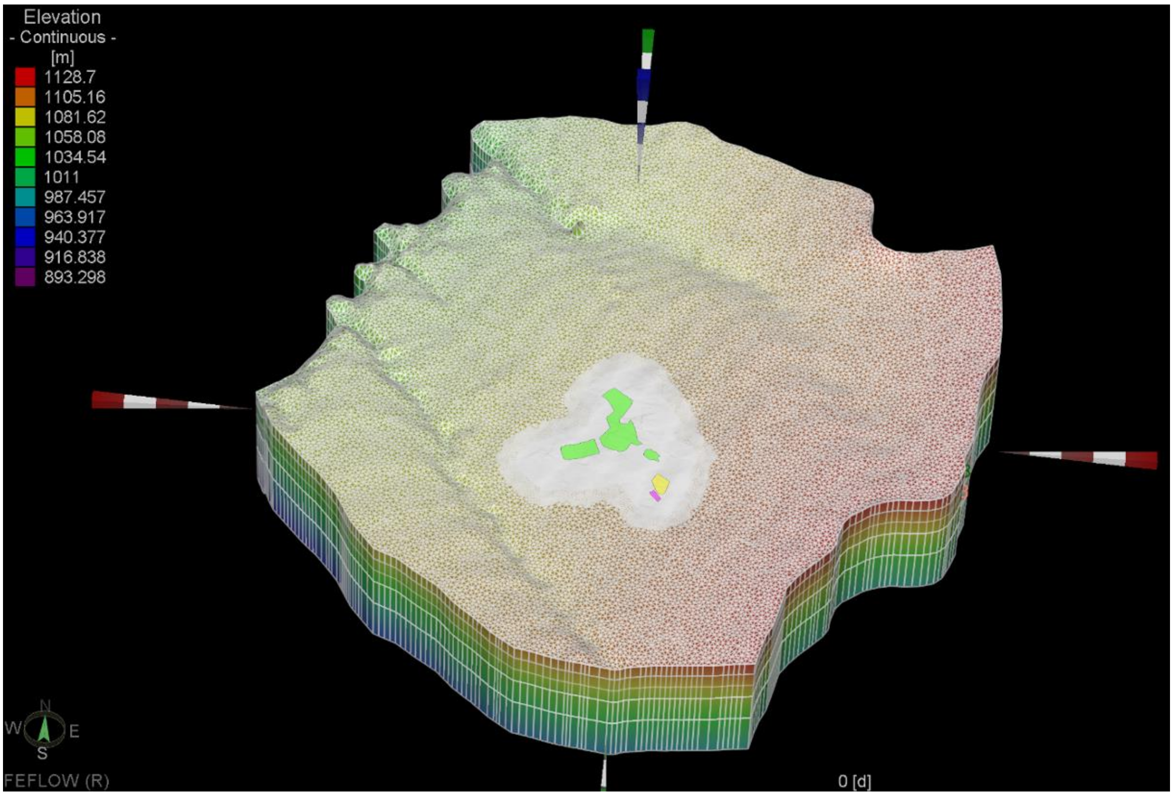


Figure 14. The Mamatwan Mine Numerical Model Topography.

Table 3. Part 1: Groundwater Level Elevation Results for the Mamatwan Mine Hydrocensus Study.

	Borehole Name	Quaternary Sub-Catchment	Locality Discription	Farm Name	Owner	Date	Coordinates (WGS84)			Casing Height (m)	Static Water Level (mbgl) [Groundwater Resource Assessment PH2 (GRA2, 2005)]	Static Water Level Elevation (mamsl)	Groundwater Flow Direction	Distance from Mamatwan Mine (km)	Comments	Verdict
							Longitude (East)	Latitude (South)	Elevation (mamsl)							
1.)	**HF/BH22**	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	London / Kameelaar	Mr. Hendrik Venter	2021/05/10	23.04543	-27.26635	1098.93	0.40	23.95	1075.38	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL is at a lower elevation then the Farm Borehole.	12.20	No water level is svailable. DWS Groundwater Resource Assessment PH2 data utilised (Modelled: 1km x1km raster). Mamatwan Mine is located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94).
2.)	**HF/BH23**	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	London / Kameelaar	Mr. Hendrik Venter	2021/05/10	23.04455	-27.26819	1099.20	0.00	13.63	1085.57	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL is at a lower elevation then the Farm Borehole.	11.80	Note that Mamatwan Mine is located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94, GWL difference between the Mine and the Farm is 38.02 m).
3.)	**HF/BH24**	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Aarpan	Ms. Ansie Venter	2021/05/10	23.08828	-27.25825	1122.31	0.36	16.57	1106.10	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL is at a lower elevation then the Farm Borehole.	15.50	Note that Mamatwan Mine is located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94, GWL difference between the Mine and the Farm is 58.98 m).
4.)	**HF/BH25**	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Aarpan	Ms. Ansie Venter	2021/05/10	23.09512	-27.26161	1128.70	0.80	23.06	1106.44	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL is at a lower elevation then the Farm Borehole.	15.60	No water level is svailable. DWS Groundwater Resource Assessment PH2 data utilised (Modelled: 1km x1km raster). Mamatwan Mine is located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94).
5.)	**HF/BH26**	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Perth 276	Mr.Eben Anthonissen	2021/05/10	22.98135	-27.29251	1070.13	0.04	25.98	1044.19	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL is at a lower elevation then the Farm Borehole.	7.10	No water level is svailable. DWS Groundwater Resource Assessment PH2 data utilised (Modelled: 1km x1km raster). Mamatwan Mine is not located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94).
6.)	**HF/BH27**	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Perth 276	Mr.Eben Anthonissen	2021/05/10	22.98135	-27.28864	1070.75	0.40	21.97	1049.18	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL is at a lower elevation then the Farm Borehole.	7.50	se	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94, GWL difference between the Mine and the Farm is 1.63 m).
7.)	**HF/BH28**	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Eldoret	Mr. Piet Swanepoel	2021/05/10	23.00597	-27.28831	1083.63	0.60	34.88	1049.35	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL is at a lower elevation then the Farm Borehole.	8.00	Note that Mamatwan Mine is not located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94, GWL difference between the Mine and the Farm is 1.80 m).
8.)	**HF/BH29**	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Eldoret	Mr. Piet Swanepoel	2021/05/10	23.03036	-27.27744	1095.45	0.60	27.00	1069.05	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL is at a lower elevation then the Farm Borehole.	10.20	Note that Mamatwan Mine is located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94, GWL difference between the Mine and the Farm is 21.50 m).
9.)	**HF/BH30**	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Rissik	Mr. Gideon Poolman	2018/07/19	23.00516	-27.31032	1080.00	0.45	22.36	1058.08	Farm groundwater flow from east to north west, not in line with mine locality. Mamatwan Mine GWL is at a lower elevation then the Farm Borehole.	5.80	Note that Mamatwan Mine is not located below drainage from the farm borehole and that the natural flow direction (E to NW) is not directly towards Mamatwan Mine.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94, GWL difference between the Mine and the Farm is 10.53 m).
10.)	**HF/BH31**	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Rissik	Mr. Gideon Poolman	2021/05/14	23.00407	-27.31317	1080.00	0.40	25.11	1055.29	Farm groundwater flow from east to north west, not in line with mine locality. Mamatwan Mine GWL at a lower elevation then the Farm Borehole.	5.50	No water level is svailable. DWS Groundwater Resource Assessment PH2 data utilised (Modelled: 1km x1km raster). Mamatwan Mine is not located below drainage from the farm borehole and that the natural flow direction (E to NW) is not directly towards Mamatwan Mine.	No dewatering has taken place at the farm borehole as the regional water table of the area depths mimics the topographical profile of the area (R-Squared value = 0.94).

Table 4. Part 2: Groundwater Level Elevation Results for the Mamatwan Mine Hydrocensus Study.

	Borehole Name	Quaternary Sub-Catchment	Locality Discription	Farm Name	Owner	Date	Coordinates (WGS84)			Casing Height (m)	Static Water Level (mbgl) [Groundwater Resource Assessment PH2 (GRA2, 2005)]	Static Water Level Elevation (mamsl)	Groundwater Flow Direction	Distance from Mamatwan Mine (km)	Comments	Verdict
							Longitude (East)	Latitude (South)	Elevation (mamsl)							
11.)	**HF/BH32**	D41K	Mamatwan Mine District	Moab	Mr. Niekie Kruger	2018/07/19	23.00551	-27.40557	1110.03	0.50	30.00	1080.53	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL is at a lower elevation then the Farm Borehole.	1.48	Note that Mamatwan Mine is located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine. Note that due to the artificially elevated GWL at the old rehabilitated Slimes Dam the groundwater flow is partly up-gradient towards HF/BH32 although the groundwater do not reached the farm borehole.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94, GWL difference between the Mine and the Farm is -11.72 m).
12.)	**HF/BH33**	D41K	Mamatwan Mine District	Milner	Mr. Niekie Kruger	2021/05/11	23.06380	-27.38234	1119.05	0.40	23.59	1095.86	Farm groundwater flow from south erast to north west, in line with mine locality. Mamatwan Mine GWL is at a lower elevation then the Farm Borehole.	7.10	Note that Mamatwan Mine is located below drainage from the farm borehole and that the natural flow direction (SE to NW) is not directly towards Mamatwan Mine.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94, GWL difference between the Mine and the Farm is 3.61 m).
13.)	**HF/BH34**	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Heunning Draai	Mr. Ampie Coetzee	2021/05/10	22.88761	-27.32795	1060.00	0.60	31.41	1029.19	Farm groundwater flow from south east to north west, in line with mine locality. Mamatwan Mine GWL is at a higher elevation then the Farm Borehole.	9.20	No water level is svailable. DWS Groundwater Resource Assessment PH2 data utilised (Modelled: 1km x1km raster). Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (SE to NW) is directly away from Mamatwan Mine in the direction of HF/BH34.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94).
14.)	**HF/BH35**	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Heunning Draai	Mr. Ampie Coetzee	2018/07/18	22.88844	-27.32523	1060.00	0.70	23.34	1037.36	Farm groundwater flow from north west to south east to wards the Gamagara River. Mamatwan Mine GWL is at a higher elevation then the Farm Borehole.	9.20	Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (NW to SE). Note that the borehole is situated west of the non-perennial river. Groundwater flow is also not in the direction of the borehole from the mine.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94, GWL difference between the Mine and the Farm is -2.22 m).
15.)	**HF/BH36**	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Smuts	Mr. Nico Smith	2021/05/10	22.86649	-27.35455	1060.00	0.27	29.13	1031.14	Farm groundwater flow from north west to south east to wards the Gamagara River. Mamatwan Mine GWL is at a higher elevation then the Farm Borehole.	10.50	Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (NW to SE). Note that the borehole is situated west of the non-perennial river. Groundwater flow is also not in the direction of the borehole from the mine.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94, GWL difference between the Mine and the Farm is -8.44 m).
16.)	**HF/BH37**	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Smuts	Mr. Nico Smith	2021/05/10	22.82764	-27.34351	1074.26	0.32	34.74	1039.84	Farm groundwater flow from north west to south east to wards the Gamagara River. Mamatwan Mine GWL is at a higher elevation then the Farm Borehole.	14.50	No water level is svailable. DWS Groundwater Resource Assessment PH2 data utilised (Modelled: 1km x1km raster). Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (NW to SE). Note that the borehole is situated west of the non-perennial river. Groundwater flow is also not in the direction of the borehole from the mine.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94, GWL difference between the Mine and the Farm is estimated at 0.26 m).
17.)	**HF/BH38**	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Cobham	Mr. Phillip van der Merwe	2018/07/19	22.90379	-27.40549	1080.00	0.60	32.20	1048.40	Farm groundwater flow from south east to north west, in line with mine locality. Mamatwan Mine GWL is at a higher elevation then the Farm Borehole.	7.60	Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (SE to NW) is directly away from Mamatwan Mine but not in the direction of HF/BH38.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94, GWL difference between the Mine and the Farm is -46.65 m).
18.)	**HF/BH39**	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Cobham	Mr. Phillip van der Merwe	2021/05/10	22.87963	-27.40732	1080.69	0.17	31.61	1049.25	Farm groundwater flow from south east to north west, in line with mine locality. Mamatwan Mine GWL is at a higher elevation then the Farm Borehole.	9.80	No water level is svailable. DWS Groundwater Resource Assessment PH2 data utilised (Modelled: 1km x1km raster). Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (SE to NW) is directly away from Mamatwan Mine but not in the direction of HF/BH39.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94).
19.)	**HF/BH40**	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Sutton	Mr. Philip Markram	2019/06/18	22.86471	-27.44708	1081.88	0.14	31.34	1050.68	Farm groundwater flow from south east to north west, in line with mine locality. Mamatwan Mine GWL is at a higher elevation then the Farm Borehole.	13.20	Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (SE to NW) is directly away from Mamatwan Mine but not in the direction of HF/BH40.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94, GWL difference between the Mine and the Farm is -44.22 m).
20.)	**HF/BH41**	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Sutton	Mr. Philip Markram	2019/06/18	22.86471	-27.44505	1081.79	0.28	23.45	1058.62	Farm groundwater flow from south east to north west, in line with mine locality. Mamatwan Mine GWLis at a higher elevation then the Farm Borehole.	13.10	Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (SE to NW) is directly away from Mamatwan Mine but not in the direction of HF/BH41.	No dewatering has taken place at the farm borehole as the regional water table of the area mimics the topographical profile (R-Squared value = 0.94, GWL difference between the Mine and the Farm is -36.28 m).

Table 5. Groundwater Level Elevation Results for the Mamatwan Mine monitoring boreholes for Groundwater Monitoring Phase 53, March 2021.

Borehole Name		Quaternary Sub-Catchment	Locality Discription	Farm Name	Owner	Date	Coordinates (WGS84)			Casing Height (m)	Static Water Level (mbgl)	Static Water Level Elevation (mamsl)	Groundwater Flow Direction	Distance from Mamatwan Mine (km)	Comments	Verdict
							Longitude (East)	Latitude (South)	Elevation (mamsl)							
1.)	**JB(RIS)04**	D41K	Mamatwan Mine Monitoring Borehole	Mamatwan	HMM / South32	2021/03/23	22.96817	-27.36241	1089.26	0.410	50.09	1039.58	Located on the Mamatwan Mine property.	On-Site	Indicate dewatering by Mamatwan Opencast Pit, together with JB(MMT)22.	Dewatering is occurring at Mamatwan Mine due to the Mamatwan Opencast Pit and the partially backfilled Adams Pit. The dewatering cone of the Mamatwan Pit and the Adams Pit are more pronounced to the north / north-west. The aerial extent of the dewatering cone has been buffered to the south by topographical changes (higher) as well as the historical activities of the rehabilitated old Tailings / Slimes Dams (near entrance of mine). The artificial groundwater mound is dissipating with time under the rehabilitated old Tailings / Slimes Dams. The impact dewatering cone of Mamatwan is also increased by Tshipi-e-Ntle Pit to the west. The mine plans are currently for the two pits to become one as the highwall separating the two pits will be mined. The Hydrocensus (2021) indicated that none of the surrounding water users (1.48 - 15.60 km away) are affected by the Mamatwan Pit dewatering. Numerical modelling indicates that it is not expected currently that surrounding water users will be impacted even at mine closure in 2035. It is recommended that Mamatwan Mine groundwater monitoring programme continues as per WUL requirements. It is also recommended that hydrocensus studies be performed as bi-annually (monitoring at private landowner boreholes). The Mamatwan numerical groundwater model is to be updated yearly to predict the future dewatering impacts as accurately as possible. This will ensure that the dewatering will be monitoring and manage effectively. Mamatwan is currently investigating the options of drilling additional boreholes to further enhance the current monitoring program to monitor the dewatering caused by the Mamatwan Opencast Pit as requested by DWS.
2.)	**JB(GLD)05**	D41K	Mamatwan Mine Monitoring Borehole	Mamatwan	HMM / South32	2021/03/23	22.97754	-27.35803	1091.45	0.380	44.28	1047.55	Located on the Mamatwan Mine property.	On-Site	Indicate dewatering by Mamatwan Opencast Pit, together with JB(MMT)22.	
3.)	**JB(MMT)17**	D41K	Mamatwan Mine Monitoring Borehole	Mamatwan	HMM / South32	2021/03/23	22.99548	-27.39074	1104.77	0.580	11.87	1093.48	Located on the Mamatwan Mine property.		Indicate groundwater levels at Waste Rock Dumps, Product Storage Facility and Sinter Plant Area.	
4.)	**JB(MMT)18**	D41K	Mamatwan Mine Monitoring Borehole	Mamatwan	HMM / South32	2021/03/23	22.99210	-27.39601	1103.48	0.230	11.46	1092.25	Located on the Mamatwan Mine property.	On-Site	Indicate the artificial water mound of the decommissioned Slimes Dams.	
5.)	**JB(MMT)19**	D41K	Mamatwan Mine Monitoring Borehole	Mamatwan	HMM / South32	2021/03/23	22.99135	-27.38582	1101.42	0.420	15.90	1085.94	Located on the Mamatwan Mine property.	On-Site	Indicate the artificial water mound of the decommissioned Slimes Dams to the south and the dewatering effects of Adams Pit to the north.	
6.)	**JB(MMT)20**	D41K	Mamatwan Mine Monitoring Borehole	Mamatwan	HMM / South32	2021/03/23	22.98965	-27.38637	1101.15	0.460	16.58	1085.03	Located on the Mamatwan Mine property.	On-Site	Indicate the artificial water mound of the decommissioned Slimes Dams to the south and the dewatering effects of Adams Pit to the north.	
7.)	**JB(MMT)21**	D41K	Mamatwan Mine Monitoring Borehole	Mamatwan	HMM / South32	2021/03/23	22.98192	-27.38288	1096.99	0.780	18.40	1079.37	Located on the Mamatwan Mine property.	On-Site	Indicate an artificial water mound that is recovering.	
8.)	**JB(MMT)22**	D41K	Mamatwan Mine Monitoring Borehole	Mamatwan	HMM / South32	2021/03/23	22.98547	-27.37719	1083.39	0.390	38.37	1045.41	Located on the Mamatwan Mine property.		Indicate dewatering by Mamatwana / Old Adams Opencast Pit as well as the groundwater level in the spoils seperating the old Adams Pit and the Mamatwan Pit.	
9.)	**JB(MMT)23**	D41K	Mamatwan Mine Monitoring Borehole	Mamatwan	HMM / South32	2021/03/23	22.98661	-27.39025	1099.74	0.380	9.78	1090.34	Located on the Mamatwan Mine property.	On-Site	Indicate the artificial water mound of the irrigated treated sewage effluent of the Mamatwan Mine Sewage Plant.	
10.)	**JB(MMT)24**	D41K	Mamatwan Mine Monitoring Borehole	Mamatwan	HMM / South32	2021/03/23	22.98924	-27.39472	1102.33	0.390	7.82	1094.90	Located on the Mamatwan Mine property.	On-Site	Indicate the artificial water mound of the decommissioned Slimes Dams and waste Rock dumps.	
11.)	**JB(MID)16**	D41K	Middelplaas Mine Monitoring Borehole	Middelplaas	HMM / South32	2021/03/23	22.93986	-27.35703	1078.12	0.650	30.32	1048.45	Located on the Mamatwan Mine property.	On-Site	Indicate no dewatering in relation to the background boreholes for the old shaft area.	Not Applicable to the Mamatwan Mine Farm Hydrocensus.
12.)	**JB(MID)25**	D41K	Middelplaas Mine Monitoring Borehole	Middelplaas	HMM / South32	2021/03/23	22.93605	-27.36207	1078.28	0.480	29.63	1049.13	Located on the Mamatwan Mine property.	On-Site	Indicate no dewatering in relation to the background boreholes for the old shaft area.	
13.)	**JB(MID)26**	D41K	Middelplaas Mine Monitoring Borehole	Middelplaas	HMM / South32	2021/03/23	22.93867	-27.36100	1078.20	0.550	29.49	1049.26	Located on the Mamatwan Mine property.	On-Site	Indicate no dewatering in relation to the background boreholes for the old shaft area.	
14.)	**JB(MID)27**	D41K	Middelplaas Mine Monitoring Borehole	Middelplaas	HMM / South32	2019/06/26	22.93572	-27.35320	1075.36	0.870	28.33	1047.90	Located on the Mamatwan Mine property.	On-Site	Indicate no dewatering in relation to the background boreholes for the old shaft area.	

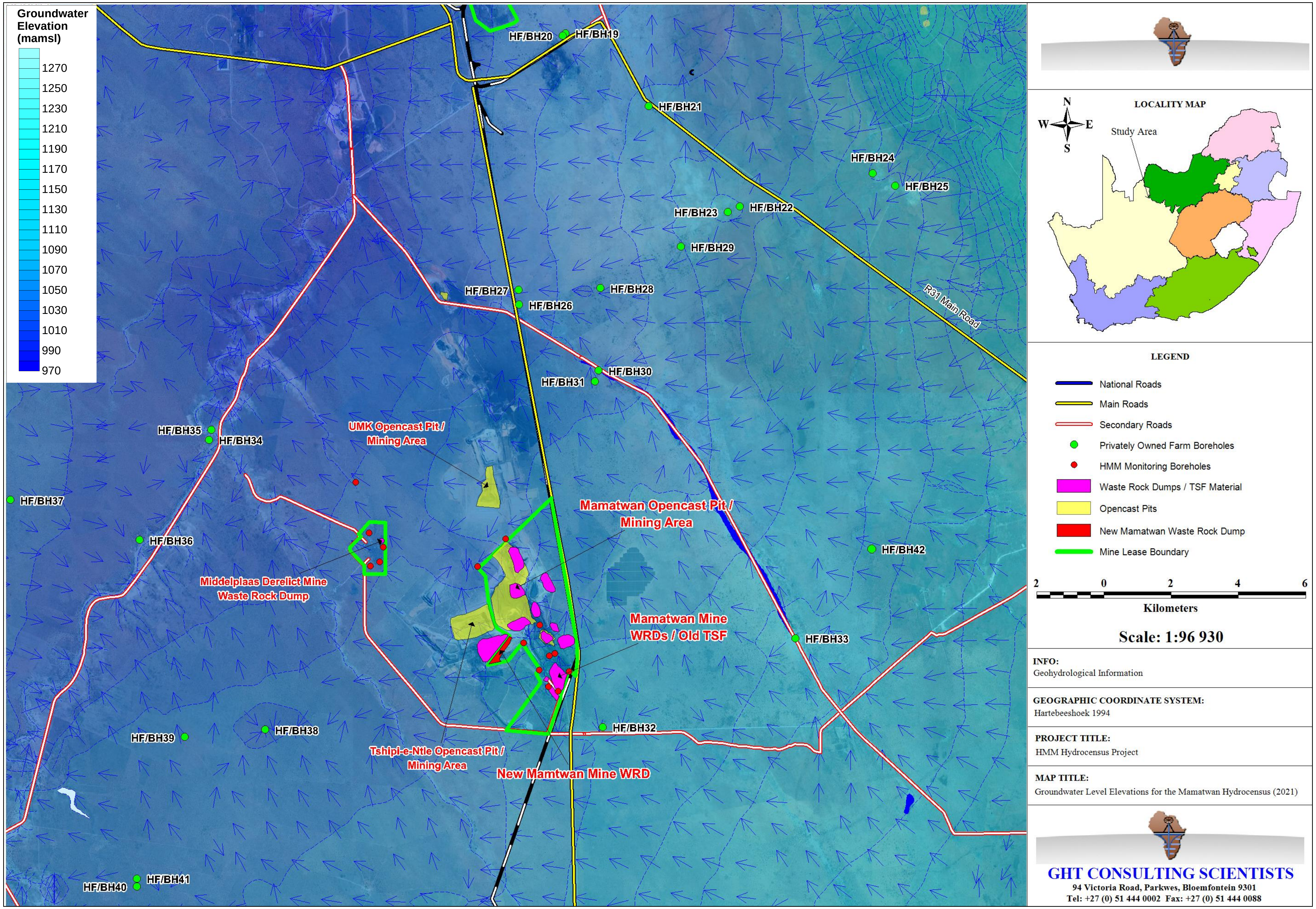


Figure 15. Groundwater elevation map contour map and flow vectors of the hydrocensus area of Mamatwan Mine. Note the groundwater flow vectors as blue arrows that indicate the groundwater flow directions.

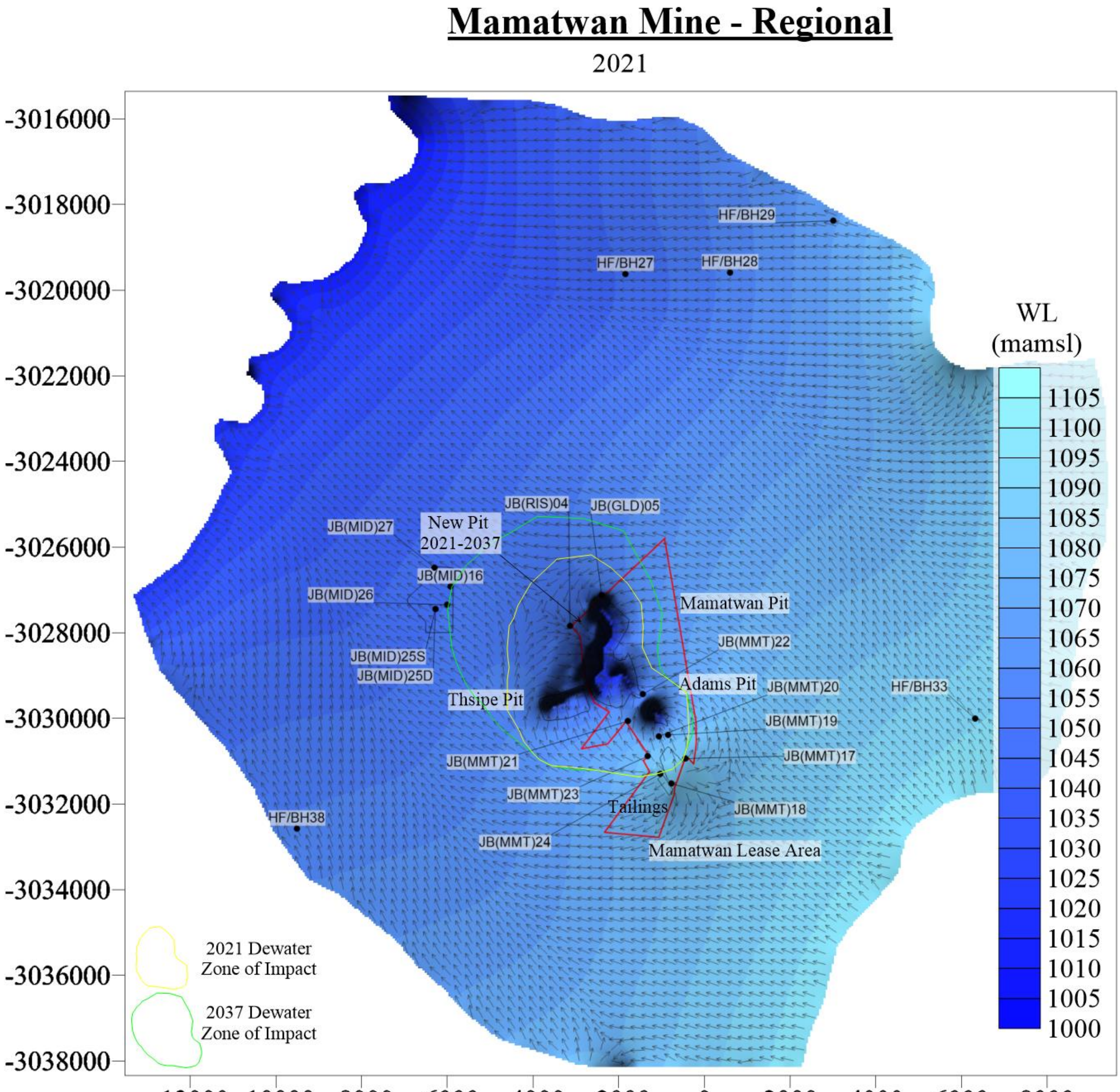


Figure 16. Numerically modelled regional groundwater levels. The dewatered pit areas indicate no impacts on regional scale in 2021. Note that the currently impacted dewatering zone does not affect any background boreholes of farm boreholes.

Mamatwan Mine

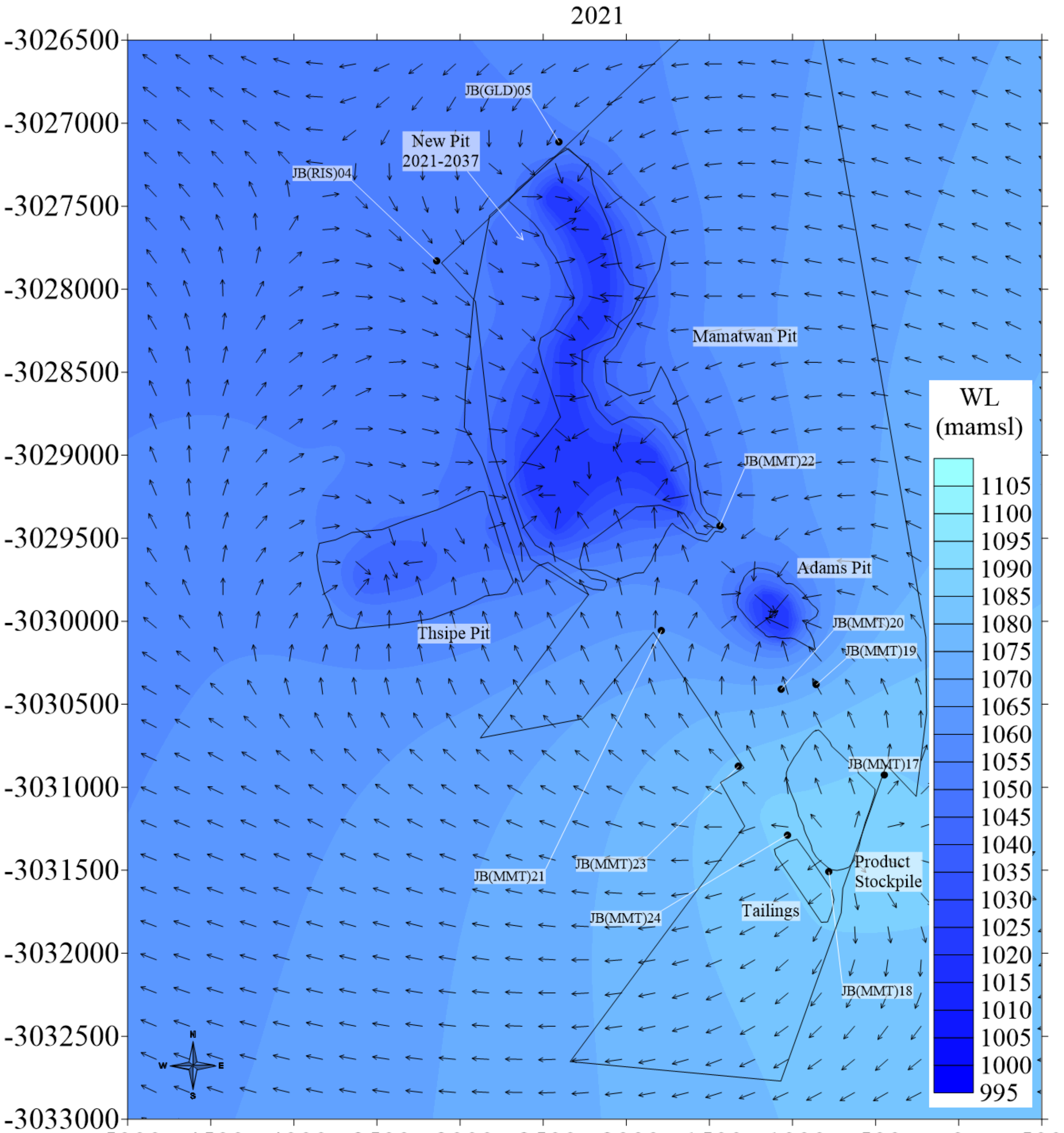


Figure 17. The localized groundwater elevations of Mamatwan Mine as numerically modelled for 2021. The dewatered pits are evident.

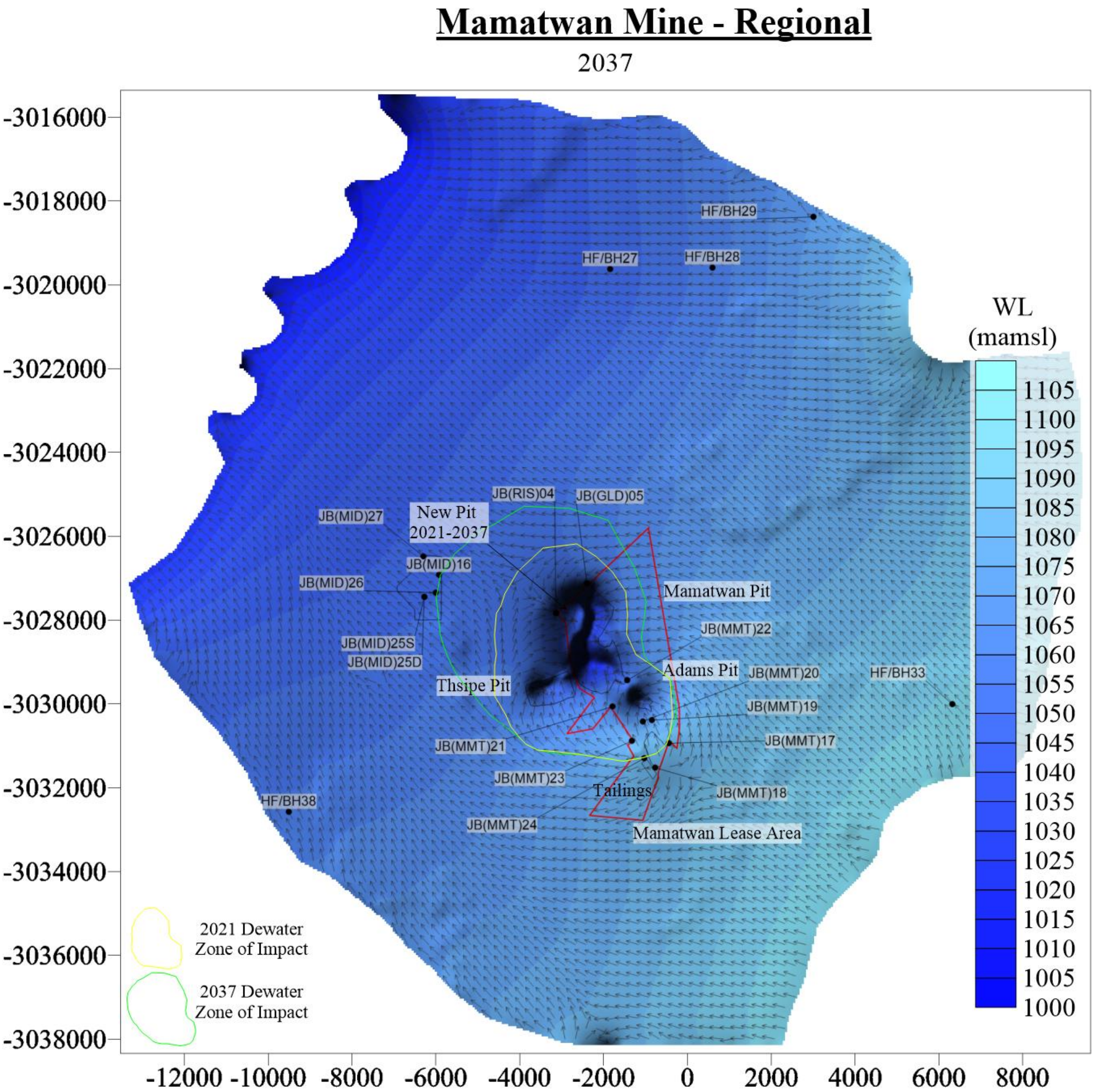


Figure 18. The simulated regional groundwater elevations of the area around Mamatwan Mine in 2037. Note that the simulated impacted dewatering zone does not affect any farmers' background boreholes.

6 IMPACT ASSESSMENT OF DEWATERING ON NEARBY GROUNDWATER USERS

6.1 DEWATERING: OPERATIONAL PHASE IMPACTS

The impact of groundwater level changes on the groundwater resource is considered in this section. The main cause for dewatering at Mamatwan Mine is the old Adams and Mamatwan Opencast Pits. It is also important to note that the dewatering impact of the surrounding area is also to be viewed as a cumulative impact as opencast pits of UMK (to the north of Mamatwan Pit, 0.85 km) and the adjacent Tshipi-e-Ntle Pit (west of Mamatwan Pit) that will be mine through to the Mamatwan Pit to create one opencast pit facility.

