Future Flow

GROUNDWATER & PROJECT MANAGEMENT SOLUTIONS

Future Flow Reference: CAB.17.036
Client Reference:

25 July 2018

Cabanga Environmental
Unit 5 & 6 Beyers Office Park
Bosbok Road
Randpark Ridge

Attention: Jane Barrett

KANAKIES GYPSUM MINE

GROUNDWATER STUDY

Good day Jane,

Please see attached the groundwater report for the Kanakies Gypsum Mine Project. The report details baseline groundwater conditions as well as the environmental impact assessment that was done.

Please do not hesitate to contact me should you have any queries.

Best regards,

Martiens Prinsloo Pr.Sci.Nat
Future Flow GPMS cc

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KANAKIES GYPSUM MINE

GROUNDWATER STUDY

For

Cabanga Environmental

Future Flow Document: CAB.17.036/EIA Report
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KANAKIES GYPSUM MINE

GROUNDWATER STUDY

For

Cabanga Environmental

Report Issue	FINAL		
Reference Number	CAB.17.036		
Title	Kanakies Gypsum Mine – Groundwater EIA / EMP study		
	Name	**Signature**	**Date**
Author	Martiens Prinsloo (M.Sc.; Pr.Sci.Nat)		25 July 2018
Reviewed			

EXECUTIVE SUMMARY

Introduction

Future Flow GPMS cc was contracted by Cabanga Environmental to conduct a geohydrological investigation for the proposed Kanakies Gypsum Mine. The client proposes to trench gypsum 90 km northwest of the town of Calvinia, Northern Cape Province of South Africa. A total mining area of ±800 ha is planned.

The deposit consists of 2 layers of gypsum i.e. a powder layer of approximate thickness 0.4 meter, which lies approximately 0.2 to 0.7 meter under the surface, followed by a nodular crystalline layer of gypsum of approximate thickness 0.9 to 1.3 meter. Total depth of trenching below surface ranges between 1.4 and 2.5 m.

Mining will be via trench mining, i.e. a trench of 100 meters by 10 m will be dug where the gypsum will be removed. The trench will be rehabilitated immediately using the overburden and discarded carrier clays after it has been screened over the mobile high frequency screen.

Surface infrastructure and operations include:

- Processing equipment consisting of a mobile crushing and high frequency screening plant will occupy a small area of less than 0.6 ha;
- A small shipping container type office block and ablution facility will occupy approximately 0.2 ha whilst a high roof shed will add 0.3 ha;
- A vehicle parking area and fuel storage area will occupy another 0.3 ha in total;
- A Stockpile area of 2.1 ha to store 8 000 to 10 000 ton of finished product and another small moving stockpile area of 0.5 ha to store 2000 ton of run of mine within a mine block;
- A total of approximately 5 ha of dirt road will be established to access the above site and mine areas (10 km by 5 m wide); and
- No new servitudes will be registered.

Desktop studies and a site specific baseline assessment including hydrocensus, drilling of groundwater boreholes, groundwater chemical analysis, and a geochemical analysis of the material that will be mined were used to characterise the baseline groundwater environment and develop a conceptual groundwater flow and contaminant transport model of the study area.

Due to the fact that the proposed development will not breach the groundwater level in the area and will not impact on the groundwater flow patterns no 3D groundwater flow modelling was done. The geochemical analysis show that Acid Mine Drainage (AMD) conditions can be expected to form and some elements including sulphate will be present in concentrations higher than that already present in the natural groundwater that occur on site. The contaminant migration assessment was done using analytical calculations. The groundwater impact assessment was based on the conceptual groundwater flow and contaminant transport model.

General site description

The proposed Mine falls within one sub-catchment, the E33A quaternary catchment. The regional topography is best described as relatively flat and locally slopes towards the streams that drain the region.

South of the proposed Mine area a non-perennial tributary to the Doringrivier drains the area. Approximately 3 to 4 km east of the proposed Mine the North / South draining Kromrivier drains the area.

Within the proposed Mine area itself the topography slopes from the north to the south. Topographical gradients are calculated to be in the order of 1:80 to 1:100. Site specific topographical elevations range between 360 metres above mean sea level (mamsl) in the north to 330 mamsl in the south.

In terms of surface water drainage systems the surface infrastructure and the mining areas fall within the E33A quaternary catchment which forms part of the Knersvlakte and ultimately the Berg Olifants Water Management Area (WMA).

Prevailing groundwater conditions

Geology

Regional geology

The site is underlain by quaternary alluvium comprising calcareous and gypsiferous soils, followed by quaternary gravel, silt and sand. These formations unconformably overlie the Besonderheid Formation of the Knersvlakte Subgroup, Vanrhynsdorp Group in the study area. The Besonderheid Formation comprises of green shale, siltstone, sandstone, gritstone and conglomerates, interbedded with shale, limestone and chert in the south east. It is believed that the ancient Doringrivier and its tributaries eroded the Besonderheid Formation and may have accumulated gypsiferous sediments in the paleochannels and topographic low points within the study area.

Local geology

The gypsum deposit covers approximately 700 hectares and is situated on a large flat lying sandy terrace at the north-eastern end of the Knersvlakte, close to the confluence of the Kromrivier and Doringrivier. The gypsum layer is between 1.3 and 1.7 meter thick and is covered with a layer of sandy soil of 0.3 to 0.7 meter thick. The main contaminant in the gypsum layer is silica sand mixed with clay.

The deposit can be divided into two generally horizontal overlapping seams of gypsum, namely:

- A 0.4 m thick seam of gypsum powder occurring in the southern portion of the deposit; and

- Another 0.9 m to 1.3 m thick main gypsum seam, which occurs throughout the entire deposit, but which decreases in quality with increasing depth.

Geochemical analyses

Total concentration (TC) and leach concentration (LC) test results are compared to guideline concentrations defined in Regulation 635. Leachable Concentration Threshold (LCT) means the leachable concentration threshold limit for particular elements and chemical substances in a waste, expressed as mg/L. The Total Concentration Threshold (TCT) means the total concentration threshold limit for particular elements or chemical substances in a waste, expressed as mg/kg.

Total concentration analysis results show that barium and fluoride can be expected to generally exceed the TCT 0 guideline values, where TCT0 limits are protective of water resources. The copper concentration at borehole KAN2 is elevated in both the overburden (30 mg/kg) and the gypsum material (23 mg/kg) compared to the TCT0 guideline value of 16 mg/kg. Arsenic at a concentration of 6 mg/kg slightly exceeds the TCT0 guideline value of 5.8 mg/kg at KAN4. All parameters comply with the TCT1 guideline values which specify land remediation values for commercial / industrial land.

The sulphate concentrations exceed the LCT0 guideline value of 250 mg/L. The measured sulphate concentration in the overburden material (soil) is measured at 826 mg/L while the sulphate concentration in the gypsum material measures around 1 400 mg/L. The boron concentration from the mixed overburden and gypsum material at KAN4 (0.516 mg/L) is slightly elevated above the LCT0 guideline value of 0.5 mg/L. All elements comply with the LCT1 guideline values.

Based on the leach and total concentration test results the material that will be handled on site is classified as Type 3.

Both the overburden and gypsum from borehole KAN2 have a Neutralising Potential Ratio (NPR) of slightly greater than 1. This coupled with a total sulphur percentage of 0.75 to 1.06 % shows that it is possible that the material will be acid generating.

The mixed overburden and gypsum from borehole KAN4 show a NPR ratio of less than 1. Coupled with a sulphur percentage of 5.34 % and a Net Neutralising Potential (NNP) of -100 it is likely that this material will be acid producing.

Hydrogeology

Three aquifers occur in the area. These three aquifers are associated with a) the upper weathered material and gypsum layer, b) the underlying competent and fractured rock material, and c) the alluvial sand in the river channels.

Upper weathered material aquifer

The upper weathered material aquifer forms due to the vertical infiltration of recharging rainfall through the weathered material and the gypsum layer being retarded by the lower permeability of the underlying competent rock material. The aquifer thickness ranges between 16 and 20 m.

Recharge is 0.03 % of the mean annual precipitation (MAP).

Typical transmissivity values for this aquifer range between 0.1 and 5 m^2/day.

The borehole yields in this aquifer are seasonally variable due to the strong dependence on rainfall recharge. Generally, it can be said that the yields of this aquifer during the rainy season can be around 1 L/s while sustainable yields will decrease markedly during the dry season. In some areas this aquifer will be laid completely dry during the dry season.

Lower fractured rock aquifer

Groundwater flows in the lower fractured rock aquifer are associated with the secondary fracturing in the competent rock and as such will be along discrete pathways associated with the fractures. Faults and fractures in the host geology can be a significant source of groundwater depending on whether the fractures have been filled with secondary mineralisation.

Alluvial aquifer associated with the stream beds

Alluvial sand has accumulated in the river beds over time as low energy stream flows deposited transported material. During rainfall events when the streams flow surface water recharge into the alluvial sand that line the river channels. This water can be pumped from the sands during times when the rivers are not actively flowing. Yields from this aquifer can be relatively high due to the sandy nature of the aquifer material. However, once the sand is dewatered the groundwater users will have to wait until after the next significant rainfall event before water can be abstracted again.

<u>Aquifer hydraulic conductivity</u>

The hydraulic conductivity of gypsum ranges between 3.5 x 10^{-8} and 2 x 10^{-3} m/day. The weathered, clayey, mudstone and siltstone that underlies the gypsum has a hydraulic conductivity in the range of 0.001 to 10 m/day.

<u>Groundwater levels</u>

Depth to groundwater level ranges between 9.45 and 12.87 metres below ground level (mbgl).

Groundwater potential contaminants

The surface trench area, temporary plant feed stockpile (that moves with the active mine / surface trench area) and waste stockpile (also of a temporary nature, as screened out material is backfilled into mined-out trenches) act as potential sources of contamination to the aquifers. It is assumed that good housekeeping such as storage of potentially hazardous material will be within properly constructed and lined or paved areas. Oil traps will be sized, operated and maintained to contain all discarded oil from working areas etc.

Leach testing results can be used to determine the potential source concentrations. The leach test results show that in general sulphate can be expected to be present in concentrations of 800 to 1 400 mg/L, which exceed the LCT0 guideline value of 250 mg/L. Leach test analysis results from the Borehole KAN4 overburden and gypsum mixture show that boron, could also be present in slightly elevated concentrations (0.516 mg/L compared to the LCT0 value of 0.5 mg/L).

Groundwater quality

In general sodium, chloride, and sulphate concentrations exceed the SANS241:2015 drinking water guidelines. Borehole KH09 also shows a fluoride concentration that at 2.5 mg/L exceeds the SANS241:2015 guideline of 1.5 mg/L somewhat. Tasting water on site showed that the groundwater in the area has a naturally brackish taste, which is confirmed by the chemical analysis results showing elevated sodium and chloride concentrations.

The chloride concentrations ranged between 1 576 and 2 649 mg/L. At chloride concentrations greater than 1 200 mg/L the water has an unacceptably salty taste. Nausea and disturbance of the electrolyte balance can occur, especially in infants, where fatalities due to dehydration may occur.

The sodium concentration range between 700 and 1 272 mg/L. At sodium concentrations between 600 and 1 000 mg/L water has a very salty taste. Health effects may be expected and the water is very undesirable for infants or persons on a sodium restricted diet. At concentrations between 1 000 and 5 000 mg/L the water has an extremely salty taste becoming bitter. Severe health effects with disturbance of the electrolyte balance can occur. The water is extremely undesirable for infants of persons on a sodium restricted diet.

With a range of 512 to 984 mg/L the sulphate concentrations in all four boreholes exceed the SANS241:2015 guideline value of 500 mg/L for health impacts. At sulphate concentrations between 400 and 600 mg/L diarrhoea is expected for most non-adapted individuals and the water has a definite salty or bitter taste. At concentrations ranging between 500 and 1 000 mg/L diarrhoea is expected for most individuals and user adaptation does not occur. The water has a pronounced salty or bitter taste.

The water has a sodium – chloride dominant character.

Aquifer characterisation

For aquifer vulnerability reference is made to the aquifer vulnerability map of South Africa which shows a low aquifer vulnerability for the study area.

The aquifers present in the area are classified as minor aquifers, but of high importance to the local landowners as it is their sole source of water for domestic and stock watering purposes.

Groundwater impact assessment

Construction phase

Groundwater inflow volumes into the excavations

During excavation of the trenches the groundwater level will not be breached and therefore no notable inflows into the trench are expected. This is based on:

- Groundwater levels in the area are more than 8 m deep;
- During the drilling program, which was undertaken during the rainy season when groundwater levels can be expected to be shallower, no groundwater strikes were intercepted at depths shallower than 20 m;

It is possible that there could be some localised seepages into the excavation, however, based on the low rainfall (133 mm/a), low recharge percentage (0.03 % of MAP), and the low hydraulic conductivity of the gypsum (3.5 x 10^{-8} to 2 x 10^{-3} m/day) such inflows are expected to be very low, less than 50 m^3/day.

Groundwater level drawdown

The groundwater level will not be breached and dewatering of the trench will not be required. Therefore, there will be no impact on the groundwater levels or surface streams in the area.

Surface construction of the temporary plant feed stockpile, the crushing and screening plant, offices and haul roads will not breach the groundwater level and is therefore not expected to have any impact on the groundwater levels.

Groundwater contamination

It is assumed that with proper maintenance of construction vehicles and other construction related best practices there will be a limited impact on the groundwater quality from the construction of the surface infrastructure.

During the construction phase little to no product will be deposited on the product stockpile, and therefore the product stockpile does not form a risk to the underlying aquifers during the construction phase.

The temporary plant feed stockpile will receive material from the trenches. However, the material will be dry due to the fact that the groundwater level lies below the level of the excavation and therefore the material will be deposited dry on the temporary plant-feed-stockpile. Taking into consideration the very low rainfall in the area (133 mm/a), and the short time span of the construction phase it is not expected that there will be notable seepage from the temporary plant feed stockpiles to the underlying aquifers during the construction phase.

Operational phase

Groundwater level changes and the zone of influence

The depth of the trench excavations will range between 1.4 and 2.5 m. Depth to groundwater level in the area is more than 8 m. The groundwater level will not be breached and no dewatering of the trench will be required. Therefore, there will be no drawdown in groundwater level, and no associated impact on the aquifers, wetlands, and stream flow volumes.

Groundwater inflows into the trench

During excavation of the trench the groundwater level will not be breached and no regional or continuous groundwater inflows into the trench are expected.

It is possible that there could be some localised seepages into the excavation, however, based on the low rainfall (133 mm/a), low recharge percentage (0.03 % of MAP), and the low hydraulic conductivity of the gypsum (3.5 x 10^{-8} to 2 x 10^{-3} m/day) such inflows are expected to be very low, less than 50 m^3/day.

Groundwater contamination

It is assumed that with proper maintenance of mining vehicles and other operations related best practices there will be a limited impact on the groundwater quality from general surface activities.

The temporary plant feed stockpile will move alongside the active trenching area. The waste generated during the crushing and screening process is expected to be approximately 24 % by volume of material mined. This waste material will then be used to rehabilitate the trench.

The waste that will be used to rehabilitate the trench area can potentially be Acid Mine Drainage (AMD) forming. Rainfall recharge into the rehabilitated material can lead to water accumulating in the rehabilitated pit area and the perched water level can lead to contaminant migration away from the rehabilitated area.

The life of mine is expected to be in excess of 30 years. It is calculated that should contamination start to migrate away from the rehabilitated area at day one of operations, contamination will migrate a maximum of 100 m from the rehabilitated area during the operations phase of the Mine. In reality, this migration is expected to be less based on:

- There will be a time delay between when the first trench is excavated and when the rehabilitation will start;
- The low rainfall in the area (133 mm/a) will mean that water will not accumulate from day one in the rehabilitated area and therefore there will not be a driving head from day one;
- There will be a time delay between trenching and when sufficient chemical reaction has taken place to oxidise the material which could lead to AMD conditions to form;
- There will be a time delay between the rainwater accumulating in the rehabilitated material and sufficient leaching from the backfill material can take place to impact the water quality significantly.

The plume migrating down gradient away from the trench area will impact on the upper reaches of the unnamed, non-perennial tributary to the Doringrivier. In total approximately 550 m of the length of the stream falls within the zone of influence of the migrating plume by the end of the life of mine. This equates to less than 1 % of the total length of the stream network that constitutes the tributary.