Table 6. Impact Characteristics: Drawdown on the Groundwater Resource.

Summary	Operational Phase
Project Aspect / Activity	The Mamatwan and Adams Opencast Pits has caused a well developed dewatering cone. The dewatering cone is also a cumulative impact as to the UMK Opencast Pit and to the west the Tshipi-e-Ntle Opencast Pit. The newly planned waste rock dump (WRDs), rehabilitated TSF, topsoil dumps and ore stockpiles have caused a marginal rise of the groundwater level or mounding underneath the footprints due to an increase in recharge.
Impact Type	Indirect. The numerical model and the existing (2002 - 2019) and current (2021) hydrocensus data indicate no GWL impact of known water users from the dewatering cone of existing pits of Mamatwan or the potentially cumulative impact due to the pits of UMK and Tshipi-e-Ntle.
Stakeholders / Receptors Affected	Private Groundwater Users.

Groundwater modelling suggests that at the end of mining drawdowns or dewatering cone impact zone can be expected to reach a lateral radius size approximately between 1.5 km to 2.0 km for Mamatwan Mine and Tshipi-e-Ntle Pit Mine combined.

Groundwater is utilised in the study area and represents the sole source of water for a number of farmers. Private groundwater users are not expected to be significantly impacted during mining as the drawdown cone remains at a distance of more than 2.0 km to 3.0 km.

The Sensitivity/Vulnerability/Importance of the groundwater resource was rated as **Medium** since the groundwater resource is an important water supply in the area, which is utilised for both livestock watering as well as domestic uses at some farms. During the operational phase the dewatering cone will increase in size to the north west in general. The activity mining will not result in the loss of an irreplaceable resource with regards to the groundwater resource as the dewatering cone will fully recover approximately after 50 years after the cessation of mining. The dewatering cone will get smaller with time after the cessation of mining.

Hydraulic head change is expected to be limited to the project site and adjacent properties belonging to the client and is **local** in extent in general. Groundwater levels are expected to recover after mine closure to the pre-mining state if the Mamatwan Pit is backfilled above the pre-mine water table level. If the Mamatwan pit is not backfilled / rehabilitated above pre-mine water table level, the pit will continue to act as a sink to local aquifer based on the elevated evaporation rate, which results in a permanent dewatering impact. The lowering of the hydraulic head due to the Mamatwan Opencast Pit mining activities mining have resulted in drawdowns of up to 1039.60 to 1047.50 mamsl in close proximity (0.1 km) from the north and north western side of the Mamatwan Pit. The dewatering impact zone radius stretches laterally within 1.5 to 3.0 km from the pit. To the southern part of the Old Adams Pit and Mamatwan Pit, the mining activities mining have resulted in drawdowns of up to 1079.40 to 1085.94 mamsl. The frequency is classified as **continuous** during operational phase due to the nature of the project and the likelihood is **likely** if the farm boreholes are close enough to Mamatwan to fall within the impact radius of the dewatering cone of the Mamatwan / Tshipi-e-Ntle / UMK Pits as the impacts has taken place locally around the pit areas but not regionally. The extent of the impact is mostly **local** in general on the two mine leases. The main impact area of the dewatering cone will manifest to the north west of the Mamatwan and Tshipi-e-Ntle Opencast Pits on the Tshipi-e-Ntle Pit Mine Lease. Lowering of the groundwater level due to the mining activities has not impacted the groundwater levels of the farm / hydrocensus boreholes as indicated by current numerical modelling and multiple hydrocensus projects since 2002 – 2021. The new waste rock dump (WRD) located on the southern side where Mamatwan and Tshipi-e-Ntle opencast pits meet, have no impact on the dewatering at the mine locally or regionally according to numerical modelling. All potential additional recharge generated by the New WRD will flow to the opencast pits directly to the north of the facility and will not contributed to any additional dewatering affects but might potentially assist to buffer the dewatering to some extend due to the potential additional recharge volume generated by rainfall.

The impact magnitude is therefore rated as **Negligible,** and the impact significance (pre-mitigation) is **NEGLIGIBLE**. The degree of confidence in this assessment is **medium to high**.

Table 7. Summary of Operational Impact: Drawdown on Groundwater Users.

Nature: Operational activities would result in a **negative direct** impact the groundwater resource in the Project Area.

Sensitivity/Vulnerability/Importance of Resource/Receptor - Medium.

Irreplaceability: The activity will **not** result in the loss of **irreplaceable** resources. It is expected that no or little impact will result on the existing groundwater users or existing production boreholes.

Impact Magnitude – Negligible (Impact of the Old Adams and Mamatwan Opencast Pits)**.**

- Extent: The extent of the impact is mostly **local** in general on the two mine leases. The main impact area of the dewatering cone will manifest to the north west of the Mamatwan and Tshipi-e-Ntle Opencast Pits on the Tshipi-e-Ntle Pit Mine Lease.
- Duration: The expected impact will be **not permanent if the pits if the pits is backfilled (ie reversible**, after >50 years after mine closure it is expected that groundwater levels will return to normal if pit is backfilled**)**.
- Scale: The drawdown cone is not anticipated to impact groundwater users off-site.
- Frequency: The frequency of the impact will be **continuous** during the operational phase.
- Likelihood: The likelihood of the impact is likely.

IMPACT SIGNIFICANCE (PRE-MITIGATION) – NEGLIGIBLE.

Degree of Confidence: The degree of confidence is **medium to high**.

6.2 DEWATERING: OPERATIONAL PHASE MITIGATION

Groundwater level change (drawdown) cannot be mitigated due safety. Groundwater level change (drawdown) cannot be mitigated. However, it is further recommended that groundwater levels in each of the known farm boreholes are monitored on a regular basis (two-yearly basis) throughout operation phase / mining phase. Should monitoring confirm that any of the private boreholes are affected by lowering the groundwater table, rendering boreholes unusable (ie loss of water supply source), the client will have to compensate affected famers for their loss, replacing the lost water supply source. This can be achieved for example by drilling new boreholes for the affected farmers outside of the drawdown cone, by increasing the depth of the existing boreholes or by providing an alternative good quality water source.

7 HYDROCENSUS GROUNDWATER HYDRO-CHEMISTRY RESULTS

The section contains the results of the regional hydro-chemistry results. The hydrocensus groundwater samples were analysed for inorganic constituents. The water samples were analysed at the Yanka Laboratory, which is a SANAS (South African National Accreditation System) accredited laboratory.

7.1 HYDROCHEMICAL IMAGING

Tables of data are the most common form in which the results of an analysis of water chemistry are reported. The data can be expressed in milligrams per litre (mg/L), milliequivalents per litre (meq/L) or millimoles per litre. For many purposes, the data may be also displayed in graphical form.

Water classification diagrams are useful for studying the distribution of water types in an area. Topographic features, rock types, or surface activities (anthropogenic influences) may influence the water type. Water classification is useful for regional groundwater studies, particularly to delineate the distribution of groundwater types and identify areas where poor quality water may occur. Such delineation of the water quality distribution in space lends itself to hydro-chemical mapping and quality classification.

Any form of hydro-chemical classification assumes that the water is in equilibrium in its environment. The nature of the classification plots is such that many points are plotted together for visual comparison of the water types.

7.1.1 Piper Diagram

According to Fetter (1994) the major ionic species in most natural waters are Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^- and CO_3^{2-} and SO_4^{2-}. A trilinear diagram can show the percentage composition of three ions. By grouping Na^+ and K^+ together, the major cations can be displayed on one trilinear diagram. Likewise, if CO_3^{2-} and HCO_3^- are grouped there are also three groups of the major anions. Figure 20 shows the form of a trilinear diagram that is commonly used in water-chemistry studies (Piper, 1944). Analyses are plotted on the basis of the percent of each cation (or anion).

Each apex of a triangle represents a 100% concentration of one of the three constituents. If a sample has two constituent groups present, then the point representing the percentage of each would be plotted on the line between the apexes for those two groups. If all three constituent groups are present, the analyses would fall in the interior field. The diamond-shaped field between the two triangles is used to represent the composition of water with respect to both cations and anions.

The cation point is projected onto the diamond-shaped field parallel to the side of the triangle labelled magnesium and the anion point is similarly projected parallel to the side of the triangle labelled sulphate. The intersection of the two lines is plotted as a point on the diamond-shaped field.

As water flows through an aquifer, it assumes a diagnostic chemical composition as a result of interaction with the lithological framework. The term hydro-chemical facies is used to describe the bodies of groundwater, in an aquifer, that differ in their chemical composition. The facies are a function of the lithology, solution kinetics and flow patterns of the aquifer. (Black, 1960 & 1966). Hydro-chemical facies can be classified on the basis of the dominant ions in the facies by means of the trilinear diagram (refer to Figure 20 on page 39).

The points for both cations and anions are plotted on the appropriate tri-axial diagrams (refer to Figure 20 on page 39). The positions of these points are projected onto the diamond-shaped field and the intersection of the projected lines is plotted.

The following classification may be introduced, which permits groundwater being placed within one of the four major categories, represented on the central diamond-shaped diagram, namely (refer to page 38, Figure 19).

- Recent groundwater having a high $Ca/MgHCO_3$ content;
- A dynamic regime containing $NaHCO_3$ groundwater;
- Stagnant groundwater conditions characterised by $Ca/MgCl_2$ and $Ca/MgSO_4$ groundwater; and
- Old or mature groundwater enriched in Na^+ and Cl^-.

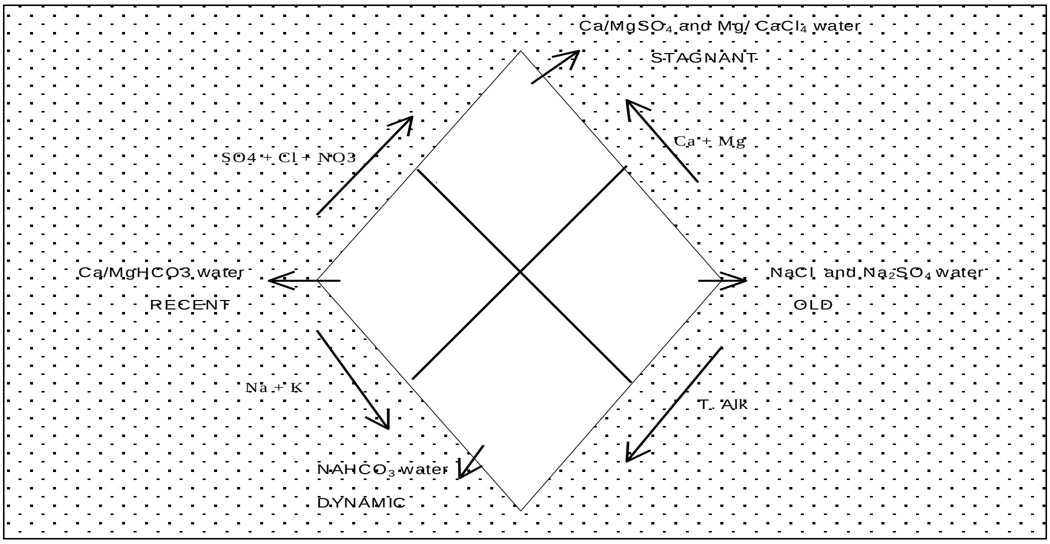


Figure 19. Classification of the diamond-shaped field of the trilinear diagram.

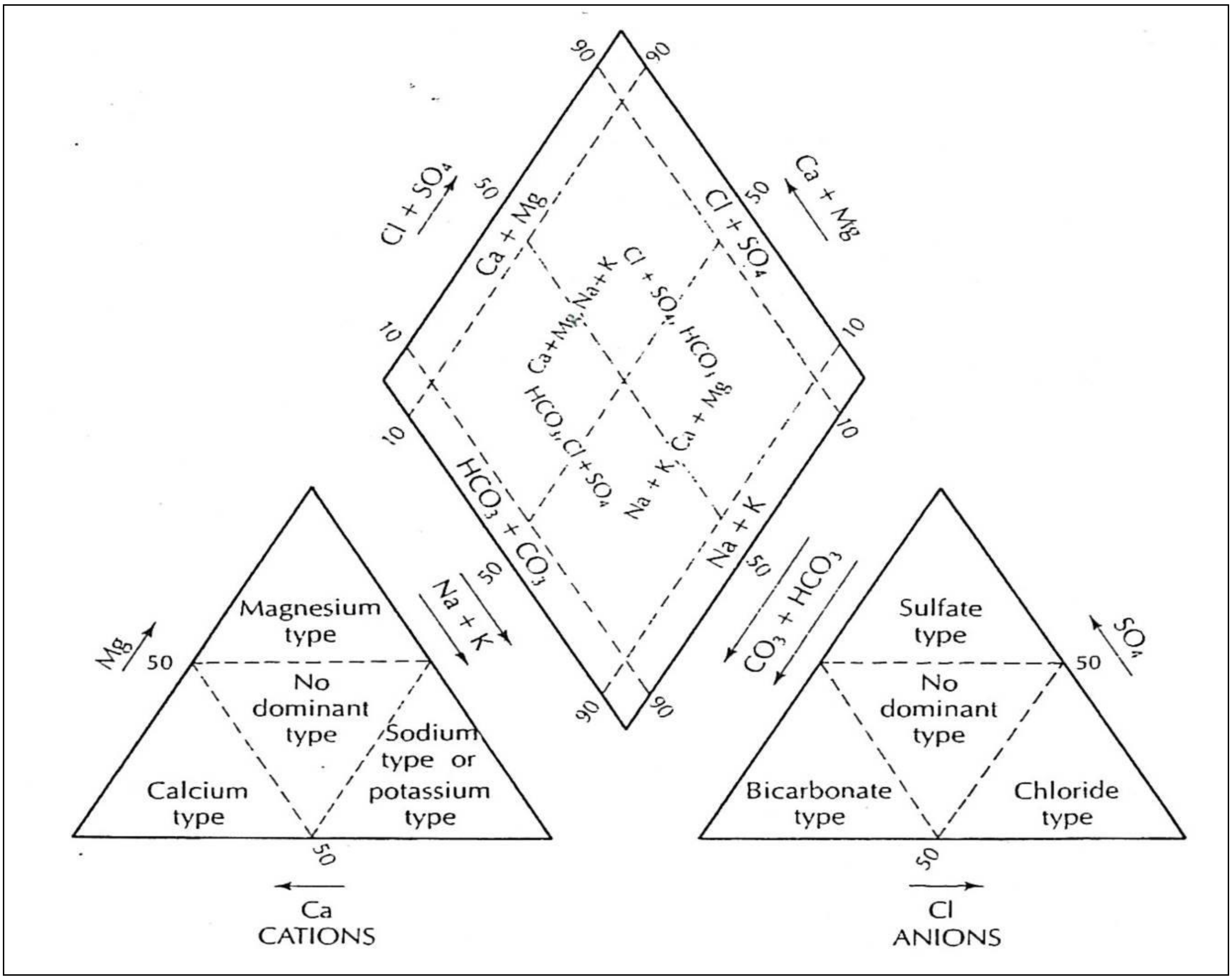


Figure 20. Hydro-Geochemical classification system for natural waters using the Piper Diagram.

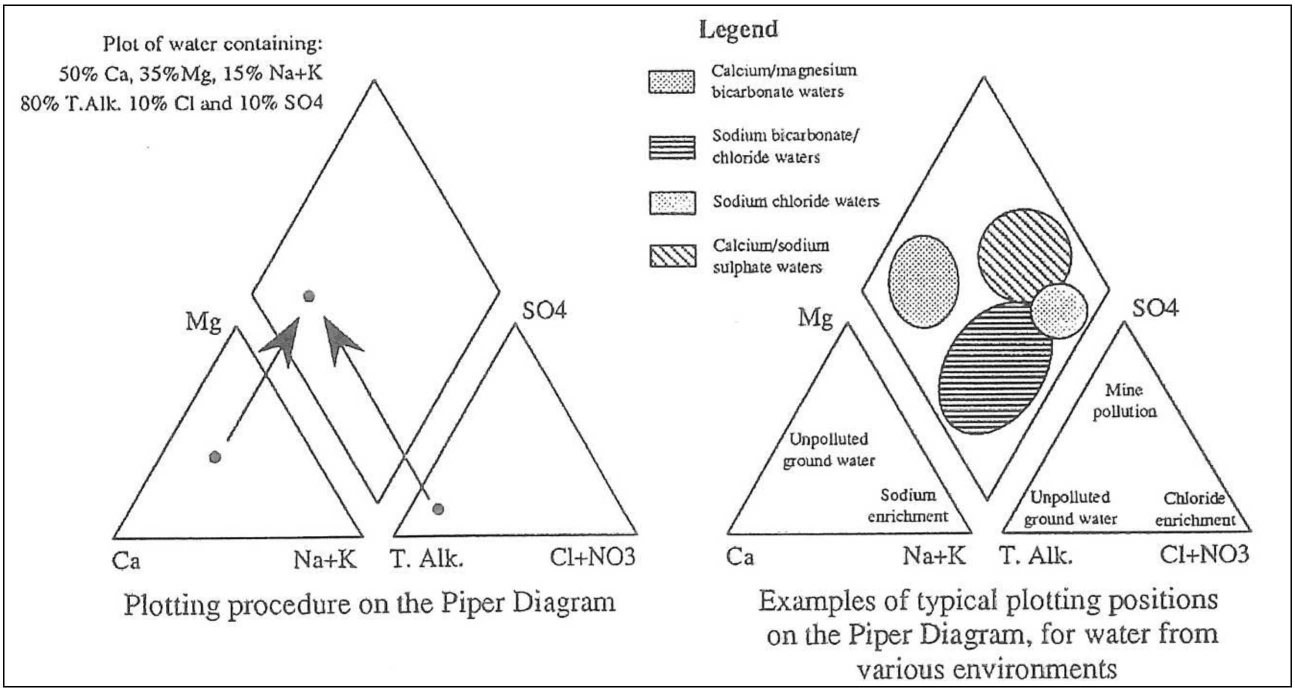


Figure 21. Hydro-Geochemical classification system for natural waters using the Piper Diagram.

Piper Diagram Description of the Mamatwan Farm Hydrocensus Boreholes:

The groundwater hydrochemistry and water type classification of the hydrocensus area can be described as follows by means of the Piper Diagram (refer to Figure 22 on page 41):

- Recent groundwater having a high $Ca/MgHCO_3$ content, which includes hydrocensus boreholes HF/BH23, HF/BH24, HF/BH25, HF/BH28, HF/BH29, HF/BH34, HFBH35, HF/BH36, HF/BH38, HF/BH39 and HF/BH40.
- Stagnant groundwater conditions characterised by $Ca/MgCl_2$ and $Ca/MgSO_4$ groundwater content, which includes hydrocensus boreholes HF/BH22, HF/BH26, HF/BH32, HF/BH33, HF/BH37,
- Old or mature groundwater enriched in Na^+ and Cl^-, which include hydrocensus borehole HF/BH40.
- A dynamic regime containing $NaHCO_3$ groundwater, which include hydrocensus borehole HF/BH36.

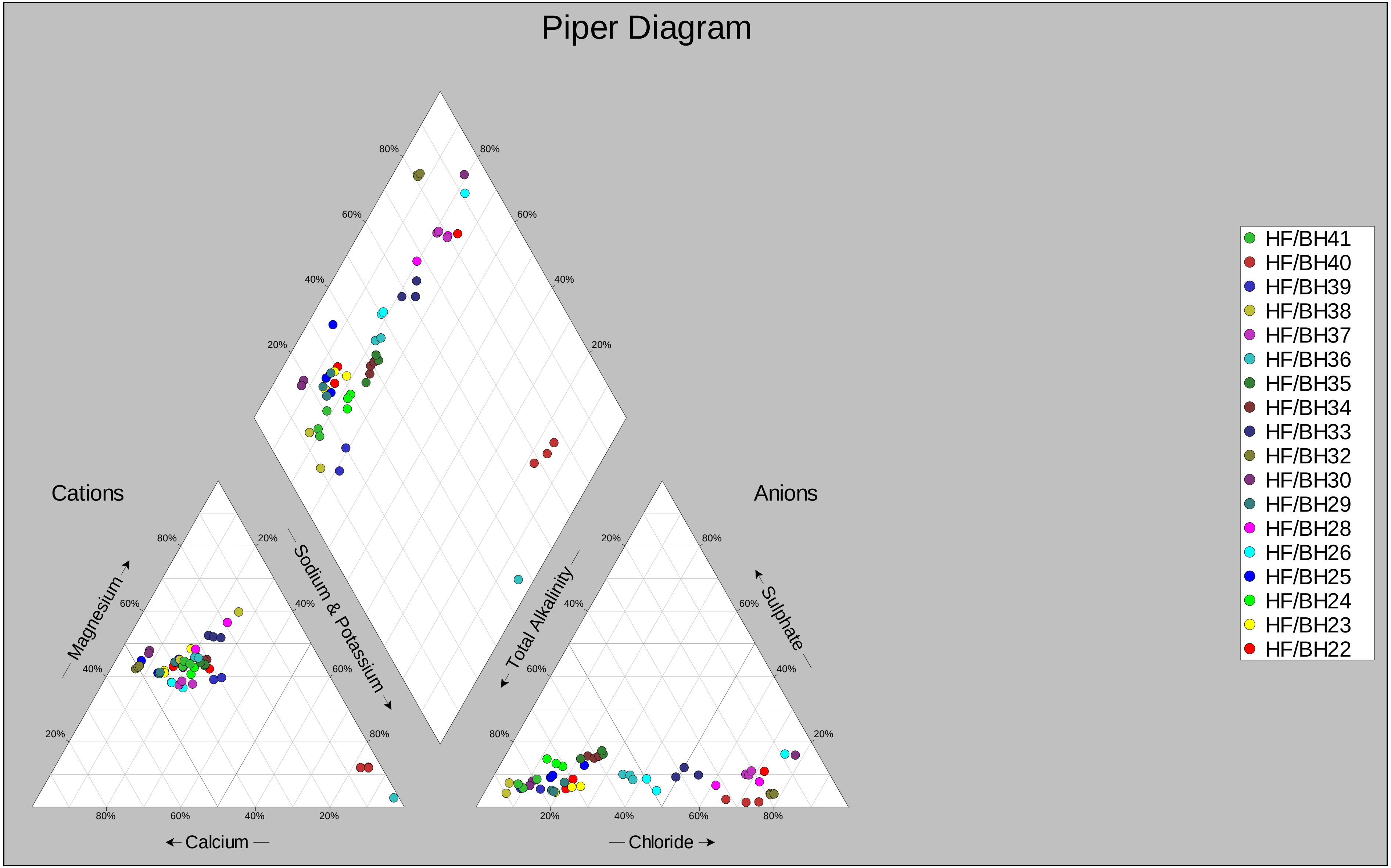


Figure 22. Piper diagram of the groundwater chemistry of the Mamatwan Hydrocensus Study (2021).

7.1.2 Expanded Durov Diagram

Water types are classified in terms of the major cations and anions. These are ratioed so that plotting the results on a classification diagram can compare relative abundance, rather than absolute values. In this project the Expanded Durov diagram was used. This diagram can be divided into nine fields, each of which represents a particular water type. The water type is named after the dominant cation and anions, which define the field.

This diagram uses similar ratio techniques to plot the concentrations of the major ions, however triangular diagrams are used, three for the anions and three for the cations, on each triangle the sum of the ions adds up to 50% and the ions are plotted in different combinations. The result is a plot with nine fields for classification, these fields give better splitting than the Piper diagram and the plot is sometimes preferred. The nine fields shown in Figure 22 on page 41 can be described as follows:

- **Field 1:** HCO_3^- and Ca^{2+} water. This water type is often a recently recharged or recharging water;
- **Field 2:** HCO_3^- and Mg^{2+} dominant or HCO_3^- and Ca^{2+} and Mg^{2+} important, indicates water often associated with dolomite or mafic igneous rocks;
- **Field 3:** HCO_3^- and Na^+ dominant, often indicates ion exchanged water;
- **Field 4:** SO_4^{2-} (or indiscriminate) and Ca^{2+} dominant, may be a recharge water in lavas or associated gypsum deposits;
- **Field 5:** No dominant anions or cations, indicates water resulting from dissolution or mixing;
- **Field 6:** SO_4^{2-} (or indiscriminate) Na^+ dominant, is a water type not frequently found and may be due to mixing influences;
- **Field 7:** Cl^- and Ca^{2+} dominant is not a common water type unless reverse ion exchange is taking place;
- **Field 8:** Cl^- and no dominant cations suggests that reverse ion exchange is taking place; and
- **Field 9:** Cl^- and Na^+ dominant, frequently indicates an end point water in a water evolution sequence.

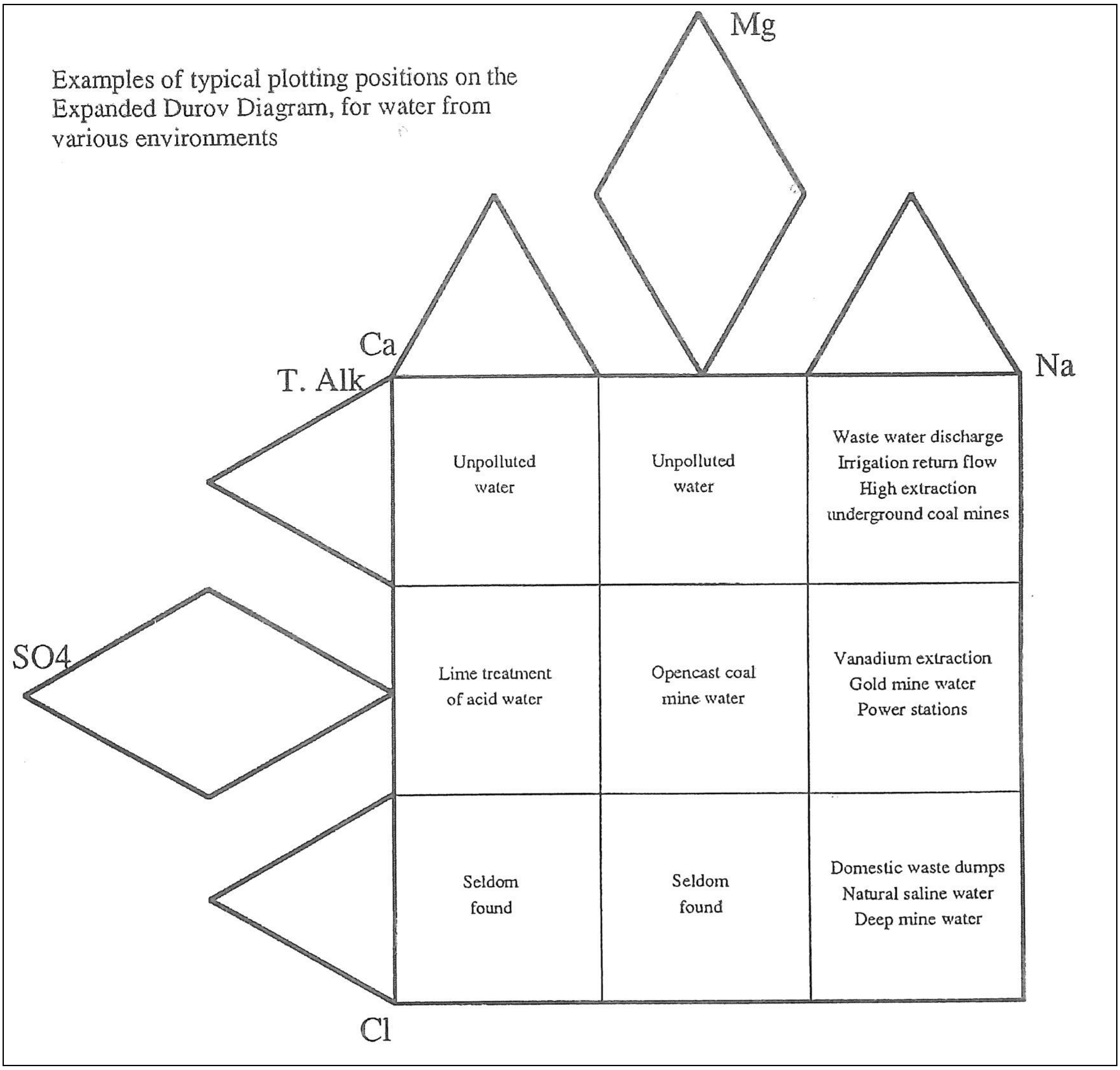


Figure 23. Hydro-Geochemical classification system for natural waters using the Expanded Durov Diagram.

Expanded Durov Diagram Description of the Mamatwan Farm Hydrocensus Boreholes:

The groundwater hydrochemistry and water type classification of the hydrocensus area can be described as follows by means of the Expanded Durov Diagram (refer to Figure 24 on pages 45):

- Expanded Durov Diagram description of the the Hydrocensus st
  - **Field 2:** HCO_3- and Mg^{2+} dominant or HCO_3^- and Ca^{2+} and Mg^{2+} important, indicates water often associated with dolomite or mafic igneous rocks, which includes hydrocensus boreholes HF/BH23, HF/BH24, HF/BH25, HF/BH29, HF/BH34, HF/BH35, HF/BH36, HF/BH37, HF/BH38, HF/BH39 and HF/BH41,
  - **Field 4:** SO_4^{2-} (or indiscriminate) and Ca^{2+} dominant, may be a recharge water in lavas or associated gypsum deposits, which includes hydrocensus borehole HF/BH36.
  - **Field 5:** No dominant anions or cations, indicates water resulting from dissolution or mixing, which includes hydrocensus boreholes HF/BH26 and HF/BH33.
  - **Field 7:** Cl^- and Ca^{2+} dominant is not a common water type unless reverse ion exchange is taking place, which includes hydrocensus borehole HF/BH32.
  - **Field 8:** Cl^- and no dominant cations suggests that reverse ion exchange is taking place, which includes hydrocensus boreholes HF/BH22, HF/BH26, HF/BH28, HF/BH32 and HF/BH33.
  - **Field 9:** Cl^- and Na^+ dominant, frequently indicates an end point water in a water evolution sequence, which includes hydrocensus borehole HF/BH22.

The majority of the hydrocensus boreholes plot in “Field 2” of the Expanded Durov Diagram, which is associated with unpolluted groundwater. To a lesser extend some hydrocensus boreholes plot in “Field 5” and “Field 8, which is associated with water resulting from dissolution or mixing or reverse ion exchange.

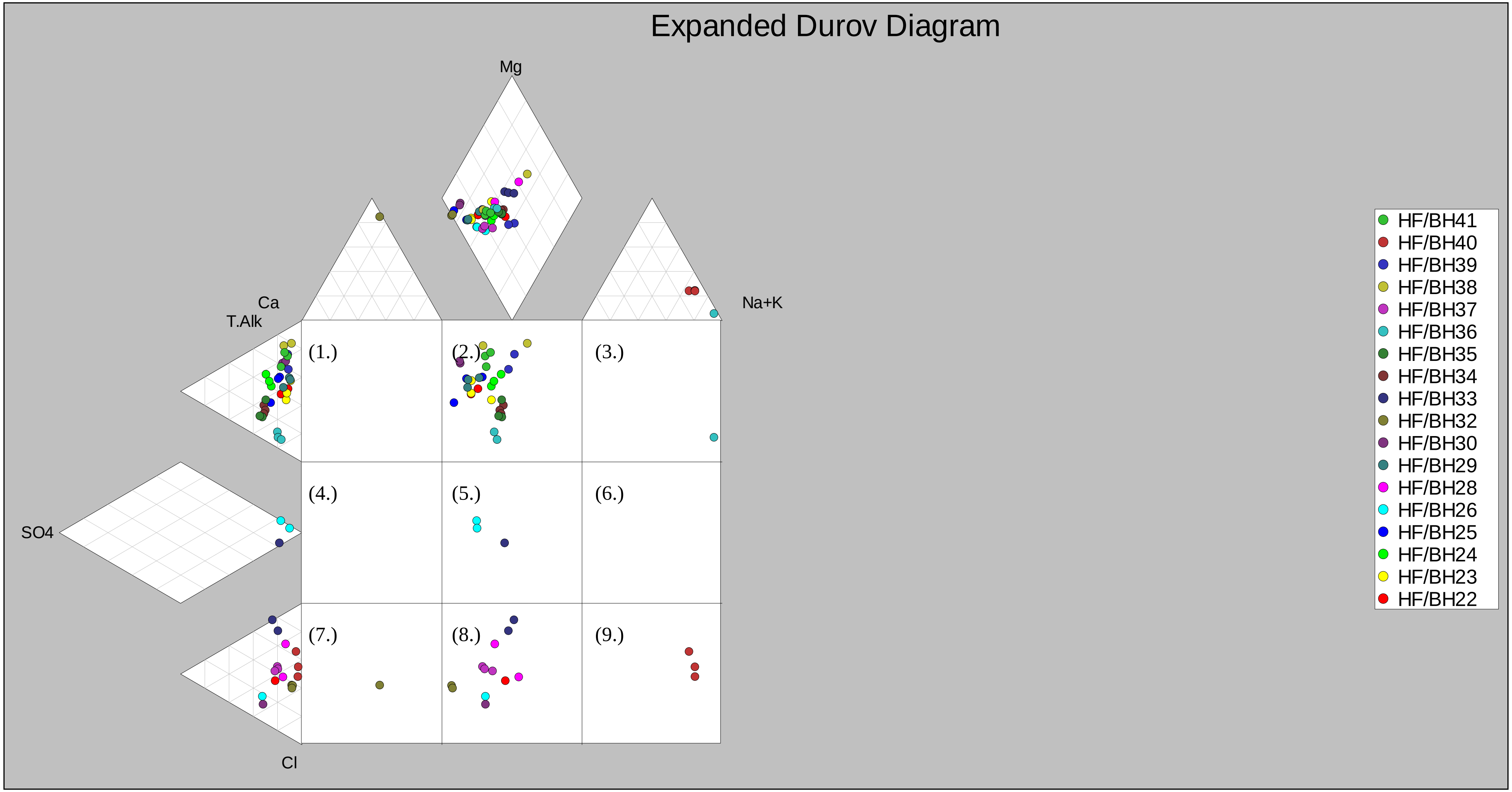


Figure 24. Expanded Durov diagram of the groundwater chemistry of the Mamatwan Hydrocensus Study (2021).

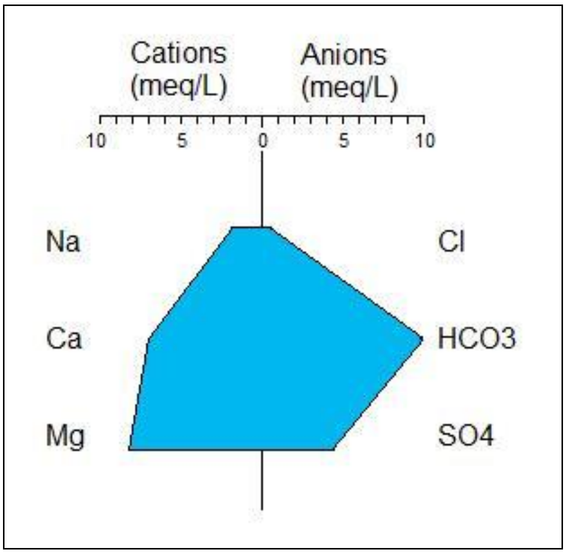
7.1.3 Stiff Diagram

A Stiff diagram, or Stiff pattern, is a graphical representation of chemical analyses, first developed by H.A. Stiff in 1951. It is widely used by hydrogeologists and geochemists to display the major ion composition of a water sample. A polygonal shape is created from four parallel horizontal axes extending on either side of a vertical zero axis. Cations are plotted in milliequivalents per litre on the left side of the zero axis, one to each horizontal axis, and anions are plotted on the right side. Stiff patterns are useful in making a rapid visual comparison between water from different sources. An alternative to the Stiff diagram is the Maucha diagram.

Stiff diagrams can be utilised for the following purposes:

- To help visualize ionically related waters from which a flow path can be determined.
- If the flow path is known, to show how the ionic composition of a water body changes over space and/or time.

Example of a Stiff diagram (see below):



A typical Stiff diagram is shown in the figure (right). By standard convention, Stiff diagrams are created by plotting the equivalent concentration of the cations to the left of the centre axis and anions to the right. The points are connected to form the figure. When comparing Stiff diagrams between different waters it is important to prepare each diagram using the same ionic species, in the same order, on the same scale.

Environmental laboratories typically report concentrations for anion and cation parameters using units of mass/volume, usually mg/L. In order to convert the mass concentration to an equivalent concentration the following mathematical relationship is used:

– (mass concentration) * (ionic charge) / (molecular weight) = (equivalent concentration)

For example, a water with a calcium concentration of 120 mg/L would have the following calcium equivalent concentration:

– (120 mg/L) * (2 meq/mmol) / (40 mg/mmol) = 6 meq/L

The following observations are made regarding the stiff diagrams for the boreholes of the Mamatwan surrounding farm hydrocensus areas (refer to Figure 25 on page 48 as well as the Hydrocensus Map in Figure 11 on page 20):

- The groundwater chemistry data indicates four distinct hydro-chemistries or groundwater areas, which are:
  - This type of hydrochemistry is found in the north eastern part of the Mamatwan hydrocensus area near R31 Main road, which connects Hotazel and Kuruman and includes farm boreholes HF/BH23, HF/BH24, HF/BH25, HF/BH26 and HF/BH29.
  - Also, a type of hydrochemistry, which is found in the north eastern part of the Mamatwan hydrocensus area near R31 Main road, which connects Hotazel and Kuruman and includes farm boreholes HF/BH22 and HF/BH28.
  - This type of hydrochemistry is found in the south western part of the Mamatwan hydrocensus area in the vicinity of the Ga-Mogara River, which includes farm boreholes HF/BH34, HF/BH35, HF/BH36, HF/BH38, HF/BH39, HF/BH41
  - Farm hydrocensus HF/BH32 and HF/BH37 indicate farm hydrocensus boreholes with high concentrations of macro salt content in the groundwater.
- The Stiff diagram of the farm hydrocensus borehole HF/BH32 and Mamatwan Mine monitoring borehole JB(MMT)17 (near old TSF and WRDs sites to the south of Mamatwan) do not indicate the same basic hydrochemistry on the stiff diagram. It is also observed that HF/BH32 also lack telltale high sulphate contend of a mine affected sited as is the case with JB(MMT)17.

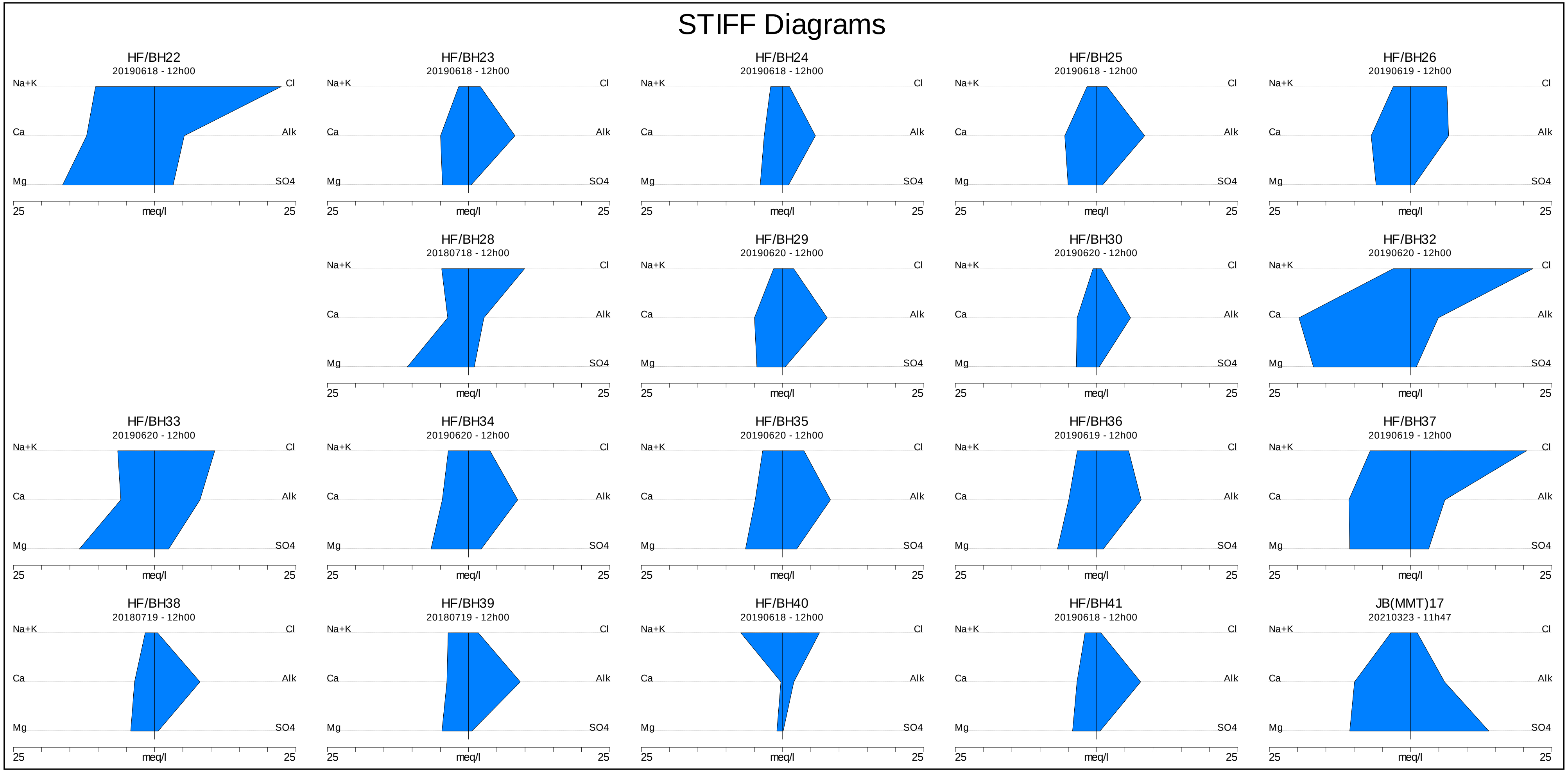


Figure 25. Stiff Diagrams for the farm hydrocensus boreholes of Mamatwan Mine as well as mine monitoring borehole JB(MMT)17.

7.2 GROUNDWATER QUALITY STANDARDS

The SANS241-1:2015, SANS241-1:2011 and SANS241:2006 standards can be studied respectively in Table 8, Table 9, Table 10 on page 49 to 52.

Table 8. SANS241-1:2015 physical, organoleptic and chemical requirements.

Determinand	Risk	Unit	Standard limits [a] (Class I)
Physical and aesthetic determinands			
Free chlorine as Cl_2 [d]	Chronic health	mg/L	≤ 5
Monochloramine [cd]	Chronic health	mg/L	≤ 3
Colour	Aesthetic	mg/L Pt-Co	≤ 15
Conductivity at 25 ° C	Aesthetic	mS/m	≤ 170
Odour or taste	Aesthetic	-	Inoffensive
Total dissolved solids	Aesthetic	mg/L	≤ 1 200
Turbidity	Operational	NTU	≤ 1
	Aesthetic	NTU	≤ 5
pH at 25 ° C [b]	Operational	pH units	≥ 5 to ≤ 9,7
Chemical determinands — macro-determinands			
Nitrate as N [ef]	Acute health	mg/L	≤ 11
Nitrite as N [d]	Acute health	mg/L	≤ 0,9
Combined Nitrate plus Nitrite [edg]	Acute health	mg/L	≤ 1
Sulfate as SO_4^{2-}	Acute health	mg/L	≤ 500
	Aesthetic	mg/L	≤ 250
Fluoride as F^-	Chronic health	mg/L	≤ 1,5
Ammonia as N	Aesthetic	mg/L	≤ 1,5
Chloride as Cl^-	Aesthetic	mg/L	≤ 300
Sodium as Na	Aesthetic	mg/L	≤ 200
Zinc as Zn	Aesthetic	mg/L	≤ 5
Chemical determinands — micro-determinands			
Antimony as Sb	Chronic health	µg/L	≤ 20
Arsenic as As	Chronic health	µg/L	≤ 10
Barium as Ba	Chronic health	µg/L	≤ 700
Boron as B	Chronic health	µg/L	≤ 2 400
Cadmium as Cd	Chronic health	µg/L	≤ 3
Total chromium as Cr	Chronic health	µg/L	≤ 50
Copper as Cu	Chronic health	µg/L	≤ 2 000
Cyanide (recoverable) as CN^-	Acute health	µg/L	≤ 200
Iron as Fe	Chronic health	µg/L	≤ 2 000
	Aesthetic	µg/L	≤ 300
Lead as Pb	Chronic health	µg/L	≤ 10
Manganese as Mn	Chronic health	µg/L	≤ 400
	Aesthetic	µg/L	≤ 100
Mercury as Hg	Chronic health	µg/L	≤ 6
Nickel as Ni	Chronic health	µg/L	≤ 70
Selenium as Se	Chronic health	µg/L	≤ 40
Uranium as U	Chronic health	µg/L	≤ 30
Aluminium as Al	Operational	µg/L	≤ 300

Determinand	Risk	Unit	Standard limits [a] (Class I)
Chemical determinands-organic determinands			
Total organic carbon as C	Chronic health	mg/L	≤10
Trihalomethanes [h]			
Chloroform	Chronic health	µg/L	≤ 300
Bromoform	Chronic health	µg/L	≤ 100
Dibromochloromethane	Chronic health	µg/L	≤ 100
Bromodichloromethane	Chronic health	µg/L	≤ 60
Combined Trihalomethane [h]	Chronic health	µg/L	≤ 1
Total Microcystin [j]	Chronic health	µg/L	≤ 1
Phenols	Aesthetic	µg/L	≤ 10

[a] Values in excess of those given un column 4 may negatively impact disinfection.

[b] Low pH values can result in structural problems in the distribution system.

[c] This equivalent to 4.1 mg/l as Cl_2/L as measured by standard DPD colorimetric and ferrous titrimetric methods.

[d] See 4.2.2.

[e] This is equivalent to nitrate at 50 mg $N0_3^-$/Land nitrite as 3 mg $N0_2^-$/L.

[f] See annex C of SANS241-2: 2014 for an example of the sum of Nitrite plus Nitrite ratio.
The sum of the ratios of the concentrations of each (as detected in the sample) to its guideline value should not exceed 1.

[g] Due to the dynanmic nature of nitrite-nitrate conversion in distributio networks and the potential health impact on bottle-fed infants, the standards is applicable at the point of consumption.

[h] See annex C of SANS241-2:2014 for an example of the sum of THM ratio.
The sum of ratios of the concentrations of each to its respective guideline value should not exceed 1.

[j] Microcystin only needs to be measured where an algal bloom (> 20 000 cyanobacteria cells per millimitre) is present in raw water source. In the absence of algal monitoring, an algal bloom is deemed to occur where the surface water is visibly green in the vicinity of the abstraction, or samples taken have a strong musty odour.

Table 9. SANS241-1:2011 physical, organoleptic and chemical requirements.

SANS 241-1:2011 - TABLE I: PHYSICAL, ORGANOLEPTIC & CHEMICAL REQUIREMENTS			
Determinand	**Risk**	**Unit**	**Standard limits [a] (Class I)**
Physical and aesthetic determinands			
Free chlorine	Chronic health	mg/L	≤ 5
Monochloramine	Chronic health	mg/L	≤ 3
Colour	Aesthetic	mg/L Pt-Co	≤ 15
Conductivity at 25 °C	Aesthetic	mS/m	≤ 170
Odour or taste	Aesthetic	-	Inoffensive
Total dissolved solids	Aesthetic	mg/L	≤ 1 200
Turbidity [b]	Operational	NTU	≤ 1
	Aesthetic	NTU	≤ 5
pH at 25 °C [c]	Operational	pH units	≥ 5 to ≤ 9,7
Chemical determinands — macro-determinands			
Nitrate as N [d]	Acute health - 1	mg/L	≤ 11
Nitrite as N [d]	Acute health - 1	mg/L	≤ 0,9
Sulfate as SO_4^{2-}	Acute health - 1	mg/L	≤ 500
	Aesthetic	mg/L	≤ 250
Fluoride as F^-	Chronic health	mg/L	≤ 1,5
Ammonia as N	Aesthetic	mg/L	≤ 1,5
Chloride as Cl^-	Aesthetic	mg/L	≤ 300
Sodium as Na	Aesthetic	mg/L	≤ 200
Zinc as Zn	Aesthetic	mg/L	≤ 5
Chemical determinands — micro-determinands			
Antimony as Sb	Chronic health	µg/L	≤ 20
Arsenic as As	Chronic health	µg/L	≤ 10
Cadmium as Cd	Chronic health	µg/L	≤ 3
Total chromium as Cr	Chronic health	µg/L	≤ 50
Cobalt as Co	Chronic health	µg/L	≤ 500
Copper as Cu	Chronic health	µg/L	≤ 2 000
Cyanide (recoverable) as CN^-	Acute health - 1	µg/L	≤ 70
Iron as Fe	Chronic health	µg/L	≤ 2 000
	Aesthetic	µg/L	≤ 300
Lead as Pb	Chronic health	µg/L	≤ 10
Manganese as Mn	Chronic health	µg/L	≤ 500
	Aesthetic	µg/L	≤ 100
Mercury as Hg	Chronic health	µg/L	≤ 6
Nickel as Ni	Chronic health	µg/L	≤ 70
Selenium as Se	Chronic health	µg/L	≤ 10
Uranium as U	Chronic health	µg/L	≤ 15
Vanadium as V	Chronic health	µg/L	≤ 200
Aluminium as Al	Operational	µg/L	≤ 300

SANS 241-1:2011 - TABLE II: PHYSICAL, ORGANOLEPTIC & CHEMICAL REQUIREMENTS			
Determinand	**Risk**	**Unit**	**Standard limits [a] (Class I)**
Chemical determinands-organic determinands			
Total organic carbon as C	Chronic health	mg/L	≤10
Trihalomethanes			
Chloroform	Chronic health	mg/L	≤ 0,3
Bromoform	Chronic health	mg/L	≤ 0,1
Dibromochloromethane	Chronic health	mg/L	≤ 0,1
Bromodichloromethane	Chronic health	mg/L	≤ 0,06
Microcystin as LR [e]	Chronic health	µg/L	≤1
Phenols	Aesthetic	µg/L	≤10

[a] The health-related standards are based on the consumption of 2 L of water per day by a person of a mass of 60 kg over a period of 70 years.

[b] Values in excess of those given in column 4 may negatively impact disinfection.

[c] Low pH values can result in structural problems in the distribution system.

[d] This is equivalent to nitrate at 50 mg $NO3^-$/Land nitrite as 3 mg $NO2^-$/L.

[e] Microcystin only needs to be measured where an algal bloom (> 20 000 cyanobacteria cells per

Table 10. SANS241:2006 physical, organoleptic and chemical requirements.

SANS 241:2006 - TABLE I: PHYSICAL, ORGANOLEPTIC & CHEMICAL REQUIREMENTS				
Determinand	**Unit**	**Class I (recommended operational limit)**	**Class II (max. allowable for limited duration)**	**Class II water consumption period,[a] max.**
Physical and organoleptic requirements				
Colour (aesthetic)	mg/L pt	< 20	20-50	No limit[b]
Conductivity at 25 °C (aesthetic)	mS/m	< 150	150-370	7 years
Dissolved solids (aesthetic)	mg/L	< 1 000	1 000-2 400	7 years
Odour (aesthetic)	TON	<5	5-10	No limit[b]
pH value at 25 °C (aesthetic/operational)	pH units	5,0 - 9,5	4,0 - 10,0	No limit[c]
Taste (aesthetic)	FTN	< 5	5-10	No limit
Turbidity (aesthetic/operational/indirect health)	NTU	< 1	1-5	No limit[d]
Chemical requirements — macro-determinand				
Ammonia as N (operational)	mg/L	< 1,0	1,0-2,0	No limit[d]
Calcium as Ca (aesthetic/operational)	mg/L	< 150	150-300	7 years
Chloride as Cl^- (aesthetic)	mg/L	< 200	200-600	7 years
Fluoride as F^- (health)	mg/L	< 1,0	1,0-1,5	1 year
Magnesium as Mg (aesthetic/health)	mg/L	< 70	70- 100	7 years
(Nitrate and nitrite) as N (health)	mg/L	< 10	10-20	7 years
Potassium as K (operational/health)	mg/L	< 50	50- 100	7 years
Sodium as Na (aesthetic/health)	mg/L	< 200	200-400	7 years
Sulfate as $S0_4^=$ (health)	mg/L	< 400	400-600	7 years
Zinc as Zn (aesthetic/health)	mg/L	< 5,0	5,0- 10	1 year

SANS 241:2006 - TABLE II: PHYSICAL, ORGANOLEPTIC & CHEMICAL REQUIREMENTS				
Determinand	**Unit**	**Class I (recommended operational limit)**	**Class II (max. allowable for limited duration)**	**Class II water consumption period," max.**
Chemical requirements — mlcro-determlnand				
Aluminium as AI (health)	mg/L	< 300	300-500	1 year
Antimony as Sb (health)	mg/L	< 10	10-50	1 year
Arsenic as As (health)	mg/L	< 10	10-50	1 year
Cadmium as Cd (health)	mg/L	<5	5- 10	6 months
Total Chromium as Cr (health)	mg/L	< 100	100-500	3 months
Cobalt as Co (health)	mg/L	< 500	500-1 000	1 year
Copper as Cu (health)	mg/L	< 1 000	1 000-2 000	1 year
Cyanide (recoverable) as CW (health)	mg/L	<50	50-70	1 week
Iron as Fe (aesthetic/ operational)	mg/L	< 200	200-2 000	7 years[b]
Lead as Pb (health)	mg/L	< 20	20-50	3 months
Manganese as Mn (aesthetic)	mg/L	< 100	100-1000	7 years
Mercury as Hg (health)	mg/L	< 1	1-5	3 months
Nickel as Ni (health)	mg/L	< 150	150- 350	1 year
Selenium as Se (health)	mg/L	< 20	20-50	1 year
Vanadium as V (health)	mg/L	< 200	200- 500	1 year
Chemical requirements — organic determinand				
Dissolved organic carbon as C (aesthetic/health)	mg/L	< 10	10-20	3 months[e]
Total trihalomethanes (health)	mg/L	< 200	200-300	10 years[f]
Phenols (aesthetic/health)	mg/L	< 10	10-70	No limi[b]

[a] The limits for the consumption of class II water are based on the consumption of 2 L water per day by a person of mass 70 kg over

[b] The limits given are based on aesthetic aspects.

[c] No primary health effect- low pH values can result in structural problems in the distribution system.

[d] These values can indicate process efficiency and risks associated with pathogens.

[e] When dissolved organic carbon is deemed of natural origin, the consumption period can be extended.

[f] This is a suggested value because trihalomethanes have not been proven to have any effect on human health.

7.3 DESCRIPTION OF THE GENERAL GROUNDWATER QUALITY (SANS241-1:2015)

The groundwater quality classification table of the Mamatwan Mine Hydrocensus according to the SANS Human Drinking Water Standard, SANS241:2015 can be viewed in Table 11 on page 55. The results of the inorganic groundwater quality according to the SANS Human Drinking Water Standards are as follows:

- The hydrocensus farm boreholes HF/BH23, HF/BH29, HF/BH34, HF/BH35, HF/BH38 and HF/BH39 are classified as "Class 1 – recommended standard limit" for inorganic water quality (SANS241-1:2015) and is suitable for lifetime consumption although most of these boreholes contain relatively hard water on the maximum allowable concentration for Total Hardness.
- The hydrocensus farm boreholes HF/BH22, HF/BH24, HF/BH25, HF/BH26, HF/BH27, HF/BH32, HF/BH33, HF/BH36 and HF/BH37 are classified as "ARS" (inorganic water quality). According to SANS241-1:2015 the water quality of the farm hydrocensus boreholes is unsuitable for consumption in general due to elevated concentrations of Electrical Conductivity (EC), Sodium (Na, lesser extent), Calcium (Ca, lesser extent), Magnesium (Mg), Chloride (Cl), Nitrate (NO_3 as N), Ammonia / Ammonium (NH_3 as N / NH_4 as N, aesthetic, lesser extent), Iron (Fe, lesser extent) and Manganese (Mn, aesthetic, lesser extent).

Table 11. Inorganic groundwater quality classification of the Mamatwan Hydrocensus Farm boreholes according to the Human Drinking Water Standard, SANS241:2015.

	Site Name	Date	Quality Class	pH	EC	TDS	Na	Ca	Mg	K	Cl	SO_4	SO_4 (Ae)	F	NO_2-N	NO_3-N	NH_3-N / NH_4-N (Ae)	PO_4	T.ALK	T. Hard	Fe	Fe (Ae)	B	Mn	Mn (Ae)	Ionbal Error
				pH Units	mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/l	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
HMM Mamatwan Mine: Hydrocensus Study of Farm Boreholes (2021)	HF/BH22	2021-05-10	"ARS"	7.35	116.00	631	42.10	98.10	61.10	3.13	89.00	22.80	22.80	0.25	0.01	12.70	0.45	0.03	430	496.57	0.010	0.010	0.010	0.010	0.010	-2.58
	HF/BH23	2021-05-10	"Class 1"	7.82	110.00	584	46.30	70.80	66.70	3.78	96.30	26.40	26.40	0.25	0.06	11.00	0.45	0.03	374	451.46	0.010	0.010	0.010	0.010	0.010	-1.63
	HF/BH24	2021-05-10	"ARS"	7.13	97.40	532	28.20	81.50	58.20	2.96	42.90	26.40	26.40	0.16	0.17	3.90	3.53	0.03	445	443.17	2.050	2.050	0.010	0.310	0.310	-1.68
	HF/BH25	2021-05-10	"ARS"	7.49	117.00	664	42.90	98.78	66.55	2.27	150.00	36.50	36.50	0.26	0.01	19.27	0.45	0.03	302	520.71	0.010	0.010	0.010	0.010	0.010	-0.27
	HF/BH26	2021-05-10	"ARS"	7.22	170.00	1015	71.60	136.92	96.12	3.32	263.00	33.20	33.20	0.09	0.01	46.33	0.45	0.03	343	737.73	0.010	0.010	0.010	0.010	0.010	-0.88
	HF/BH27	2021-05-10	"ARS"	7.23	226.00	1045	25.95	91.70	36.47	25.46	324.00	2.11	2.11	0.16	0.01	1.08	165.31	0.03	532.4	379.17	1.146	1.146	0.010	0.293	0.293	3.06
	HF/BH29	2021-05-10	"Class 1"	7.39	103.00	560	37.80	82.81	57.60	3.34	70.20	15.52	15.52	0.18	0.04	10.20	1.33	0.03	409	443.97	0.010	0.010	0.010	0.010	0.010	-2.19
	HF/BH32	2021-05-11	"ARS"	7.25	392.00	2274	65.70	371.30	209.93	7.99	845.00	47.70	47.70	0.09	0.76	130.00	0.45	0.03	250	1791.62	0.010	0.010	0.010	0.010	0.010	-0.39
	HF/BH33	2021-05-11	"ARS"	8.30	225.00	1369	157.41	54.70	170.37	11.90	382.92	110.64	110.64	0.47	0.38	55.03	0.45	0.03	391	838.19	0.010	0.010	0.470	0.010	0.010	-2.00
	HF/BH34	2021-05-10	"Class 1"	7.80	132.00	769	75.40	86.19	76.78	6.91	123.79	93.01	93.01	0.49	0.01	8.29	0.45	0.03	449	531.40	0.010	0.010	0.100	0.010	0.010	-3.14
	HF/BH35	2021-05-10	"Class 1"	7.96	140.00	827	97.30	64.29	89.38	7.88	175.27	132.27	132.27	0.44	0.01	6.11	0.45	0.03	388	528.58	0.010	0.010	0.160	0.010	0.010	-2.90
	HF/BH36	2021-05-10	"ARS"	7.57	148.00	879	273.04	16.80	27.00	2.28	205.00	69.00	69.00	0.47	0.01	11.08	0.45	0.03	394	153.14	0.010	0.010	0.060	0.010	0.010	-3.15
	HF/BH37	2021-05-10	"ARS"	7.14	289.00	1655	140.00	230.56	136.78	25.90	764.00	161.00	161.00	0.09	0.01	2.73	0.45	0.03	307	1138.95	0.010	0.010	0.060	0.010	0.010	-3.02
	HF/BH38	2021-05-10	"Class 1"	7.99	72.40	386	38.10	32.40	52.70	5.41	23.60	13.10	13.10	0.67	0.02	1.10	0.47	0.03	358	297.92	0.010	0.010	0.010	0.010	0.010	-2.37
	HF/BH39	2021-05-10	"Class 1"	8.08	120.00	685	90.60	61.18	67.63	8.44	121.00	37.50	37.50	0.39	0.03	7.10	0.45	0.15	443	431.27	0.010	0.010	0.070	0.010	0.010	-3.01

Quality of Domestic Water Supplies, DWA&F, Second Edition 1998

Class 0	**Ideal water quality Suitable for lifetime use.**
Class 1	**Good water quality Suitable for use, rare instances of negative effects.**
Class 2	**Marginal water quality Conditionally acceptable. Negative effects may occur in some sensitive groups**
Class 3	**Poor water quality Unsuitable for use without treatment. Chronic effects may occur.**
Class 4	**Dangerous water quality Totally unsuitable for use. Acute effects may occur.**

SABS South Africa National Standard: Drinking Water, SANS 2411:2015 Edition 2

Class 1	**Recommended standard limit Suitable for lifetime use.**
ARS	Above recommended standard limit Unsuitable for lifetime human consumption.

SABS South Africa National Standard: Drinking Water, SANS 241:2006 Edition 6.1

Class 1	**Recommended operational limit Suitable for lifetime use.**
Class 2	Maximum allowable limit Suitable for limited duration use only.
AMA	Above maximum allowable limit Unsuitable for human consumption.

*** (Ae) Aesthetic standards.**

:a Water Quality Guidelines, Volume 1: Domestic Use, DWA&F, First Edition 1993 & Second E

NR	Target water quality range No risk.
IR	**Good water quality Insignificant risk. Suitable for use, rare instances of negative effects.**
LR	Marginal water quality Allowable low risk. Negative effects may occur in some sensitive groups
HR	Poor water quality Unsuitable for use without treatment. Chronic effects may occur.

7.4 ANALYSIS OF THE BACKGROUND GROUNDWATER QUALITY CONCENTRATIONS VERSUS THE MINE MONITORING BOREHOLE CONCENTRATIONS

The baseline groundwater quality averages of the chemical parameters of the farm hydrocensus boreholes as well as the Mamatwan Mine monitoring boreholes indicate that the only mine groundwater chemical parameters to display considerable higher averaged values then the background / baseline groundwater qualities were Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium (Na), Calcium (Ca), Sulphate (SO_4) and Nitrates (NO_3-N).

The difference in averaged values between the mine groundwater and the background farm boreholes for the chemical parameters mention above are as follows (refer to Table 12 on page 57):

- Electrical Conductivity (EC) averaged difference was 33.82 mg/L. The average mine EC value is 214.46 mg/L and the background farm borehole EC value is 180.64 mg/L.
- Total Dissolved Solids (TDS) averaged difference was 423.43 mg/L. The average mine TDS value is 1613.65 mg/L and the background farm borehole TDS value is 1190.22 mg/L.
- Calcium (Ca) averaged difference was 32.38 mg/L. The average mine Ca value is 182.20 mg/L and the background farm borehole Ca value is 149.81 mg/L.
- Sulphate (SO_4) averaged difference was 128.05 mg/L. The average mine SO_4 value is 196.06 mg/L and the background farm borehole SO_4 value is 68.01 mg/L.
- Nitrate (NO_3-N) averaged difference was 42.62 mg/L. The average mine NO_3-N value is 98.35 mg/L and the background farm borehole NO_3-N value is 55.72 mg/L.
- To a lesser extent Sodium (Na), Magnesium (Mg), Chloride (Cl) and Boron (B) is slightly higher on average for the Mamatwan Mine monitoring boreholes compared to the farm hydrocensus boreholes.

Table 12. The groundwater quality averages of the chemical parameters of the farm hydrocensus boreholes as well as the Mamatwan Mine monitoring boreholes. Note that the only mine groundwater chemical parameters to display higher averaged values then the background groundwater quality were Electrical Conductivity (EC), Total Dissolved Solids (TDS), Calcium (Ca), Sulphate (SO_4) and Nitrates (NO_3 as N) and to a lesser extent Sodium (Na), Magnesium (Mg), Chloride (Cl) and Boron (B).

Groundwater Quality: Farm Boreholes Background Averages

Parameter Average	7.88	180.64	1190.22	90.69	149.81	96.27	8.23	273.74	68.01	0.37	0.26	55.72	5.03	0.15	339.37	0.08	0.32	0.02
Geometric Mean	7.86	142.35	878.79	73.44	90.79	72.78	5.73	155.95	44.45	0.28	0.03	12.18	0.32	0.07	310.85	0.02	0.18	0.01
Standard Deviation	0.54	178.41	1484.40	68.09	274.57	82.94	9.42	349.56	73.69	0.27	1.45	189.40	34.11	0.36	155.98	0.27	0.46	0.05
Chemical Parameters	**pH**	**EC**	**TDS**	**Na**	**Ca**	**Mg**	**K**	**Cl**	**SO_4**	**F**	**NO_2-N**	**NO_3-N**	**NH_4-N**	**PO_4**	**T.ALK**	**Fe**	**B**	**Mn**

Groundwater Quality: Mamatwan Mine Monoitoring Borehole Averages

Parameter Average	7.52	214.46	1613.65	114.28	182.20	115.28	8.80	277.71	196.06	0.32	0.15	98.35	1.34	0.37	245.53	0.16	1.92	0.24
Geometric Mean	7.52	208.28	1507.34	104.73	172.51	109.11	8.51	237.34	140.16	0.30	0.12	82.38	0.36	0.36	243.26	0.08	0.94	0.08
Standard Deviation	0.10	49.57	611.36	51.28	57.75	37.44	2.38	148.70	162.08	0.12	0.17	53.72	3.42	0.06	36.04	0.21	3.18	0.38
Chemical Parameters	**pH**	**EC**	**TDS**	**Na**	**Ca**	**Mg**	**K**	**Cl**	**SO_4**	**F**	**NO_2-N**	**NO_3-N**	**NH_4-N**	**PO_4**	**T.ALK**	**Fe**	**B**	**Mn**

Difference between the Background Averages and the Mamatwan Mine Monoitoring Borehole Averages

Difference in mg/L or mS/m	-0.36	33.82	423.43	23.59	32.39	19.01	0.57	3.97	128.05	-0.05	-0.10	42.62	-3.68	0.22	-93.84	0.08	1.60	0.22
Chemical Parameters	**pH**	**EC**	**TDS**	**Na**	**Ca**	**Mg**	**K**	**Cl**	**SO_4**	**F**	**NO_2-N**	**NO_3-N**	**NH_4-N**	**PO_4**	**T.ALK**	**Fe**	**B**	**Mn**

7.5 POLLUTION INDEX AND CONTAMINANT ASSESSMENT OF HYDROCENSUS FARM BOREHOLES

The pollution indexes for the groundwater at Mamatwan Mine are calculated by comparison of the indicator element concentrations of the groundwater at the mine with the concentrations measured in hydrocensus boreholes on farms adjacent to the Mamatwan Mine lease.

Pollution Index Tables are used to obtain a first estimate of the probability that contaminants have been impacting on the surface- and groundwater at Mamatwan Mine and adjacent farm properties. The Pollution Index (PI) for a specific indicator element is calculated by relating the current concentration to the concentrations recorded at a number of background sites, and by assuming that the indicator element concentrations of the background samples follow a normal distribution.

The PI for each indicator element under consideration is calculated by taking the difference between the current concentration and the average concentration obtained for the background samples. This difference is then divided by the standard deviation of the background samples, as explained in the equation below.

PI Equation:

$$(PI)_{indicator element A} = \frac{(Current conc. - Ave\ \ background\ conc.)_{indicator element A}}{(St.dev.\ \ of\ \ \ background\ conc)_{indicator element A}}$$

To interpret the PI's, the following should be noted:

- Negative PI's imply that the indicator elements concentrations of the groundwater/surface water are lower than the average background concentration and that contaminant impacts are therefore not visible.
- PI's greater than 0.5 imply that the indicator elements concentrations of the groundwater/surface water are more than half a standard deviation larger than the average concentration measured at the background sampling sites. The likelihood of obtaining a concentration of this magnitude in an uncontaminated sample is <30.9%. The sample could possibly be contaminated.
- PI's greater than unity imply that the indicator elements concentrations of the groundwater/surface water are more than one standard deviation larger than the average concentration measured at the background sampling sites. The likelihood of obtaining a concentration of this magnitude in an uncontaminated sample is <15.9%. There is therefore a high probability that the sample is contaminated.
- PI's greater than two imply that the indicator elements concentrations of the groundwater/surface water are more than two standard deviations larger than the average concentration measured at the background sampling sites. The likelihood of obtaining a concentration of this magnitude in an uncontaminated sample is <2.3%. There is therefore a very high probability that the sample is contaminated.

Mamatwan Mine monitoring boreholes indicate that the only mine groundwater chemical parameters to display considerable higher averaged values then the background / baseline groundwater quality (Farm Hydrocensus Boreholes) were Electrical Conductivity (EC) / Total Dissolved Solids (TDS), Sodium (Na), Calcium (Ca), Sulphate (SO_4) and Nitrates (NO_3-N) and to a lesser extent Sodium (Na), Magnesium (Mg) and Chloride (Cl).

The results pollution index of the hydrocensus boreholes indicate that the farm boreholes is not affected by Mamatwan Mine mining activities or cumulative groundwater quality impacts of the other mines surrounding Mamatwan Mine, which includes Tshipi-e-Ntle Mine to the west and United Manganese of the Kalahari (UMK) to the north (refer to Table 13 on page 59). Farm Hydrocensus Boreholes HF/BH32, HF/BH33 and HF/BH37 do indicate some impacts but analysis of groundwater elevations and numerical modelling (groundwater flow and mass-transport / plume modelling) indicated that the groundwater quality of these boreholes have not been affected by Mamatwan Mining activities but relate to local natural water qualities or potential local surface activities.

Farm Hydrocensus Borehole HF/BH32 could have been potentially impacted by historical impacts of the old, rehabilitated tailings /slimes when the facility was still functional with associated higher elevated groundwater mounds forcing groundwater contaminants up-gradient of natural flow in the direction of farm borehole HF/BH32. The potential possibility of impacts on chemical parameters, which includes EC, TDS, Ca, Mg and Cl do exists, but Numerical Modelling (refer to Figure 26, Figure 27 and Figure 28 on pages 60 to 62) indicated that no pollution plume reaching is reaching HF/BH32 from the old TSF and WRDs and Stiff / Expanded Durov Diagrams do not indicate the same type of groundwater chemistry at the sites. Therefore, the current information is not conclusive if farm borehole HF/BH32 is impacted or affected by the mining activities of Mamatwan Mine. By drilling a new monitoring borehole between the old TSF and HF/BH32 might be the only approach to discern if the borehole was historically impacted by the TSF activities of Mamatwan.

It is therefore concluded that groundwater flow directions results and hydrochemistry results of the Farm Hydrocensus Boreholes indicate that Mamatwan Mine mining activities is not directly impacting the groundwater quality of the farm boreholes of the surrounding groundwater users (refer to Table 14 and Table 15 on pages 63 and 64).

Table 13. Pollution Index – Mamatwan Mine Farm Hydrocensus Boreholes (2021).

Site Name	Pollution Index - Mamatwan Mine								
	pH	EC	TDS	Na	Ca	Mg	Cl	SO_4	NO_3-N
HF/BH22	-0.984	-0.362	-0.377	-0.714	-0.188	-0.424	-0.528	-0.613	-0.227
HF/BH23	-0.112	-0.396	-0.409	-0.652	-0.288	-0.356	-0.508	-0.565	-0.236
HF/BH24	-1.392	-0.467	-0.444	-0.918	-0.249	-0.459	-0.660	-0.565	-0.274
HF/BH25	-0.724	-0.357	-0.355	-0.702	-0.186	-0.358	-0.354	-0.428	-0.192
HF/BH26	-1.225	-0.060	-0.118	-0.280	-0.047	-0.002	-0.031	-0.472	-0.050
HF/BH27	-1.206	0.254	-0.098	-0.951	-0.212	-0.721	0.144	-0.894	-0.289
HF/BH29	-0.910	-0.435	-0.425	-0.777	-0.244	-0.466	-0.582	-0.712	-0.240
HF/BH32	-1.169	1.185	0.730	-0.367	0.807	1.370	1.634	-0.276	0.392
HF/BH33	0.778	0.249	0.120	0.980	-0.346	0.893	0.312	0.578	-0.004
HF/BH34	-0.149	-0.273	-0.284	-0.224	-0.232	-0.235	-0.429	0.339	-0.250
HF/BH35	0.148	-0.228	-0.244	0.097	-0.311	-0.083	-0.282	0.872	-0.262
HF/BH36	-0.576	-0.183	-0.209	2.678	-0.484	-0.835	-0.197	0.013	-0.236
HF/BH37	-1.373	0.607	0.313	0.724	0.294	0.488	1.402	1.262	-0.280
HF/BH38	0.203	-0.607	-0.542	-0.772	-0.428	-0.525	-0.716	-0.745	-0.288
HF/BH39	0.370	-0.340	-0.341	-0.001	-0.323	-0.345	-0.437	-0.414	-0.257

PI > 0.5 - Possibility of contaminant impacts.
PI > 1.0 - High probability of contaminant impacts.
PI > 2.0 - Very high probability of contaminant impacts.