The maximum expected salt load contribution to the stream is calculated to be 1.3 kg/day. This contribution will be for only a very short period of time, and will only occur after prolonged rainfall events where continuous recharge from rainfall can increase the groundwater level to near surface so that the groundwater can contribute to the stream flow volume through baseflow contribution. It is expected that this will not be a regular or even yearly occurrence due to the low rainfall in the area. In addition, any baseflow contribution to the stream will be diluted by surface runoff caused by the rainfall as the non-perennial stream will receive the majority of its flow volume from surface runoff during rainfall events.

The total impact on the stream water qualities is expected to be intermittent and negligible due to the combined effect of:

- The stream flow is non-perennial and the stream will mostly only flow during and shortly after rainfall events when surface sheet flow / runoff contributes the vast majority of the stream flows;
- Prolonged and significant rainfall events are required to raise the groundwater level to near surface so that the aquifer can contribute poor quality seepage to the stream in the form of baseflow contribution;
- The impacts length of the stream is less than 1 % of the total length of streams that constitutes the tributary;

No privately owned and used groundwater supply boreholes are impacted.

The product stockpile will continuously be removed when the product is sold and transported off site. Rainfall in the area is low and intermittent and it is not expected that there will be significant seepage from the product stockpile towards the underlying aquifers. Therefore, the impact on the groundwater quality and surrounding environment from the product stockpile is expected to be low.

Decommissioning phase

Groundwater level recovery

Because there were no impacts on the groundwater level during the operational phase, there is no recovery of groundwater levels.

Contaminant migration

Contaminant migration similar to the operational phase will continue. Surface pollution sources will be removed; therefore, the plume concentrations can start to decrease. However, the decommissioning phase is expected to the short duration, therefore there will not be a notable change in contamination during this phase.

Long term post-closure phase

Recovery of groundwater levels

Because there were no impacts on the groundwater level during the operational phase, there is no recovery of groundwater levels.

Decant potential

The topographical elevation within the trench area ranges between 334 and 360 mamsl. With the trench being between 1.4 and 2.5 m deep, it is possible that decant can take place when the water level in the rehabilitated area rises due to rainfall recharge and a portion of the trench area is submerged to 334 m elevation.

However, using the hydraulic conductivity of the soil underlying the trench it is calculated that the rate of seepage into the underlying weathered material will exceed the rate of recharge into the rehabilitated material and therefore it is not expected that decant will take place.

Contamination migration

Contaminant migration away from the rehabilitated trench will continue in the post-mining environment. Natural attenuation through dilution with uncontaminated groundwater and recharging rainfall will mitigate the developing contaminant plume. Calculations show that the contaminant plume will migrate up to 250 m from the edge of the trench in a down gradient direction.

The upper reaches of the unnamed, non-perennial tributary to the Doringrivier will be impacted by the developing contaminant plume. The plume migrating down gradient away from the trench area will impact on the upper reaches of the unnamed, non-perennial tributary to the Doringrivier. In total, approximately 850 m of the length of the stream falls within the zone of influence of the migrating plume by 100 years after the end of the life of mine. This equates to less than 1 % of the total length of the stream network that constitutes the tributary.

The maximum expected salt load contribution to the stream is calculated to be 1.6 kg/day. This contribution will be for only a very short period of time, and will only occur after prolonged rainfall events where continuous recharge from rainfall can increase the groundwater level to near surface so that the groundwater can contribute to the stream flow volume through baseflow contribution. It is expected that this will not be a regular or even yearly occurrence due to the low rainfall in the area. In addition, any baseflow contribution to the stream will be diluted by surface runoff caused by the rainfall as the non-perennial stream will receive the majority of its flow volume from surface runoff during rainfall events.

The total impact on the stream water qualities is expected to be intermittent and negligible due to the combined effect of:

- The stream flow is non-perennial and the stream will mostly only flow during and shortly after rainfall events when surface sheet flow / runoff contributes the vast majority of the stream flows;
- Prolonged and significant rainfall events are required to raise the groundwater level to near surface so that the aquifer can contribute poor quality seepage to the stream in the form of baseflow contribution;
- The impacts length of the stream is less than 1 % of the total length of streams that constitutes the tributary.

No privately owned and used groundwater supply boreholes are impacted.

Mitigating and management measures to be included in the EMP and IWULA

Monitoring program

A water monitoring program that incorporates the proposed operations, with focus on the possible sources of impact, has to be implemented. These sources of impacts include the trench area as well as proposed surface areas including the stockpiles.

It is recommended that the monitoring program start with a monthly interval for the first year. Ideally, the monitoring program should start a year before mining starts in order to be able to build a database that is not impacted by the mining activities.

Once the monthly database is established the monitoring frequency can change to quarterly.

Parameters and elements to be monitored for should comply with the mine Water Use License, and also correspond to the parameters suitable to monitor mining activities. Recommended parameters and elements are summarised below:

- General chemistry such as pH, Total Dissolved Solids (TDS) and Electrical Conductivity (EC);
- Major elements such as calcium, magnesium, sodium, potassium, sulphate, nitrate, fluoride, chloride, phosphate;
- An Inductively Coupled Plasma (ICP) scan of minor elements including aluminium, arsenic, barium, boron, bismuth, cadmium, copper, chrome (total), cyanide, iron, manganese, mercury, molybdenum, nickel, lead, antimony, selenium, vanadium and zinc.

The monitoring program should include:

- The groundwater monitoring boreholes drilled during this study: KAN1 to KAN4; and
- Hydrocensus points which lie close to the zones of impact and could possibly be at risk: KH01 and KH04.

Remediation of the physical activity

The trench area will be rehabilitated continuously during the life of mine. The waste material produced during the crushing and screening process will be used to backfill the trench area.

The stockpile areas will be remediated concurrently with mining as Run of Mine will be fed to the processing plant and screened-out waste material will be backfilled to the excavations continuously. Final product stockpiles as well as the offices will be remediated during the decommissioning phase.

Remediation of storage facilities

Surface storage facilities will be cleared and remediated.

Remediation of environmental impacts

It will be impossible to prevent and rehabilitate the impacts of contaminant migration away from all the pollution sources (trench and stockpiles). Therefore, it is recommended that the groundwater monitoring program be continued for a period of at least 5 years after mine closure to monitor the contaminant migration. Based on these results remediation requirements can be identified and a remediation plan put in place.

Remediation of water resources impacts

The contaminant migration calculation results show that it is possible that there will be a slight impact on the surface water courses in the area. In addition, the geochemical assessment show that the material handled on site can be expected to potentially form AMD conditions.

Therefore, it is recommended that the streams be monitored during the times that the streams do flow and management systems be put in place. This could include cut-off trenches down gradient of the pollution sources and management of the seepage.

Reasoned professional opinion

It is recommended that the project be authorized. This recommendation is based on:

- The impact assessment shows that there will be no impact on the groundwater levels in the area. No privately owned boreholes will be impacted in terms of groundwater level;
- Contaminant migration away from the trench does not impact on private groundwater users;
- The impact on the stream water quality is expected to be limited.

Conditions for authorisation

There are no conditions for authorisation, except commitment to optimal management and monitoring of the expected impacts as described in Sections 9 and 10 of this report.

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LIST OF ACRONYMS

Acronym	Description
AMD	Acid Mine Drainage
ARD	Acid Rock Drainage
DMR	Department of Mineral Resources
DWS	Department of Water Affairs and Sanitation
EIA	Environmental Impact Assessment
EMP	Environmental Management Program
ha	Hectare
IWUL	Integrated Water Use Licence
IWULA	Integrated Water Use Licence Application
IWWMP	Integrated Water and Waste Management Plan
Kg/day	Kilogram per day
L/s	Litres per second
LCT	Leachate concentration threshold
LCT0	Lowest concentration for human health effects for Drinking Water in South Africa (Regulation 635)
LOM	Life of mine
m	Metre
m/day	Metre per day
m^3/day	Cubic metre per day
mamsl	Metres above mean sea level
MAP	Mean Annual precipitation
mbgl	metres below ground level
mg/L	Milligram per litre
mm/a	Millimetres per annum
MPRDA	Mineral and Petroleum Resources Development Act (Act 28 of 2002) as amended
NEM:WA	National Environmental Management: Waste Act (Act 39 of 2004) as amended
NEMA	National Enviromental Management Act (act 107 of 1998) as amended
PCD	Pollution Control Dam
ROM	Run of Mine
SWD	Storm Water Dam
TCT	Total Concentration Threshold
TCT0	Total concentration threshold to protect water resources (Regulation 635)
TCT1	Total concentration threshold remediation values for commercial / industrial land (Regulation 635)
WMA	Water Management Area
WRD	Waste Rock Dump

1. Introduction

1.1. Background introduction

Future Flow GPMS cc was contracted by Cabanga Environmental to conduct a geohydrological investigation for the proposed Kanakies Gypsum Mine. The Applicant proposes to trench-mine gypsum 90 km northwest of the town of Calvinia, Northern Cape Province of South Africa.

The deposit consists of 2 layers of gypsum i.e. a powder layer of approximate thickness 0.4 meter, which lies approximately 0.2 to 0.7 meter under the surface, followed by a nodular crystalline layer of gypsum of approximate thickness 0.9 to 1.3 meter. Total depth of trenching below surface ranges between 1.4 and 2.5 m.

Mining will be via trench mining, i.e. a trench of 100 meters by 50 m will be trenched where the gypsum will be removed. The trench will be rehabilitated immediately using the overburden and discarded carrier clays after it has been screened over the mobile high frequency screen.

A total mining area of ±800 ha is planned.

Surface infrastructure and operations include:

- Processing equipment consisting of a mobile crushing and high frequency screening plant will occupy a small area of less than 0.6 ha;
- A small shipping container type office block and ablution facility will occupy approximately 0.2 ha whilst a high roof shed will add 0.3 ha;
- A vehicle parking area and fuel storage area will occupy another 0.3 ha in total;
- A Stockpile area of 2.1 ha to store 8 000 to 10 000 ton of finished product and another small moving stockpile area of 0.5 ha to store 2000 ton of run of mine within a mine block (the temporary plant feed stockpile);
- A total of approximately 5 ha of dirt road will be established to access the above site and mine areas (10 km by 5 m wide); and
- No new servitudes will be registered.

Desktop studies and a site-specific baseline assessment including hydrocensus, drilling of groundwater boreholes, groundwater chemical analysis, and a geochemical analysis of the material that will be mined were used to characterise the baseline groundwater environment and develop a conceptual groundwater flow and contaminant transport model of the study area.

Due to the fact that the proposed development will not breach the groundwater level in the area and will not impact on the groundwater flow patterns no 3D groundwater flow modelling was done. The geochemical analysis show that Acid Mine Drainage (AMD) conditions can be expected to form and some elements including sulphate will be present in concentrations higher than that already present in the natural groundwater that occur on site. The contaminant migration assessment was done using analytical calculations. The groundwater impact assessment was based on the conceptual groundwater flow and contaminant transport model.

1.2. Potential impacts

As discussed above, the excavations will not breach the groundwater level. Therefore, there will be no impact on the groundwater flow patterns due to the trenching activities.

The geochemical assessment shows that AMD conditions and the associate elevated salt concentrations can have some impact on the groundwater qualities. The impacts on the groundwater qualities can extend to the surface water qualities in the event that sufficient rainfall occurs to raise the groundwater levels to near surface to enable poor quality leachate to enter the stream in the form of baseflow contribution.

1.3. Aim of the investigation

The aim of the groundwater investigation is twofold:

The first phase of the study focuses on characterising the current baseline groundwater environment. This includes aspects such as:

- Identification of existing groundwater users in the area;
- Identification and characterisation of the aquifers present in the area;
- Aspects that control groundwater flow through the area (geological structures etc.)
- Groundwater flow patterns;
- Recharge from rainfall;
- Predevelopment groundwater quality; and
- Surface water / groundwater interaction.

The second phase of the study involves a characterisation and quantification of the expected impacts on the surrounding groundwater environment due to the proposed mining activities.

1.4. Timing of the investigation

The field investigation was performed during May to June 2018, and in particular within days following good rainfall in the region that flooded shallow stream courses and caused ponding of water on surface. As such, the field investigation was performed during the rainy season, as the study area falls within a winter rainfall climatic area. This has some implications:

- The groundwater levels that were measured are expected to be representative of the wet season. This means that measured groundwater levels are expected to be relatively shallow; and
- The groundwater qualities are expected to be representative of the rainy season with added implication of improved groundwater qualities due to recent recharge from rainfall.

1.5. Specialist expertise

Future Flow GPMS is a privately held consulting company based in Pretoria, South Africa that has been in operation since 2008. We provide specialist groundwater consulting services. Our clients range from mining companies and energy suppliers to private developers operating throughout Africa.

Key staff allocated to this project includes:

Martiens Prinsloo: Martiens is a principal hydrogeologist at Future flow GPMS cc, and holds an MSc degree in hydrogeology from the University of the Free State, South Africa. Martiens has more than 18 years' experience in water management studies and environmental impact assessments and has been involved in more than 200 groundwater studies during the past decade. Martiens is responsible for data analysis, the conceptual model, the impact assessment and reporting.

His CV can be viewed in Appendix H.

1.6. Declaration of independence

We, Future Flow Groundwater & Project Management Solutions cc, act as the independent specialists in the environmental impact assessment processes for the Kanakies Gypsum Mine Project. We performed the work relating to the environmental authorisation applications in an objective manner, even if this results in views and findings that are not favourable to the applicant.

We declare that there are no circumstances that may compromise our objectivity in performing such work. We have expertise in conducting the groundwater specialist study and report relevant to the environmental authorisation applications. We confirm that we have knowledge of the relevant environmental Acts, Regulations and Guidelines that have relevance to the proposed activity and my/our field of expertise and will comply with the requirements therein.

We have no, and will not engage in, conflicting interests in the undertaking of the activity.

We undertake to disclose to the applicant and the competent authority all material information in our possession that reasonably has, or may have, the potential of influencing any decision to be taken with respect to the application.

All particulars furnished by me/us in this report are true and correct. We realise that a false declaration is an offence in terms of regulation 48 of the National Environmental Management Act, 107 of 1998 (NEMA) and is punishable in terms of Section 24F of the Act.