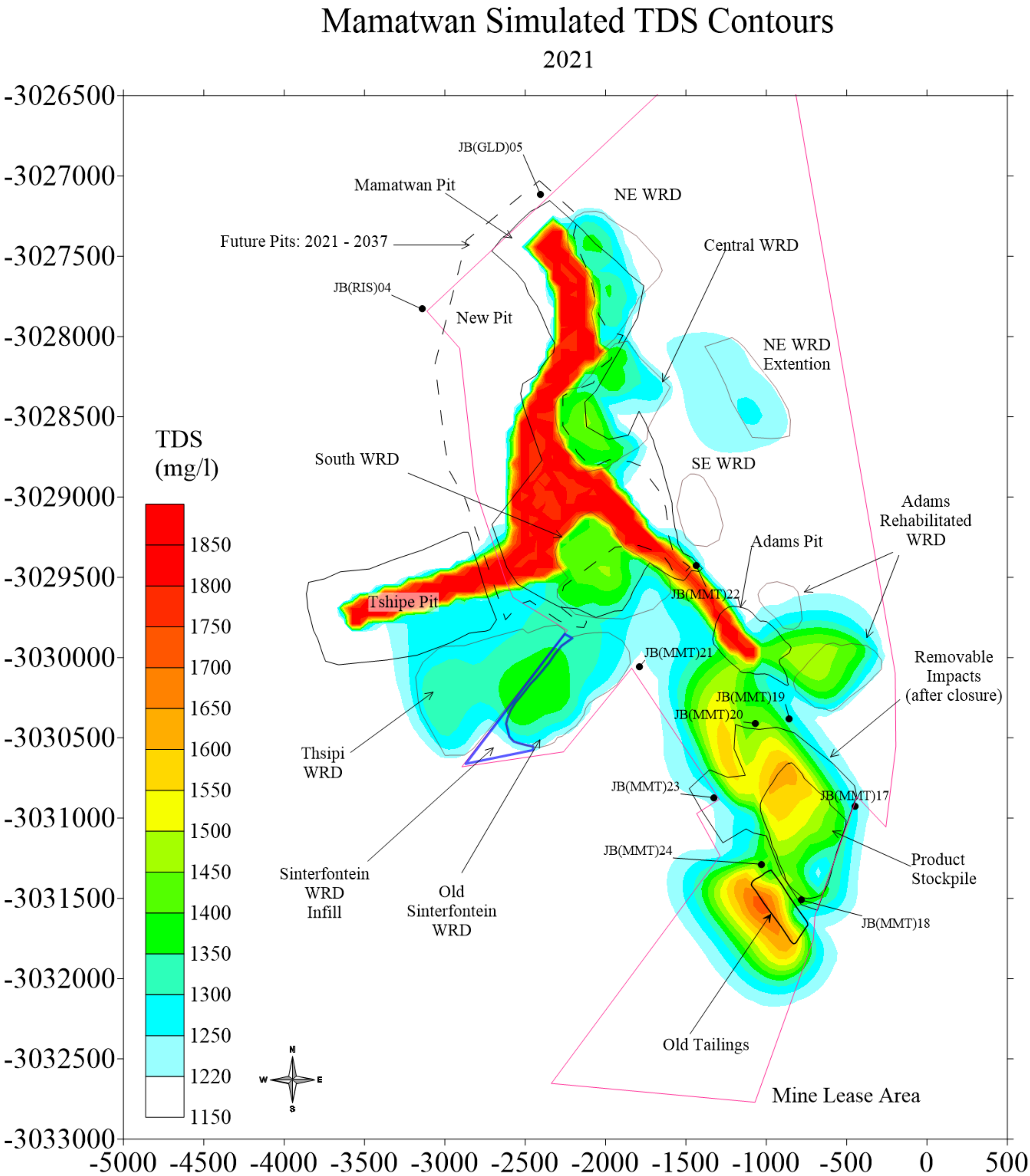


Figure 26. The numerical mass transport results of the contaminant plume migration patterns for Mamatwan Mine in 2021.

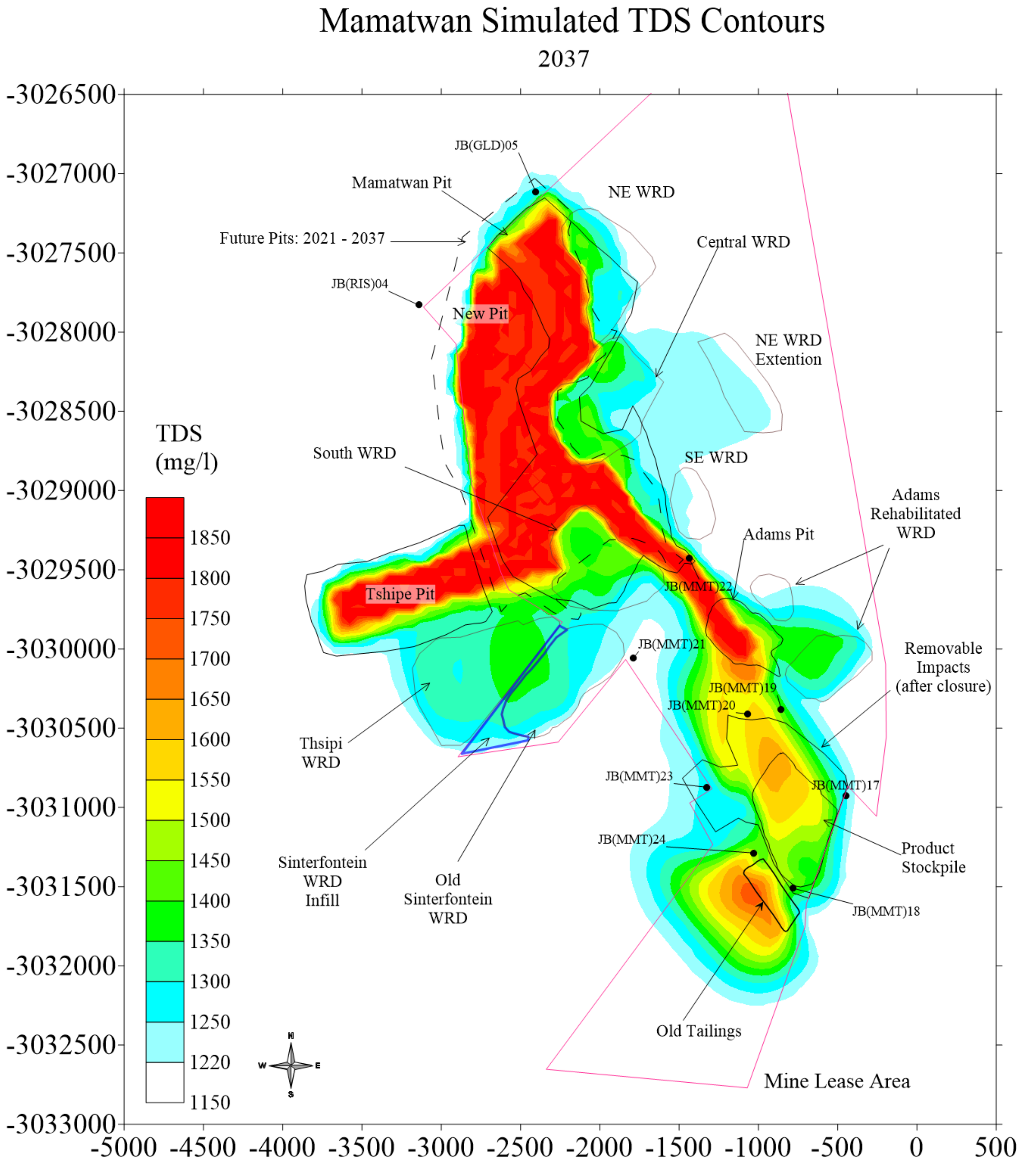


Figure 27. The numerical mass transport results of the contaminant plume migration patterns for Mamatwan Mine in 2037 at mine closure.

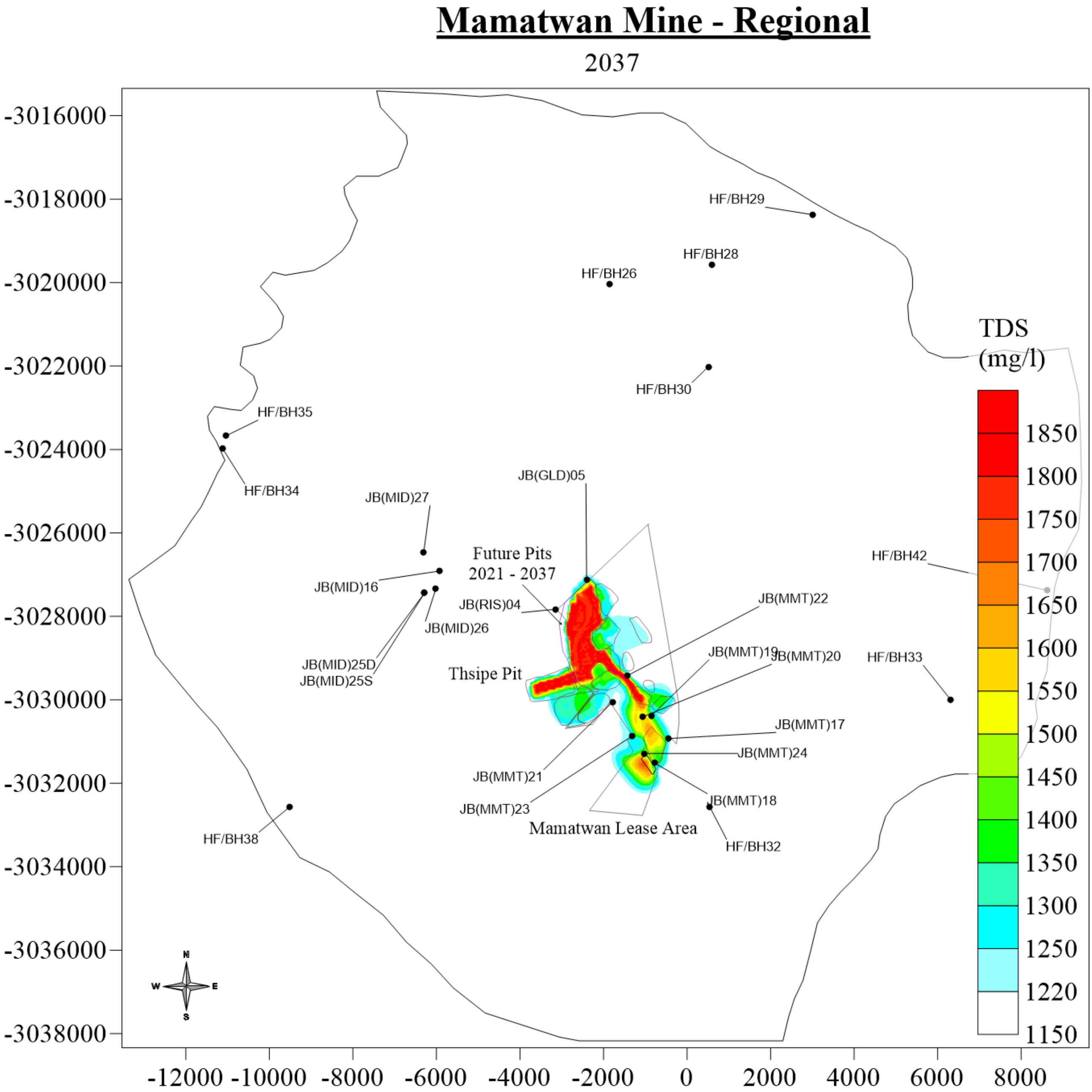


Figure 28. The numerical mass transport results of the regional contaminant plume migration patterns for Mamatwan Mine in 2037 at mine closure. The simulated pollution plumes do not impact upon any boreholes beyond the mine lease area.

Table 14. Part 1: Contaminant assessment of the Farm Hydrocensus Boreholes of Mamatwan Mine.

	Borehole Name	Locality Discription	Farm Name	Owner	Date	Coordinates (WGS84) Longitude (East)	Latitude (South)	Elevation (mamsl)	Groundwater Flow Direction	Distance from Wessels Mine (km)	Comments	Verdict
1.)	**HF/BH22**	Mamatwan Mine / Smart-Rissk / UMK Mine District	London / Kameelaar	Mr. Hendrik Venter	2021/05/10	23.04543	-27.26635	1098.93	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL at a lower elevation then the Farm Borehole.	12.20	No water level is svailable. DWS Groundwater Resource Assessment PH2 data utilised (Modelled: 1km x1km raster). Mamatwan Mine is located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	The farm borehole is up-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH22 from Mamatwan Mine. The groundwater quality data and the calculated Pollution Index also gives no real indication that the borehole chemistry has been affected by mine contaminated groundwater. Therefore, farm borehole HF/BH22 is not impacted by mining activities of Mamatwan Mine.
2.)	**HF/BH23**	Mamatwan Mine / Smart-Rissk / UMK Mine District	London / Kameelaar	Mr. Hendrik Venter	2021/05/10	23.04455	-27.26819	1099.20	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL at a lower elevation then the Farm Borehole.	11.80	Note that Mamatwan Mine is located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	The farm borehole is up-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH23 from Mamatwan Mine. The groundwater quality data and the calculated Pollution Index also gives no real indication that the borehole chemistry has been affected by mine contaminated groundwater. Therefore, farm borehole HF/BH23 is not impacted by mining activities of Mamatwan Mine.
3.)	**HF/BH24**	Mamatwan Mine / Smart-Rissk / UMK Mine District	Aarpan	Ms. Ansie Venter	2021/05/10	23.08828	-27.25825	1122.31	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL at a lower elevation then the Farm Borehole.	15.50	Note that Mamatwan Mine is located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	The farm borehole is up-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH24 from Mamatwan Mine. The groundwater quality data and the calculated Pollution Index also gives no real indication that the borehole chemistry has been affected by mine contaminated groundwater. Therefore, farm borehole HF/BH24 is not impacted by mining activities of Mamatwan Mine.
4.)	**HF/BH25**	Mamatwan Mine / Smart-Rissk / UMK Mine District	Aarpan	Ms. Ansie Venter	2021/05/10	23.09512	-27.26161	1128.70	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL at a lower elevation then the Farm Borehole.	15.60	No water level is svailable. DWS Groundwater Resource Assessment PH2 data utilised (Modelled: 1km x1km raster). Mamatwan Mine is located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	The farm borehole is up-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH25 from Mamatwan Mine. The groundwater qualitydata and the calculated Pollution Index also gives no real indication that the borehole chemistry has been affected by mine contaminated groundwater. Therefore, farm borehole HF/BH25 is not impacted by mining activities of Mamatwan Mine.
5.)	**HF/BH26**	Mamatwan Mine / Smart-Rissk / UMK Mine District	Perth 276	Mr.Eben Anthonissen	2021/05/10	22.98135	-27.29251	1070.13	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL at a lower elevation then the Farm Borehole.	7.10	No water level is svailable. DWS Groundwater Resource Assessment PH2 data utilised (Modelled: 1km x1km raster). Mamatwan Mine is not located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	The farm borehole is up-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH26 from Mamatwan Mine. The groundwater quality data and the calculated Pollution Index also gives no real indication that the borehole chemistry has been affected by mine contaminated groundwater. Therefore, farm borehole HF/BH26 is not impacted by mining activities of Mamatwan Mine.
6.)	**HF/BH27**	Mamatwan Mine / Smart-Rissk / UMK Mine District	Perth 276	Mr.Eben Anthonissen	2021/05/10	22.98135	-27.28864	1070.75	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL at a lower elevation then the Farm Borehole.	7.50	Note that Mamatwan Mine is not located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	The farm borehole is up-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH27 from Mamatwan Mine. The groundwater quality data and the calculated Pollution Index also gives no real indication that the borehole chemistry has been affected by mine contaminated groundwater. Therefore, farm borehole HF/BH27 is not impacted by mining activities of Mamatwan Mine.
7.)	**HF/BH28**	Mamatwan Mine / Smart-Rissk / UMK Mine District	Eldoret	Mr. Piet Swanepoel	2021/05/10	23.00597	-27.28831	1083.63	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL at a lower elevation then the Farm Borehole.	8.00	Note that Mamatwan Mine is not located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	The farm borehole is up-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH28 from Mamatwan Mine. Therefore, farm borehole HF/BH28 is not impacted by mining activities of Mamatwan Mine.
8.)	**HF/BH29**	Mamatwan Mine / Smart-Rissk / UMK Mine District	Eldoret	Mr. Piet Swanepoel	2021/05/10	23.03036	-27.27744	1095.45	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL at a lower elevation then the Farm Borehole.	10.20	Note that Mamatwan Mine is located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine.	The farm borehole is up-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH29 from Mamatwan Mine. The groundwater quality data and the calculated Pollution Index also gives no real indication that the borehole chemistry has been affected by mine contaminated groundwater. Therefore, farm borehole HF/BH29 is not impacted by mining activities of Mamatwan Mine.
9.)	**HF/BH30**	Mamatwan Mine / Smart-Rissk / UMK Mine District	Rissik	Mr. Gideon Poolman	2018/07/19	23.00516	-27.31032	1080.00	Farm groundwater flow from east to north west, not in line with mine locality. Mamatwan Mine GWL at a lower elevation then the Farm Borehole.	5.80	Note that Mamatwan Mine is not located below drainage from the farm borehole and that the natural flow direction (E to NW) is not directly towards Mamatwan Mine.	The farm borehole is up-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH30 from Mamatwan Mine. Therefore, farm borehole HF/BH30 is not impacted by mining activities of Mamatwan Mine.
10.)	**HF/BH31**	Mamatwan Mine / Smart-Rissk / UMK Mine District	Rissik	Mr. Gideon Poolman	2021/05/14	23.00407	-27.31317	1080.00	Farm groundwater flow from east to north west, not in line with mine locality. Mamatwan Mine GWL at a lower elevation then the Farm Borehole.	5.50	No water level is svailable. DWS Groundwater Resource Assessment PH2 data utilised (Modelled: 1km x1km raster). Mamatwan Mine is not located below drainage from the farm borehole and that the natural flow direction (E to NW) is not directly towards Mamatwan Mine.	The farm borehole is up-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH31 from Mamatwan Mine. Therefore, farm borehole HF/BH31 is not impacted by mining activities of Mamatwan Mine.

Table 15. Part 2: Contaminant assessment of the Farm Hydrocensus Boreholes of Mamatwan Mine.

Borehole Name		Locality Discription	Farm Name	Owner	Date	Coordinates (WGS84)			Groundwater Flow Direction	Distance from Wessels Mine (km)	Comments	Verdict
						Longitude (East)	Latitude (South)	Elevation (mamsl)				
11.)	**HF/BH32**	Mamatwan Mine District	Moab	Mr. Niekie Kruger	2018/07/19	23.00551	-27.40557	1110.03	Farm groundwater flow from east to west, not in line with mine locality. Mamatwan Mine GWL at a lower elevation then the Farm Borehole.	1.48	Note that Mamatwan Mine is located below drainage from the farm borehole and that the natural flow direction (E to W) is not directly towards Mamatwan Mine. Note that due to the artificially elevated GWL at the old rehabilitated Slimes Dam the groundwater flow is partly up-gradient towards HF/BH32 although the groundwater do not reached the farm borehole.	Farm Hydrocensus Borehole HF/BH32 could have been potentially impacted by historical impacts of the old, rehabilitated tailings /slimes when the facility was still functional with associated higher elevated groundwater mounds forcing groundwater contaminants up-gradient of natural flow in the direction of farm borehole HF/BH32. The potential possibility of impacts on chemical parameters, which includes EC, TDS, Ca, Mg and Cl do exists, but Numerical Modelling indicated that no pollution plume reaching is reaching HF/BH32 from the old TSF and WRDs and Stiff / Expanded Durov Diagrams do not indicate the same type of groundwater chemistry at the sites. Therefore, the current information is not conclusive if farm borehole HF/BH32 is impacted or affected by the mining activities of Mamatwan Mine. By drilling a new monitoring borehole between the old TSF and HF/BH32 might be the only approach to discern if the borehole was historically impacted by the TSF activities of Mamatwan.
12.)	**HF/BH33**	Mamatwan Mine District	Milner	Mr. Niekie Kruger	2021/05/11	23.06380	-27.38234	1119.05	Farm groundwater flow from south east to north west, in line with mine locality. Mamatwan Mine GWL at a lower elevation then the Farm Borehole.	7.10	Note that Mamatwan Mine is located below drainage from the farm borehole and that the natural flow direction (SE to NW) is not directly towards Mamatwan Mine.	The farm borehole is up-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH33 from Mamatwan Mine. Note that HF/BH33 display above average concentrations of pH, Na, Mg and SO_4, which indicates that some hydrocensus boreholes has naturally occurring higher concentrations of site specific chemical parameters or has been affect water quality wise by farm local on-site activities.
13.)	**HF/BH34**	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Heunning Draai	Mr. Ampie Coetzee	2021/05/10	22.88761	-27.32795	1060.00	Farm groundwater flow from south east to north west, in line with mine locality. Mamatwan Mine GWL at a higher elevation then the Farm Borehole.	9.20	No water level is svailable. DWS Groundwater Resource Assessment PH2 data utilised (Modelled: 1km x1km raster). Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (SE to NW) is directly away from Mamatwan Mine in the direction of HF/BH34.	The farm borehole HF/BH34 is located in a separated sub-catchment that flows groundwater wise in a westerly direction towards the Gamagara River. Therefore, farm borehole HF/BH34 is not impacted by mining activities of Mamatwan Mine. The groundwater quality and the calculated Pollution Index also gives no real indication that the borehole chemistry has been affected by mine contaminated groundwater.
14.)	**HF/BH35**	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Heunning Draai	Mr. Ampie Coetzee	2018/07/18	22.88844	-27.32523	1060.00	Farm groundwater flow from north west to south east to wards the Gamagara River. Mamatwan Mine GWL at a higher elevation then the Farm Borehole.	9.20	Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (NW to SE). Note that the borehole is situated west of the non-perennial river. Groundwater flow is also not in the direction of the borehole from the mine.	The farm borehole HF/BH35 is located in a separated sub-catchment that flows groundwater wise in a westerly direction towards the Gamagara River. Therefore, farm borehole HF/BH35 is not impacted by mining activities of Mamatwan Mine. The groundwater quality and the calculated Pollution Index also gives no real indication that the borehole chemistry has been affected by mine contaminated groundwater.
15.)	**HF/BH36**	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Smuts	Mr. Nico Smith	2021/05/10	22.86649	-27.35455	1060.00	Farm groundwater flow from north west to south east to wards the Gamagara River. Mamatwan Mine GWL at a higher elevation then the Farm Borehole.	10.50	Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (NW to SE). Note that the borehole is situated west of the non-perennial river. Groundwater flow is also not in the direction of the borehole from the mine.	The farm borehole HF/BH36 is located in a separated sub-catchment that flows groundwater wise in a westerly direction towards the Gamagara River. Therefore, farm borehole HF/BH36 is not impacted by mining activities of Mamatwan Mine. The groundwater quality and the calculated Pollution Index also gives no real indication that the borehole chemistry has been affected by mine contaminated groundwater.
16.)	**HF/BH37**	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Smuts	Mr. Nico Smith	2021/05/10	22.82764	-27.34351	1074.26	Farm groundwater flow from north west to south east to wards the Gamagara River. Mamatwan Mine GWL at a higher elevation then the Farm Borehole.	14.50	No water level is svailable. DWS Groundwater Resource Assessment PH2 data utilised (Modelled: 1km x1km raster). Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (NW to SE). Note that the borehole is situated west of the non-perennial river. Groundwater flow is also not in the direction of the borehole from the mine.	The farm borehole HF/BH37 is located in a separated sub-catchment that flows groundwater wise in a westerly direction towards the Gamagara River. Therefore, farm borehole HF/BH37 is not impacted by mining activities of Mamatwan Mine. The groundwater quality and the calculated Pollution Index also gives no real indication that the borehole chemistry has been affected by mine contaminated groundwater.
17.)	**HF/BH38**	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Cobham	Mr. Phillip van der Merwe	2018/07/19	22.90379	-27.40549	1080.00	Farm groundwater flow from south east to north west, in line with mine locality. Mamatwan Mine GWL at a higher elevation then the Farm Borehole.	7.60	Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (SE to NW) is directly away from Mamatwan Mine but not in the direction of HF/BH38.	The farm borehole is 7.60 km down-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH38 from Mamatwan Mine as indicated by Numerical Modelling. The groundwater quality data and the calculated Pollution Index also gives no real indication that the borehole chemistry has been affected by mine contaminated groundwater. Therefore, farm borehole HF/BH38 is not impacted by mining activities of Mamatwan Mine.
18.)	**HF/BH39**	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Cobham	Mr. Phillip van der Merwe	2021/05/10	22.87963	-27.40732	1080.69	Farm groundwater flow from south east to north west, in line with mine locality. Mamatwan Mine GWL at a higher elevation then the Farm Borehole.	9.80	No water level is svailable. DWS Groundwater Resource Assessment PH2 data utilised (Modelled: 1km x1km raster). Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (SE to NW) is directly away from Mamatwan Mine but not in the direction of HF/BH39.	The farm borehole is 9.80 km down-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH39 from Mamatwan Mine as indicated by Numerical Modelling. The groundwater quality data and the calculated Pollution Index also gives no real indication that the borehole chemistry has been affected by mine contaminated groundwater. Therefore, farm borehole HF/BH39 is not impacted by mining activities of Mamatwan Mine.
19.)	**HF/BH40**	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Sutton	Mr. Philip Markram	2019/06/18	22.86471	-27.44708	1081.88	Farm groundwater flow from south east to north west, in line with mine locality. Mamatwan Mine GWL at a higher elevation then the Farm Borehole.	13.20	Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (SE to NW) is directly away from Mamatwan Mine but not in the direction of HF/BH40.	The farm borehole is 13.20 km down-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH40 from Mamatwan Mine as indicated by Numerical Modelling. Therefore, farm borehole HF/BH40 is not impacted by mining activities of Mamatwan Mine.
20.)	**HF/BH41**	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Sutton	Mr. Philip Markram	2019/06/18	22.86471	-27.44505	1081.79	Farm groundwater flow from south east to north west, in line with mine locality. Mamatwan Mine GWL at a higher elevation then the Farm Borehole.	13.10	Mamatwan Mine is located above drainage from the farm borehole and that the natural flow direction (SE to NW) is directly away from Mamatwan Mine but not in the direction of HF/BH41.	The farm borehole is 13.10 km down-gradient from groundwater flow from the Mamatwan mining site / lease. No groundwater contamination can reach the farm borehole HF/BH41 from Mamatwan Mine as indicated by Numerical Modelling. Therefore, farm borehole HF/BH41 is not impacted by mining activities of Mamatwan Mine.

7.6 DESCRIPTION OF THE HYDROCENSUS DATA ACCORDING TO THE DWS WATER RESOURCE QUALITY OBJECTIVES (RQO)

The Department of Water and Sanitation (DWS) has specified the Water Resource Quality Objectives (RQO) for the catchment D41K in the HMM Water Licenses. The DWS, RQO for catchments D41K was applied to the Mamatwan Mine hydrocensus data of 2021 (refer to Table 16 on page 66). The number of hydrocensus boreholes that did not adhere to the DWS, RQO for catchment D41K is 15 (all of the farm hydrocensus boreholes) for the chemical parameters of pH (lesser extent), Electrical Conductivity (EC), Sodium (Na, lesser extent), Calcium (Ca, lesser extent), Magnesium (Mg), Chloride (Cl), Sulphate (SO_4), Nitrate (NO_3 as N, lesser extent) and Total Alkalinity (T.Alk). The closest hydrocensus borehole is 1.48 km from the mining operations and the furthest is 15.60 km.

Thus, the water quality data of the Mamatwan mine, as well as the regional water quality data, indicate that the DWS, RQO for catchment D41K are not a true reflection of the average baseline groundwater quality conditions of catchment D41K. The DWS, RQO standards for catchment D41K in mg/L for each chemical parameter, which includes pH (lesser extent), Electrical Conductivity (EC), Sodium (Na, lesser extent), Calcium (Ca), Magnesium (Mg), Chloride (Cl), Sulphate (SO_4), Nitrate (NO_3 as N) and Total Alkalinity (T.Alk) is lower than the background water quality averages of the hydrocensus groundwater quality data. It is therefore recommended that mine management engages with DWS to review the current the DWS, RQO standards for catchment D41K to address the current discrepancies for WUL No.: 10/D41K/AGJ/1537.

Table 16. Farm Hydrocensus Borehole Results for the DWS Water License Conditions for Mamatwan Mine, water resource quality objectives for catchment D41K for (Amended, WUL No.: 10/D41K/AGJ/1537).

	Site Name	Date	pH	EC	Na	Ca	Mg	Cl	SO_4	F	NO_3-N	T.ALK
			pH Units	mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
HMM Mamatwan Mine: Hydrocensus Study of Farm Boreholes (2021)	HF/BH22	2021-05-10	7.35	116.00	42.10	98.10	61.10	89.00	22.80	0.25	12.70	430.00
	HF/BH23	2021-05-10	7.82	110.00	46.30	70.80	66.70	96.30	26.40	0.25	11.00	374.00
	HF/BH24	2021-05-10	7.13	97.40	28.20	81.50	58.20	42.90	26.40	0.16	3.90	445.00
	HF/BH25	2021-05-10	7.49	117.00	42.90	98.78	66.55	150.00	36.50	0.26	19.27	302.00
	HF/BH26	2021-05-10	7.22	170.00	71.60	136.92	96.12	263.00	33.20	0.09	46.33	343.00
	HF/BH27	2021-05-10	7.23	226.00	25.95	91.70	36.47	324.00	2.11	0.16	1.08	532.40
	HF/BH29	2021-05-10	7.39	103.00	37.80	82.81	57.60	70.20	15.52	0.18	10.20	409.00
	HF/BH32	2021-05-11	7.25	392.00	65.70	371.30	209.93	845.00	47.70	0.09	130.00	250.00
	HF/BH33	2021-05-11	8.30	225.00	157.41	54.70	170.37	382.92	110.64	0.47	55.03	391.00
	HF/BH34	2021-05-10	7.80	132.00	75.40	86.19	76.78	123.79	93.01	0.49	8.29	449.00
	HF/BH35	2021-05-10	7.96	140.00	97.30	64.29	89.38	175.27	132.27	0.44	6.11	388.00
	HF/BH36	2021-05-10	7.57	148.00	273.04	16.80	27.00	205.00	69.00	0.47	11.08	394.00
	HF/BH37	2021-05-10	7.14	289.00	140.00	230.56	136.78	764.00	161.00	0.09	2.73	307.00
	HF/BH38	2021-05-10	7.99	72.40	38.10	32.40	52.70	23.60	13.10	0.67	1.10	358.00
	HF/BH39	2021-05-10	8.08	120.00	90.60	61.18	67.63	121.00	37.50	0.39	7.10	443.00

DWA, Resource Quality Objectives (RQO)

Below RQO - **Below Resource Quality Objective.**
Above RQO - **Above Resource Quality Objective.**

Table 17. Mamatwan Mine Monitoring Borehole Results for DWS Water License Conditions, water resource quality objectives for catchment D41K (Amended, WUL No.: 10/D41K/AGJ/1537).

	Site Name	Date	pH	EC	Na	Ca	Mg	Cl	SO_4	F	NO_3-N	T.ALK
				mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Mamatan Mine	JB(GLD)05	2021/03/23	7.22	247.00	57.80	246.89	135.82	467.00	22.50	0.09	98.50	216.00
	JB(MMT)17	2021/03/23	7.42	182.00	74.64	198.94	130.88	41.90	665.83	0.23	21.34	301.00
	JB(MMT)18	2021/03/23	7.58	108.00	106.00	75.10	40.90	47.30	135.00	0.34	34.40	240.00
	JB(MMT)19	2021/03/23	7.39	212.00	193.00	148.00	74.80	228.00	254.00	0.32	83.80	274.00
	JB(MMT)20	2021/03/23	7.26	293.00	143.00	286.00	153.00	360.00	206.00	0.13	191.00	195.00
	JB(MMT)21	2021/03/23	7.53	179.00	117.00	141.00	82.40	21.70	37.20	0.16	162.00	261.00
	JB(MMT)22	2021/03/23	7.04	403.00	97.60	434.19	248.00	592.00	138.38	0.09	265.00	256.00
	JB(MMT)23	2021/03/23	7.64	152.00	225.03	56.10	33.90	148.00	93.50	0.69	45.10	348.00
	JB(MMT)24	2021/03/23	7.05	339.00	65.35	459.90	266.07	727.02	760.15	0.11	7.46	343.00
	JB(RIS)04	2021/03/23	7.33	188.00	54.80	186.00	119.00	276.00	22.90	0.09	70.10	491.00

DWA, Resource Quality Objectives (RQO)

Below RQO - **Below Resource Quality Objective.**
Above RQO - **Above Resource Quality Objective.**

Table 18. Baseline Groundwater Quality Standards (WUL No.: 10/D41K/AGJ/1537).

Substance / Parameter	Limit (DWS)
Electrical Conductivity [EC]	160.78
Sodium (Na) in mg/L	97.89
pH	7.971
Magnesium (Mg) in mg/L	92.34
Calcium (Ca) in mg/L	118.25
Chloride (Cl) in mg/L	262.24
Sulphate (SO_4) in mg/L	78.39
Nitrate (NO_3 as N) in mg/L	24.49
Fluoride (F) in mg/L	0.36
Total Alkalinity (T.ALK) in mg/L	269.85

8 IMPACT ASSESSMENT OF GROUNDWATER QUALITY ON NEARBY GROUNDWATER USERS

8.1 WATER QUALITY: OPERATIONAL PHASE IMPACTS

This section considers the potential impact of water quality on groundwater users. Potential groundwater contamination sources of Mamatwan includes the following:

- Explosives Magazine:
  - Spillages or leakages of residual explosives liquids may cause groundwater contamination (increase in nitrates).
- Tailings/Slimes Dam and Waste Rock Dumps:
  - Volume of leachate seeping into the underlying receiving aquifer.
  - Quality of leachate seeping into the underlying receiving aquifer.
- RWD Storage of Dirty or Process Water:
  - Dirty water contains wastewater management facilities or dams may impact on groundwater quality by means of seepage to underlying receiving aquifer (increase salt loading to aquifer).
- Groundwater contamination as a result of pit mining and water inflows into the opencast workings:
- Septic Tanks and Sewage Treatment Works:
  - Seepages into the surrounding and underlying receiving aquifer.
  - Residual waste material from sewage ponds may cause groundwater contamination (increased salt loads to aquifers, such as nitrates).
- Possible other contaminant sources could be Ore Processing Plant (OPP), Dense Material Separator (DMS), and sinter plant:
  - The mine Captain's compound overlooking Mamatwan pit; and
  - Ablution facilities at the primary crusher.

Table 19. Impact Characteristics: Groundwater Users

Summary	Operational Phase
Project Aspect / Activity	Contaminated leachate from the opencast pits, waste rock dumps (WRDs, existing and new), tailing facilities (TSF), topsoil dumps and ore stockpiles. Spillage from mining equipment. Contamination through residuals of explosives used in the mining process.
Impact Type	Indirect. The numerical model and existing (2002 to 2019) and current (2021) hydrocensus data indicate no impact of known water users.
Stakeholders / Receptors Affected	Groundwater Users.

Groundwater is used in the area and represents the sole source of water for a number of farmers despite groundwater quality in the study area being considered in general to be unsuitable for domestic use when compared to South African Water Quality Guidelines (South African National Standards, SANS241-2015). Farm borehole closest to Mamatwan

Mine is located 1.48 km (Borehole: HF/BH32) from the mine whereas the furthest borehole is located 15.60 km (Borehole: HF/BH25) from the mine.

At the end of mining modelled TDS plumes at are mainly confined within the immediate footprint of the opencast pits, Waste Rock Dumps (WRDs), Old Rehabilitated Tailings / Slimes Dam (TSF) and Product Stockpiles and the area immediately down-gradient of groundwater flow of the contaminant sources and are not expected to affect any private groundwater users (refer to Figure 27 and Figure 28 on pages 61 and 62).