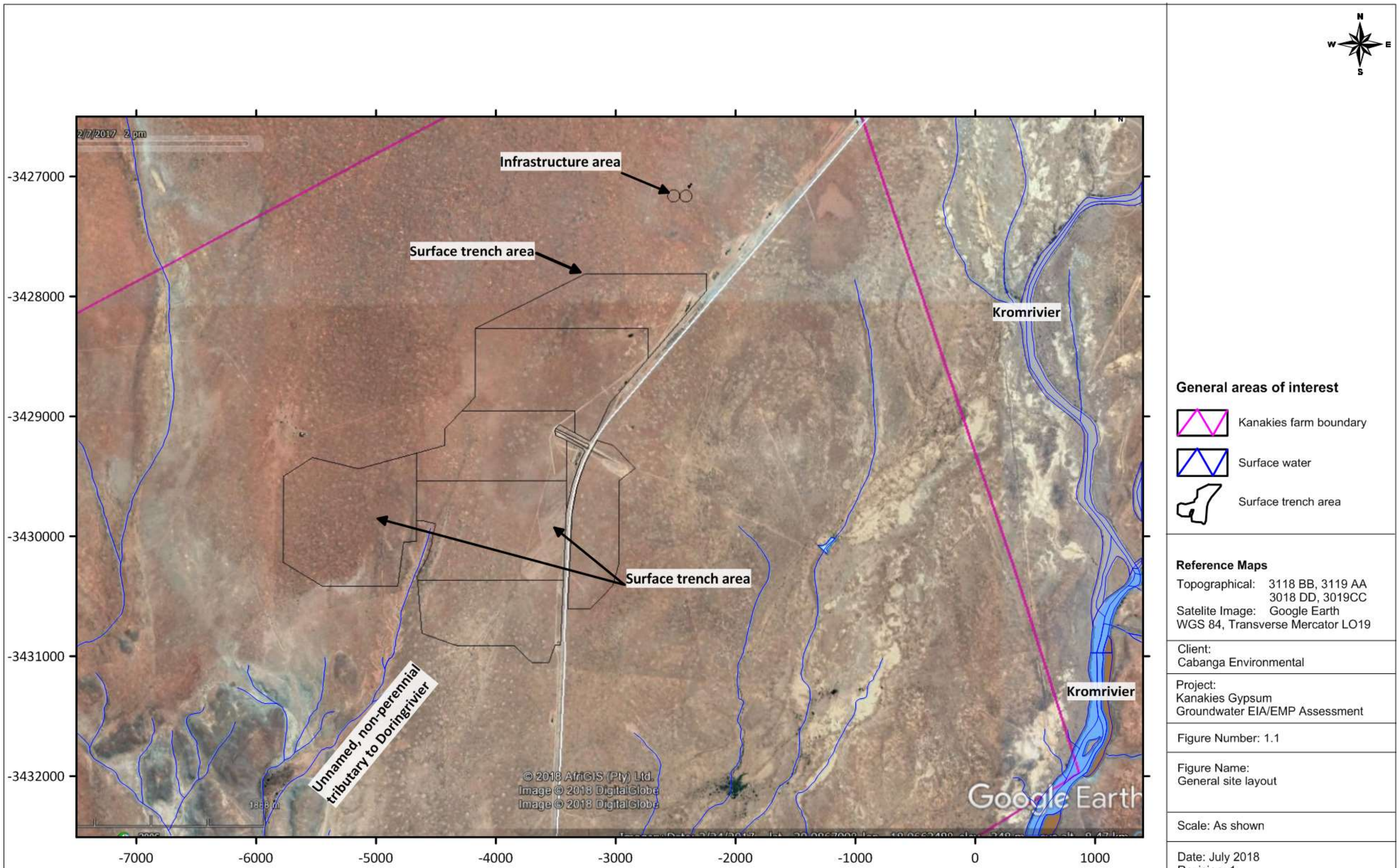
____2018/07/25____

Signed Date

1.7. Consultation process

The consultation process included:

- Discussion with the client: The client has a working relationship with the surrounding land owners who are in regular contact with the Applicant.
- Concerns raised during the hydrocensus and drilling program where groundwater boreholes were visited:
    - Concerns regarding impacts on the groundwater supply volume and quality due to the proposed trenching activities.



Reference Maps
Topographical: 3118 BB, 3119 AA
3018 DD, 3019CC
Satelite Image: Google Earth
WGS 84, Transverse Mercator LO19

Client:
Cabanga Environmental

Project:
Kanakies Gypsum
Groundwater EIA/EMP Assessment

Figure Number: 1.1

Figure Name:
General site layout

Scale: As shown

Date: July 2018
Revision: 1

Designed: MP
Approved:

Future Flow
705 Petrus Street, Rietvalleirand, Pretoria, 0181
Postnet Suite 71, Private Bag X8, Elarduspark, 0047
Pretoria, South Africa

2. Geographical setting

2.1. Topography and drainage

The proposed Mining area falls within one sub-catchment (E33A). The regional topography is best described as relatively flat and locally slopes towards the streams that drain the region. South of the proposed Mining area a non-perennial tributary to the Doringrivier drains the area. Approximately 3 to 4 km east of the proposed Mining area the North / South draining Kromrivier drains the area.

Within the proposed Mining area itself the topography slopes from the north to the south. Topographical gradients are calculated to be in the order of 1:80 to 1:100.

Site specific topographical elevations range between 360 metres above mean sea level (mamsl) in the north to 330 mamsl in the south.

In terms of surface water drainage systems the surface infrastructure and the trench areas fall within the E33A quaternary catchment as delineated by the Department of Water and Sanitation (DWS). Quaternary catchment E33A forms part of the Knersvlakte and ultimately the Berg Olifants Water Management Area (WMA).

2.2. Climate

A description of the climate of the study area is taken from the project scoping report.

The area is characterised by typical semi-arid conditions with warm summers, and cold winters. Temperature fluctuations vary from 35˚C in Summer to sub-zero temperatures in Winter (Hantam Local Municipality, 2015/2016).

According to the Water resources of South Africa, 2005 Study (WR2005) (Middleton & Bailey, 2005), the mean annual precipitation (MAP) for the project area is estimated at 133 mm per annum whilst the mean annual evaporation (MAE) is 1 760 mm (lake evaporation) resulting in a negative climatic water balance for the area.

3. Scope of work

The scope of work includes:

- Phase 1 - Project initiation:
  - Collect and evaluate all available data including site specific information supplied by the Applicant. This included reports on the mine works program, the trench progression plan, previous groundwater and EMP / EIA studies done in the area, and the geological model. Also included in the desk study is the collection of public domain information (geological and other maps). The data was analysed to compile a provisional conceptual groundwater model including:
    - Aquifers present;
    - Surface water / groundwater interaction;
    - Recharge from rainfall;
    - Depth to groundwater; and
    - Groundwater quality;
  - An initial site visit to view the site.
- Phase 2 – Baseline characterisation:
  - Hydrocensus of the study area to collect data on the current groundwater use (type and volume), depth to groundwater level, and other relevant information;
  - Drilling of groundwater boreholes: This entailed drilling of groundwater boreholes during which important information on the baseline groundwater conditions (depth to groundwater level, groundwater strike depth and yields, presence of structures etc.) was collected. The boreholes were drilled to 20 m depth. This is considered sufficient to monitor any impact on groundwater levels and qualities as the trench excavations will only be between 1.4 and 2.5 m deep. The boreholes were dry during the time of drilling, but still serve as long-term groundwater monitoring boreholes around the operational areas where increased recharge into the rehabilitated material can lead to an accumulation of water and a resulting driving head of poor quality seepage away from the trench area;
  - Laboratory testing of groundwater samples obtained from hydrocensus points to characterise the pre-development groundwater quality; and
  - Geochemical testing of the material that will be handled on site. This allows characterisation of the waste streams (overburden and gypsum) in accordance with Regulations 634, 635, and 636 as well as SANS 10234. The leach test results are also used to determine the long term quality of leachate seeping from the rehabilitated trench areas and surface stockpiles into the underlying aquifers and possibly eventually the surface water bodies.
- Phase 3 - Groundwater inflow and impact assessment:
  - Calculation of groundwater inflow volumes into the trench area over the life of mine;
  - Calculation of drawdown in groundwater levels around the trench area due to dewatering and the associated impacts on surrounding groundwater users;
  - Impacts on surface water bodies due to reduced baseflow contribution due to dewatering;

- Calculation of the extent of the contaminant plume and the potential impacts on surrounding aquifers as well as nearby surface water bodies.
- Phase 4 - Reporting:
  - The findings of the study are discussed in detail in this Report.

4. Methodology

4.1. Desk study

Maps relevant to the study area include:

- 1:50 000 scale topographical maps (3118BB, 3118DD, 3119AA, and 3119CC);
- Satellite image of the area (Google Earth);
- Surface layouts provided by the client; and
- Other published data on the study area.

4.2. Hydrocensus

A hydrocensus was undertaken in the project area. In total 16 privately owned groundwater points were located in the field (please refer to Figure 5.3 for the positions). In addition to this are the four groundwater monitoring boreholes drilled as part of this study.

Information gathered at these points included field coordinates, elevation, static groundwater level (SWL), groundwater use and type and any other information that was available.

4.3. Drilling and siting of monitoring boreholes

Four groundwater monitoring boreholes were drilled to act as long-term groundwater level and quality monitoring points (please refer to Figure 5.3 for the borehole positions). During the drilling program geological and hydrogeological information was collected. The collected data include:

- Lithology;
- Fracturing, geological contacts; and
- Groundwater strike depths and yields.

These drilled boreholes include KAN1 to KAN4. Boreholes KAN1, KAN2 and KAN4 were installed around the trench area, while KAN3 was installed down gradient of the proposed surface stockpile areas. The geological logs are supplied in Appendix B.

4.4. Aquifer testing

Monitoring boreholes KAN1 to KAN4 were dry and therefore no aquifer tests could be conducted on the monitoring boreholes.

4.5. Sampling and chemical analysis

A total of four groundwater samples were taken from hydrocensus boreholes around the project area and submitted to an ISO17025 / SANAS accredited laboratory for chemical analysis.

4.6. Groundwater recharge calculations

Groundwater recharge calculations are based on the total area of the sub-catchments covered by the proposed mining activities. Reference is made to the recharge values specified in the Groundwater Resource Assessment II – Task 3aE Recharge report (Department: Water Affairs and Forestry, 2006). An average recharge percentage of 0.03 % of the mean annual precipitation (MAP) is used in the resource calculation.

4.7. Groundwater modelling

Due to the fact that the proposed development will not breach the groundwater level in the area and will not impact on the groundwater flow patterns no 3D groundwater flow modelling was done.

The geochemical analysis show that Acid Mine Drainage (AMD) conditions can be expected to form and some elements including sulphate will be present in concentrations higher than that already present in the natural groundwater that occur on site. The contaminant migration assessment was done using analytical calculations. The groundwater impact assessment was based on the conceptual groundwater flow and contaminant transport model.

4.8. Groundwater availability assessment

The groundwater availability was assessed at the hand of:

- The geology encountered in the area, and the general groundwater potential associated with the lithologies;
- The results from the hydrocensus (borehole yields and groundwater use volumes and types).

Based on the results from the assessment it is concluded that groundwater is available from deeper aquifers present in the area. Personal communication with local landowners shows that groundwater strikes are encountered at depths greater than 80 m during drilling. The general yields of the aquifer are relatively low (less than 1 L/s). Only one borehole is reportedly relatively high yielding. However, the yield of this reportedly higher yielding borehole is not known.

5. Prevailing groundwater conditions

5.1. Geology

The description of the regional and site specific geological conditions on site are taken from the project Mining Works Program (Witkop Fluorspar Mine (Pty) Ltd, 09 March 2018).

5.1.1. Regional geology

The site is underlain by quaternary alluvium comprising calcareous and gypsiferous soils, followed by quaternary gravel, silt and sand. These formations unconformably overlie the Besonderheid Formation of the Knersvlakte Subgroup, Vanrhynsdorp Group in the study area. The Besonderheid Formation comprises of green shale, siltstone, sandstone, gritstone and conglomerates, interbedded with shale, limestone and chert in the south east. It is believed that the ancient Doringrivier and its tributaries eroded the Besonderheid Formation and may have accumulated gypsiferous sediments in the paleochannels and topographic low points within the study area.

5.1.2. Site specific geology

The gypsum deposit covers approximately 700 hectares and is situated on a large flat lying sandy terrace at the north-eastern end of the Knersvlakte, close to the confluence of the Kromrivier and Doringrivier. The gypsum layer is between 1.3 and 1.7 meter thick and is covered with a layer of sandy soil of 0.3 to 0.7 meter thick. The main contaminant in the gypsum layer is silica sand mixed with clay.

The deposit can be divided into two generally horizontal overlapping seams of gypsum, namely:

- A 0.4 m thick seam of gypsum powder occurring in the southern portion of the deposit and overlying; and
- Another 0.9 m to 1.3 m thick main gypsum seam, which occurs throughout the entire deposit, but which decreases in quality with increasing depth.

A typical geological log is shown in Figure 5.1.

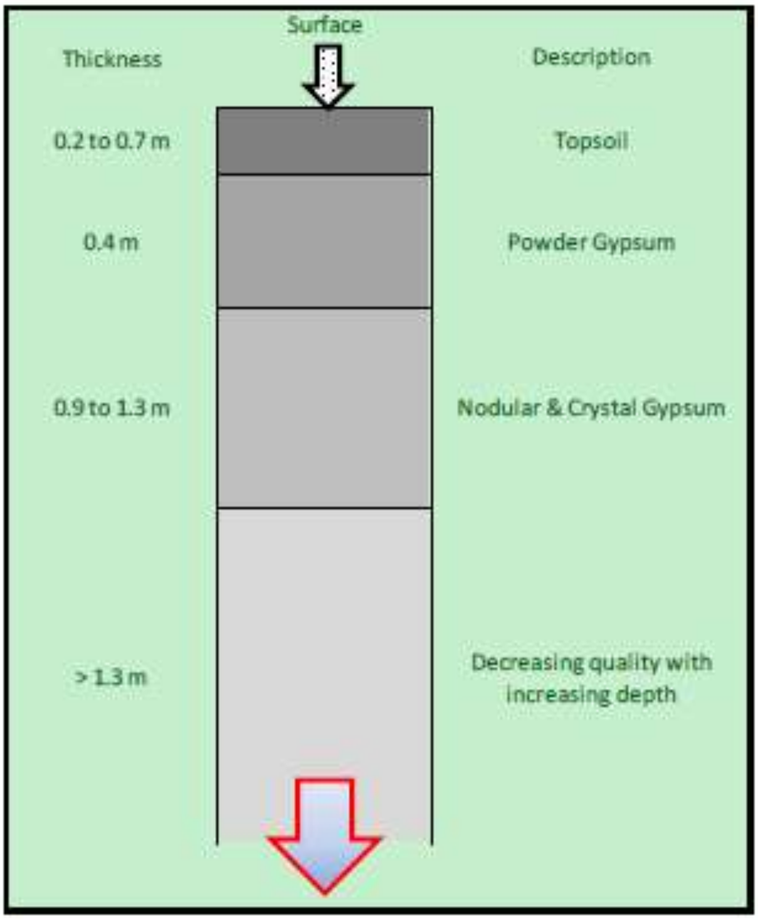


Figure 5.1: Typical Kanakies geological log (taken from the project Mine Workings Program)

5.2. Geochemical analyses

Representative samples from the lithologies typically found on site were collected from the drill chips obtained during the drilling of the four groundwater monitoring boreholes. The samples represent the overburden as well as the gypsum that will be trenched. A total of three representative samples were collected and submitted to a laboratory for analysis. A summary of the samples is shown in Table 5.1.

The testing that was done on the material complies with the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008) Waste Classification Regulations. These regulations include:

- Regulation 634 do: NEM:WA: Waste Classification and Management Regulations;
- Regulation 635 do.: National Norms and Standards for the assessment of waste for landfill disposal;
- Regulation 636 do.: National norms and Standards for disposal of waste to landfill.

Based on the above listed regulations, the following tests were performed on the material:

- Total concentration testing;

- Leach concentration testing using distilled water.

In addition to the above Acid-Base-Accounting testing was also done on the samples to determine what material is expected to form acid mine drainage conditions.

Table 5.1: Sample description – Waste classification & acid-base-accounting testing

Sample ID	Lithology
KAN2 OVBN	Weathered overburden soil.
KAN2 Calc	Gypsum
KAN4	Combined overburden and gypsum

5.2.1. Waste classification testing following Regulation 635

Waste classification testing performed on the material samples described in Table 5.1 provides an indication of the total concentration and the expected leach quality of seepage from the material handled on site based on the guidelines provided in Regulation 635. The material was subjected to distilled water leach tests based on the fact that the material is non-putrescible, and it is not expected that any other wastes will be co-disposed.

5.2.1.1. Total concentration test results

The total concentration analysis results summarised in Table 5.2 show that barium and fluoride can be expected to generally exceed the TCT0 guideline values. The TCT0 guideline values are protective of water resources. The copper concentration at borehole KAN2 is elevated in both the overburden (30 mg/kg) and the gypsum material (23 mg/kg) compared to the TCT0 guideline value of 16 mg/kg. Arsenic at a concentration of 6 mg/kg slightly exceeds the TCT0 guideline value of 5.8 mg/kg at KAN4.

All parameters comply with the TCT1 guideline values. The TCT1 values are derived from the land remediation values for commercial / industrial land.

5.2.1.2. Leachable concentration test results using reagent water

The leach concentration test results are available in Table 5.3. From the table it can be seen that generally the sulphate concentrations exceed the LCT0 guideline value of 250 mg/L. The measured sulphate concentration in the overburden material (soil) is measured at 826 mg/L while the sulphate concentration in the gypsum material measures around 1 400 mg/L.

The boron concentration from the mixed overburden and gypsum material at KAN4 (0.516 mg/L) is slightly elevated above the LCT0 guideline value of 0.5 mg/L.

All elements comply with the LCT1 guideline values.