It is therefore concluded that groundwater flow directions results, and hydrochemistry results of the Farm Hydrocensus Boreholes indicate that Mamatwan Mine mining activities is not directly impacting the groundwater quality of the farm boreholes of the surrounding groundwater users at the current time or at the end of mining, hence during the Operational Phase.

The new waste rock dump (WRD) in the southern side where Mamatwan and Tshipi-e-Ntle opencast pits meet, will have no contaminant impacts on the surrounding groundwater user boreholes in the operational phase as all potential contaminants generated by the WRD will flow towards the Mamatwan and Tshipi-e-Ntle opencast pits (dewatering cone) directly to the north and will therefore not migrated towards the farm hydrocensus boreholes.

Sensitivity/Vulnerability/Importance of the groundwater resource was rated as **Medium**. The planned activity will **not** result in the loss of **irreplaceable** resources with regards to the groundwater resource.

Groundwater quality impacts are expected to be limited to the footprints and the area immediately down-gradient of groundwater flow of the WRDs, Topsoil Dumps and Ore Stockpiles and are **local** in extent (indicated by the numerical modelling results). Groundwater quality is not expected to improve after mine closure for the Opencast Pits, TSF and WRDs, hence it will be a permanent impact. The groundwater resource is expected to remain **unaltered** for the surrounding farm areas except for the footprint and the immediate area down-gradient of groundwater flow of the WRDs. The frequency is classified as **continuous** due to the nature of the project and the likelihood is **certain**.

The impact magnitude is therefore rated as **Negligible,** and the impact significance (pre-mitigation) is **NEGLIGIBLE**. The degree of confidence in this assessment is **medium**.

Table 20. Summary of Operational Impact: Groundwater Quality on Groundwater Users.

Nature: Operational activities would result in a **negative direct** impact the groundwater resource in the Project Area.

Sensitivity/Vulnerability/Importance of Resource/Receptor - Medium.

Irreplaceability: The activity will **not** result in the loss of **irreplaceable** resources.

Impact Magnitude – Negligible.

- Extent: The extent of the impact is confined mostly to the site and is **local** in general.
- Duration: The expected impact will **not** be **permanent (ie reversible)**.
- Scale: The groundwater resource is expected to remain unaltered except for the footprint and the immediate area down-gradient of groundwater flow of Opencast Pits, WRDs, TSFs, Topsoil Dumps and Ore Stockpiles.
- Frequency: The frequency of the impact will be **continuous** in close proximity to the mine.
- Likelihood:The likelihood of the impact is **certain**.

IMPACT SIGNIFICANCE (PRE-MITIGATION) – NEGLIGIBLE.

Degree of Confidence: The degree of confidence is **medium to high**.

8.2 WATER QUALITY: OPERATIONAL PHASE MITIGATION

Groundwater quality should be monitored at the existing (known) private boreholes in regular intervals (two-yearly basis) to confirm modelling results. Should monitoring data confirm impact on private users, the client will compensate affected famers for their loss, replacing the lost water supply source.

9 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are based on the information supplied in this report:

Mamatwan Mine are located in the Northern Cape Province. The hydrocensus area is located about 17 km south of Hotazel, 44 km northwest of Kuruman and approximately 35 km north east of Kathu and is located within the D41K quaternary catchment.

A hydrocensus was conducted on the farms in the district surrounding Mamatwan Mine in May 2021. The hydrocensus study included site visits and gathering of all relevant geohydrological data from twenty farm boreholes in the vicinity of Mamatwan Mine (investigation radius: 15.60 km). The farms investigated included of London, Kameelaar, Aarpan, Perth 276, Eldoret, Rissik, Moab, Milner, Heunning Draai, Smuts, Cobham and Sutton. The groundwater resource is utilised in the study area and represents the sole source of water for the farmers. The groundwater use is mainly for livestock watering, although some farmers also utilise the groundwater resource for domestic purposes. Borehole equipment used to abstract the groundwater from boreholes ranges from submersible pumps, solar pumps and windmills.

The activities of the Mamatwan Farm Borehole Hydrocensus included the following:

- The sampling localities were determined by consulting each private landowner in regard to the boreholes in use for each of the farms.
- The hydrocensus boreholes were surveyed by means of a Garmin GPS (Global Positioning System) to obtained accurate coordinates for mapping purposes.
- The groundwater levels of the hydrocensus boreholes were measure by means of a dipmeter where possible to determine the depth of the regional and local aquifers surrounding Mamatwan Mine.
- The hydrocensus boreholes sampled were predominantly equipped with mono or submersible pumps or with wind driven pumps. Therefore, the boreholes were sampled at pump outlets or in dams located next to the borehole. Where possible the unequipped boreholes were sampled by means of a specific depth bailer.

Description of the Hydrocensus Groundwater Elevations Results:

The lowering of the hydraulic head due to the Mamatwan Opencast Pit mining activities (dewatering) have resulted in drawdowns of up to 1039.60 to 1047.50 mamsl in close proximity (0.1 km) from the north and north western side of the Mamatwan Pit. The dewatering impact zone radius stretches laterally within 2,0 to 3.0 km from the pit. To the southern part of the Old Adams Pit and Mamatwan Pit, the mining activities mining have resulted in drawdowns of up to 1079.40 to 1085.94 mamsl.

The southern parts of Mamatwan Mine indicates no dewatering effects, which this is partly due to an artificial groundwater mound that has developed under the old, rehabilitated slimes dam. The artificial groundwater mound has caused the groundwater to flow up gradient of natural groundwater flow and topographical drainage in a south-eastern direction towards borehole HF/BH32 (Moab Farm).

The groundwater flow vectors indicated that the impacted area is more pronounce to the north and north west of the pit (1.5 to 3.0 km) than to the south where the impact may only be a 1.0

km or less due to the artificial groundwater mound of the old slimes dam. The R-Squared value is 0.67 for the Mamatwan Mine area, which value indicates that the natural groundwater table of the local mine aquifer has been dewatered by the Old Adams Pit and Mamatwan Opencast Pit mining activities as well as the newer the newer Tshipi-e-Ntle Opencast Pit.

The R-Squared value is 0.94 for the farm boreholes in the vicinity Mamatwan Mine, Tshipi-e-Ntle Mine as well as UMK Mine. This indicates that aquifer is mimicking the topographical elevations and that the dewatering cone at opencast pit operations have not impacted the farm hydrocensus boreholes of the farms of London, Kameelaar, Aarpan, Perth 276, Eldoret, Rissik, Moab, Milner, Heunning Draai, Smuts, Cobham and Sutton.

The new waste rock dump (WRD) in the southern side where Mamatwan and Tshipi-e-Ntle opencast pits meet, have no impact on the dewatering at the mine locally or regionally according to numerical modelling. All potential additional recharge generated by the New WRD will flow to the opencast pits directly to the north of the facility and will not contributed to any additional dewatering affects but might potentially assist to buffer the dewatering to some extend due to the potential additional recharge volume generated by rainfall.

It is important to note that the opencast pit operations of Mamatwan Mine, Tshipi-e-Ntle Mine and United Manganese of the Kalahari (UMK) must be viewed as a cumulative dewatering impact and that any potential future in pact on the farm hydrocensus boreholes.

The new waste rock dump (WRD) located the southern side where Mamatwan and Tshipi-e-Ntle opencast pits meet, have no impact on the dewatering at the mine locally or regionally according to numerical modelling. All potential additional recharge generated by the New WRD will flow to the opencast pits directly to the north of the facility and will not contributed to any additional dewatering affects but might actually help to buffer the dewatering to some extend due to the potential additional recharge volume generated by rainfall.

Hydraulic head change or dewatering is expected to be limited to the project site and adjacent properties belonging to the client or adjacent mines [Tshipi-e-Ntle Mine and United Manganese of the Kalahari (UMK)] and is local in extent in general. The impact significance of Mamatwan Mine dewatering on the farm hydrocensus boreholes is currently rated as negligible as opencast pit operations have not impacted the groundwater levels farm boreholes.

The frequency is classified as continuous during operational phase due to the nature of the project and the likelihood is likely if the farm boreholes are close enough to Mamatwan to fall within the impact radius of the dewatering cone of the Mamatwan / Tshipi-e-Ntle / UMK Pits as the impacts has taken place locally around the pit areas but not regionally. The extent of the impact is mostly **local** in general on the two mine leases. The main impact area of the dewatering cone will manifest to the north west of the Mamatwan and Tshipi-e-Ntle Opencast Pits on the Tshipi-e-Ntle Pit Mine Lease. The extent of the impact is mostly **local** in general on the two mine leases. The main impact area of the dewatering cone will manifest to the north west of the Mamatwan and Tshipi-e-Ntle Opencast Pits on the Tshipi-e-Ntle Pit Mine Lease. Lowering of the groundwater level due to the mining activities has not impacted the groundwater levels of the farm / hydrocensus boreholes as indicated by current numerical modelling and multiple hydrocensus projects since 2002 – 2021. The new waste rock dump (WRD) located on the southern side where Mamatwan and Tshipi-e-Ntle opencast pits meet, have no impact on the dewatering at the mine locally or regionally according to numerical modelling. All potential additional recharge generated by the New WRD will flow to the opencast pits directly to the north of the facility and will not contributed to any additional dewatering affects but might potentially assist to buffer the dewatering to some extend due to the potential additional recharge volume generated by rainfall.

The impact magnitude is therefore rated as Negligible, and the impact significance (pre-mitigation) is Negligible. Groundwater level change (drawdown) cannot be mitigated due safety. Groundwater level change (drawdown) cannot be mitigated. Should monitoring confirm that any of the private boreholes are affected by lowering the groundwater table, rendering boreholes unusable (ie loss of water supply source), the client will have to compensate affected famers for their loss, replacing the lost water supply source. This can be achieved for example by drilling new boreholes for the affected farmers outside of the drawdown cone, by increasing the depth of the existing boreholes or by providing an alternative good quality water source.

Description of the Groundwater Baseline and Water Quality Results:

The baseline groundwater quality averages of the chemical parameters of the farm hydrocensus boreholes as well as the Mamatwan Mine monitoring boreholes indicate that the only mine groundwater chemical parameters to display considerable higher averaged values then the background / baseline groundwater qualities were Electrical Conductivity (EC) / Total Dissolved Solids (TDS), Sodium (Na), Calcium (Ca), Sulphate (SO_4) and Nitrates (NO_3-N).

The results pollution index of the hydrocensus boreholes indicate that the farm boreholes is not affected by Mamatwan Mine mining activities or cumulative groundwater quality impacts of the other mines surrounding Mamatwan Mine, which includes Tshipi-e-Ntle Mine to the west and United Manganese of the Kalahari (UMK) to the north. Farm Hydrocensus Boreholes HF/BH32, HF/BH33 and HF/BH37 do indicate some impacts but analysis of groundwater elevations and numerical modelling (groundwater flow and mass-transport / plume modelling) indicated that the groundwater quality of these boreholes have not been affected by Mamatwan Mining activities but relate to local natural water qualities or potential local surface activities.

Farm Hydrocensus Borehole HF/BH32 could have been potentially impacted by historical impacts of the old, rehabilitated tailings /slimes when the facility was still functional with associated higher elevated groundwater mounds forcing groundwater contaminants up-gradient of natural flow in the direction of farm borehole HF/BH32. The potential possibility of impacts on chemical parameters, which includes EC, TDS, Ca, Mg and Cl do exists, but Numerical Modelling indicated that no pollution plume reaching is reaching HF/BH32 from the old TSF and WRDs and Stiff / Expanded Durov Diagrams do not indicate the same type of groundwater chemistry at the sites. Therefore, the current information is not conclusive if farm borehole HF/BH32 is impacted or affected by the mining activities of Mamatwan Mine. By drilling a new monitoring borehole between the old TSF and HF/BH32 might be the only approach to discern if the borehole was historically impacted by the TSF activities of Mamatwan.

It is therefore concluded that groundwater flow directions results, and hydrochemistry results of the Farm Hydrocensus Boreholes indicate that Mamatwan Mine mining activities is not directly impacting the groundwater quality of the farm boreholes of the surrounding groundwater users at the current time or at the end of mining, hence during the Operational Phase.

The new waste rock dump (WRD) in the southern side where Mamatwan and Tshipi-e-Ntle opencast pits meet, will have no contaminant impacts on the surrounding groundwater user boreholes in the operational phase as all potential contaminants generated by the WRD will flow towards the Mamatwan and Tshipi-e-Ntle opencast pits (dewatering cone) directly to the north and will therefore not migrated towards the farm hydrocensus boreholes.

Groundwater quality impacts are expected to be limited to the footprints and the area immediately down-gradient of groundwater flow of the WRDs, Topsoil Dumps and Product Stockpiles and are local in extent (indicated by the numerical modelling results). Groundwater quality is not expected to improve after mine closure for the Opencast Pits, TSF and WRDs, hence it will be a permanent impact. The groundwater resource is expected to remain unaltered for the surrounding farm areas except for the footprint and the immediate area down-gradient of groundwater flow of the WRDs, TSF and Product Stockpiles. The frequency is classified as continuous due to the nature of the project and the likelihood is certain.

The impact magnitude is therefore rated as Negligible, and the impact significance (pre-mitigation) is Negligible. Should monitoring data confirm impact on private users, the client will compensate affected famers for their loss, replacing the lost water supply source as per WUL recommendation.

Description of the Water Resource Quality Objectives (RQO) Results:

The Department of Water and Sanitation (DWS) has specified the Water Resource Quality Objectives (RQO) for the catchment D41K in the HMM Water Licenses. The DWS, RQO for catchments D41K was applied to the Mamatwan Mine hydrocensus data of 2021. The number of hydrocensus boreholes that did not adhere to the DWS, RQO for catchment D41K is 15 (all of the farm hydrocensus boreholes) for the chemical parameters of pH (lesser extent), Electrical Conductivity (EC), Sodium (Na, lesser extent), Calcium (Ca, lesser extent), Magnesium (Mg), Chloride (Cl), Sulphate (SO_4), Nitrate (NO_3 as N, lesser extent) and Total Alkalinity (T.Alk). The closest hydrocensus borehole is 1.48 km from the mining operations and the furthest is 15.60 km.

Thus, the water quality data of the Mamatwan mine, as well as the regional water quality data, indicate that the DWS, RQO for catchment D41K are not a true reflection of the average baseline groundwater quality conditions of catchment D41K. The DWS, RQO standards for catchment D41K in mg/L for each chemical parameter, which includes pH (lesser extent), Electrical Conductivity (EC), Sodium (Na, lesser extent), Calcium (Ca), Magnesium (Mg), Chloride (Cl), Sulphate (SO_4), Nitrate (NO_3 as N) and Total Alkalinity (T.Alk) is lower than the background water quality averages of the hydrocensus groundwater quality data. It is therefore recommended that mine management engages with DWS to review the current the DWS, RQO standards for catchment D41K to address the current discrepancies for WUL No.: 10/D41K/AGJ/1537.

Report Recommendations:

The recommendations are as follows:

- It is recommended that the hydrocensus boreholes of the surrounding farms be monitored in regard to groundwater levels and groundwater quality on a two-yearly basis for potential mine dewatering and contaminant impacts on the surrounding groundwater users. It is also recommended that the Mamatwan Numerical Model be updated on a two-year basis in conjunction with the Mamatwan Hydrocensus.
- It is recommended that the currently updated Mamatwan Numerical Groundwater Flow Model be utilised to investigate potential new areas or sites for additional mine monitoring boreholes to ensure adequate groundwater monitoring coverage in terms of groundwater elevations and water quality of the local aquifer.
- It is recommended that the numerical groundwater model be updated and recalibrated on a two-yearly basis with the quarterly mine monitoring program results as well as the

hydrocensus results to predict potential groundwater impacts for the operational and post closure phases of Mamatwan Mine.

- It is recommended that a regional numerical groundwater model be constructed to model the cumulative dewatering and contamination migration impacts of Mamatwan Mine, Tshipi-e-Ntle Mine and United Manganese of the Kalahari (UMK) on the surrounding hydrocensus farm areas for the operational and post closure phases of the three mines.
- It is also recommended that Mamatwan mine management engages with DWS to review the current the DWS, Water Resource Quality Objectives (RQO) standards for catchment D41K to address the current discrepancies as the current groundwater quality baseline conditions of the farm boreholes do not adhere to the current RQO for WUL No.: 10/D41K/AGJ/1537.

10 REFERENCES

BEAN J, HOUGH JHH & RUDOLPH DC (2003) Geohydrology of the Kalahari Manganese Field, Report No. RVN308.2/471.

Department of Water Affairs and Forestry (1996) South African Water Quality Guidelines (second edition). Volume 1: Domestic Use.

Department of Water Affairs and Forestry (1998) Quality of Domestic Water Supply, Volume 1: Assessment Guide. WRC Report No. TT101/98.

Department of Water Affairs and Forestry (1993) South African Water Quality Guidelines (first edition). Volume 1: Domestic Use.

HOUGH JJH & RUDOLPH DC (2019) HMM Regional Hydrocensus Study, Report No.: RVN8571/1952.

HOUGH JJH, STAATS S & RUDOLPH DC (2018) Update of the Geohydrological for Mamatwan Mine, Report Number: RVN823.1/1858.

HOUGH JJH & RUDOLPH DC (2021) HMM Mamatwan Mine Phase 53, 1st Quarter 2021: Routine Groundwater Monitoring Report, Report No.: RVN893.1/2076.

HOUGH JJH, STAATS S & RUDOLPH DC (2021) Update of the FeFlow Numerically groundwater Flow Model for Mamatwan Mine, Report Number: RVN 899.1/2098.

LLOYD JW & HEATHCOTE JA (1985) Natural inorganic Hydro-Chemistry in relation to groundwater. Clarendon Press, Oxford.

LUKAS E, (2002) Windows interpretation system for hydrogeologists (WISH) Software developed by Institute for Groundwater Studies (IGS).

NAZARI MM, BURSTON, MW, BISHOP PK & LERNER DN (1993) Urban Groundwater Pollution: A Case Study from Coventry, United Kingdom. Groundwater, Volume 31, No. 3.

South African National Standard, SANS241:2006 (2006) Drinking Water, Edition 6.1, ISBN 0-626-18876-8.

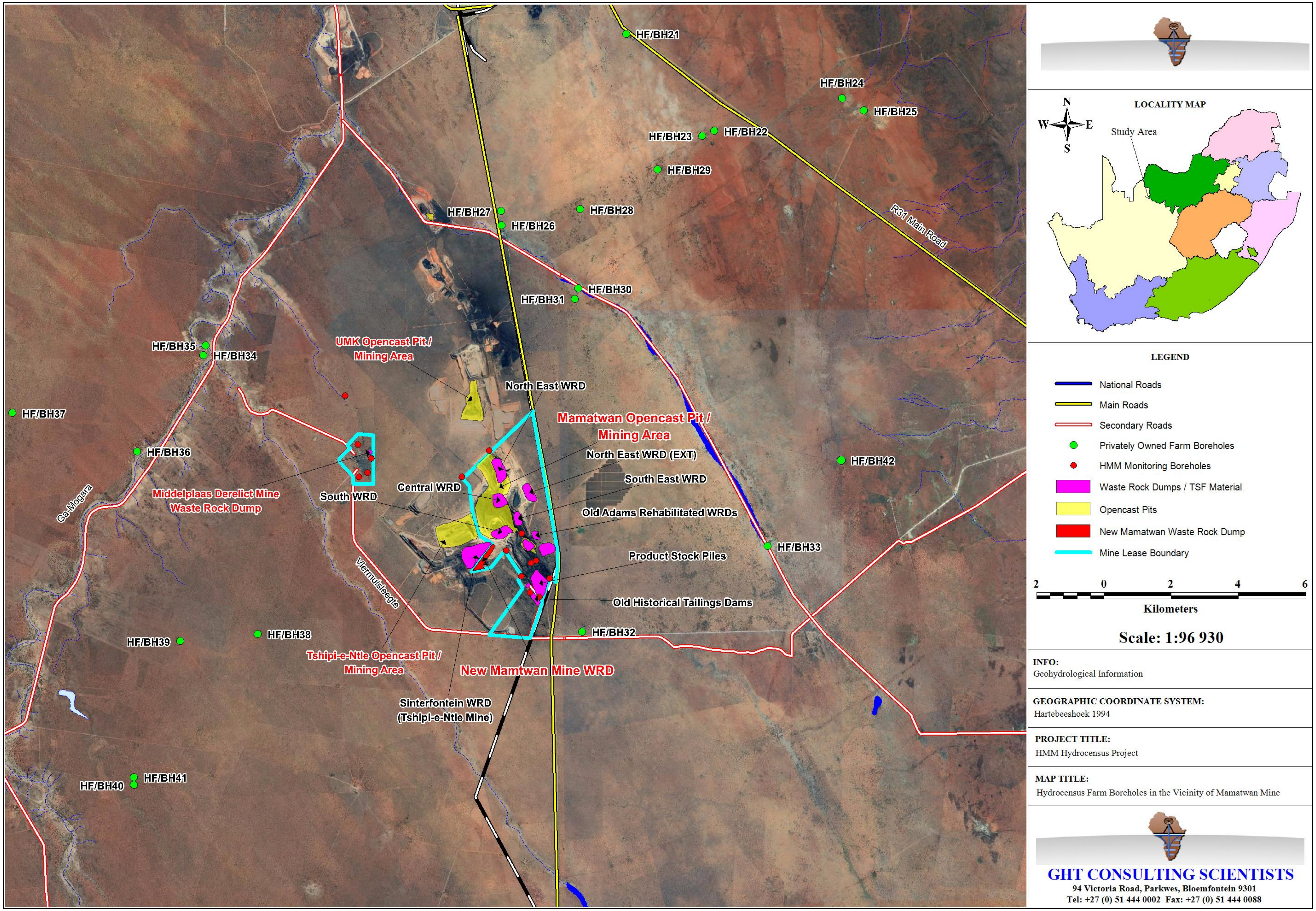
South African National Standard, SANS241-1:2011 (2011) Drinking Water - Part 1: Microbiological, physical, aesthetic and chemical determinants, Edition 1, ISBN 978-0-626-26115-3.

South African National Standard, SANS241-2:2011 (2011) Drinking Water - Part 2: Application of SANS241-1, Edition 1, ISBN 978-0-626-26116-0.

South African National Standard, SANS241-1:2015 (2015) Drinking Water - Part 1: Microbiological, physical, aesthetic and chemical determinants, Edition 2, ISBN 978-0-626-29841-8.

South African National Standard, SANS241-2:2015 (2015) Drinking Water - Part 2: Application of SANS241-1, Edition 2, ISBN 978-0-626-31245-9.

11 APPENDIX A: LOCALITY MAPS



12 APPENDIX B: FIELDWORK SHEETS

	Borehole Name	Topographic Map Reference	Quaternary Sub-Catchment	Locality Discription	Farm Name	Owner	Mobile Number	Date	Coordinates (WGS84) Longitude (East)	Coordinates (WGS84) Latitude (South)	Coordinates (WGS84) Elevation (mamsl)	General Borhole Information Casing Height (m)	General Borhole Information Casing Diameter (mm)	General Borhole Information Borehole Depth (m)	General Borhole Information Borehole Equipment [Pump Outlet Diammeter (mm)]	Rest Water Level (mbgl)	Water Use	Comments
1.)	**HF/BH22**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	London / Kameelaar	Mr. Dawid Venter	(082) 507-7716	2021/05/10	23.04815	-27.26684	1098.93	0.40	160	n/a	Submersible Pump.	n/a	* LS & * DD	Borehole top is closed. No WL.
2.)	**HF/BH23**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	London / Kameelaar	Mr. Hendrik Venter	(082) 507-7716	2021/05/10	23.04455	-27.26819	1099.20	0.00	160	n/a	Windpomp / Wind Powered Pump (50 mm).	13.63	* LS	~
3.)	**HF/BH24**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Aarpan	Ms. Ansie Venter	(082) 873-4856	2021/05/10	23.08828	-27.25825	1122.31	0.36	160	n/a	Solar Powered Pump (40 mm).	16.57	Not utilised	Not utilised, Pump broken
4.)	**HF/BH25**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Aarpan	Ms. Ansie Venter	(082) 873-4856	2021/05/10	23.09512	-27.26161	1128.70	0.80	160	n/a	Submersible Pump (40 mm).	n/a	* LS	Borehole top is closed. No WL.
5.)	**HF/BH26**	2722BD	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Perth 276	Mr.Eben Anthonissen	(073) 163-4665	2021/05/10	22.98135	-27.29251	1070.13	0.04	160	n/a	Mono Pump (40 mm).	n/a	* LS	~
6.)	**HF/BH27**	2722BD	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Perth 276	Mr.Eben Anthonissen	(073) 163-4665	2021/05/10	22.98135	-27.28864	1070.75	0.40	160	n/a	Borehole Is Blocked.	21.97	Not Utilised.	~
7.)	**HF/BH28**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Eldoret	Mr. Piet Swanepoel	(072) 758-3331	2021/05/10	23.00597	-27.28831	1083.63	0.60	160	n/a	Windpomp / Wind Powered Pump (50 mm).	34.88	Not Utilised.	~
8.)	**HF/BH29**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Eldoret	Mr. Piet Swanepoel	(072) 758-3331	2021/05/10	23.03036	-27.27744	1095.45	0.60	160	n/a	Windpomp / Wind Powered Pump (50 mm).	27.00	* LS	~
9.)	**HF/BH30**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Rissik	Mr. Gideon Poolman	(082) 805-4280	2021/05/14	23.00516	-27.31032	1080.00	0.45	160	n/a	Submersible Pump (40 mm).	n/a	* LS	Farmers not responding to calls. Owner not available.
10.)	**HF/BH31**	2723AC	D41K	Mamatwan Mine / Smart-Rissk / UMK Mine District	Rissik	Mr. Gideon Poolman	(082) 805-4280	2021/05/14	23.00407	-27.31317	1080.00	0.40	200	n/a	Borehole Is Blocked.	n/a	Not Utilised.	Farmers not responding to calls. Owner not available.
11.)	**HF/BH32**	2723AC	D41K	Mamatwan Mine District	Moab	Mr. Niekie Kruger	(082) 879-7451	2021/05/11	23.00551	-27.40557	1110.03	0.50	180	n/a	Windpomp / Wind Powered Pump (50 mm).	n/a	* LS	~
12.)	**HF/BH33**	2723AC	D41K	Mamatwan Mine District	Milner	Mr. Niekie Kruger	(082) 879-7451	2021/05/11	23.06380	-27.38234	1119.05	0.40	160	n/a	Windpomp / Wind Powered Pump (25 mm).	23.59	* LS	~
13.)	**HF/BH34**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Heunning Draai	Mr. Ampie Coetzee	(082) 559-8161	2021/05/10	22.88761	-27.32795	1060.00	0.60	130	n/a	Submersible Pump (40 mm).	n/a	* LS & * DD	~
14.)	**HF/BH35**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Heunning Draai	Mr. Ampie Coetzee	(082) 559-8161	2021/05/10	22.88844	-27.32523	1060.00	0.70	166	n/a	Submersible Pump (40 mm).	n/a	* LS & * DD	~
15.)	**HF/BH36**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Smuts	Mr. Nico Smith	(072) 323-3060	2021/05/10	22.86649	-27.35455	1060.00	0.27	200	n/a	Submersible Pump (50 mm).	29.13	* LS & * DD	~
16.)	**HF/BH37**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Smuts	Mr. Nico Smith	(072) 323-3060	2021/05/10	22.82764	-27.34351	1074.26	0.32	170	n/a	Solar Powered Pump (40 mm).	n/a	* LS	~
17.)	**HF/BH38**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Cobham	Mr. Phillip van der Merwe	(083) 379-7547	2021/05/10	22.90379	-27.40549	1080.00	0.60	200	n/a	Windpomp / Wind Powered Pump (50 mm).	n/a	* LS	Owner not available.
18.)	**HF/BH39**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Cobham	Mr. Phillip van der Merwe	(083) 379-7547	2021/05/10	22.87963	-27.40732	1080.69	0.17	160	n/a	Windpomp / Wind Powered Pump (50 mm).	n/a	* LS	Owner not available.
19.)	**HF/BH40**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Sutton	Mr. Philip Markram	(073) 228-9555	2021/05/14	22.86471	-27.44708	1081.88	0.14	150	n/a	No Equipment.	n/a	Not Utilised.	Farmers not responding to calls. Owner not available.
20.)	**HF/BH41**	2722BD	D41K	Mamatwan Mine / Tshipi-e-Ntle Mine / Middelplaas Abandoned Mine District	Sutton	Mr. Philip Markram	(073) 228-9555	2021/05/14	22.86471	-27.44505	1081.79	0.28	160	n/a	No Equipment.	n/a	Not Utilised.	Farmers not responding to calls. Owner not available.

* DD - Domestic Water/Drinking Water
* LS - Livestock Watering
** New Boreholes / Replacement Boreholes

13 APPENDIX C: LABORATORY WATER QUALITY RESULTS

Laboratory Certification

CERTIFICATE OF ACCREDITATION

In terms of section 22(2) (b) of the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act, 2006 (Act 19 of 2006), read with sections 23(1), (2) and (3) of the said Act, I hereby certify that:-

YANKA LABORATORIES (PTY) LTD
Co. Reg. No.: 2012/113891/07

Facility Accreditation Number: **T0647**

is a South African National Accreditation System accredited facility provided that all conditions and requirements are complied with

This certificate is valid as per the scope as stated in the accompanying schedule of accreditation, Annexure "A", bearing the above accreditation number for

CHEMICAL AND MICROBIOLOGICAL ANALYSIS

The facility is accredited in accordance with the recognised International Standard

ISO/IEC 17025:2017

The accreditation demonstrates technical competency for a defined scope and the operation of a quality management system

While this certificate remains valid, the Accredited Facility named above is authorised to use the relevant accreditation symbol to issue facility reports and/or certificates

Mr R Josias
Chief Executive Officer

Effective Date: 29 January 2020
Certificate Expires: 28 January 2025

ANNEXURE A

SCHEDULE OF ACCREDITATION

Facility Number: **T0647**

Permanent Address of Laboratory:

Yanka Laboratories (Pty) Ltd
40 Minerva Avenue
Reyno Ridge
Witbank

Technical Signatories:

Ms R Botha (All Methods)
Ms E Lindeque (All Methods)
Mr H Mouton (All Methods)
Ms M Jansen van Rensburg (All Microbiology Methods)

Postal Address:

P O Box 11396
Aerorand
Middelburg, 1055

Nominated Representative:

Mr H Mouton

Tel: (013) 692-8448/(087) 317-3140
Fax: (086) 551-1071
E-mail: yanka@yanka.co.za

Issue No.: 03
Date of Issue: 29 January 2020
Expiry Date: 28 January 2025

Material or Products Tested	Type of Tests/ Properties Measured, Range of Measurement	Standard Specifications, Techniques / Equipment Used
CHEMICAL		
Water	Spectrometry:	YE070AK
	Fluoride	
	Nitrate	
	Nitrite	
	Phosphate - Ortho	
	Phenol	
	Sulphate	
	Ammonia	
	Chloride	
	Chromium (VI)	
	Colour	
	ICP Spectrometry:	YE060ICP
	Calcium	
	Chromium - Total	
	Cobalt	
	Copper	
	Iron	
	Lead	

Facility Number: T0647

Water	Magnesium	
	Manganese	
	Molybdenum	
	Nickel	
	Potassium	
	Tin	
	Silicon	
	Sodium	
	Strontium	
	Uranium	
	Thallium	
	Titanium	
	Vanadium	
	Zinc	
	Antimony	
	Aluminium	
	Arsenic	
	Barium	
	Boron	
	Cadmium	
	Thorium	
	Titrimetric (Indicator/pH): Alkalinity	YE010Alk
	Titrimetric (indicator/pH): Acidity	YE011Ac
	Conductimetric: Conductivity	YE020Con
	pH: Electrometric	YE030pH
	Solids - Suspended: Gravimetric (103 - 105°C)	YE081TSS
	Chemical Oxygen Demand: Closed Reflux, Colorimetric	YE052COD
	Oxygen absorbed: Permanganate Oxidation	YE050OA
	Turbidity	YE082TB
	Hardness	YE061H
	Total and Dissolved Organic Carbon	YE090TOC

Page 2 of 3

Facility Number: T0647

MICROBIOLOGY

Water	Standard Plate Count	YE100SPC
	Total Coliforms	YE101TC
	Faecal Coliforms	YE102FC
	Escherichia coli	YE102EC

Original Date of Accreditation: 29 January 2015

ISSUED BY THE SOUTH AFRICAN NATIONAL ACCREDITATION SYSTEM

Accreditation Manager

Page 3 of 3

Results of Water Analysis

YANKA LABORATORIES

CHEMISTRY TEST RESULTS

LABORATORY NUMBER	Unit	Test Method **	SpGHT 1	SpGHT 2	SpGHT 3	SpGHT 4	SpGHT 5	SpGHT 6	SpGHT 7	SpGHT 8	SpGHT 9	SpGHT 10	SpGHT 11	SpGHT 12
SAMPLE DESCRIPTION			HF / BH 01	HF / BH 02	HF / BH 03	HF / BH 04	HF / BH 05	HF / BH 06	HF / BH 19	HF / BH 21	HF / BH 22	HF / BH 23	HF / BH 24	HF / BH 25
SAMPLE NUMBER			E49116-001	E49116-002	E49116-003	E49116-004	E49116-005	E49116-006	E49116-007	E49116-008	E49116-009	E49116-010	E49116-011	E49116-012
SAMPLED			2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00
Remarks			Clear	Clear	Clear	Brownish	Clear	Clear	Clear	Clear	Clear	Clear	Brownish	Clear
Total Alkalinity (pH>4.5)	mg $CaCO_3$/L	YE010Alk	252	191	401	83.8	237	415	297	384	430	374	445	302
Bicarbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	252	147	401	83.8	237	415	297	384	430	374	445	302
Carbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	0.00	44.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M Alkalinity (8.3>pH>4.5)	mg $CaCO_3$/L	YE010Alk	252	169	401	83.8	237	415	297	384	430	374	445	302
P Alkalinity (pH>8.3)	mg $CaCO_3$/L	YE010Alk	0.00	22.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Conductivity (Laboratory)	mS/m	YE020CON	130	90.9	117	85.9	284	135	415	224	116	110	97.4	117
pH (Laboratory)		YE030pH	7.96	8.69	7.30	7.50	7.68	7.35	7.33	7.54	7.35	7.82	7.13	7.49
Total Hardness	mg $CaCO_3$/L	YE061H	523	335	522	202	1636	605	1756	962	497	451	443	521
Calcium Hardness	mg $CaCO_3$/L	YE061H	168	101	181	73.0	571	217	662	402	245	177	204	247
Magnesium Hardness	mg $CaCO_3$/L	YE061H	356	234	341	129	1065	389	1094	560	252	275	240	274
Total Dissolved Solids (TDS)	mg/L	Calculation	756	524	636	454	2293	778	2535	1274	631	584	532	664
Temperature	°C	Thermometer	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
Ammonia and Ammonium	mg N/L	YE070AK	<0.45	<0.45	<0.45	2.26	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	3.53	<0.45
Calcium	mg Ca/L	YE060ICP	67.1	40.3	72.4	29.2	229	86.8	265	161	98.1	70.8	81.5	98.8
Chloride	mg Cl/L	YE070AK	190	135	112	240	1018	152	741	366	89.0	96.3	42.9	150
Magnesium	mg Mg/L	YE060ICP	86.3	56.9	82.9	31.3	259	94.3	266	136	61.1	66.7	58.2	66.6
Nitrate	mg N/L	YE070AK	33.4	8.37	6.42	0.95	45.0	6.48	198	47.2	12.7	11.0	3.90	19.3
Nitrite	mg N/L	YE070AK	<0.01	0.81	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	0.17	<0.01
Ortho Phosphate	mg P/L	YE070AK	0.07	0.20	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Potassium	mg K/L	YE060ICP	11.6	13.2	3.76	5.21	40.4	11.8	7.89	3.60	3.13	3.78	2.96	2.27
Sodium	mg Na/L	YE060ICP	65.9	58.7	40.3	87.6	217	65.5	134	73.4	42.1	46.3	28.2	42.9
Silicon	mg Si/L	YE060ICP	18.8	10.7	12.1	<0.1	18.6	9.57	15.8	27.0	27.5	28.0	18.6	27.0
Sulphate	mg SO_4/L	YE070AK	35.5	67.0	56.0	2.04	187	89.4	64.1	93.9	22.8	26.4	26.4	36.5
Aluminium	mg Al/L	YE060ICP	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	mg As/L	YE060ICP	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
Boron	mg B/L	YE060ICP	<0.01	<0.01	<0.01	<0.01	0.45	<0.01	0.05	0.03	<0.01	<0.01	<0.01	<0.01
Fluoride	mg F/L	YE070AK	0.22	0.14	<0.09	0.68	<0.09	0.22	<0.09	0.27	0.25	0.25	0.16	0.26
Iron	mg Fe/L	YE060ICP	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	2.05	<0.01
Manganese	mg Mn/L	YE060ICP	<0.01	<0.01	<0.01	0.07	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.31	<0.01
Langelier Index (indicative, not SANS)		Calculation	0.62	1.03	0.20	-0.65	0.80	0.34	0.61	0.74	0.41	0.69	0.14	0.40
pHs (indicative, not SANS)		Calculation	7.34	7.66	7.10	8.15	6.88	7.01	6.72	6.80	6.94	7.13	6.99	7.09
Sodium Absorption Ratio (indicative)		Calculation	1.25	1.39	0.76	2.67	2.32	1.15	1.38	1.03	0.82	0.94	0.58	0.81
TDS to EC Ratio (indicative, not SANS)		Calculation	5.81	5.76	5.44	5.28	8.07	5.76	6.11	5.69	5.44	5.31	5.46	5.67
Corrosion Ratio (indicative, not SANS)		Calculation	2.20	2.18	0.86	8.10	12.53	1.14	7.15	2.82	0.61	0.76	0.30	1.46
Ryznar Index (indicative, not SANS)		Calculation	6.72	6.63	6.90	8.79	6.08	6.68	6.12	6.06	6.52	6.45	6.86	6.68
Anion Sum			13.61	9.71	12.85	8.69	40.98	14.97	42.63	23.48	12.54	11.58	10.96	12.48
Cation Sum			13.71	9.65	12.38	8.18	43.44	15.35	41.42	22.67	11.91	11.21	10.60	12.41
Difference			0.10	-0.06	-0.47	-0.51	2.46	0.38	-1.21	-0.82	-0.63	-0.37	-0.36	-0.07
% Difference			0.38%	-0.30%	-1.86%	-3.02%	2.91%	1.25%	-1.43%	-1.77%	-2.58%	-1.63%	-1.68%	-0.27%

LABORATORY NUMBER	SpGHT 13	SpGHT 14	SpGHT 15	SpGHT 16	SpGHT 17	SpGHT 18	SpGHT 19	SpGHT 20	SpGHT 21	SpGHT 22	SpGHT 23	SpGHT 24	SANS 241:2015 STANDARD LIMIT [Operational] [Aesthetic] [2011/other] (Domestic Water. Class II is for information only; SANS 241:2015 / 2011 / 2006)	Class II (Max Allowance for Limited Duration) *2006	Class II Water Consumption Period, a max *2006	SEWAGE LIMIT GENERAL LIMIT	SEWAGE LIMIT SPECIAL LIMIT
SAMPLE DESCRIPTION	HF / BH 26	HF / BH 27	HF / BH 29	HF / BH 32	HF / BH 33	HF / BH 34	HF / BH 35	HF / BH 36	HF / BH 37	HF / BH 38	HF / BH 39	HF / BH 43					
SAMPLE NUMBER	E49116-013	E49116-014	E49116-015	E49116-016	E49116-017	E49116-018	E49116-019	E49116-020	E49116-021	E49116-022	E49116-023	E49116-024					
SAMPLED	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00	2021/05/11 00:00					
Remarks	Clear	Brownish	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear					
Total Alkalinity (pH>4.5)	343	532	409	250	391	449	388	394	307	358	443	279					
Bicarbonate Alkalinity	343	532	409	250	378	449	388	394	307	358	443	279					
Carbonate Alkalinity	0.00	0.00	0.00	0.00	12.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
M Alkalinity (8.3>pH>4.5)	343	532	409	250	385	449	388	394	307	358	443	279					
P Alkalinity (pH>8.3)	0.00	0.00	0.00	0.00	6.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
Conductivity (Laboratory)	170	226	103	392	225	132	140	148	289	72.4	120	297	< 170	150 - 370	7 years	* < 70	* < 50
pH (Laboratory)	7.22	7.23	7.39	7.25	8.30	7.80	7.96	7.57	7.14	7.99	8.08	7.56	5.0 - 9.7	4.0 - 10.0	No limit	5.5-9.5	5.5-7.5
Total Hardness	738	379	444	1792	838	531	529	153	1139	298	431	1105					
Calcium Hardness	342	229	207	927	137	215	161	41.9	576	80.9	153	413					
Magnesium Hardness	396	150	237	864	702	316	368	111	563	217	279	692					
Total Dissolved Solids (TDS)	1015	1045	560	2274	1369	769	827	879	1655	386	685	1928	< 1200	1000-2400	7 years		
Temperature	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0					
Ammonia and Ammonium	<0.45	165	1.33	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	0.47	<0.45	<0.45	< 1.5			< 6	< 2
Calcium	137	91.7	82.8	371	54.7	86.2	64.3	16.8	231	32.4	61.2	165	< 150	150 - 300	7 years		
Chloride	263	324	70.2	845	383	124	175	205	764	23.6	121	464	< 300	200 - 600	7 years		
Magnesium	96.1	36.5	57.6	210	170	76.8	89.4	27.0	137	52.7	67.6	168	< 70	70 - 100	7 years		
Nitrate	46.3	1.08	10.2	130	55.0	8.29	6.11	11.1	2.73	1.10	7.10	137	< 12	10 - 20	7 years	< 15	<1.5
Nitrite	<0.01	<0.01	0.04	0.76	0.38	<0.01	<0.01	<0.01	<0.01	0.02	0.03	1.12	< 0.9				
Ortho Phosphate	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.15	<0.03	< 5			< 10	< 1
Potassium	3.32	25.5	3.34	7.99	11.9	6.91	7.88	2.28	25.9	5.41	8.44	36.7	< 50	50 - 100	7 years		
Sodium	71.6	25.9	37.8	65.7	157	75.4	97.3	273	140	38.1	90.6	177	< 200	200 - 400	7 years		
Silicon	20.4	2.40	24.7	17.3	20.7	23.2	22.8	23.1	22.6	15.0	21.8	14.8					
Sulphate	33.2	2.11	15.5	47.7	111	93.0	132	69.0	161	13.1	37.5	143	< 500	400 - 600	7 years		
Aluminium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	< 0.3	0.3 - 0.5	1 year		
Arsenic	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.01			<0.02	<0.01
Boron	<0.01	<0.01	<0.01	<0.01	0.47	0.10	0.16	0.06	0.06	<0.01	0.07	0.19	< 0.3			<1.0	<0.5
Fluoride	<0.09	0.16	0.18	<0.09	0.47	0.49	0.44	0.47	<0.09	0.67	0.39	0.12	< 1.5	1.0 - 1.5	1 year	<1.0	<1.0
Iron	<0.01	1.15	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.17	< 2	0.2 - 2.0	7 years	<0.3	<0.3
Manganese	<0.01	0.29	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	< 0.4	0.1 - 1.0	7 years	< 0.1	< 0.1
Langelier Index (indicative, not SANS)	0.31	0.33	0.36	0.60	1.03	0.82	0.78	-0.19	0.39	0.52	0.95	0.62	-0.5 - 0.5	negative: water may corrode surfaces; positive: water may form			
pHs (indicative, not SANS)	6.91	6.90	7.03	6.65	7.27	6.98	7.18	7.76	6.75	7.47	7.13	6.94		Saturation pH (used in calculations)			
Sodium Absorption Ratio (indicative)	1.14	0.58	0.78	0.67	2.35	1.42	1.83	9.55	1.80	0.96	1.89	2.31	< 1.5	Relevant in irrigation and			
TDS to EC Ratio (indicative, not SANS)	5.97	4.62	5.43	5.80	6.08	5.83	5.91	5.94	5.73	5.34	5.71	6.49		Analytical indicator			
Corrosion Ratio (indicative, not SANS)	2.21	1.72	0.50	9.63	2.91	0.89	1.45	1.56	7.29	0.20	0.81	4.96	0 - 0.3	A.k.a. Larson-Skold Index; >0.3: water may (>1.2 would) corrode			
Ryznar Index (indicative, not SANS)	6.60	6.56	6.66	6.04	6.23	6.17	6.39	7.94	6.36	6.96	6.18	6.33	6 - 7	< 6: water may form scale on surfaces; > 7: water may corrode			
Anion Sum	18.38	20.03	11.25	39.43	25.07	15.08	16.00	16.00	31.52	8.22	13.65	31.61					
Cation Sum	18.05	21.30	10.77	39.12	24.08	14.16	15.09	15.02	29.68	7.84	12.85	30.91					
Difference	-0.32	1.27	-0.48	-0.31	-0.98	-0.92	-0.90	-0.98	-1.85	-0.38	-0.80	-0.69					
% Difference	-0.88%	3.06%	-2.19%	-0.39%	-2.00%	-3.14%	-2.90%	-3.15%	-3.02%	-2.37%	-3.01%	-1.11%					

Methods adapted to accommodate local laboratory conditions. SM refers to the Standard Methods for the Examination of Water and Wastewater.

Unless analysis is indicated as "Total", tests are performed on filtered samples as per ISO 11885.

Ion balance is not used as QC check where pH<3.5.

**** Methods Starting with YE are accredited, and based on ISO, SANS, and/or other national or international standards, please see http://www.yanka.co.za/TestsAndStandards.htm . For ranges, uncertainties, etc., please contact us.**

YANKA LABORATORIES

CHEMISTRY TEST RESULTS

LABORATORY NUMBER			SpGHT 1	SpGHT 2	SpGHT 3	SpGHT 4	SpGHT 5	Domestic Water. Class II is for information only — SANS 241:2015 / 2011 / 2006				
SAMPLE DESCRIPTION			HF / BH 09	HF / BH 11	HF / BH 12	HF / BH 14	HF / BH 17	SANS 241:2015 STANDARD LIMIT [Operational] [Aesthetic] [2011/other]	Class II (Max Allowance for Limited Duration) *2006	Class II Water Consumption Period, a max *2006	SEWAGE LIMIT GENERAL LIMIT	SEWAGE LIMIT SPECIAL LIMIT
SAMPLE NUMBER			E49173-001	E49173-002	E49173-003	E49173-004	E49173-005					
SAMPLED		Test Method **	2021/05/05 00:00	2021/05/05 00:00	2021/05/05 00:00	2021/05/05 00:00	2021/05/05 00:00					
Remarks			Clear	Brownish	Clear	Clear	Clear					
Total Alkalinity (pH>4.5)	mg $CaCO_3$/L	YE010Alk	269	212	1104	256	199					
Bicarbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	269	191	1104	256	199					
Carbonate Alkalinity	mg $CaCO_3$/L	YE010Alk	0.00	21.2	0.00	0.00	0.00					
M Alkalinity (8.3>pH>4.5)	mg $CaCO_3$/L	YE010Alk	269	201	1104	256	199					
P Alkalinity (pH>8.3)	mg $CaCO_3$/L	YE010Alk	0.00	10.6	0.00	0.00	0.00					
Conductivity (Laboratory)	mS/m	YE020CON	69.0	78.9	281	118	1172	< 170	150 - 370	7 years	* < 70	* < 50
pH (Laboratory)		YE030pH	6.89	8.31	7.81	7.29	6.70	5.0 - 9.7	4.0 - 10.0	No limit	5.5-9.5	5.5-7.5
Total Hardness	mg $CaCO_3$/L	YE061H	238	261	38.3	413	6839					
Calcium Hardness	mg $CaCO_3$/L	YE061H	126	120	13.7	223	5124					
Magnesium Hardness	mg $CaCO_3$/L	YE061H	112	141	24.6	190	1715					
Total Dissolved Solids (TDS)	mg/L	Calculation	384	415	1398	635	9972	< 1200	1000-2400	7 years		
Temperature	°C	Thermometer	21.0	21.0	21.0	21.0	21.0					
Ammonia and Ammonium	mg N/L	YE070AK	<0.45	<0.45	291	<0.45	1.57	< 1.5			< 6	< 2
Calcium	mg Ca/L	YE060ICP	50.3	48.1	5.49	89.4	2052	< 150	150 - 300	7 years		
Chloride	mg Cl/L	YE070AK	31.9	84.9	157	204	1292	< 300	200 - 600	7 years		
Magnesium	mg Mg/L	YE060ICP	27.2	34.3	5.98	46.2	416	< 70	70 - 100	7 years		
Nitrate and Nitrite (TON)	mg N/L	YE070AK	5.96	8.07	<0.35	6.85	1329	< 12	10 - 20	7 years	< 15	<1.5
Nitrite	mg N/L	YE070AK	<0.01	0.59	<0.01	<0.01	19.5	< 0.9				
Ortho Phosphate	mg P/L	YE070AK	<0.03	<0.03	1.53	<0.03	<0.03	< 5			< 10	< 1
Potassium	mg K/L	YE060ICP	7.39	8.32	67.3	11.1	12.8	< 50	50 - 100	7 years		
Sodium	mg Na/L	YE060ICP	48.0	47.2	113	65.6	152	< 200	200 - 400	7 years		
Silicon	mg Si/L	YE060ICP	18.0	17.3	3.02	29.6	9.89					
Sulphate	mg SO_4/L	YE070AK	30.3	28.9	3.30	33.8	33.5	< 500	400 - 600	7 years		
Aluminium	mg Al/L	YE060ICP	<0.01	<0.01	0.05	<0.01	<0.01	< 0.3	0.3 - 0.5	1 year		
Arsenic	mg As/L	YE060ICP	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01			<0.02	<0.01
Boron	mg B/L	YE060ICP	0.07	0.09	0.27	0.15	0.61	< 0.3			<1.0	<0.5
Fluoride	mg F/L	YE070AK	0.33	0.13	0.22	0.16	1.27	< 1.5	1.0 - 1.5	1 year	<1.0	<1.0
Iron	mg Fe/L	YE060ICP	<0.01	0.05	1.94	<0.01	0.02	< 2	0.2 - 2.0	7 years	<0.3	<0.3
Manganese	mg Mn/L	YE060ICP	<0.01	<0.01	<0.01	<0.01	0.52	< 0.4	0.1 - 1.0	7 years	< 0.1	< 0.1
Langelier Index (indicative, not SANS)		Calculation	-0.51	0.78	-0.01	0.09	0.63	-0.5 - 0.5	negative: water may corrode surfaces; positive: water may form			
pHs (indicative, not SANS)		Calculation	7.40	7.53	7.82	7.20	6.07		Saturation pH (used in calculations)			
Sodium Absorption Ratio (indicative)		Calculation	1.35	1.27	7.90	1.40	0.80	< 1.5	Relevant in irrigation and			
TDS to EC Ratio (indicative, not SANS)		Calculation	5.56	5.26	4.97	5.38	8.51		Analytical indicator			
Corrosion Ratio (indicative, not SANS)		Calculation	0.39	1.20	0.40	2.32	18.40	0 - 0.3	A.k.a. Larson-Skold Index; >0.3: water may (>1.2 would) corrode			
Ryznar Index (indicative, not SANS)		Calculation	7.92	6.75	7.83	7.11	5.44	6 - 7	< 6: water may form scale on surfaces; > 7: water may corrode			
Anion Sum			7.37	7.86	26.82	12.16	136.68					
Cation Sum			7.06	7.53	28.33	11.46	144.38					
Difference			-0.31	-0.33	1.51	-0.71	7.70					
% Difference			-2.17%	-2.13%	2.74%	-3.00%	2.74%					

Methods adapted to accommodate local laboratory conditions. SM refers to the Standard Methods for the Examination of Water and Wastewater.

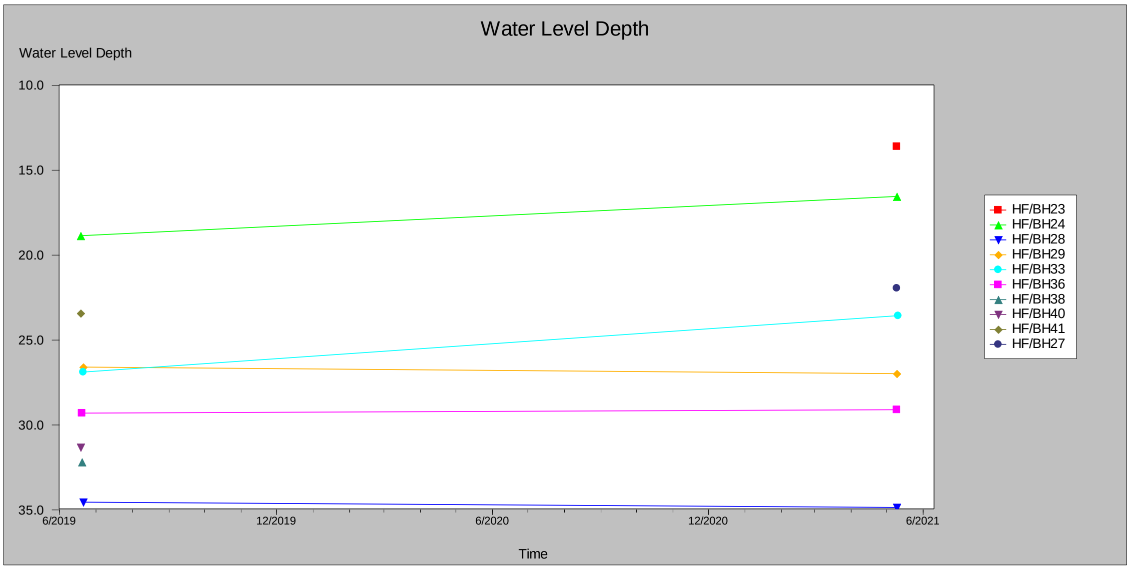
Unless analysis is indicated as "Total", tests are performed on filtered samples as per ISO 11885.

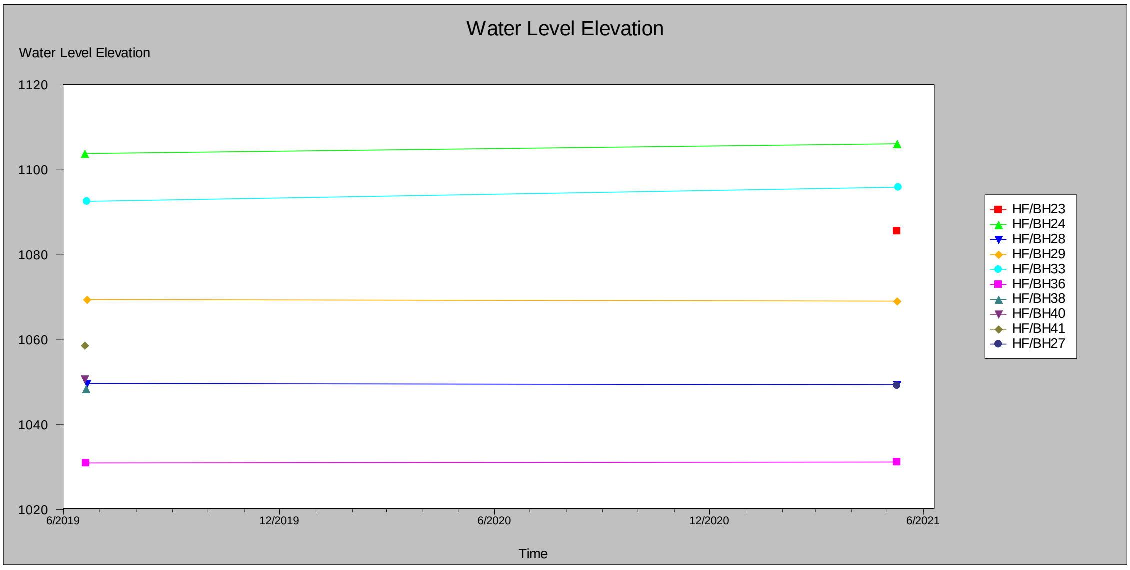
Ion balance is not used as QC check where pH<3.5.

**** Methods Starting with YE are accredited, and based on ISO, SANS, and/or other national or international standards, please see http://www.yanka.co.za/TestsAndStandards.htm . For ranges, uncertainties, etc., please contact us.**

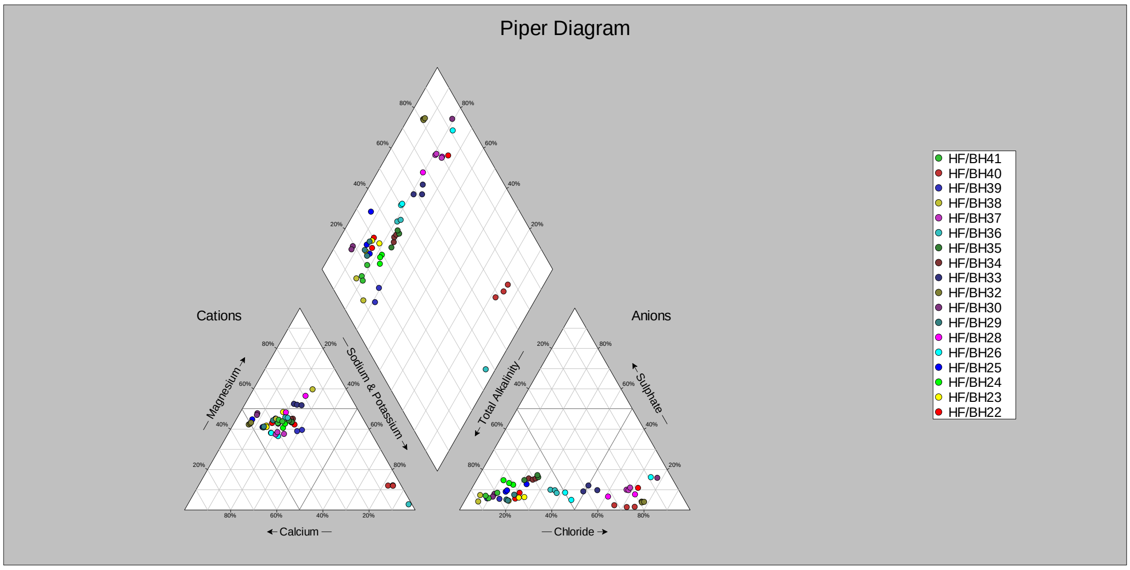
14 APPENDIX D: GWL, CHEMICAL DIAGRAMS & GRAPHS

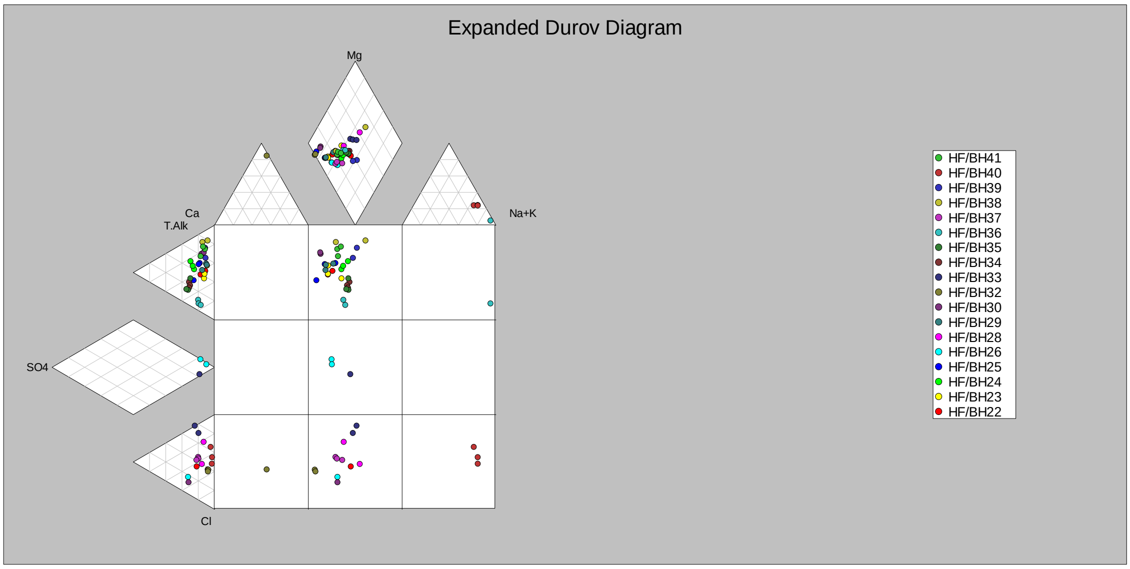
Mamatwan Mine Hydrocensus Study: Farm Borehole Groundwater Level Depth and Elevation Temporal Plots

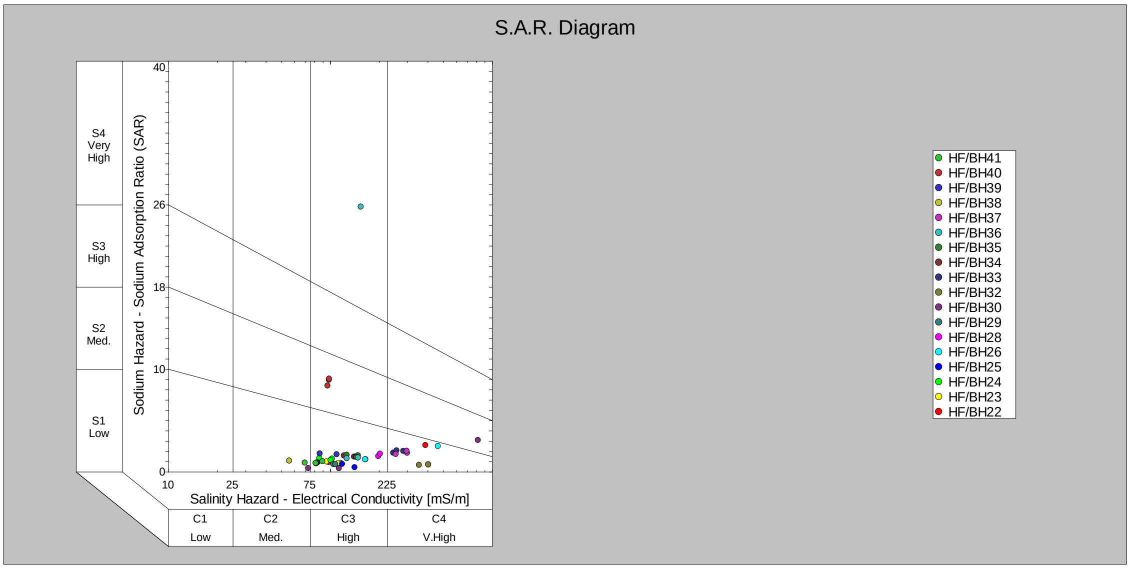


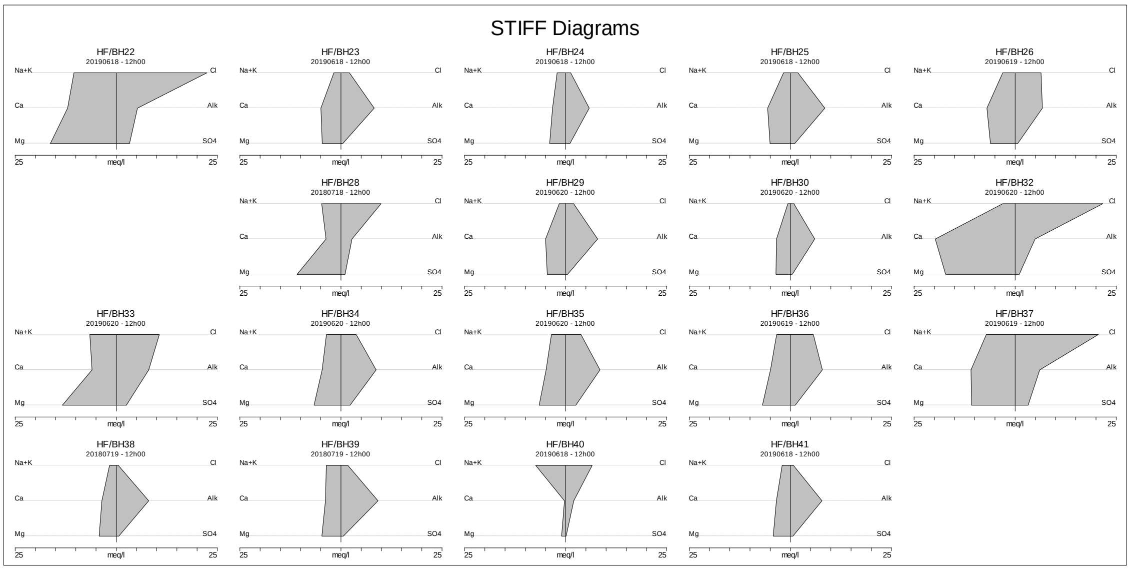


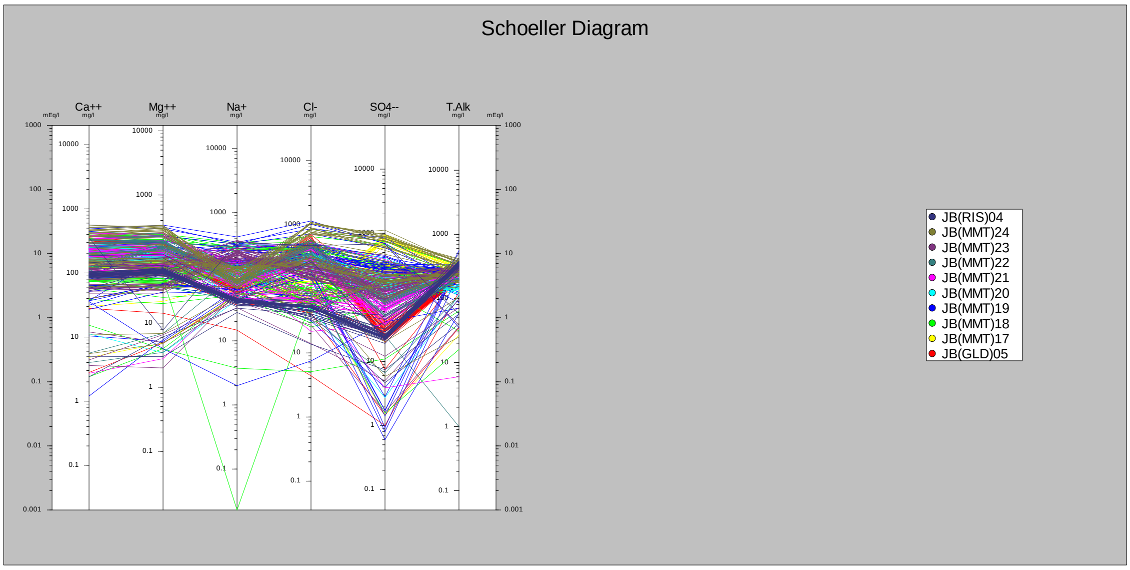
Mamatwan Mine Hydrocensus Study: Farm Borehole Groundwater Chemical Diagrams and Temporal Plots

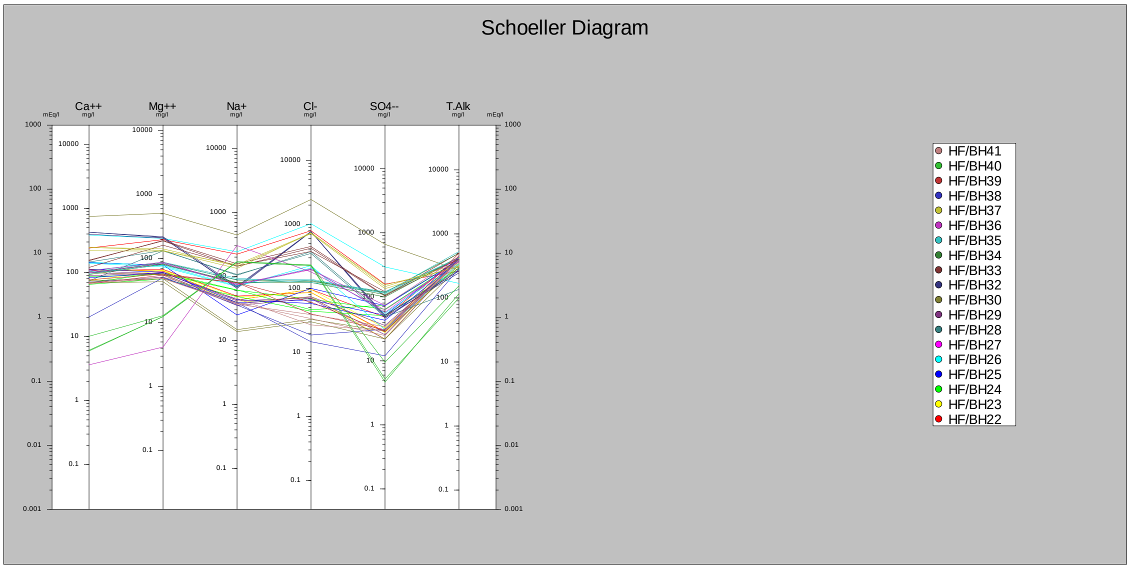


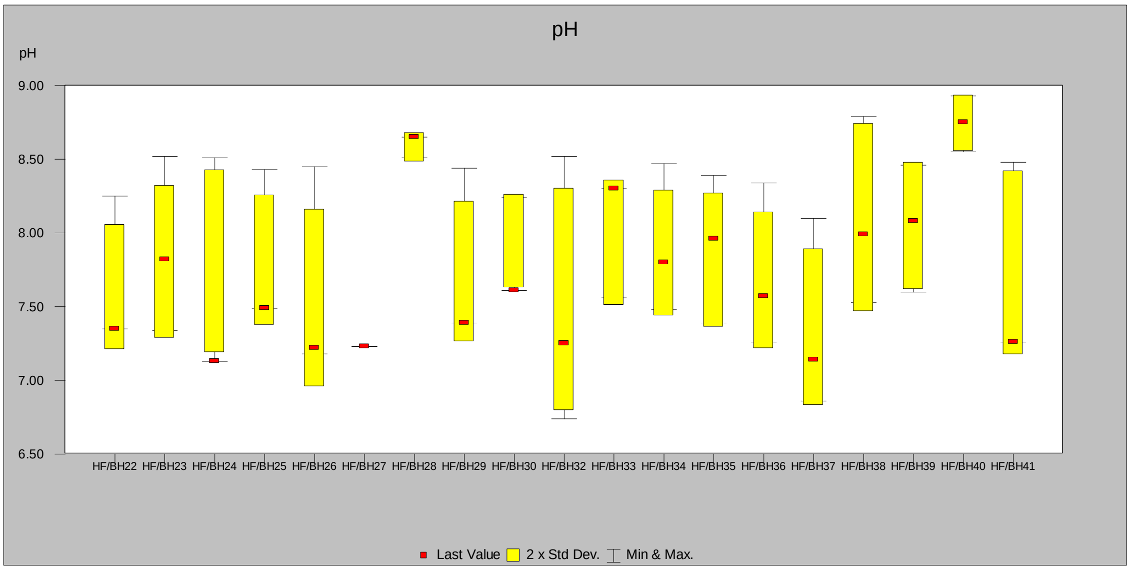


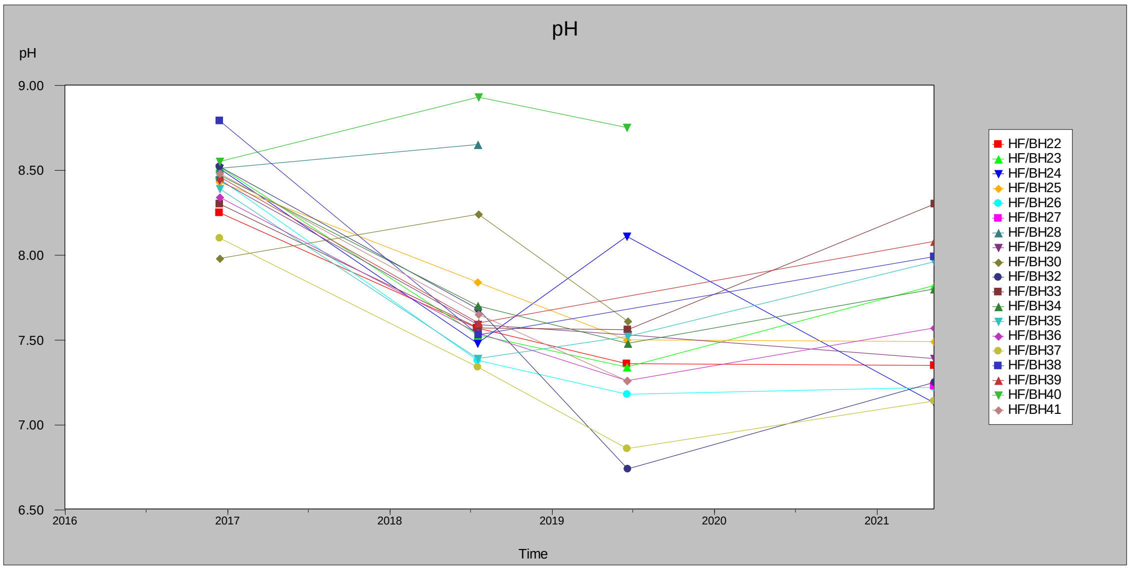

S.A.R. Diagram
Sodium Hazard - Sodium Adsorption Ratio (SAR)
Salinity Hazard - Electrical Conductivity [mS/m]
S4 Very High
S3 High
S2 Med.
S1 Low
C1 Low
C2 Med.
C3 High
C4 V.High
HF/BH41
HF/BH40
HF/BH39
HF/BH38
HF/BH37
HF/BH36
HF/BH35
HF/BH34
HF/BH33
HF/BH32
HF/BH30
HF/BH29
HF/BH28
HF/BH26
HF/BH25
HF/BH24
HF/BH23
HF/BH22