5.2.1.3. Classification based on TC and LC analyses

The waste classification as defined in GN 635 (Section 7) are summarised as:

- Wastes with any element or chemical substance concentration above LCT3 or TCT2 limits (LC>LCT3 or TC>TCT2) are Type 0 Wastes;
- Wastes with any element or chemical substance concentration above the LCT2 but below or equal to the LCT3 limits, or above the TCT1 but below or equal to the TCT2 limits (LCT2<LC<LCT3 or TCT1<TC<TCT2), are Type 1 Wastes;
- Wastes with any element or chemical substance concentration above the LCT1 but below or equal to the LCT2 limits, and all concentrations below or equal to the TCT1 limits (LCT1<LC<LCT2 or TC<TCT1), are Type 2 Wastes;
- Wastes with any element or chemical substance concentration above the LCT0 but below or equal to the LCT1 limits, and all concentrations below or equal to the TCT1 limits (LCT0<LC<LCT1 or TC<TCT1), are Type 3 Wastes; or
- Wastes with all elements and chemical substance concentration levels for metal ions and inorganic anions below or equal to the LCT0 and TCT0 limits (LC≤LCT0 and TC≤TCT0), and with all chemical substance concentration levels also below the relevant concentration limits for organics and pesticides, are Type 4 Wastes (no organics or pesticides are included in the waste rock material and therefore that requirement is not applicable);
- If a particular chemical substance in a waste is not listed with corresponding LCT and TCT limits in the norms and standards, and the waste has been classified as hazardous in terms of regulation 4(2) of the Regulations based on the health or environmental hazard characteristics of the particular element or chemical substance, the waste is considered to be Type 1 Waste (not applicable to this study);
- If the TC of an element or chemical substance is above the TCT2 limit, and the concentration cannot be reduced to below TCT2 limit, but the LC for the particular element or chemical substance is below the LCT3 limit, the waste is considered Type 1 Waste;
- Wastes listed in item (2)(b) of Annexure 1 to the regulations are considered to be Type 1 Waste, unless assessed and determined otherwise in terms of the Norms and Standards;
- Wastes with all element or chemical substances leachable concentration levels for metal ions and inorganic anions below or equal to the LCT0 limits are considered to be Type 3 Waste, irrespective of the total concentration of elements or chemical substances in the waste provided that:
  - The concentration levels are below the relevant limits for organics and pesticides;
  - The inherent waste and chemical character of the waste is stable and will not change over time; and
  - The waste is disposed of to landfill without any other waste.

Based on the leach and total concentration test results the material that will be handled on site is classified as Type 3.

Table 5.2: Total concentration test results compared to TCT guideline values

Constituent	Units	TCT Guidelines Values			KAN2 OVBN	KAN2 Calc	KAN4
		TCT0	TCT1	TCT2			
Arsenic (As)	mg/kg	5.8	500	2 000	5.20	4.80	6.00
Boron (B)	mg/kg	150	15 000	60 000	50	28	53
Barium (Ba)	mg/kg	62.5	6 250	25 000	305	1 120	440
Cadmium (Cd)	mg/kg	7.5	260	1 040	6.40	3.20	4.40
Cobalt (Co)	mg/kg	50	5 000	20 000	<10	<10	<10
Total Chromium (Cr)	mg/kg	46 000	800 000	N/A	119	115	132
Copper (Cu)	mg/kg	16	19 500	78 000	30	23	14
Mercury (Hg)	mg/kg	0.93	160	640	<0.400	<0.400	<0.400
Manganese (Mn)	mg/kg	1 000	25 000	100 000	520	224	353
Molybdenum (Mo)	mg/kg	40	1 000	4 000	<10	<10	<10
Nickel (Ni)	mg/kg	91	10 600	42 400	28	10	15
Lead (Pb)	mg/kg	20	1 900	7 600	15	18	14
Antimony(Sb)	mg/kg	10	75	300	<0.400	<0.400	<0.400
Selenium (Se)	mg/kg	10	50	200	<0.400	<0.400	<0.400
Vanadium (V)	mg/kg	150	2 680	10 720	68	<10	32
Zinc (Zn)	mg/kg	240	160 000	640 000	82	28	33
Hexavalent Chromium (Cr^{6+})	mg/kg	6.5	500	2 000	<5	<5	<5
Fluoride (F)	mg/kg	100	10 000	40 000	785	574	347

Exceed TCT0 guideline value

Table 5.3: Leachable concentration test results compared to LCT guideline values

Constituent	Units	LCT Guidelines Values				KAN2 OVBN	KAN2 Calc	KAN4
		LCT0	LCT1	LCT2	LCT3			
Arsenic (As)	mg/L	0.01	0.5	1	4	<0.001	<0.001	<0.001
Boron (B)	mg/L	0.5	25	50	200	0.393	0.114	0.516
Barium (Ba)	mg/L	0.7	35	70	280	<0.025	0.045	<0.025
Cadmium (Cd)	mg/L	0.003	0.15	0.3	1.2	<0.003	<0.003	<0.003
Cobalt (Co)	mg/L	0.5	25	50	200	<0.025	<0.025	<0.025
Total Chromium (Cr)	mg/L	0.1	5	10	40	<0.025	<0.025	<0.025
Hexavalent Chromium (Cr^{6+})	mg/L	0.05	2.5	5	20	<0.010	<0.010	<0.010
Copper (Cu)	mg/L	2.0	100	200	800	<0.025	<0.025	<0.025
Mercury (Hg)	mg/L	0.006	0.3	0.6	2.4	<0.001	<0.001	<0.001
Manganese (Mn)	mg/L	0.5	25	50	200	<0.025	<0.025	<0.025
Molybdenum (Mo)	mg/L	0.07	3.5	7	28	<0.025	<0.025	<0.025
Nickel (Ni)	mg/L	0.07	3.5	7	28	<0.025	<0.025	<0.025
Lead (Pb)	mg/L	0.01	0.5	1	4	<0.010	<0.010	<0.010
Antimony (Sb)	mg//L	0.02	1.0	2	8	<0.001	<0.001	<0.001
Selenium (Se)	mg/L	0.01	0.5	1	4	0.003	0.003	0.001
Vanadium (V)	mg/L	0.2	10	20	80	<0.025	<0.025	<0.025
Zinc (Zn)	mg/L	5.0	250	500	2 000	<0.025	<0.025	0.052
Total dissolved solids (TDS)	mg/L	1 000	12 500	25 000	100 000	1 440	2 358	2 568
Chloride (Cl)	mg/L	300	15 000	30 000	120 000	147	23	110
Sulphate (SO_4)	mg/L	250	12 500	25 000	100 000	826	1 394	1 432
Nitrate (NO_3)	mg/L	11	550	1 100	4 400	0.2	0.1	<0.1
Fluoride (F)	mg/L	1.5	75	150	600	0.9	1.0	<0.2

Exceed LCT0 guideline value

5.2.2. Acid-Base-Accounting testing

Acid base accounting is a screening analytical procedure that provides values to help assess the acid-producing and acid-neutralising potential of waste rock or gypsum material in order to evaluate the acid mine drainage producing potential of the material that will be handled on site. In this procedure, the amount of acid-producing rock is compared with the amount of acid-neutralising rock, and a prediction of the water quality at the site (whether acidic or alkaline) is obtained.

The values that are compared are called the acid potential (AP) and the neutralising potential (NP). The comparison may be the difference between the two values, called the net neutralising potential (NNP) or the ratio of the two values, called the neutralisation potential ratio (NPR). Below are three tables showing the comparison ranges as well as the classification of the rock samples.

Table 5.4 summarises the criteria against which the acid forming potential is measured based on the neutralisation potential ratio (NPR). Table 5.5 summarises the deduced acid generating potential based on the net neutralising potential (NNP). Table 5.6 summarises the rock classification based on a combination of the potential for acid formation and the sulphur content.

Table 5.4: Neutralisation Potential Ratio (NPR)

NPR = NP/AP	Acid generating potential	Comments
<1:1	Likely	Likely AMD generating
1:1 to 2:1	Possible	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides
2:1 to 4:1	Low	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive
>4:1	Unlikely	No further AMD testing required unless materials are to be used as a source of alkalinity

Table 5.5: Net neutralising potential

Net neutralising potential (NNP) NNP = NP-AP	Acid generating potential
< -20	Likely to be acid generating
>20	Not likely to be acid generating
Between -20 and 20	Uncertain range

Table 5.6: Rock classification

Classification	Acid forming potential	Criteria
TYPE I	Potential acid forming	Total S(%) > 0.25% and AP:NP ratio 1:1 or less
TYPE II	intermediate	Total S(%) > 0.25% and AP:NP ratio 1:3 or less
TYPE III	Non acid-forming	Total S(%) < 0.25% and AP:NP ratio 1:3 or greater

Sulphide percentage guidelines from (Price, Morin, & Hutt, 1997) are summarised in Table 5.7.

Table 5.7: Sulphide – S percentage guidelines

	NAG pH	NPR	ARD Potential	Comment
Sulphide-S <0.3%	>5.5	-	None	No further AMD testing required provided there are no other metal leaching concerns. Exceptions: host rock with no basic minerals, sulphide minerals that are weakly acid soluble.
Sulphide-S >0.3%	<5.5	<1	Likely	Likely to be AMD generating
		1-2	Possibly	Possibly AMD generating if NP is insufficiently reactive or is depleted at a rate faster than that of sulphides
		2-4	Low	Not potentially AMD generating unless significant preferential exposure of sulphides occurs along fractures or extremely reactive sulphides are present together with insufficiently reactive NP
		>4	None	No further AMD testing required unless materials are to be used as a source of alkalinity.

5.2.2.1. ABA test Results

Three representative samples as described in Table 5.1 were submitted to the laboratory for analysis. The results from the tests are summarised in Table 5.8. From Table 5.8 it can be seen that both the overburden and gypsum from borehole KAN2 have an NPR of slightly greater than 1. This coupled with a total sulphur percentage of 0.75 to 1.06 % shows that it is possible that the material will be acid generating.

The mixed overburden and gypsum from borehole KAN4 show a NPR ratio of less than 1. Coupled with a sulphur percentage of 5.34 % and an NNP of -100 it is likely that this material will be acid producing.

Table 5.8: ABA test results

Sample	Paste pH	Total Sulphur %	Acid Potential (AP) (kg/t)	Neutralisation potential (NP)	Net Neutralisation Potential (NNP)	Neutralising Potential Ratio (NPR) (NP:AP)	Rock Type
KAN2 OVBN	7.7	0.75	23	27	3.65	1.16	II
KAN2 Calc	8.2	1.06	33	52	18	1.56	II
KAN4	8.3	5.34	167	67	-100	0.399	I

5.3. Hydrogeology

Three aquifers occur in the area. These three aquifers are associated with a) the upper weathered material and gypsum layer, b) the underlying competent and fractured rock material, and c) the alluvial sand in the river channels.

5.3.1. Upper weathered material aquifer

The upper aquifer forms due to the vertical infiltration of recharging rainfall through the weathered material and the gypsum layer being retarded by the lower permeability of the underlying competent rock material. Groundwater collecting above the weathered / unweathered material contact migrates down gradient along the contact to lower lying areas. Based on the results from the drilling program the aquifer thickness range between 16 and 20 m.

Following the GRA 3aE report (Department: Water Affairs and Forestry, 2006) recharge is 0.03 % of the MAP.

Typical transmissivity values for this aquifer range between 0.1 and 5 m^2/day.

The borehole yields in this aquifer are seasonally variable due to the strong dependence on rainfall recharge. Generally, it can be said that the yields of this aquifer during the rainy season can be around 1 L/s while sustainable yields will decrease markedly during the dry season. In some areas this aquifer will be laid completely dry during the dry season.

5.3.2. Lower fractured rock aquifer

Although the lower permeability of the unweathered rock material will retard vertical infiltration of groundwater, a percentage of the water in the upper aquifer will recharge the lower aquifer. Direct recharge from rainfall can occur where the fractured, competent rock outcrops. In areas where the stream bases of the non-perennial rivers are located directly on top of the competent rock the aquifer can be directly recharged from the surface stream.

Groundwater flows in the lower aquifer are associated with the secondary fracturing in the competent rock and as such will be along discrete pathways associated with the fractures. Faults and fractures in the host geology can be a significant source of groundwater depending on whether the fractures have been filled with secondary mineralisation.

5.3.3. Alluvial aquifer associated with the stream beds

The third aquifer that occurs in the area is localised along the stream beds. Alluvial sand has accumulated in the river beds over time as low energy stream flows deposited transported material.

During rainfall events when the streams flow surface water recharge into the alluvial sand that line the river channels. This water can be pumped from the sands during times when the rivers are not actively flowing.

Yields from this aquifer can be relatively high due to the sandy nature of the aquifer material. However, once the sand is dewatered the groundwater users will have to wait until after the next significant rainfall event before water can be abstracted again.

5.4. Hydraulic conductivity

Reference is made to literature to obtain an indication of the aquifer parameters. The hydraulic conductivity of gypsum is listed as ranging between 3.5 x 10^{-8} and 2 x 10^{-3} m/day (Domenico, 1990).

The weathered, clayey, mudstone and siltstone that underlies the gypsum has a hydraulic conductivity in the range of 0.001 to 10 m/day (Domenico, 1990).

5.5. Groundwater levels

A hydrocensus was undertaken during June 2018. In total sixteen groundwater points were located in the field (please refer to Figure 5.3 for the positions).

The results of the hydrocensus are summarised in Table 5.9 and the measured depth to groundwater level is shown graphically in Figure 5.2. Of the sixteen boreholes identified in the field, only two could be accessed to measure the depth to groundwater level. The boreholes in the area are equipped with windpumps which does not allow access to the borehole due to the surface clamps holding the piping in place. The two boreholes used by Transnet for water supply to Lus 6 (boreholes KH10 and KH11) are equipped with submersible pumps, but are enclosed within containers and there is no access to these two boreholes. Figure 5.2 shows that the depth to groundwater level is measured in boreholes KH03 and KH07 at 9.45 and 12.87 mbgl respectively.

Borehole KH03 was being pumped during the time of the hydrocensus. Therefore, the measured depth to groundwater level in the borehole does not represent the static groundwater level in this area.

In areas where there are no large scale external impacts on the groundwater environment, such as the lowering of groundwater level through dewatering, and where the geology and aquifer interactions are not excessively complex it is expected that the groundwater level contours will reflect topographical contours, although at a moderated gradient.

Bayesian interpolation is used to interpolate the groundwater levels throughout the study area for the weathered material aquifer. Groundwater level elevation contours for the weathered material aquifer are shown in Figure 5.3.