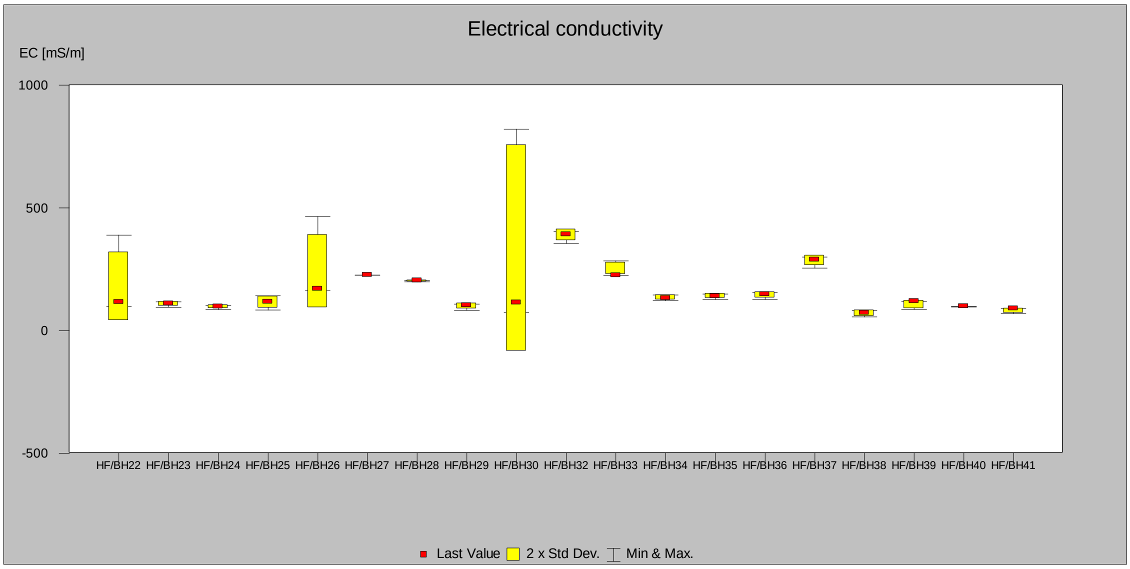

STIFF Diagrams
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

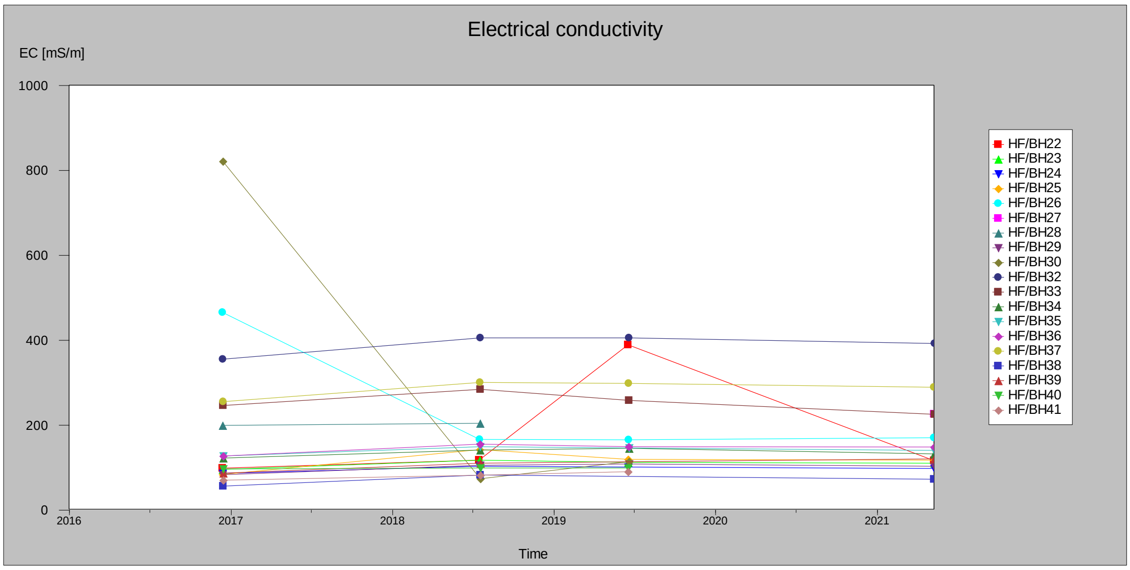

Schoeller Diagram
Ca++
Mg++
Na+
Cl-
SO4--
T.Alk
JB(RIS)04
JB(MMT)24
JB(MMT)23
JB(MMT)22
JB(MMT)21
JB(MMT)20
JB(MMT)19
JB(MMT)18
JB(MMT)17
JB(GLD)05

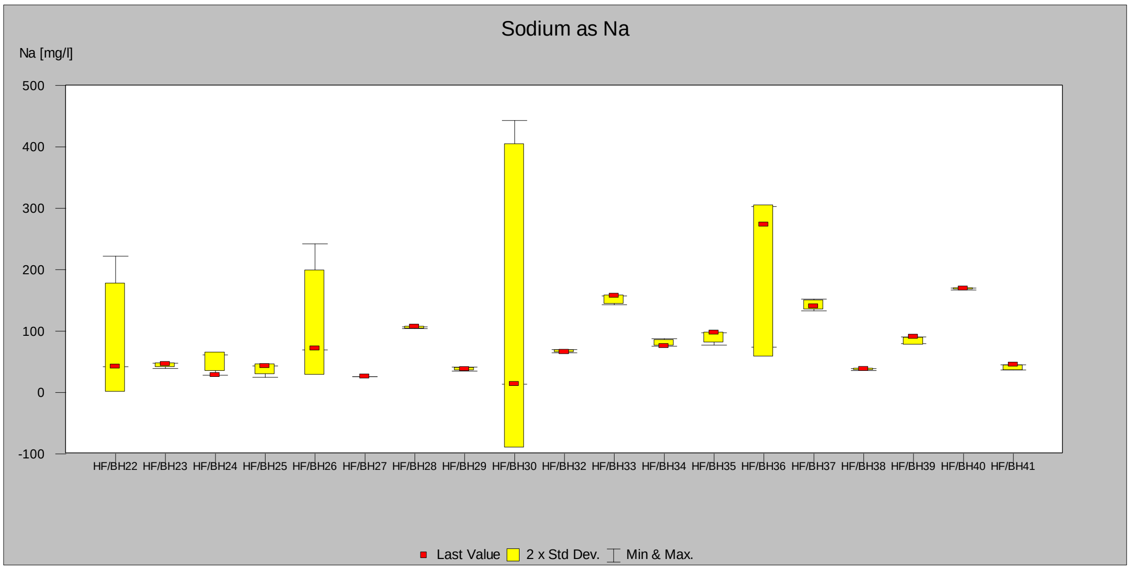

Schoeller Diagram
Ca++
Mg++
Na+
Cl-
SO4--
T.Alk
HF/BH41
HF/BH40
HF/BH39
HF/BH38
HF/BH37
HF/BH36
HF/BH35
HF/BH34
HF/BH33
HF/BH32
HF/BH30
HF/BH29
HF/BH28
HF/BH27
HF/BH26
HF/BH25
HF/BH24
HF/BH23
HF/BH22

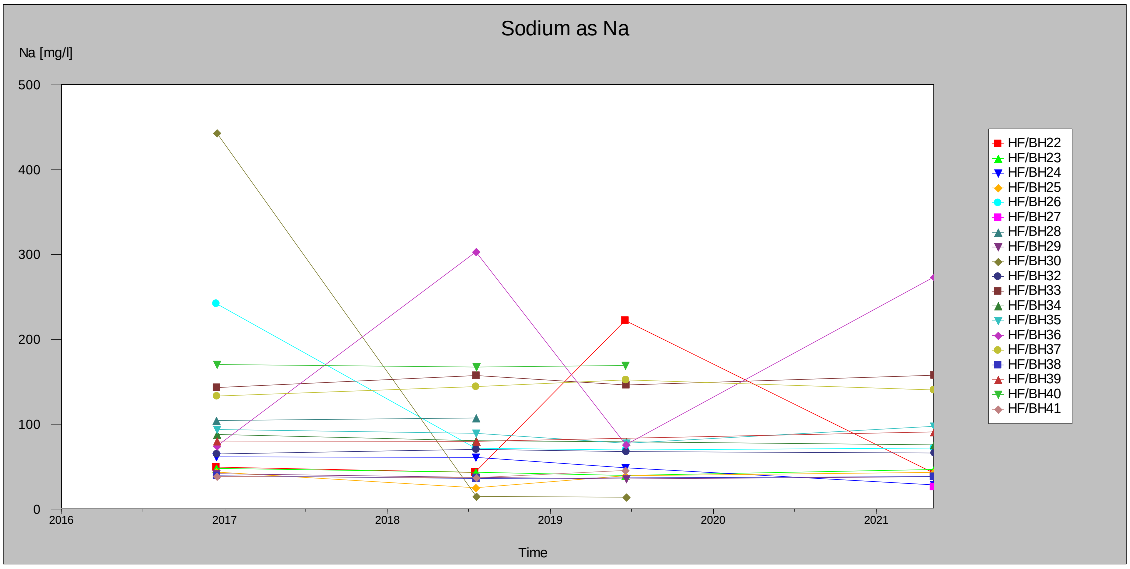

pH
pH
9.00
8.50
8.00
7.50
7.00
6.50
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value
2 x Std Dev.
Min & Max.

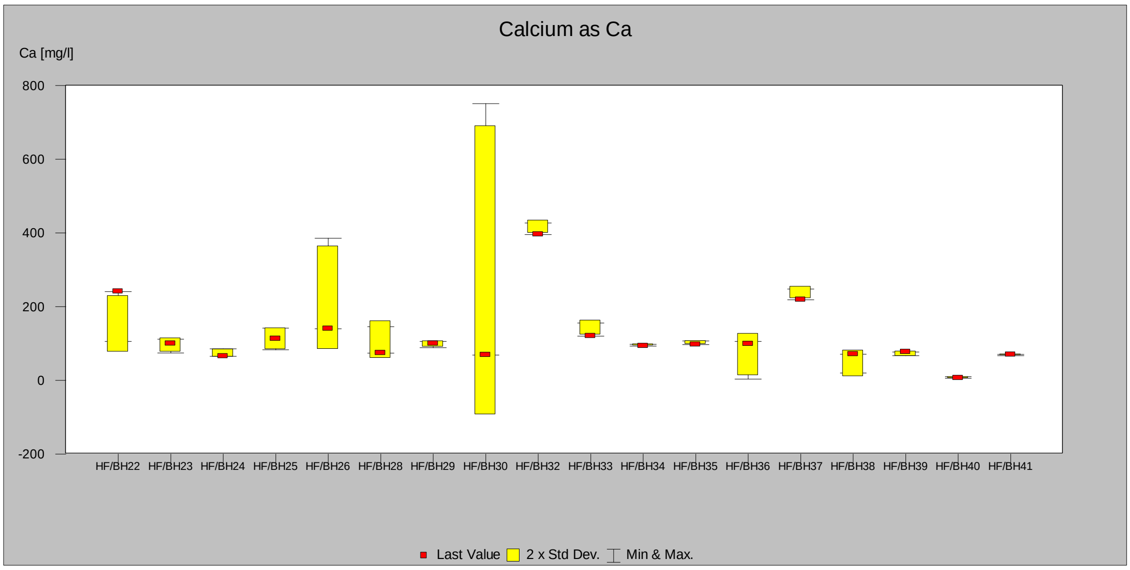

pH
pH
9.00
8.50
8.00
7.50
7.00
6.50
2016
2017
2018
2019
2020
2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

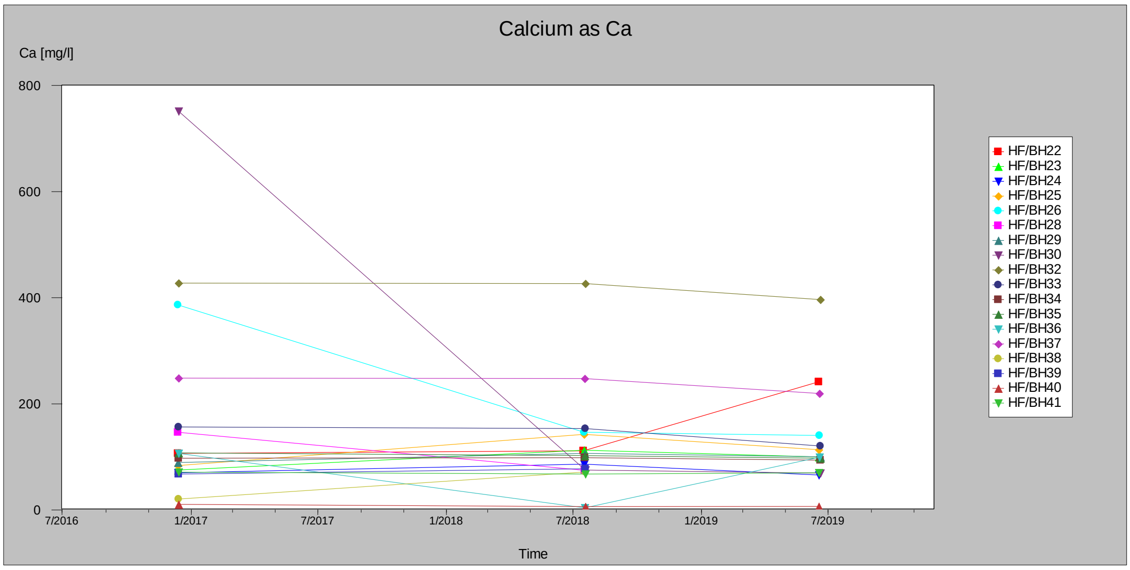

Electrical conductivity
EC [mS/m]
1000
500
0
-500
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value 2 x Std Dev. Min & Max.

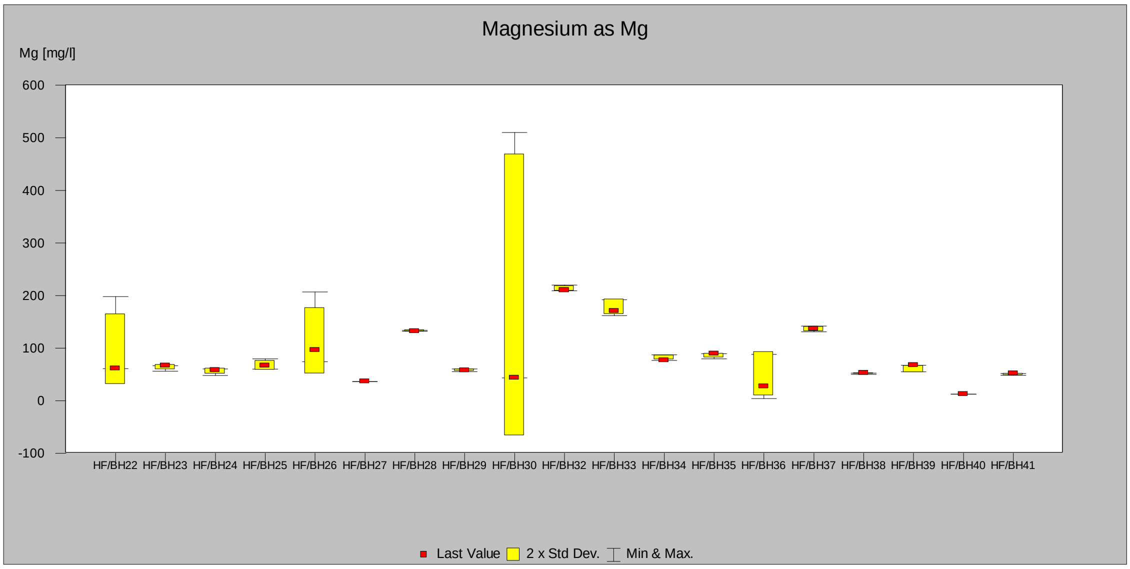

Electrical conductivity
EC [mS/m]
1000
800
600
400
200
0
2016 2017 2018 2019 2020 2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

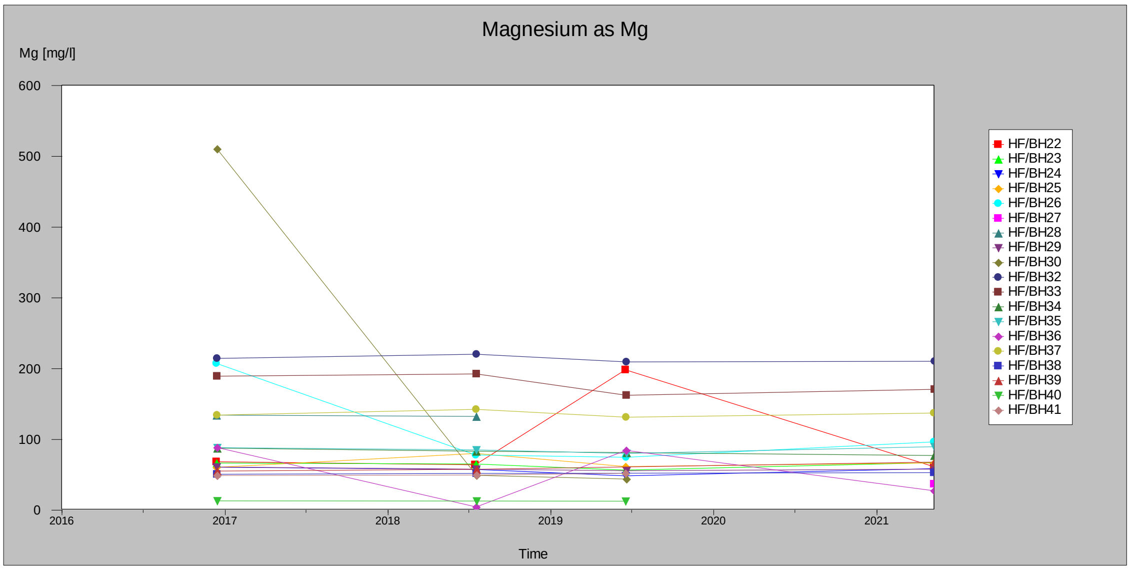

Sodium as Na
Na [mg/l]
500
400
300
200
100
0
-100
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value 2 x Std Dev. Min & Max.

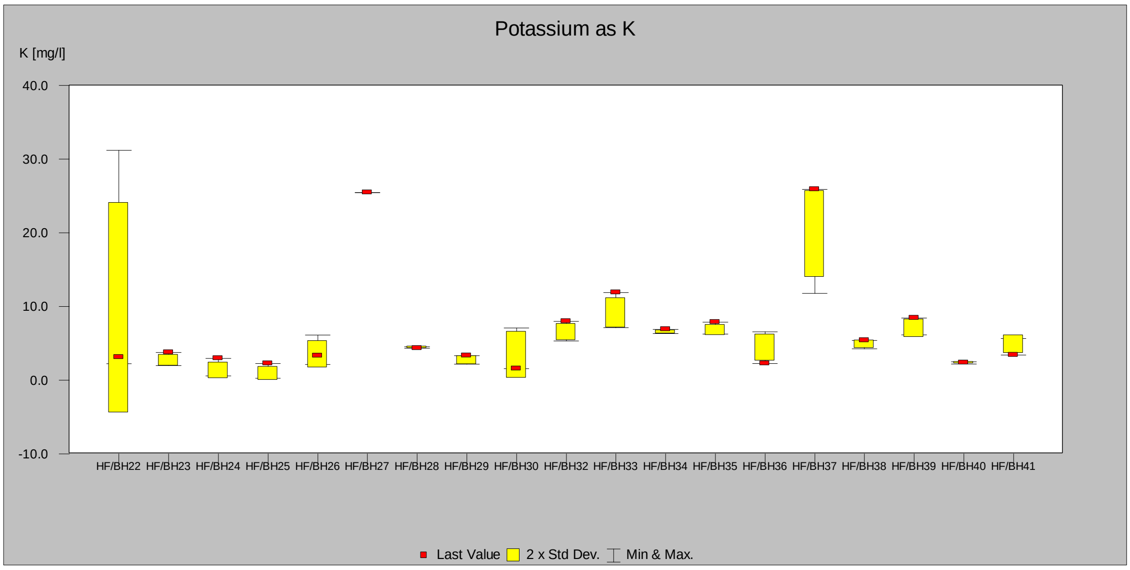

Sodium as Na
Na [mg/l]
500
400
300
200
100
0
2016
2017
2018
2019
2020
2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

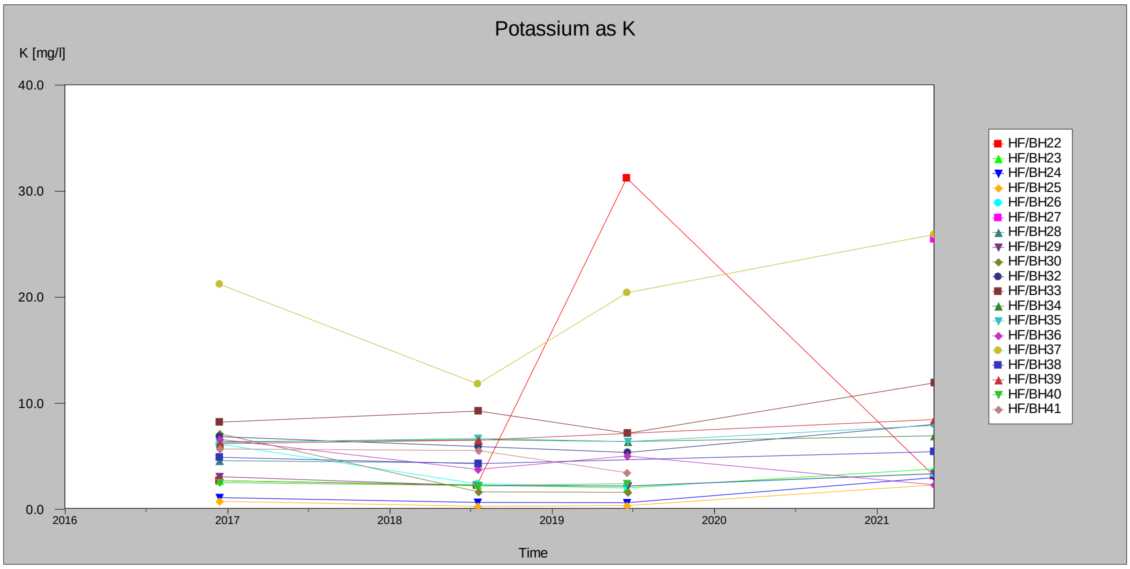

Calcium as Ca
Ca [mg/l]
800
600
400
200
0
-200
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41
Last Value
2 x Std Dev.
Min & Max.

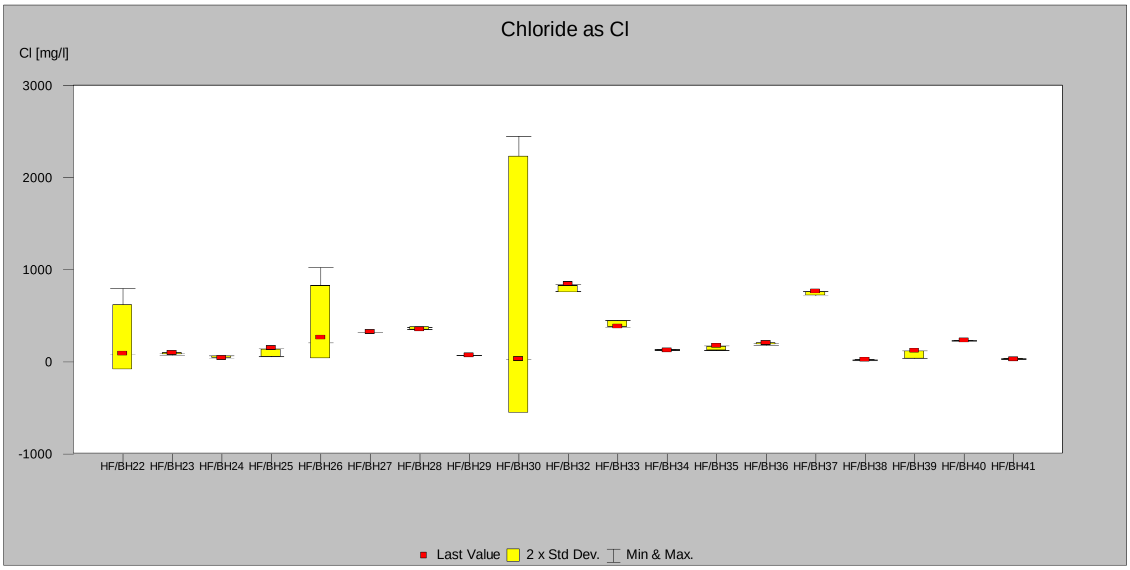

Calcium as Ca
Ca [mg/l]
800
600
400
200
0
7/2016
1/2017
7/2017
1/2018
7/2018
1/2019
7/2019
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

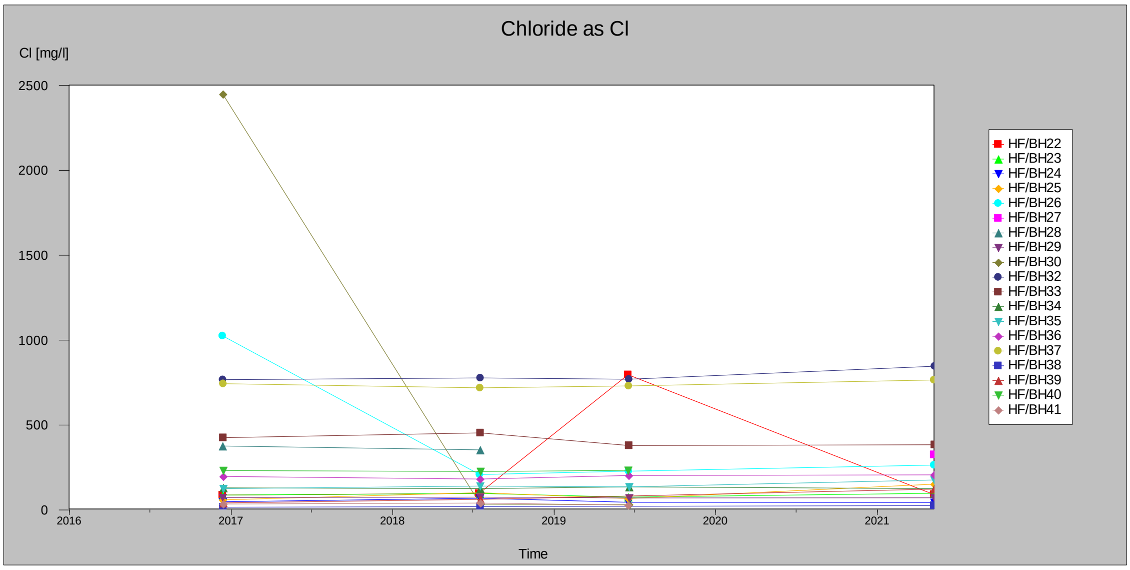

Magnesium as Mg
Mg [mg/l]
600
500
400
300
200
100
0
-100
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value
2 x Std Dev.
Min & Max.

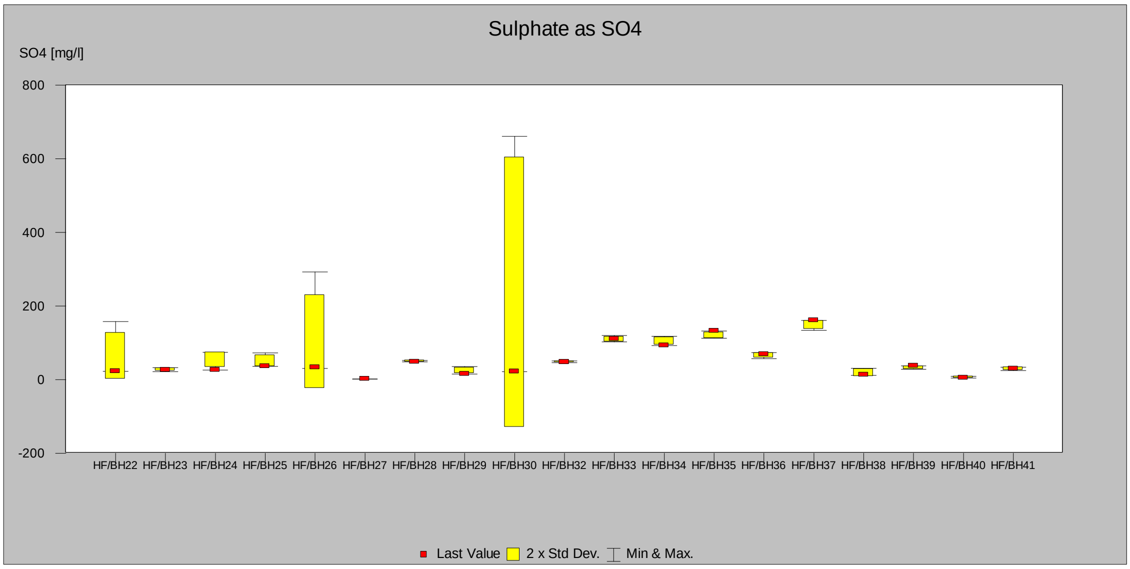

Magnesium as Mg
Mg [mg/l]
600
500
400
300
200
100
0
2016
2017
2018
2019
2020
2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

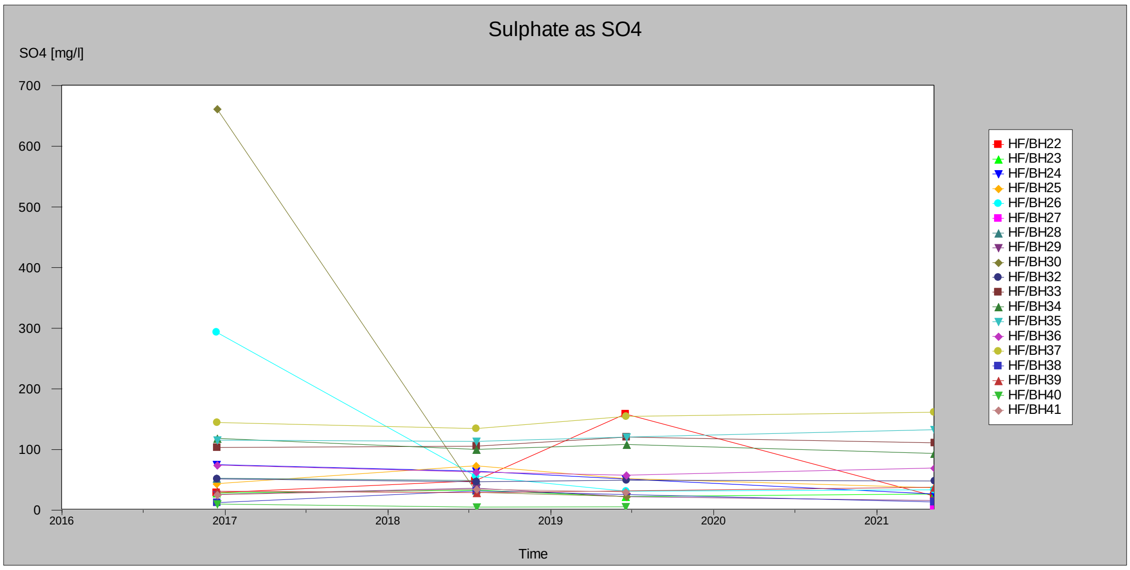

Potassium as K
K [mg/l]
40.0
30.0
20.0
10.0
0.0
-10.0
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value
2 x Std Dev.
Min & Max.

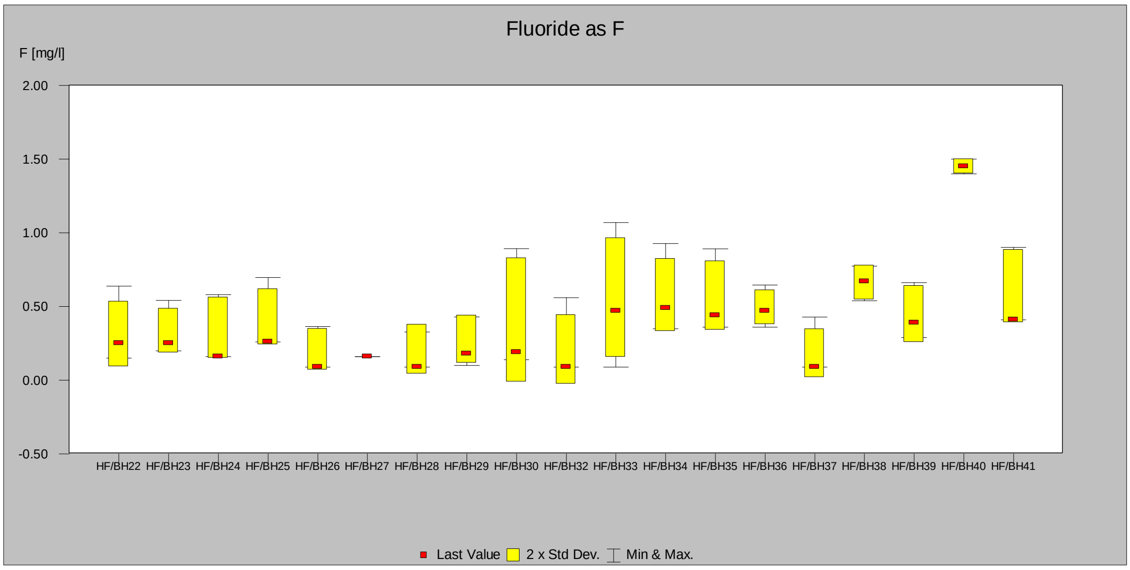

Potassium as K
K [mg/l]
40.0
30.0
20.0
10.0
0.0
2016
2017
2018
2019
2020
2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

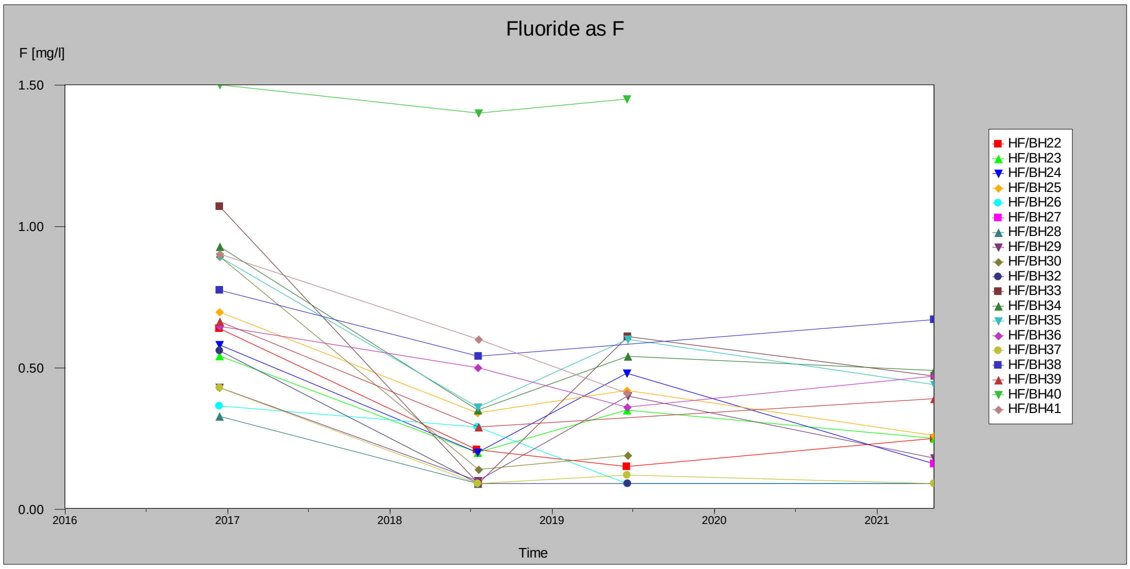

Chloride as Cl
Cl [mg/l]
3000
2000
1000
0
-1000
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value
2 x Std Dev.
Min & Max.