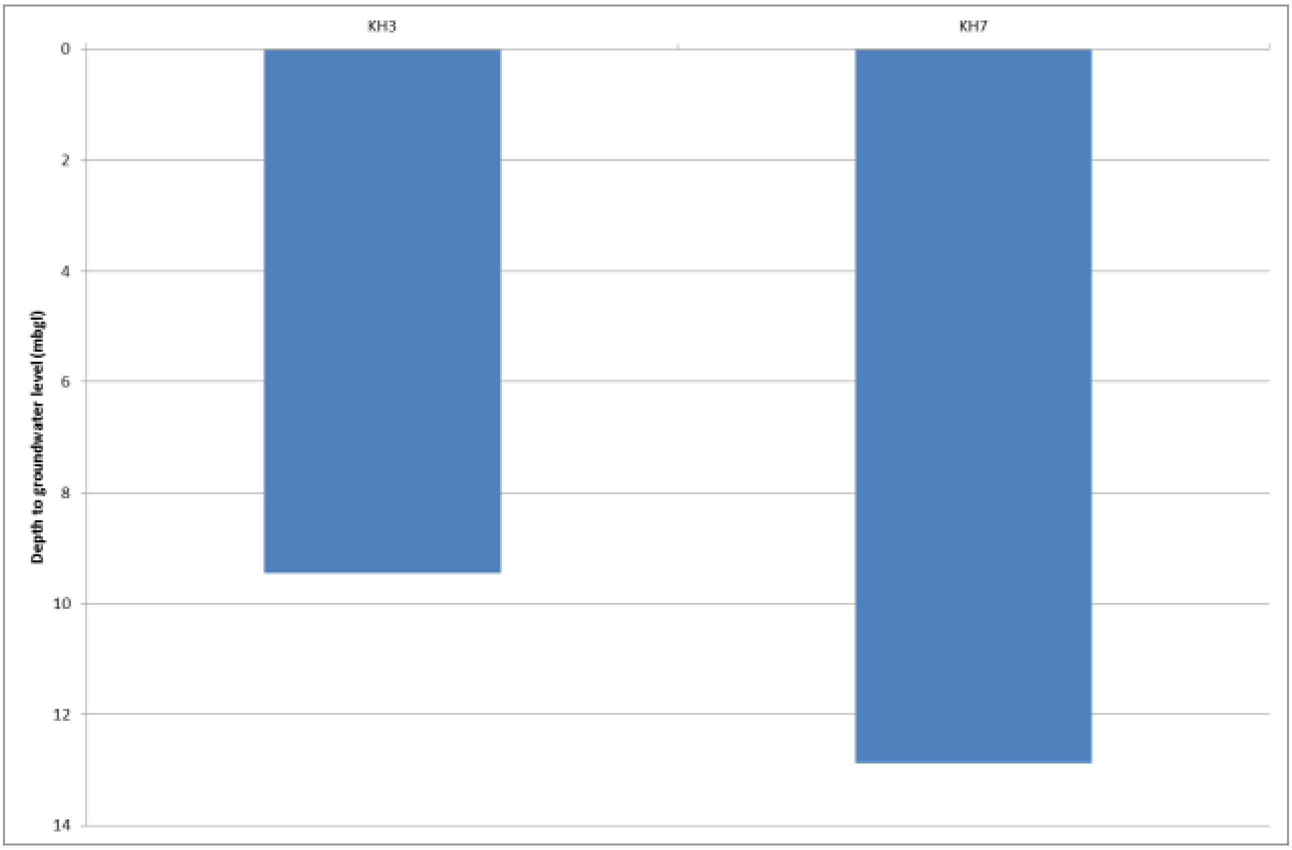
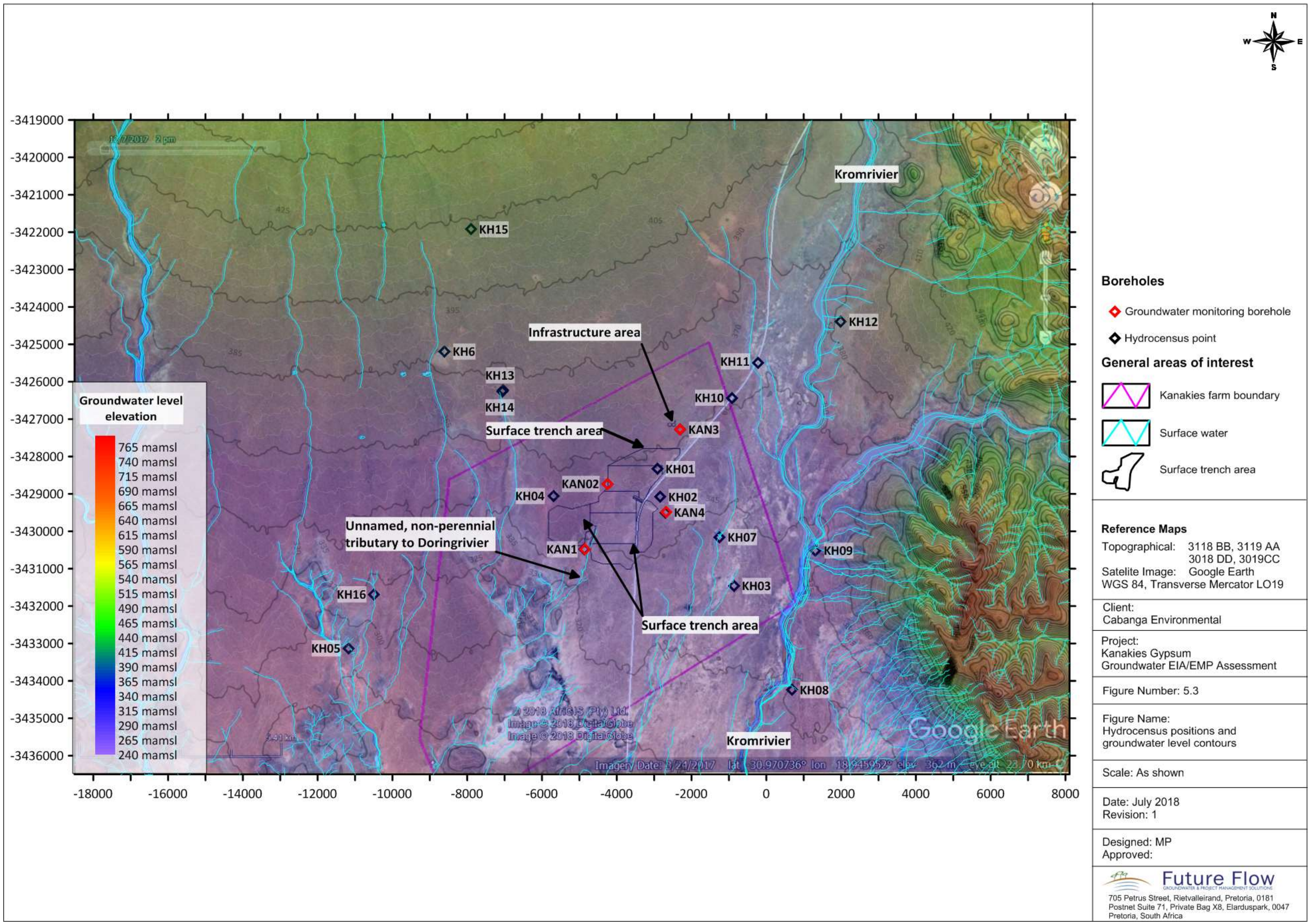


Figure 5.2: Depth to groundwater level


Kromrivier
KH15
KH12
Infrastructure area
KH6
KH11
KH13
KH14
KH10
KAN3
Surface trench area
KH01
KAN02
KH04
KH02
KAN4
Unnamed, non-perennial
tributary to Doringrivier
KH07
KAN1
KH09
KH03
KH16
Surface trench area
KH05
KH08
Kromrivier
Groundwater level
elevation
765 mamsl
740 mamsl
715 mamsl
690 mamsl
665 mamsl
640 mamsl
615 mamsl
590 mamsl
565 mamsl
540 mamsl
515 mamsl
490 mamsl
465 mamsl
440 mamsl
415 mamsl
390 mamsl
365 mamsl
340 mamsl
315 mamsl
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-16000
-14000
-12000
-10000
-8000
-6000
-4000
-2000
0
2000
4000
6000
8000
N
W
E
S
Boreholes
Groundwater monitoring borehole
Hydrocensus point
General areas of interest
Kanakies farm boundary
Surface water
Surface trench area
Reference Maps
Topographical: 3118 BB, 3119 AA
3018 DD, 3019CC
Satelite Image: Google Earth
WGS 84, Transverse Mercator LO19
Client:
Cabanga Environmental
Project:
Kanakies Gypsum
Groundwater EIA/EMP Assessment
Figure Number: 5.3
Figure Name:
Hydrocensus positions and
groundwater level contours
Scale: As shown
Date: July 2018
Revision: 1
Designed: MP
Approved:
Future Flow
GROUNDWATER & PROJECT MANAGEMENT SOLUTIONS
705 Petrus Street, Rietvalleirand, Pretoria, 0181
Postnet Suite 71, Private Bag X8, Elarduspark, 0047
Pretoria, South Africa

Table 5.9: Hydrocensus results

BH	East	North	Elevation	Water level		Farm	Owner	Use type	Equipment
	WGS84, LO19	WGS84, LO19	mamsl	mbgl	mamsl				
KH01	-2 916	-3 428 324	355	No access for measurement		Kanakies 332	Witkop Fluorspar	Stock watering (van der Merwe)	Windpump
KH02	-2 847	-3 429 079	346	No access for measurement		Kanakies 332	Witkop Fluorspar	Stock watering (van der Merwe)	Only reservoir found
KH03	-856	-3 431 463	346	9.45	336.55	Kanakies 332	Witkop Fluorspar	Stock watering	Windpump
KH04	-5 693	-3 429 056	346	No access for measurement		Kanakies 332	Witkop Fluorspar	Domestic & stock watering	Windpump
KH05	-11 173	-3 433 128	346	No access for measurement		Kalk Gat 84	M de Kock	Domestic	Windpump
KH06	-8 609	-3 425 189	346	No access for measurement		Lot B Drooge Houts Berg Vlakte 83	C van der Merwe	Domestic & stock watering	Windpump
KH07	-1 254	-3 430 162	336	12.87	323.13	Kanakies 332	Kanakies	Not used	None
KH08	696	-3 434 246	321	No access for measurement		Stinkfontein 461	Unknown	Not used	None
KH09	1 316	-3 430 517	337	No access for measurement		Klein Graaf Water 333	Unknown	Domestic	Windpump
KH10	-923	-3 426 434	357	No access for measurement		Klein Graaf Water 333	Transnet (Lus 6)	Domestic	Submersible
KH11	-228	-3 425 491	358	No access for measurement		Klein Graaf Water 333	Transnet (Lus 6)	Domestic	Submersible
KH12	1 982	-3 424 399	380	No access for measurement		Klein Graaf Water 333	K van der Merwe	Domestic	Submersible
KH13	-7 043	-3 426 220	366	No access for measurement		Lot B Drooge Houts Berg Vlakte 83	C van der Merwe	Stock watering	Windpump
KH14	-7 058	-3 426 260	364	No access for measurement		Lot B Drooge Houts Berg Vlakte 83	C van der Merwe	Stock watering	Windpump
KH15	-7 900	-3 421 925	408	No access for measurement		Lot B Drooge Houts Berg Vlakte 83	C van der Merwe	Stock watering	Windpump
KH16	-10 488	-3 431 687	303	No access for measurement		Kalk Gat 84	M de Kock	Stock watering	Windpump
KAN1	-4 860	-3 430 484	357	Dry	Dry	Kanakies 332	Witkop Fluorspar	Monitoring	None
KAN2	-4 238	-3 428 733	361	Dry	Dry	Kanakies 332	Witkop Fluorspar	Monitoring	None
KAN3	-2 302	-3 427 285	356	Dry	Dry	Kanakies 332	Witkop Fluorspar	Monitoring	None
KAN4	-2 693	-3 429 493	357	Dry	Dry	Kanakies 332	Witkop Fluorspar	Monitoring	None

N/A = Not available
mbgl = metres below ground level
mamsl = metres above mean sea level
All coordinates are provided in Transverse Mercator projection (LO19), and WGS84 datum

5.6. Groundwater potential contaminants

The surface trench area, temporary plant feed stockpile (that moves with the active mine area) and waste stockpile (that moves with the active mine area) act as potential sources of contamination to the aquifers. For the purpose of this discussion it is assumed that good housekeeping such as storage of potentially hazardous material will be within properly constructed and lined or paved areas. Oil traps will be sized, operated and maintained to contain all discarded oil from working areas etc.

Leach testing results can be used to determine the potential source concentrations (please refer to Table 5.3). The leach test results show that in general sulphate can be expected to be present in concentrations of 800 to 1 400 mg/L, which exceed the LCT0 guideline value of 250 mg/L. Leach test analysis results from the Borehole KAN4 overburden and gypsum mixture show that boron, could also be present in slightly elevated concentrations (0.516 mg/L compared to the LCT0 value of 0.5 mg/L).

5.7. Groundwater quality

A total of 4 groundwater samples were collected for chemical analysis during the hydrocensus. The samples were submitted to an ISO17025 / SANAS accredited laboratory for chemical analysis.

5.7.1. Element concentrations

The chemical analysis results of the four groundwater samples taken from the study area are summarised in Table 5.10 and are compared to the SANS 241:2015 drinking water standards. The standard represents a numerical limit of the listed element concentrations that will protect the health of the consumer over a lifetime of consumption. All elements that exceed the guidelines are highlighted and their aesthetic and health impacts discussed below at the hand of the information contained in the South African Water Quality Guidelines for domestic use as published by the Department of Water Affairs in 1996.

In general sodium, chloride, and sulphate concentrations exceed the SANS241:2015 drinking water guidelines. Borehole KH09 also shows a fluoride concentration that at 2.5 mg/L exceeds the SANS241:2015 guideline of 1.5 mg/L somewhat.

Tasting water on site showed that the groundwater in the area has a naturally brackish taste, which is confirmed by the chemical analysis results showing elevated sodium and chloride concentrations.

Chloride: The chloride concentrations in all the boreholes exceed the SANS241:2015 guideline value of 300 mg/L. The measured concentrations range between 1 576 and 2 649 mg/L.

Chloride is a common constituent in water, is highly soluble, and once in solution tends to accumulate. The taste threshold and the corrosion acceleration threshold of chloride are dependent on the action of other water quality constituents such as associated cations, the pH and the calcium carbonate concentration.

Chloride is only detectable by taste at concentrations exceeding approximately 200 mg/L. A salty taste becomes quite distinctive at 400 mg/L and objectionable at greater than 600 mg/L. At chloride concentrations greater than 2 000 mg/L nausea may occur, while at 10 000 mg/L vomiting and dehydration may be induced.

Chloride accelerates the corrosion rate of iron and certain other metals well below the concentration at which it is detectable by taste. The threshold for an increased corrosion rate is approximately 50 mg/L. At chloride concentrations greater than 200 mg/L, there is likely to be a significant shortening of the lifetime of domestic appliances as a result of corrosion.

At concentrations greater than 1 200 mg/L the water has an unacceptably salty taste. Nausea and disturbance of the electrolyte balance can occur, especially in infants, where fatalities due to dehydration may occur.

Sodium: The sodium concentration in all four samples exceeds the SANS241:2015 guideline value of 200 mg/L. The measured concentrations range between 700 and 1 272 mg/L.

Sodium is ubiquitous in the environment and usually occurs as sodium chloride, but sometimes as sodium sulphate, bicarbonate or even nitrate.

Sodium is highly soluble in water and does not precipitate when water evaporates, unless saturation occurs. Hence, water in arid areas often contains elevated concentrations of sodium.

The taste threshold for sodium in water varies from 135 - 200 mg/L, depending on the associated anion. The common ones include chloride, sulphate, nitrate, bicarbonate and carbonate.

Sodium intake can exacerbate certain disease conditions. Persons suffering from hypertension, cardiovascular or renal diseases should restrict their sodium intake. In the case of bottle-fed infants, sodium intake should also be restricted.

At concentrations between 600 and 1 000 mg/L water has a very salty taste. Health effects may be expected and the water is very undesirable for infants or persons on a sodium restricted diet. At concentrations between 1 000 and 5 000 mg/L the water has an extremely salty taste becoming bitter. Severe health effects with disturbance of the electrolyte balance can occur. The water is extremely undesirable for infants of persons on a sodium restricted diet.

Sulphate: With a range of 512 to 984 mg/L the sulphate concentrations in all four boreholes exceed the SANS241:2015 guideline value of 500 mg/L for health impacts.

Sulphate is a common constituent of water and arises from the dissolution of mineral sulphates in soil and rock, particularly calcium sulphate (gypsum) and other partially soluble sulphate minerals.

Since most sulphates are soluble in water, and calcium sulphate relatively soluble, sulphates when added to water tend to accumulate to progressively increasing concentrations.

High concentrations of sulphate exert predominantly acute health effects (diarrhoea). These are temporary and reversible since sulphate is rapidly excreted in the urine. Individuals exposed to elevated sulphate concentrations in their drinking water for long periods, usually become adapted and cease to experience these effects. Sulphate concentrations of 600 mg/L and more cause diarrhoea in most individuals and adaptation may not occur.

Sulphate imparts a salty or bitter taste to water. The taste threshold for sulphate falls in the range of 200 - 400 mg/L and depends on whether the sulphate is predominantly associated with either sodium, potassium, calcium or magnesium, or mixtures thereof. Elevated sulphate concentrations also increase the erosion rate of metal fittings in distribution systems.

At concentrations between 400 and 600 mg/L diarrhoea is expected for most non-adapted individuals and the water has a definite salty or bitter taste. At concentrations ranging between 500 and 1 000 mg/L diarrhoea is expected for most individuals and user adaptation does not occur. The water has a pronounced salty or bitter taste.

5.7.2. Chemical character

The groundwater character is shown at the hand of a Piper diagram in Figure 5.4. The Piper diagram was created using the AQQA program. The Piper diagram, introduced by Arthur Piper in 1944, is one of the most commonly used techniques to interpret groundwater chemistry data. This method proposed the plotting of cations and anions on adjacent tri-linear fields with these points then being extrapolated to a central diamond field. Here the chemical character of water, in relation to its environment, could be observed and changes in the quality interpreted. The cation and anion plotting points are derived by computing the percentage equivalents per million for the main diagnostic cations of calcium, magnesium and sodium, and anions chloride, sulphate and bi-carbonate.

Different waters from different environments always plot in diagnostic areas. The upper half of the diamond normally contains water of static and dis-ordinate regimes, while the middle area normally indicates an area of dissolution and mixing. The lower triangle of this diamond shape indicates an area of dynamic and co-ordinated regimes. Sodium chloride brines normally plot on the right hand corner of the diamond shape while recently recharged water plots on the left-hand corner of the diamond plot. The top corner normally indicates water contaminated with gypsum.

In general the top half of the diamond contains static waters and other unusual waters high in magnesium/calcium chloride and calcium/magnesium sulphate. The lower half contains those waters normally found in a dynamic basin environment. Mixtures of any two waters in any proportion plot along a line joining their respective points in each of these diagrams. Water therefore being invaded by an industrial effluent will plot as a vector towards the analysis of the invading fluid.

Figure 5.4 shows that the water plots in the upper right-hand section of the diamond. All four water samples have a sodium – chloride dominant character.

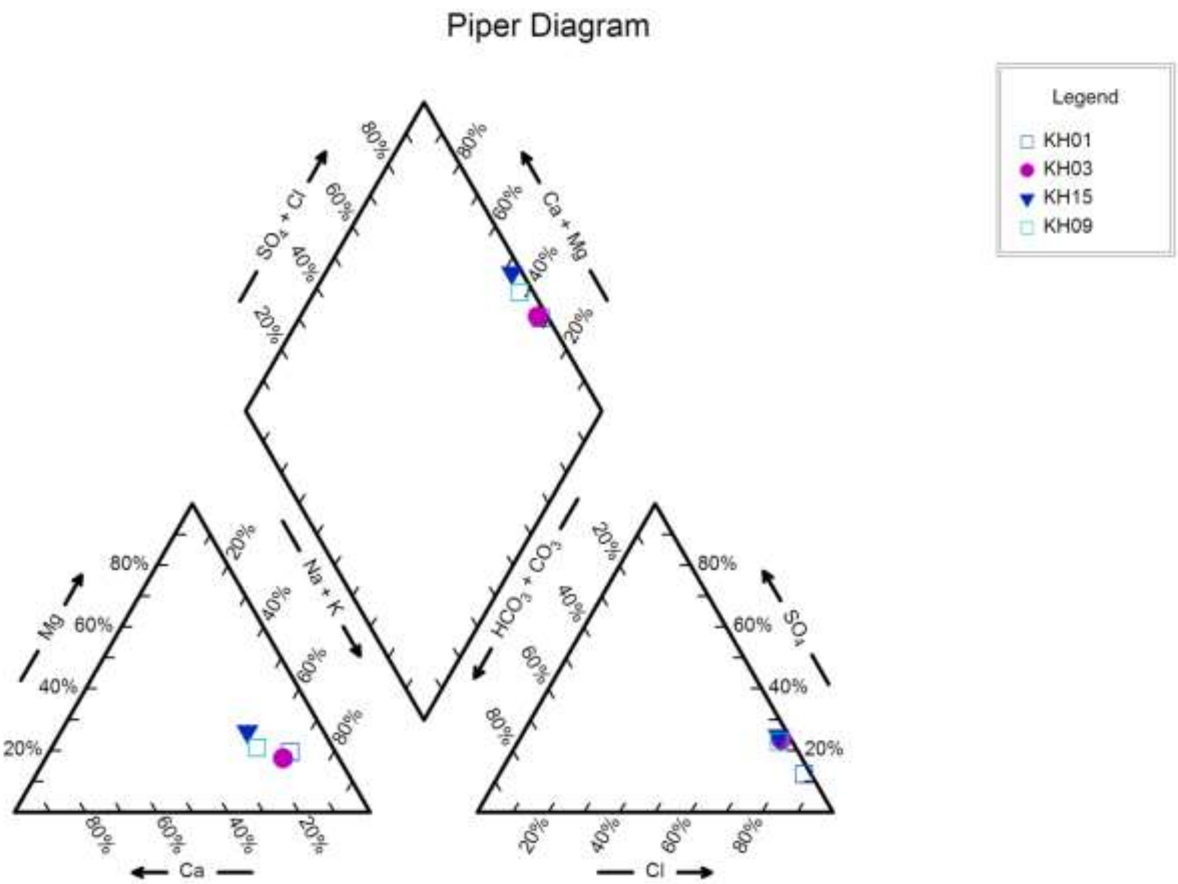


Figure 5.4: Piper diagram

Table 5.10: Groundwater chemical analysis results

Analysis	Units	SANS 241:2015 guideline value	KH01	KH03	KH15	KH09
pH		≥5 - ≤9.7	7.8	7.83	7.7	7.72
Electrical Conductivity (EC)	mS/m	≤170	560	538	463	497
Alkalinity	mg/L $CaCO_3$	N/G	112	146	113	146
Chloride (Cl)	mg/L	≤300	2 649	2 277	1 576	1 600
Sulphate (SO_4)	mg/L	≤500 (health)	512	984	726	674
Nitrate (NO_3)	mg/L	≤11	2.72	2.79	4.59	0.919
Ammonium (NH_4)	mg/L	N/G	0.046	0.033	0.038	0.035
Orthophosphate (PO_4)	mg/L	N/G	<0.005	<0.005	<0.005	<0.005
Fluoride (F)	mg/L	≤1.5	1.1	0.561	0.72	2.56
Calcium (Ca)	mg/L	N/G	211	263	252	271
Magnesium (Mg)	mg/L	N/G	194	177	184	160
Sodium (Na)	mg/L	≤200	1 272	1 272	700	833
Potassium (K)	mg/L	N/G	17.1	8.27	5.19	10
Aluminium (Al)	mg/L	≤0.3	<0.002	<0.002	<0.002	<0.002
Iron (Fe)	mg/L	≤2 (health)	<0.004	<0.004	<0.004	<0.004
Manganese (Mn)	mg/L	≤0.4 (health)	0.001	<0.001	<0.001	<0.001
Chromium (Cr)	mg/L	≤0.05	<0.003	<0.003	<0.003	<0.003
Copper (Cu)	mg/L	≤2	<0.002	<0.002	<0.002	<0.002
Nickel (Ni)	mg/L	≤0.07	<0.002	<0.002	<0.002	<0.002
Zinc (Zn)	mg/L	≤5	0.054	0.067	0.032	0.213
Cobalt (Co)	mg/L	N/G	<0.003	<0.003	<0.003	0.003
Cadmium (Cd)	mg/L	≤0.003	<0.002	<0.002	<0.002	<0.002
Lead (Pb)	mg/L	≤0.01	<0.004	<0.004	<0.004	<0.004
Total Hardness	mg/L $CaCO_3$	N/G	1 325	1 385	1 386	1 335
Bicarbonate	mg/L $CaCO_3$	N/G	112	145	112	146

Exceed SANS241:2015 guideline value

mS/m = milliSiemens/metre
mg/L = milligram per litre

6. Aquifer characterisation

6.1. Groundwater vulnerability

For aquifer vulnerability reference is made to the aquifer vulnerability map of South Africa which shows a low aquifer vulnerability for the project area.

6.2. Aquifer classification

The aquifers present in the area are classified as minor aquifers, but of high importance to the local landowners as it is their sole source of water for domestic and agricultural (stock watering) purposes.

7. Conceptual model summary

7.1. Groundwater flows

The baseline data is analysed and compiled into a conceptual model which is summarised below.

Three aquifers occur in the area. These three aquifers are associated with a) the upper weathered material and gypsum layer, b) the underlying competent and fractured rock material, and c) the alluvial sand in the river channels. The upper aquifer has an average thickness of approximately 16 to 20 m.

Groundwater flow in the lower fractured aquifer is associated with the secondary fracturing in the competent rock and as such will be along discrete pathways associated with the fractures. Faults and fractures in the host geology can be a source of groundwater depending on whether the fractures have been filled with secondary mineralisation.

Depth to groundwater level is in the order of 8 to 12 mbgl. Based on a relatively homogenous geology and no large scale dewatering schemes in the region, it is expected that the groundwater flow contours mimic topography.

Based on the GRA II 3aE report 0.03 % of the mean annual precipitation recharges the groundwater table.

7.2. Contaminant transport

The surface trench area and stockpiles (that moves with the active mine area), as well as the waste stockpile (that moves with the active mine area) act as potential sources of contamination to the aquifers. For the purpose of this discussion it is assumed that good housekeeping such as storage of potentially hazardous material will be within properly constructed and lined or paved areas. Oil traps will be sized, operated and maintained to contain all discarded oil from working areas etc.

Leach testing results can be used to determine the potential source concentrations (please refer to Table 5.3). The leach test results show that in general sulphate can be expected to be present in concentrations of 800 to 1 400 mg/L, which exceed the LCT0 guideline value of 250 mg/L. Leach test analysis results from the Borehole KAN4 overburden and gypsum mixture show that boron, could also be present in slightly elevated concentrations (0.516 mg/L compared to the LCT0 value of 0.5 mg/L).

8. Geohydrological impacts

The groundwater impact assessment is conducted based on the available information. Due to the fact that the proposed development will not breach the groundwater level in the area and will not impact on the groundwater flow patterns no 3D groundwater flow modelling was done. The geochemical analysis show that Acid Mine Drainage (AMD) conditions can be expected to form and some elements including sulphate will be present in concentrations higher than that already present in the natural groundwater that occur on site. The contaminant migration assessment was done using analytical calculations. The groundwater impact assessment was based on the conceptual groundwater flow and contaminant transport model.

Impacts from the proposed mining activities were evaluated and include:

- Impacts on groundwater levels, flow patterns and volumes;
- Impacts on groundwater qualities and plume migration; and
- Impacts on surface water qualities due to poor quality groundwater seeping into the surface water in the form of baseflow contribution.

During the risk assessment the risk to the groundwater levels and quality were evaluated. Each of the identified risks was then rated. The rating methodology used is as described in Table 8.1.

The rating is described as follows:

Score out of 100	Significance
1 to 20	Low
21 to 40	Moderate to Low
41 to 60	Moderate
61 to 80	Moderate to high
81 to 100	High

Will **mitigation** be possible (yes or no)? Mitigation measures are further discussed in the EMP section, where post mitigation significance of impacts is also given.

The **Degree of irreplaceable loss of resource** has also been evaluated in the impact assessment table. This has been rated in three categories, including:

Degree of loss	
Low	The resource is renewable or able to recover and therefore negligible loss expected.
Moderate	Resource is at risk of permanent loss but management measures can reduce risk of loss or resource can recover over time or with rehabilitation efforts.
High	Resource will be severely affected and loss will be irreplaceable or very long term, or rehabilitation efforts would be unduly expensive and not economically viable.

Table 8.1: Impact rating methodology

The status of an impact		
Score	**Status**	**Description**
Pos	Positive:	a benefit to the holistic environment
Neg	Negative:	a cost to the holistic environment
Neut	Neutral:	no cost or benefit
The duration of the impact		
Score	**Duration**	**Description**
1	Short term	Less than 2 years
2	Short to medium term	2 – 5 years
3	Medium term	6 – 25 years
4	Long term	26 – 45 years
5	Permanent	46 years or more
The extent of an impact		
Score	**Extent**	**Description**
1	Site specific	Within the site boundary
2	Local	Affects immediate surrounding areas
3	Regional	Extends substantially beyond the site boundary
4	Provincial	Extends to almost entire province or larger region
5	National	Affects country or possibly world
The reversibility of the impact		
Score	**Reversibility**	**Description**
1	Completely reversible	Reverses with minimal rehabilitation & negligible residual affects
3	Reversible	Requires mitigation and rehabilitation to ensure reversibility
5	Irreversible	Cannot be rehabilitated completely/rehabilitation not viable
The effect (severe or beneficial) of the impact		
Score	**Severe/beneficial effect**	**Description**
1	Slight	Little effect - negligible disturbance/benefit
2	Slight to moderate	Effects observable - environmental impacts reversible with time
3	Moderate	Effects observable - impacts reversible with rehabilitation
4	Moderate to high	Extensive effects - irreversible alteration to the environment
5	High	Extensive permanent effects with irreversible alteration
The probability of the impact		
Score	**Rating**	**Description**
1	Unlikely	Less than 15% sure of an impact occurring
2	Possible	Between 15% and 40% sure of an impact occurring
3	Probable	Between 40% and 60% sure that the impact will occur
4	Highly Probable	Between 60% and 85% sure that the impact will occur
5	Definite	Over 85% sure that the impact will occur
The Consequence		= Severity + Spatial Scale + Duration + Reversibility.
The Significance		= Consequence x Probability.

8.1. Construction phase

During the construction phase trenches will be excavated. The depth of the excavation will be between 1.4 and 2.5 m deep. A product stockpile area for finished product, as well as a small moving temporary plant feed stockpile area, will be established on surface. Surface infrastructure including the mobile crushing and screening plant, container type office block and ablution facility, vehicle parking area, and dirt roads will be constructed.

The construction phase time span is assumed to be less than 6 months.

8.1.1. Groundwater inflow volumes into the excavations

During excavation of the trenches the groundwater level will not be breached and therefore no notable inflows into the trench are expected. This is based on:

- Groundwater levels in the area are more than 8 m deep;
- During the drilling program, which was undertaken during the rainy season when groundwater levels can be expected to be shallower, no groundwater strikes were intercepted at depths shallower than 20 m.

It is possible that there could be some localised seepages into the excavation, however, based on the low rainfall (133 mm/a), low recharge percentage (0.03 % of MAP), and the low hydraulic conductivity of the gypsum (3.5×10^{-8} to 2×10^{-3} m/day) such inflows are expected to be very low, less than 50 m^3/day.

8.1.2. Groundwater level drawdown and associated impacts on aquifers, wetlands and surface streams

As discussed in Section 8.1.1 the groundwater level will not be breached and dewatering of the trench due to groundwater inflows from the surrounding aquifers will not be required. Therefore, there will be no impact on the groundwater levels or surface streams in the area.

Surface construction of the stockpiles, the mobile crushing and screening plant, mobile offices and haul roads will not breach the groundwater level and is therefore not expected to have any impact on the groundwater levels.

8.1.3. Contaminant migration away from pollution sources

It is assumed that with proper maintenance of construction vehicles and other construction related best practices there will be a limited impact on the groundwater quality from the construction of the surface infrastructure.

The weathered material aquifer is vulnerable to contamination from surface sources, including the stockpiles where the material that will be deposited have been shown to be potentially AMD forming, with associated elevated sulphate concentrations.

During the construction phase little to no product will be deposited on the product stockpile, and therefore the product stockpile does not form a risk to the underlying aquifers during the construction phase.

The temporary plant feed stockpile can receive some material from the trenching. However, the material will be dry due to the fact that the groundwater level lies below the level of the excavation and therefore the material will be deposited dry on the stockpile. Taking into consideration the very low rainfall in the area (133 mm/a), and the short time span of the construction phase it is not expected that there will be notable seepage from the stockpile to the underlying aquifers during the construction phase.

Table 8.2: Impact rating – Construction phase

Impact	Status	Effect	Extent	Duration	Reversibility	Consequence	Probability	Significance	Mitigation	Degree of irreplaceable loss	Mitigation	Status	Effect	Extent	Duration	Reversibility	Consequence	Probability	Significance
Impacts on groundwater volumes due to active dewatering of the trench area	Neg	1	1	1	1	4	1	4	Y	Low	No impact expected, no mitigation required								
Impacts on groundwater quality due to poor quality seepage from the operational area	Neg	1	1	5	5	12	1	12	Y	Low	No impact expected, no mitigation required								
Impacts on surface water and wetland volumes due to active dewatering of the trench area	Neg	1	1	1	1	4	1	4	Y	Low	No impact expected, no mitigation required								
Impacts on surface water quality due to poor quality seepage from the pollution source areas	Neg	1	1	4	5	11	1	11	Y	Mod	No impact expected, no mitigation required								

8.2. Operational phase

Mining will be via trench mining, i.e. a trench of 100 meters by 50 m will be trenched where the gypsum will be removed. The first step involves removing the overburden layer of between 0.2 and 0.7 m, followed by the selective removal of the powder layer of approximately 0.4 m and subsequently by removal of the crystal-containing clay layer of between 0.9 and 1.3 m. The powder will be screened to remove foreign materials and is expected to be recovered by a minimum margin of at least 40% by volume harvested, inclusive of waste generated during screening, which should be less than 2% combined from dust generated and foreign objects removed during screening. The clay layer will be roll-crushed and screened by means of high frequency technology alongside the trench to concentrate the average gypsum composition from between 40 and 50 % to between 80 and 90%. The harvesting recovery margin is estimated at 65% by volume extracted whilst the efficiency of the high frequency screening process is expected to be no less than 37%, calculating to an overall 76% mean loss by volume of material harvested.