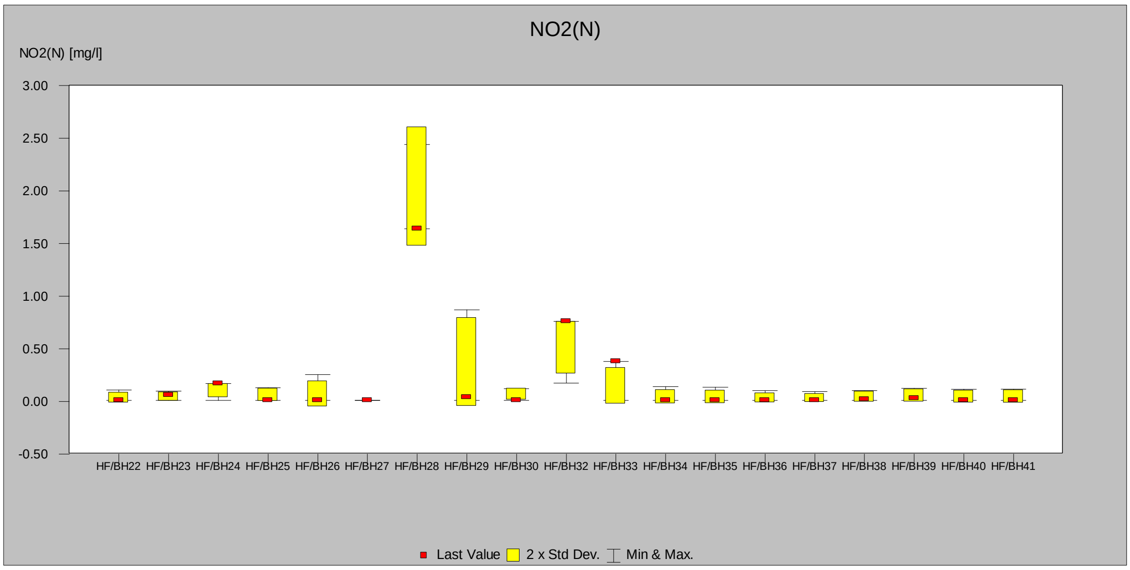

Chloride as Cl
Cl [mg/l]
2500
2000
1500
1000
500
0
2016
2017
2018
2019
2020
2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

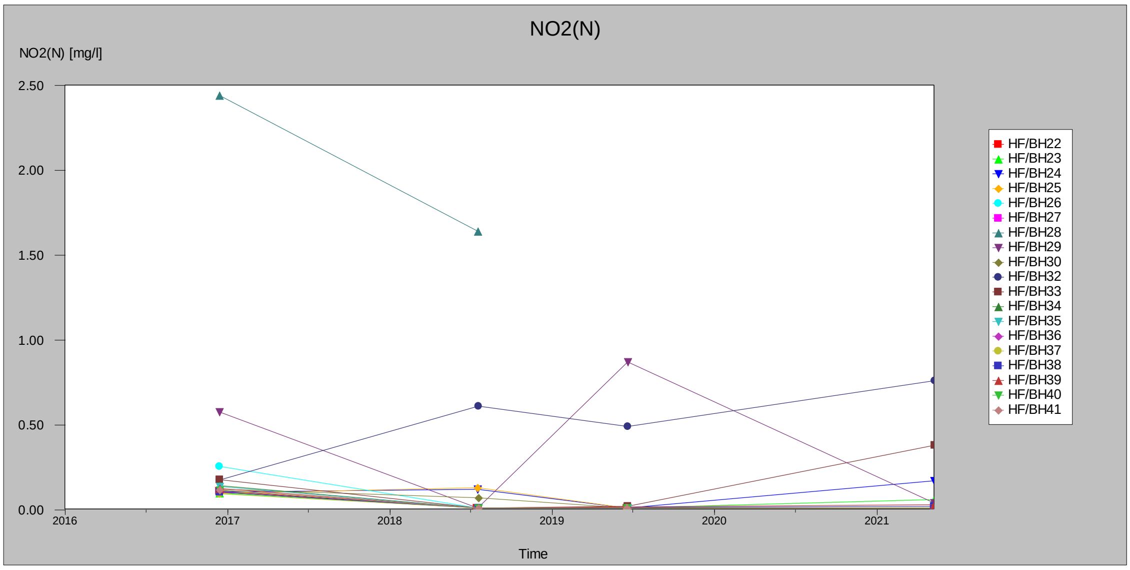

Sulphate as SO4
SO4 [mg/l]
800
600
400
200
0
-200
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value
2 x Std Dev.
Min & Max.

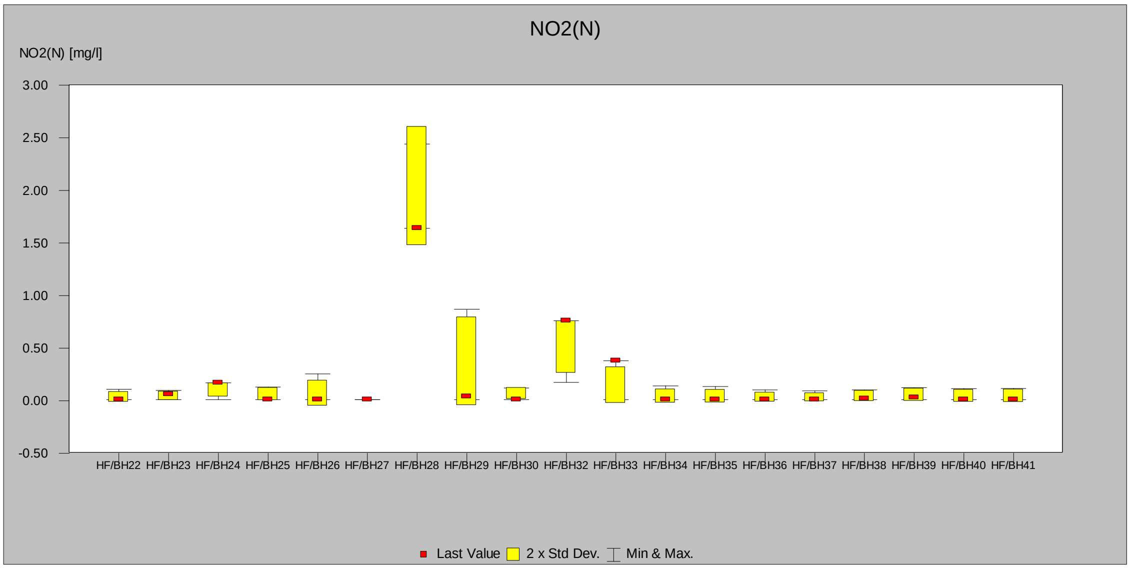

Sulphate as SO4
SO4 [mg/l]
700
600
500
400
300
200
100
0
2016 2017 2018 2019 2020 2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

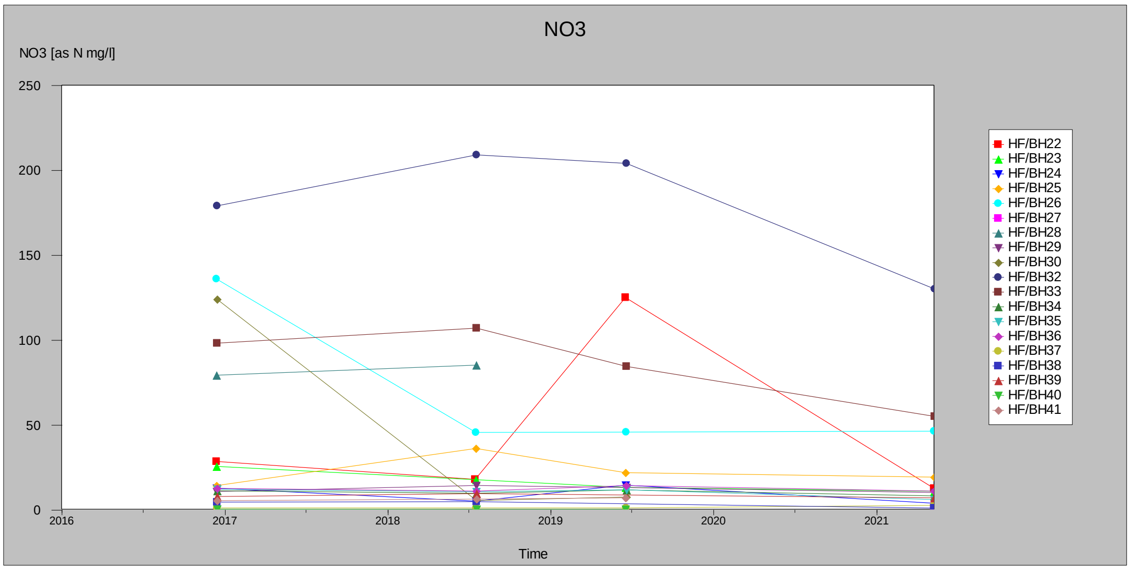

Fluoride as F
F [mg/l]
2.00
1.50
1.00
0.50
0.00
-0.50
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value
2 x Std Dev.
Min & Max.

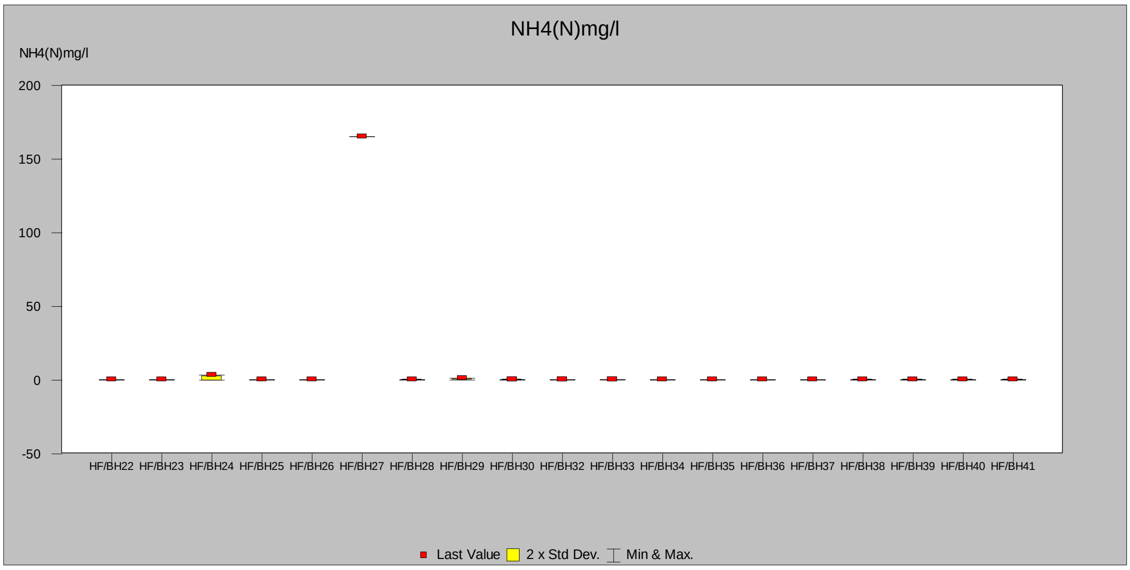

Fluoride as F
F [mg/l]
1.50
1.00
0.50
0.00
2016
2017
2018
2019
2020
2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

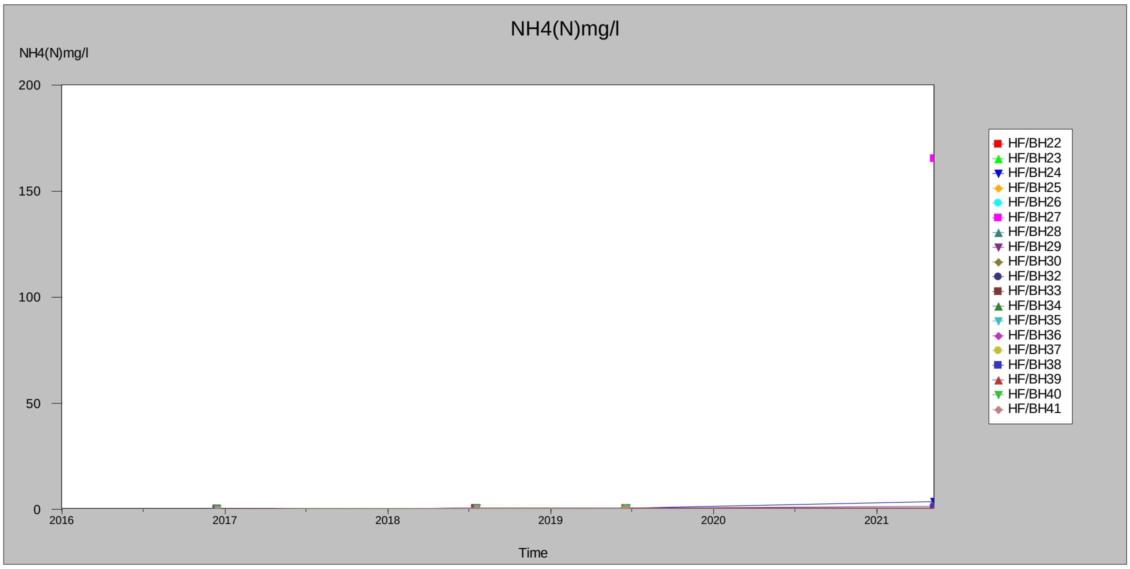

NO2(N)
NO2(N) [mg/l]
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value
2 x Std Dev.
Min & Max.

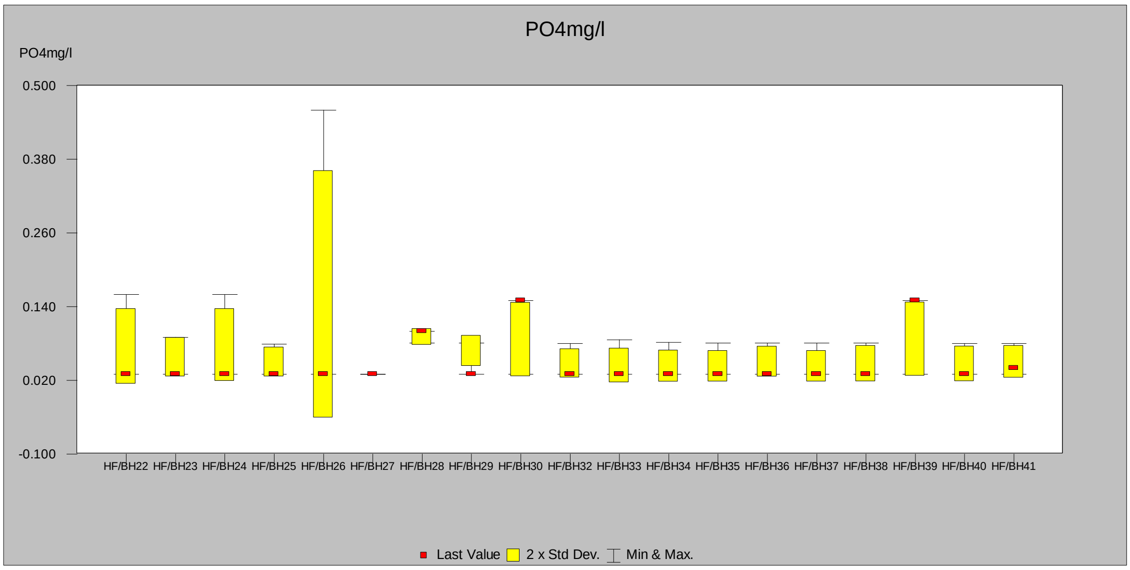

NO2(N)
NO2(N) [mg/l]
2.50
2.00
1.50
1.00
0.50
0.00
2016
2017
2018
2019
2020
2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

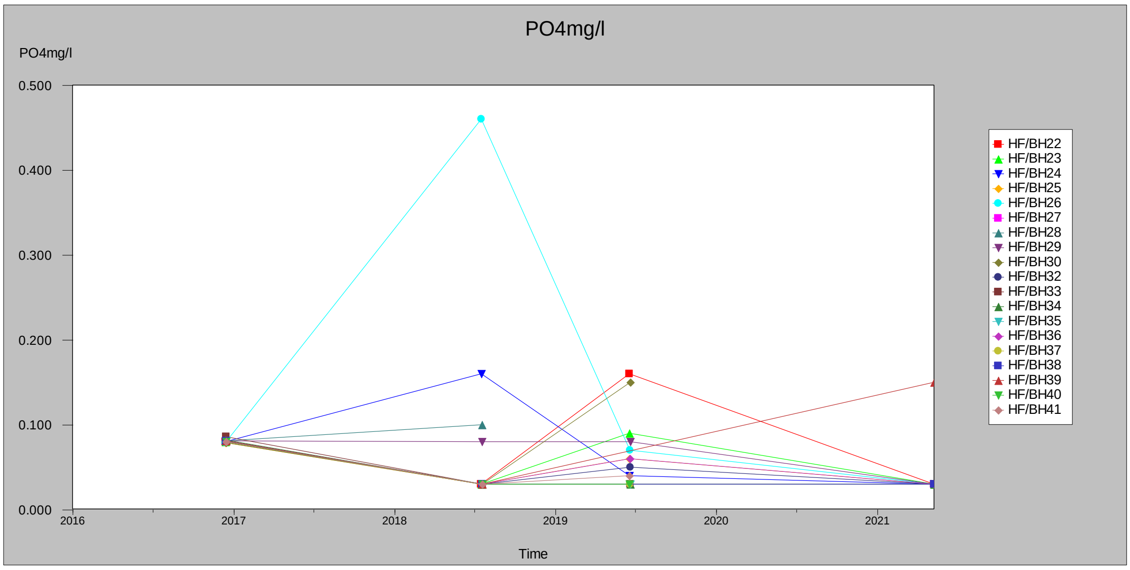

NO2(N)
NO2(N) [mg/l]
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value
2 x Std Dev.
Min & Max.

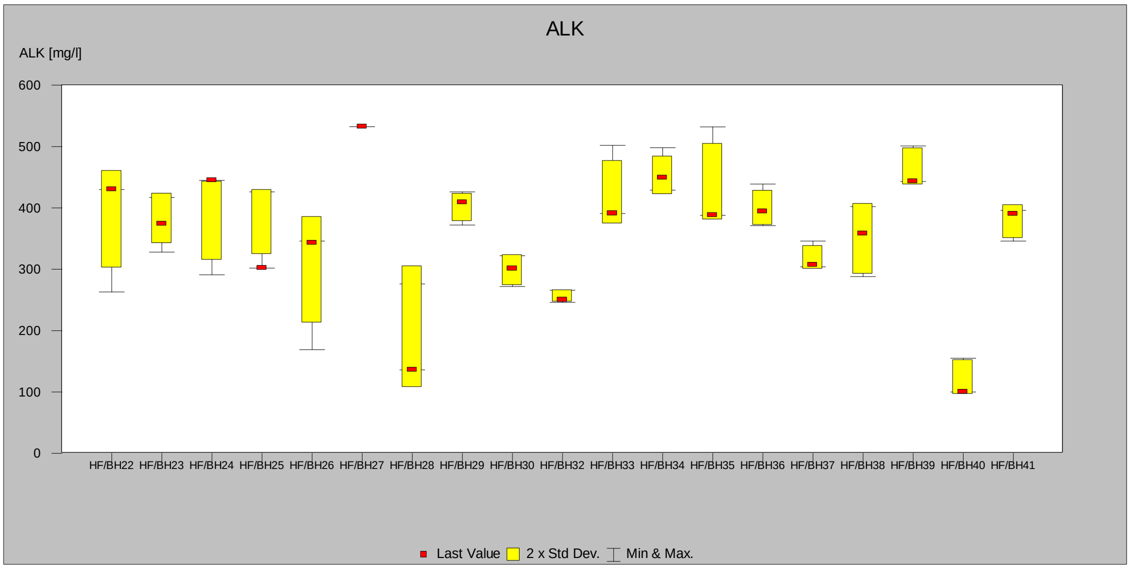

NO3
NO3 [as N mg/l]
250
200
150
100
50
0
2016
2017
2018
2019
2020
2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

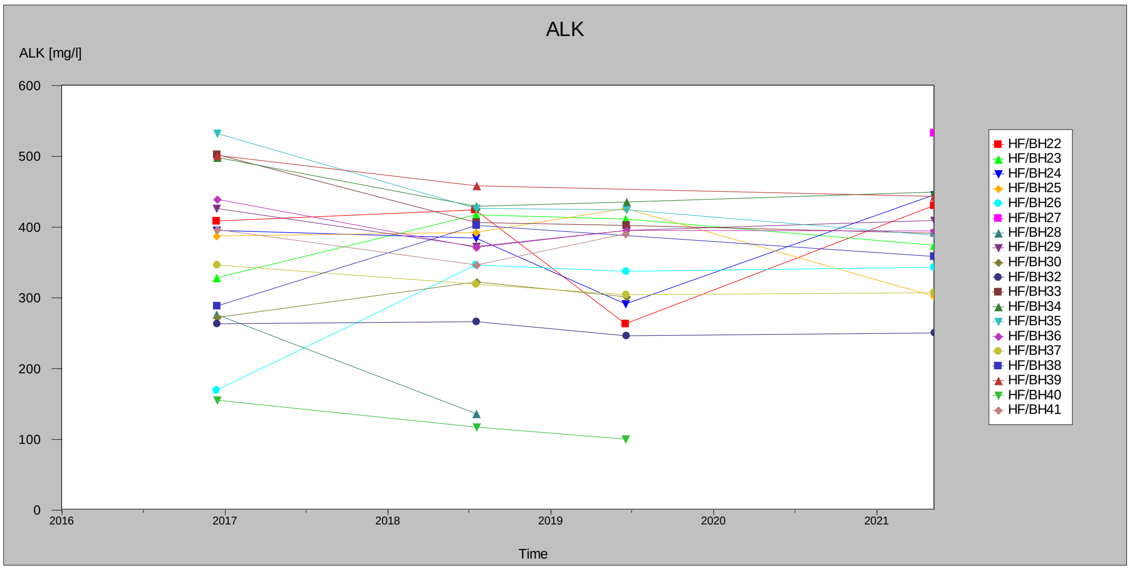

NH4(N)mg/l
NH4(N)mg/l
200
150
100
50
0
-50
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value
2 x Std Dev.
Min & Max.

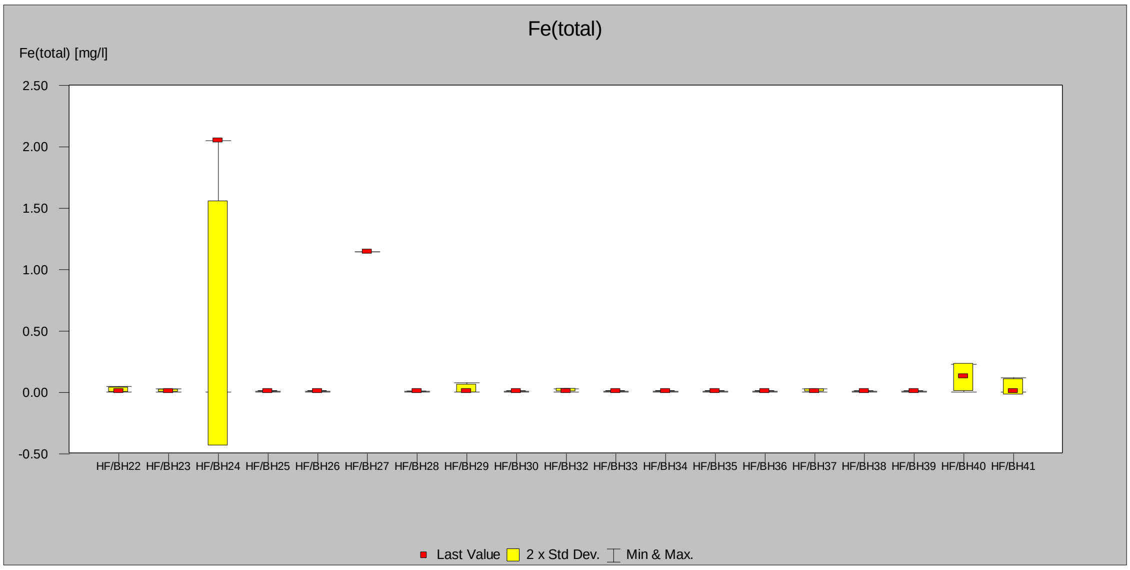

NH4(N)mg/l
NH4(N)mg/l
200
150
100
50
0
2016
2017
2018
2019
2020
2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

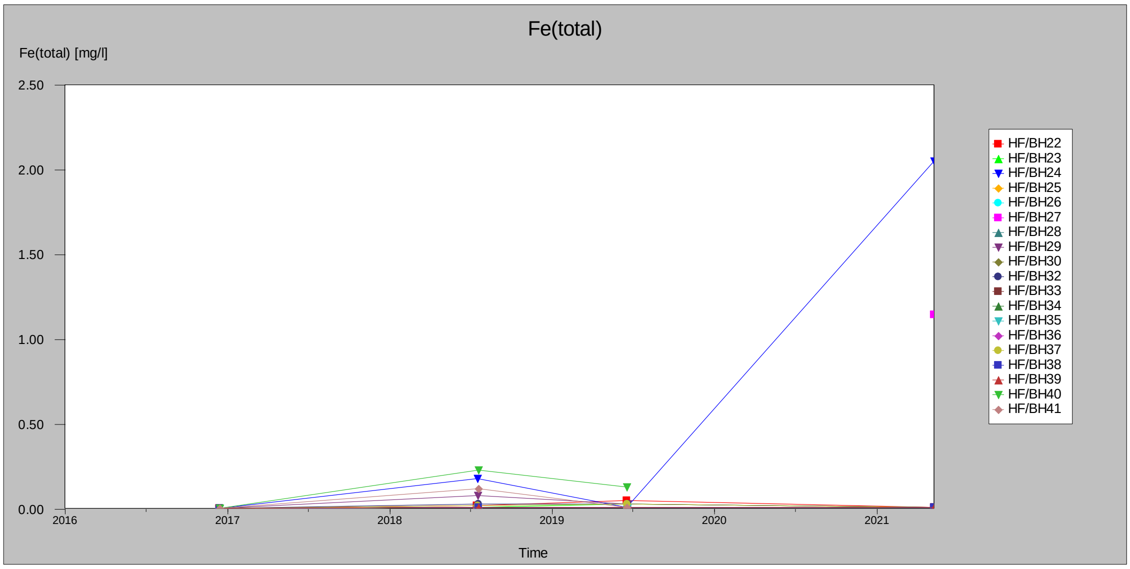

PO4mg/l
PO4mg/l
0.500
0.380
0.260
0.140
0.020
-0.100
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value
2 x Std Dev.
Min & Max.

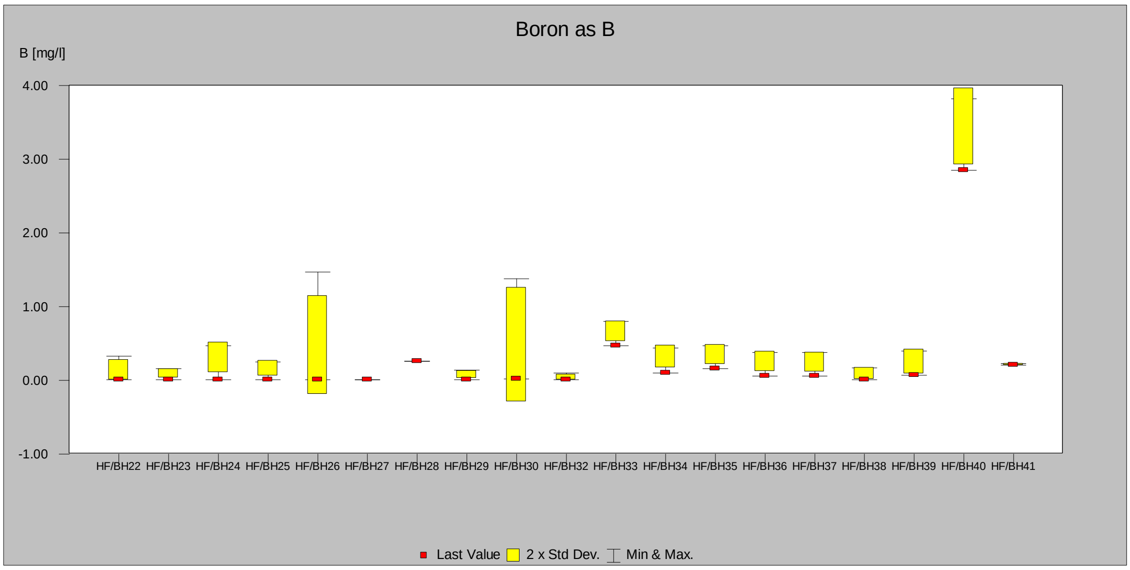

PO4mg/l
PO4mg/l
0.500
0.400
0.300
0.200
0.100
0.000
2016
2017
2018
2019
2020
2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

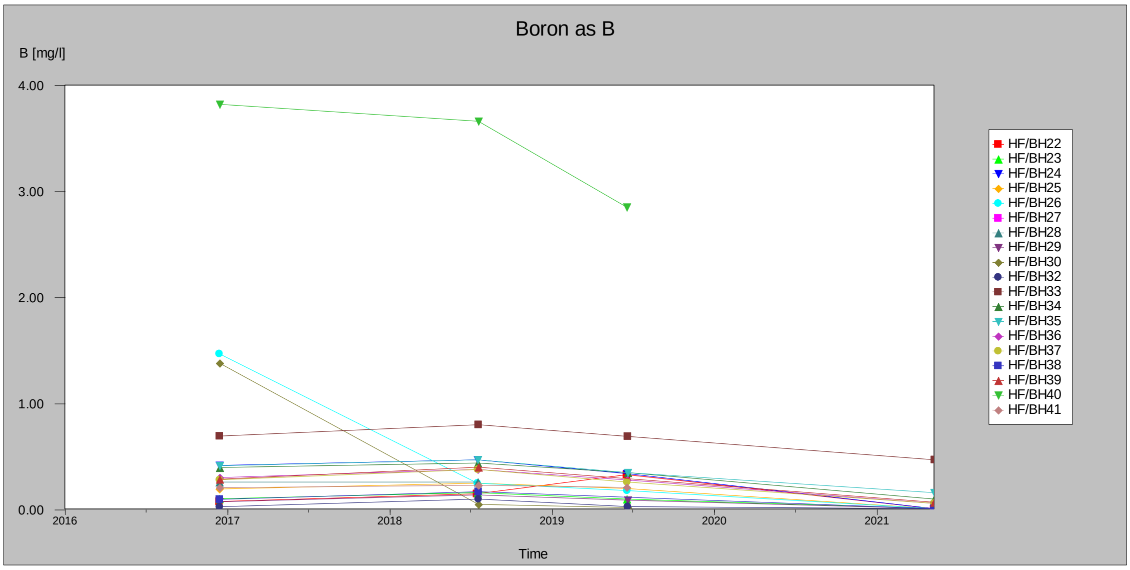

ALK
ALK [mg/l]
600
500
400
300
200
100
0
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value
2 x Std Dev.
Min & Max.

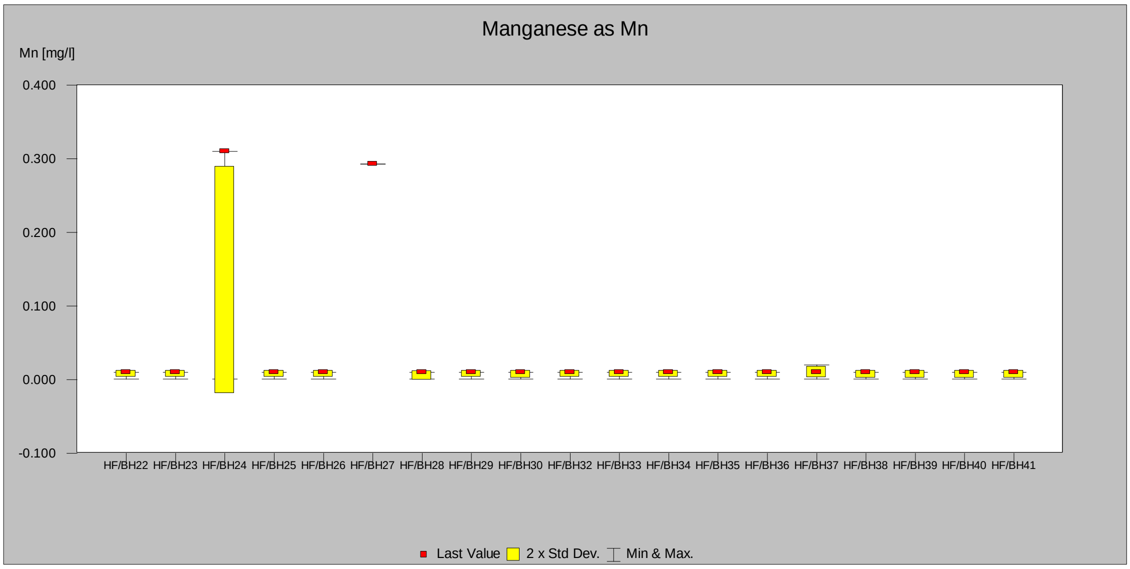

ALK
ALK [mg/l]
600
500
400
300
200
100
0
2016
2017
2018
2019
2020
2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41

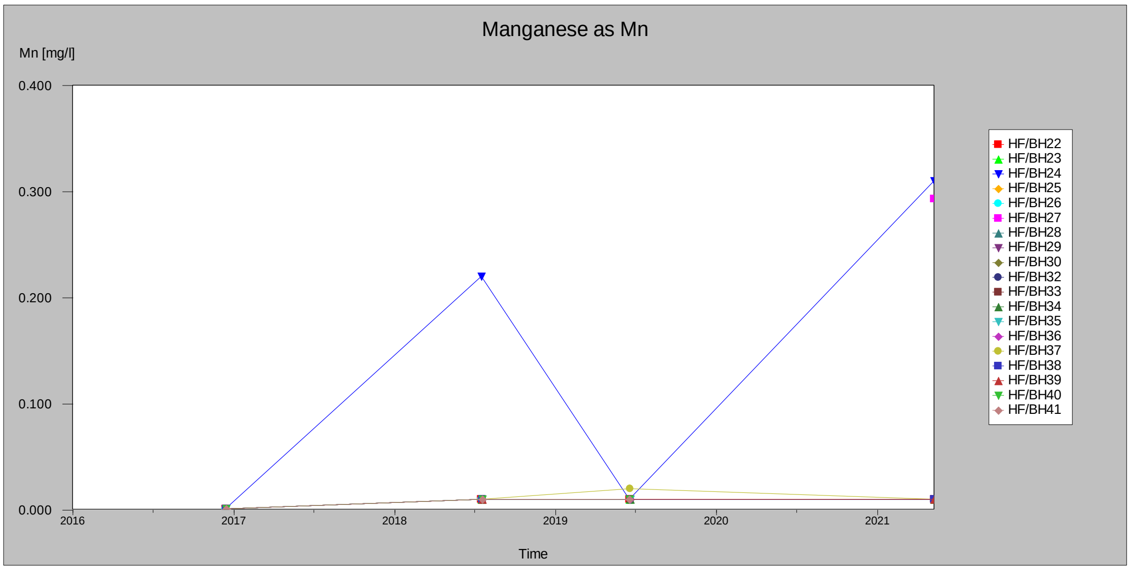

Fe(total)
Fe(total) [mg/l]
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value
2 x Std Dev.
Min & Max.


Fe(total)
Fe(total) [mg/l]
2.50
2.00
1.50
1.00
0.50
0.00
2016
2017
2018
2019
2020
2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41


Boron as B
B [mg/l]
4.00
3.00
2.00
1.00
0.00
-1.00
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value
2 x Std Dev.
Min & Max.


Boron as B
B [mg/l]
4.00
3.00
2.00
1.00
0.00
2016
2017
2018
2019
2020
2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41


Manganese as Mn
Mn [mg/l]
0.400
0.300
0.200
0.100
0.000
-0.100
HF/BH22 HF/BH23 HF/BH24 HF/BH25 HF/BH26 HF/BH27 HF/BH28 HF/BH29 HF/BH30 HF/BH32 HF/BH33 HF/BH34 HF/BH35 HF/BH36 HF/BH37 HF/BH38 HF/BH39 HF/BH40 HF/BH41
Last Value
2 x Std Dev.
Min & Max.


Manganese as Mn
Mn [mg/l]
0.400
0.300
0.200
0.100
0.000
2016
2017
2018
2019
2020
2021
Time
HF/BH22
HF/BH23
HF/BH24
HF/BH25
HF/BH26
HF/BH27
HF/BH28
HF/BH29
HF/BH30
HF/BH32
HF/BH33
HF/BH34
HF/BH35
HF/BH36
HF/BH37
HF/BH38
HF/BH39
HF/BH40
HF/BH41