The trench will be rehabilitated immediately using the overburden and discarded carrier clays after it has been screened over the mobile high frequency screen.

In all other instances, best practices as utilised in the industry have been selected and, where applicable, SANS standards and legislative requirements will be followed in design, construction and management of infrastructure and activities on site.

8.2.1. Impacts on groundwater quantity

8.2.1.1. Groundwater level drawdown and associated impacts on aquifers, wetlands and stream flow volumes

The depth of the trench excavations will range between 1.4 and 2.5 m. Depth to groundwater level in the area is more than 8 m. The groundwater level will not be breached and no dewatering of the trench will be required. Therefore, there will be no drawdown in groundwater level, and no associated impact on the aquifers, wetlands, and stream flow volumes.

8.2.1.2. Groundwater inflows into the trench

During excavation of the trench the groundwater level will not be breached and no regional or continuous groundwater inflows into the trench are expected.

It is possible that there could be some localised seepages into the excavation, however, based on the low rainfall (133 mm/a), low recharge percentage (0.03 % of MAP), and the low hydraulic conductivity of the gypsum (3.5×10^{-8} to 2×10^{-3} m/day) such inflows are expected to be very low, less than 50 m^3/day.

8.2.2. Groundwater contamination

It is assumed that with proper maintenance of mining vehicles and other operations-related best practices there will be a limited impact on the groundwater quality from general surface activities. The weathered material aquifer will however be vulnerable to contamination from the stockpiles on surface.

The temporary plant feed stockpile will move alongside the active trenching area. As described in the mining work program and scoping report the excavated gypsum material will be crushed and screened alongside the trench using the mobile plant to recover the saleable gypsum. The waste generated during the crushing and screening process is expected to be approximately 24 % by volume of material mined. This waste material will then be used to backfill the trench.

Geochemical analysis results show that the waste material (overburden as well as low grade gypsum) that will be used to rehabilitate the trench area can potentially be AMD forming. Rainfall in the area is on average 133 mm/a, but recharge into the rehabilitated material can be expected to be higher than the regional recharge of 0.03 % of MAP that is stated in the GRA 3aE report (Department: Water Affairs and Forestry, 2006). Recharge from rainfall into rehabilitated material can range between 14 and 20 % of the MAP in the short term and reduce to approximately 8 % over time as the material settles and vegetation is re-established. The increased recharge can lead to water accumulating in the rehabilitated trench area and the water level in the rehabilitated material rising. This rising, and perched water level can lead to contaminant migration away from the rehabilitated area.

The life of mine as obtained from the mine work program is 30+ years. Using the hydraulic gradient, the aquifer hydraulic conductivity and the effective porosity of gypsum the average groundwater flow velocity can be calculated for the saturated zone. It can be assumed that under ideal conditions contaminant migration will be at a similar velocity as the groundwater flow in the saturated zone. In reality contaminant migration can be expected to be slower due to natural processes including dispersion, advection, tortuosity, adhesion and others.

The hydraulic conductivity of the soil underlying the gypsum ranges between 0.001 and 10 m/day. Based on the clayey content of the soil as seen from the drilling program, for the purpose of this calculation an average of 0.1 m/day is used. The effective porosity of the soil is considered to be in the order of 0.2. The groundwater flow gradient is estimated based on the topographical gradient to be in the order of 1:100 to 1:150.

It is calculated that should contamination start to migrate away from the rehabilitated area at day one of operations, contamination will migrate a maximum of 45 m from the rehabilitated area during the operations phase of the operations. In reality, this migration is expected to be less based on:

- There will be a time delay between when the first trench is excavated and when the rehabilitation will start;

- The low rainfall in the area (133 mm/a) will mean that water will not accumulate from day one in the rehabilitated area and therefore there will not be a driving head from day one;
- There will be a time delay between trenching and when sufficient chemical reaction has taken place to oxidise the material which could lead to AMD conditions to form;
- There will be a time delay between the rainwater accumulating in the rehabilitated material and sufficient leaching from the backfill material can take place to impact the water quality significantly.

The plume migrating down gradient away from the trench area will impact on the upper reaches of the unnamed, non-perennial tributary to the Doringrivier. In total approximately 550 m of the length of the stream falls within the zone of influence of the migrating plume by the end of the life of mine. This equates to less than 1 % of the total length of the stream network that constitutes the tributary.

The maximum expected salt load contribution to the stream is calculated to be 1.3 kg/day. This contribution will be for only a very short period of time, and will only occur after prolonged rainfall events where continuous recharge from rainfall can increase the groundwater level to near surface so that the groundwater can contribute to the stream flow volume through baseflow contribution. It is expected that this will not be a regular or even yearly occurrence due to the low rainfall in the area.

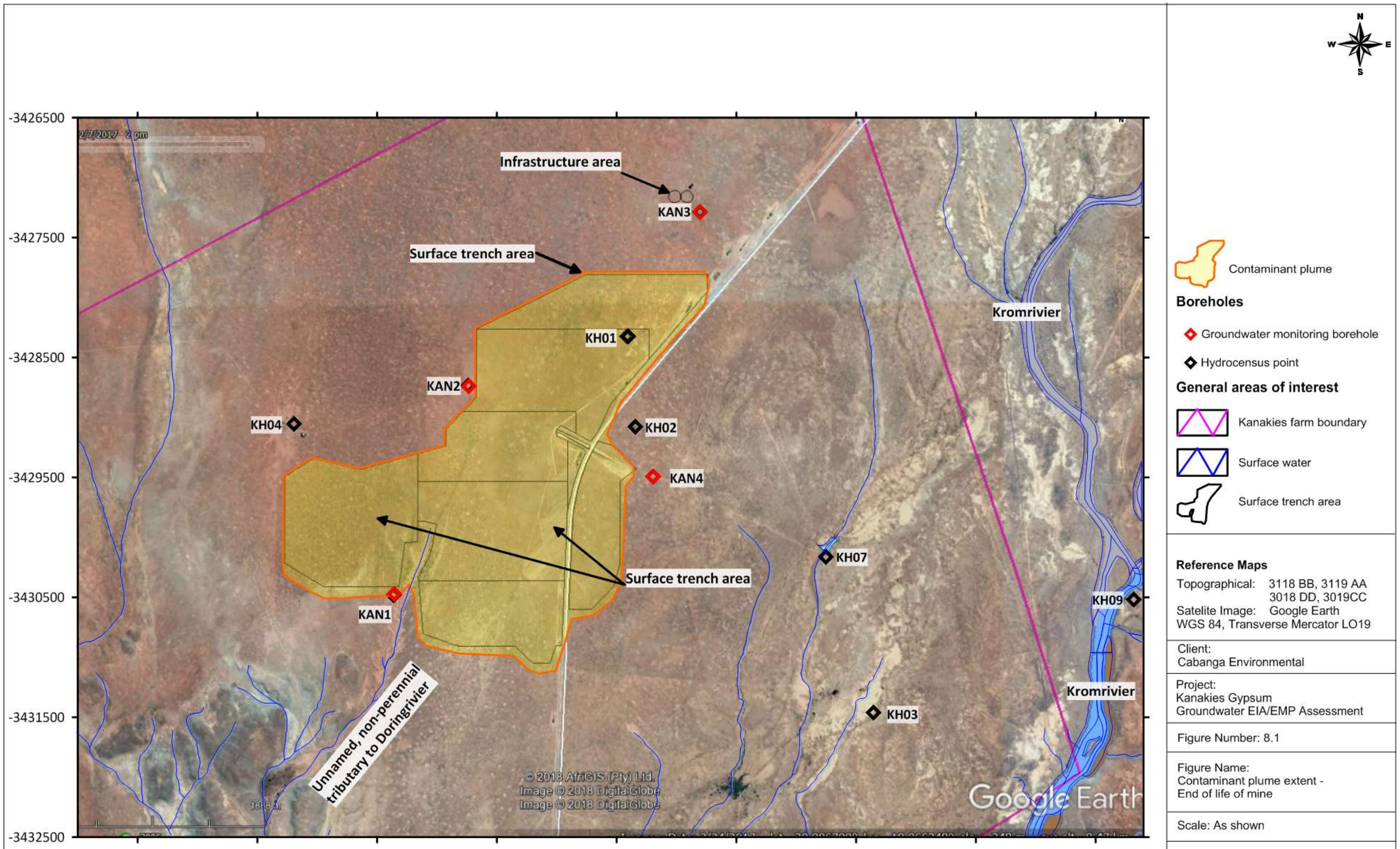
In addition, any baseflow contribution to the stream will be diluted by surface runoff caused by the rainfall as the non-perennial stream will receive the majority of its flow volume from surface runoff during rainfall events.

The total impact on the stream water qualities is expected to be intermittent and negligible due to the combined effect of:

- The stream flow is non-perennial and the stream will mostly only flow during and shortly after rainfall events when surface sheet flow / runoff contributes the vast majority of the stream flows;
- Prolonged and significant rainfall events are required to raise the groundwater level to near surface so that the aquifer can contribute poor quality seepage to the stream in the form of baseflow contribution;
- The impacts length of the stream is less than 1 % of the total length of streams that constitutes the tributary.

No privately owned and used groundwater supply boreholes are impacted.

The product stockpile will continuously be removed when the product is sold and transported off site. Rainfall in the area is low and intermittent and it is not expected that there will be significant seepage from the product stockpile towards the underlying aquifers. Therefore, the impact on the groundwater quality and surrounding environment from the product stockpile is expected to be low.



Reference Maps
Topographical: 3118 BB, 3119 AA 3018 DD, 3019CC
Satelite Image: Google Earth
WGS 84, Transverse Mercator LO19

Client:
Cabanga Environmental

Project:
Kanakies Gypsum
Groundwater EIA/EMP Assessment

Figure Number: 8.1

Figure Name:
Contaminant plume extent -
End of life of mine

Scale: As shown

Date: July 2018
Revision: 1

Designed: MP
Approved:

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Table 8.3: Impact rating – Operational phase

Impact	Status	Effect	Extent	Duration	Reversibility	Consequence	Probability	Significance	Mitigation	Degree of irreplaceable loss	Mitigation	Status	Effect	Extent	Duration	Reversibility	Consequence	Probability	Significance
Impacts on groundwater volumes due to active dewatering of the trench area	Neg	1	1	1	1	4	1	4	Y	Low	No impact expected, no mitigation required								
Impacts on groundwater quality due to poor quality seepage from the operational area	Neg	3	1	5	5	14	3	42	Y	Low	Monitor groundwater quality; Implement management measures as necessary	Neg	2	1	5	5	13	3	39
Impacts on surface water and wetland volumes due to active dewatering of the trench mining area	Neg	1	1	1	1	4	1	4	Y	Low	No impact expected, no mitigation required								
Impacts on surface quality due to poor quality seepage from the pollution source areas	Neg	1	1	4	5	11	1	11	Y	Mod	Monitor surface water quality								

8.3. Decommissioning phase

During the decommissioning phase backfilling and rehabilitation of the trench area will be completed. The remaining waste from the plant will be backfilled into the trench area, removing the contaminant threat from surface. The product stockpile area will be rehabilitated, removing all potential sources of contamination. The mobile crushing and screening plant will be decommissioned and removed from site.

8.3.1. Recovery of groundwater levels

Because there were no impacts on the groundwater level during the operational phase, there is no recovery of groundwater levels.

8.3.2. Contaminant migration

Contaminant migration similar to the operational phase will continue. Surface pollution sources will be removed; therefore, the plume concentrations can start to decrease. However, the decommissioning phase is expected to the short duration, therefore there will not be a notable change in contamination during this phase.

8.4. Long term post-operational phase

8.4.1. Recovery of groundwater levels

Because there were no impacts on the groundwater level during the operational phase, there is no recovery of groundwater levels.

8.4.2. Decant potential

The topographical elevation within the trench area ranges between 334 and 360 mamsl. With the trench being between 1.4 and 2.5 m deep, it is possible that decant can take place when the water level in the rehabilitated area rises due to rainfall recharge and a portion of the trench area is submerged to 334 m elevation.

However, using the hydraulic conductivity of the soil underlying the trench it is calculated that the rate of seepage into the underlying weathered material will exceed the rate of recharge into the rehabilitated material and therefore it is not expected that decant will take place.

8.4.3. Contaminant migration

Contaminant migration away from the rehabilitated trench areas will continue in the post-mining environment. Natural attenuation through dilution with uncontaminated groundwater and recharging rainfall will mitigate the developing contaminant plume. Calculations show that the contaminant plume will migrate up to 250 m from the edge of the trench in a down gradient direction (please refer to Figure 8.2).

Figure 8.2 show that the upper reaches of the unnamed, non-perennial tributary to the Doringrivier will be impacted by the developing contaminant plume. The plume migrating down gradient away from the trench area will impact on the upper reaches of the unnamed, non-perennial tributary to the Doringrivier. In total approximately 850 m of the length of the stream falls within the zone of influence of the migrating plume by 100 years after the end of the life of mine. This equates to less than 1 % of the total length of the stream network that constitutes the tributary.

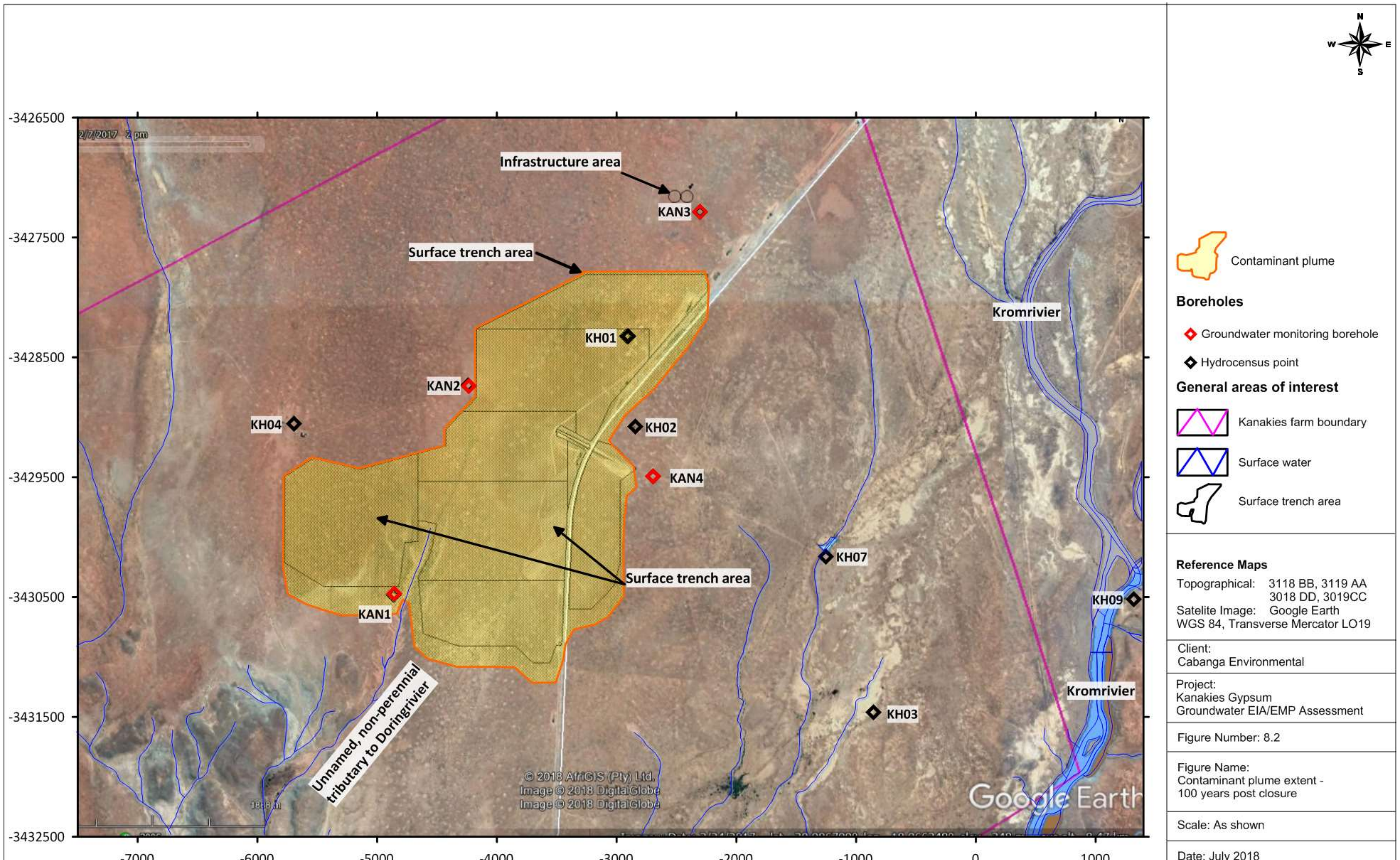
The maximum expected salt load contribution to the stream is calculated to be 1.6 kg/day. This contribution will be for only a very short period of time, and will only occur after prolonged rainfall events where continuous recharge from rainfall can increase the groundwater level to near surface so that the groundwater can contribute to the stream flow volume through baseflow contribution. It is expected that this will not be a regular or even yearly occurrence due to the low rainfall in the area.

In addition, any baseflow contribution to the stream will be diluted by surface runoff caused by the rainfall as the non-perennial stream will receive the majority of its flow volume from surface runoff during rainfall events.

The total impact on the stream water qualities is expected to be intermittent and negligible due to the combined effect of:

- The stream flow is non-perennial and the stream will mostly only flow during and shortly after rainfall events when surface sheet flow / runoff contributes the vast majority of the stream flows;
- Prolonged and significant rainfall events are required to raise the groundwater level to near surface so that the aquifer can contribute poor quality seepage to the stream in the form of baseflow contribution;
- The impacts length of the stream is less than 1 % of the total length of streams that constitutes the tributary.

No privately owned and used groundwater supply boreholes are impacted.



Reference Maps Topographical: 3118 BB, 3119 AA 3018 DD, 3019CC Satelite Image: Google Earth WGS 84, Transverse Mercator LO19
Client: Cabanga Environmental
Project: Kanakies Gypsum Groundwater EIA/EMP Assessment
Figure Number: 8.2
Figure Name: Contaminant plume extent - 100 years post closure
Scale: As shown
Date: July 2018 Revision: 1
Designed: MP Approved:
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Table 8.4: Impact rating – long term post-operational phase

Impact	Status	Effect	Extent	Duration	Reversibility	Consequence	Probability	Significance	Mitigation	Degree of irreplaceable loss	Mitigation	Status	Effect	Extent	Duration	Reversibility	Consequence	Probability	Significance
Groundwater level recovery	Pos	1	1	1	1	4	1	4	Y	Low	Positive impact, no mitigation required	-	-	-	-	-	-	-	-
Impacts on groundwater quality due to poor quality seepage from the trench area	Neg	4	2	5	5	16	3	48	Y	Mod	Monitor the groundwater quality	Neg	2	2	5	5	14	2	28
Impacts on surface quality due to poor quality seepage from the pollution source areas	Neg	1	1	5	5	12	2	24	N	Mod - low	-								

9. Groundwater monitoring system

9.1. Groundwater monitoring network

9.1.1. Source, plume, impact and background monitoring

A water monitoring program that incorporates the proposed operations, with focus on the possible sources of impact, has to be implemented. These sources of impacts include the trench area as well as proposed surface areas including the stockpiles.

9.1.2. Monitoring frequency

It is recommended that the monitoring program start with a monthly interval for the first year. Ideally, the monitoring program should start a year before mining starts in order to be able to build a database that is not impacted by the mining activities.

Once the monthly database is established the monitoring frequency can change to quarterly.

9.2. Monitoring parameters

Parameters and elements to be monitored for should comply with the mine Water Use License, and also correspond to the parameters suitable to monitor gypsum mining activities. Recommended parameters and elements are summarised below:

- General chemistry such as pH, TDS and EC;
- Major elements such as calcium, magnesium, sodium, potassium, sulphate, nitrate, fluoride, chloride, phosphate;
- An ICP scan of minor elements including aluminium, arsenic, barium, boron, bismuth, cadmium, copper, chrome (total), cyanide, iron, manganese, mercury, molybdenum, nickel, lead, antimony, selenium, vanadium and zinc.

9.3. Monitoring boreholes

The monitoring program should include:

- The groundwater monitoring boreholes drilled during this study: KAN1 to KAN4; and
- Hydrocensus points which lie close to the zones of impact and could possibly be at risk: KH01 and KH04.

10. Groundwater environmental management programme

10.1. Current groundwater conditions

Please refer to Section 5 of this report.

10.2. Predicted impacts of facility

Please refer to Section 8 of this report.

10.3. Mitigation measures

10.3.1. Lowering of groundwater levels during facility operation

The depth of the trench excavations will range between 1.4 and 2.5 m. Depth to groundwater level in the area is more than 8 m. The groundwater level will not be breached and no dewatering of the trench will be required. Therefore, there will be no drawdown in groundwater level, and no associated impact on the aquifers, wetlands, and stream flow volumes. No mitigation measures are required.

10.3.2. Rise of groundwater levels post-facility operation

No rise in groundwater level is expected during the post-closure phase because there will be no drawdown in groundwater level during the operational phase. In addition groundwater level recovery would be a positive impact and does not require any mitigation measures.

10.3.3. Spread of groundwater pollution post-facility operation

The spread of groundwater contamination is discussed in more detail in Section 8.4.3 of this report. Management measures include:

- Proper removal of, and rehabilitation of, surface stockpiles during decommissioning;

11. Post closure management plan

11.1. Remediation of physical activity

The trench area will be rehabilitated continuously during the life of mine. The waste material produced during the crushing and screening process will be used to backfill the trench area.

The stockpile areas, as well as the offices will be remediated during the decommissioning phase.

11.2. Remediation of storage facilities

Surface storage facilities will be cleared and remediated (stockpile, fuel storage area, workshop, mobile offices and ablutions etc.).

11.3. Remediation of environmental impacts

It will be impossible to prevent and rehabilitate the impacts of contaminant migration away from all the pollution sources (trench and potentially stockpiles etc.). Therefore, it is recommended that the groundwater monitoring program be continued for a period of at least 5 years after mine closure to monitor the contaminant migration. Based on these results remediation requirements can be identified and a remediation plan put in place.

11.4. Remediation of water resources impacts

The contaminant migration calculation results show that it is possible that there will be a slight impact on the surface water courses in the area. In addition, the geochemical assessment show that the material handled on site can be expected to potentially form AMD conditions.

Therefore, it is recommended that the streams be monitored and management systems be put in place. This could include cut-off trenches down gradient of the pollution sources and management of the seepage.

12. Conclusions and recommendations

12.1. General conclusions

- The proposed trench area falls within one sub-catchment. The regional topography is best described as relatively flat and locally slopes towards the streams that drain the region;
- South of the proposed trench area a non-perennial tributary to the Doringrivier drains the area. Approximately 3 to 4 km east of the proposed trench area the `North / South draining Kromrivier drains the area;
- Within the proposed trench area itself the topography slopes from the north to the south. Topographical gradients are calculated to be in the order of 1:80 to 1:100. Site specific topographical elevations range between 360 metres above mean sea level (mamsl) in the north to 330 mamsl in the south; and
- In terms of surface water drainage systems the surface infrastructure and the trench areas fall within the E33A quaternary catchment which forms part of the Knersvlakte and ultimately the Berg Olifants Water Management Area (WMA).

12.2. Baseline groundwater conditions

- Three aquifers occur in the area. These three aquifers are associated with a) the upper weathered material and gypsum layer, b) the underlying competent and fractured rock material, and c) the alluvial sand in the river channels;
- Upper weathered material aquifer:
    - The upper weathered material aquifer forms due to the vertical infiltration of recharging rainfall through the weathered material and the gypsum layer being retarded by the lower permeability of the underlying competent rock material. The aquifer thickness range between 16 and 20 m;
    - Recharge is 0.03 % of the MAP;
    - Typical transmissivity values for this aquifer range between 0.1 and 5 m^2/day;
    - The borehole yields in this aquifer are seasonally variable due to the strong dependence on rainfall recharge. Generally, it can be said that the yields of this aquifer during the rainy season can be around 1 L/s while sustainable yields will decrease markedly during the dry season. In some areas this aquifer will be laid completely dry during the dry season;
- Groundwater flows in the lower fractured rock aquifer are associated with the secondary fracturing in the competent rock and as such will be along discrete pathways associated with the fractures. Faults and fractures in the host geology can be a significant source of groundwater depending on whether the fractures have been filled with secondary mineralisation;
- The third aquifer that occurs in the area is localised along the stream beds. Alluvial sand has accumulated in the river beds over time as low energy stream flows deposited transported material. During rainfall events when the streams flow surface water recharge into the alluvial sand that line the river channels. This water can be pumped from the sands during times when the rivers are not actively flowing. Yields from this aquifer can be

relatively high due to the sandy nature of the aquifer material. However, once the sand is dewatered the groundwater users will have to wait until after the next significant rainfall event before water can be abstracted again;

- The hydraulic conductivity of gypsum ranges between 3.5 x 10^{-8} and 2 x 10^{-3} m/day. The weathered, clayey, mudstone and siltstone that underlies the gypsum has a hydraulic conductivity in the range of 0.001 to 10 m/day;
- Depth to groundwater level ranges between 9.45 and 12.87 mbgl;
- The groundwater qualities in general comply with the SANS241:2015 drinking water guidelines. Sodium, chloride, and sulphate concentrations exceed the SANS241:2015 drinking water guidelines. Borehole KH09 also shows a fluoride concentration that at 2.5 mg/L exceeds the SANS241:2015 guideline of 1.5 mg/L somewhat;
    - At chloride concentrations greater than 1 200 mg/L the water has an unacceptably salty taste. Nausea and disturbance of the electrolyte balance can occur, especially in infants, where fatalities due to dehydration may occur;
    - At sodium concentrations between 600 and 1 000 mg/L water has a very salty taste. Health effects may be expected and the water is very undesirable for infants or persons on a sodium restricted diet. At concentrations between 1 000 and 5 000 mg/L the water has an extremely salty taste becoming bitter. Severe health effects with disturbance of the electrolyte balance can occur. The water is extremely undesirable for infants of persons on a sodium restricted diet;
    - At sulphate concentrations between 400 and 600 mg/L diarrhoea is expected for most non-adapted individuals and the water has a definite salty or bitter taste. At concentrations ranging between 500 and 1 000 mg/L diarrhoea is expected for most individuals and user adaptation does not occur. The water has a pronounced salty or bitter taste;
- The water plots in the upper right-hand section of the piper diagram diamond. All four water samples have a sodium – chloride dominant character;
- For aquifer vulnerability reference is made to the aquifer vulnerability map of South Africa which shows a low aquifer vulnerability for the project area; and
- The aquifers present in the area are classified as minor aquifer, but of high importance to the local landowners as it is their sole source of water for domestic and stock watering purposes.

12.3. Waste classification and AMD potential

- Total concentration analysis results show that barium and fluoride can be expected to generally exceed the TCT0 guideline values. The copper concentration at borehole KAN2 is elevated in both the overburden (30 mg/kg) and the gypsum material (23 mg/kg) compared to the TCT0 guideline value of 16 mg/kg. Arsenic at a concentration of 6 mg/kg slightly exceeds the TCT0 guideline value of 5.8 mg/kg at KAN4. All parameters comply with the TCT1 guideline values;
- The sulphate concentrations exceed the LCT0 guideline value of 250 mg/L. The measured sulphate concentration in the overburden material (soil) is measured at 826 mg/L while the sulphate concentration in the gypsum material measures around 1 400 mg/L. The boron

concentration from the mixed overburden and gypsum material at KAN4 (0.516 mg/L) is slightly elevated above the LCT0 guideline value of 0.5 mg/L. All elements comply with the LCT1 guideline values;

- Based on the leach and total concentration test results the material that will be handled on site is classified as Type 3;
- Both the overburden and gypsum from borehole KAN2 have an NPR of slightly greater than 1. This coupled with a total sulphur percentage of 0.75 to 1.06 % shows that it is possible that the material will be acid generating; and
- The mixed overburden and gypsum from borehole KAN4 show a NPR ratio of less than 1. Coupled with a sulphur percentage of 5.34 % and an NNP of -100 it is likely that this material will be acid producing.

12.4. Environmental impact assessment

12.4.1. Construction phase

12.4.1.1. Groundwater inflow volumes into the trench area

- During excavation of the trenches the groundwater level will not be breached and therefore no notable inflows into the trench are expected. This is based on:
    - Groundwater levels in the area are more than 8 m deep;
    - During the drilling program, which was undertaken during the rainy season when groundwater levels can be expected to be shallower, no groundwater strikes were intercepted at depths shallower than 20 m;
- It is possible that there could be some localised seepages into the excavation, however, based on the low rainfall (133 mm/a), low recharge percentage (0.03 % of MAP), and the low hydraulic conductivity of the gypsum (3.5 x 10^{-8} to 2 x 10^{-3} m/day) such inflows are expected to be very low, less than 50 m^3/day.

12.4.1.2. Groundwater level drawdown

- The groundwater level will not be breached and dewatering of the trench will not be required. Therefore, there will be no impact on the groundwater levels or surface streams in the area; and
- Surface construction of the stockpiles, the crushing and screening plant, offices and haul roads will not breach the groundwater level and is therefore not expected to have any impact on the groundwater levels.

12.4.1.3. Groundwater contamination

- It is assumed that with proper maintenance of construction vehicles and other construction related best practices there will be a limited impact on the groundwater quality from the construction of the surface infrastructure;

- During the construction phase little to no product will be deposited on the product stockpile, and therefore the product stockpile does not form a risk to the underlying aquifers during the construction phase; and
- The temporary plant feed stockpile can receive some material from the trenches. However, the material will be dry due to the fact that the groundwater level lies below the level of the excavation and therefore the material will be deposited dry on the temporary plant feed stockpile. Taking into consideration the very low rainfall in the area (133 mm/a), and the short time span of the construction phase it is not expected that there will be notable seepage from the temporary plant feed stockpile to the underlying aquifers during the construction phase.

12.4.2. Operational phase

12.4.2.1. Groundwater level drawdown

- The depth of the trench excavations will range between 1.4 and 2.5 m. Depth to groundwater level in the area is more than 8 m. The groundwater level will not be breached and no dewatering of the trench will be required. Therefore, there will be no drawdown in groundwater level, and no associated impact on the aquifers, wetlands, and stream flow volumes.

12.4.2.2. Groundwater inflow volumes into the trench

- During excavation of the trench the groundwater level will not be breached and no regional or continuous groundwater inflows into the trench is expected;
- It is possible that there could be some localised seepages into the excavation, however, based on the low rainfall (133 mm/a), low recharge percentage (0.03 % of MAP), and the low hydraulic conductivity of the gypsum (3.5×10^{-8} to 2×10^{-3} m/day) such inflows are expected to be very low, less than 50 m^3/day.

12.4.2.3. Groundwater contamination

- It is assumed that with proper maintenance of mining vehicles and other operations related best practices there will be a limited impact on the groundwater quality from general surface activities;
- The temporary plant feed stockpile will move alongside the active trenching area. The waste generated during the crushing and screening process is expected to be approximately 24 % by volume of material mined. This waste material will then be used to rehabilitate the trench;
- The waste that will be used to rehabilitate the trench area can potentially be AMD forming. Rainfall recharge into the rehabilitated material can lead to water accumulating in the rehabilitated pit area and the perched water level can lead to contaminant migration away from the rehabilitated area;

- The life of mine is expected to be +30 years. It is calculated that should contamination start to migrate away from the rehabilitated area at day one of operations, contamination will migrate a maximum of 45 m from the rehabilitated area during the operations phase of the operations. In reality, this migration is expected to be less based on:
    - There will be a time delay between when the first trench is excavated and when the rehabilitation will start;
    - The low rainfall in the area (133 mm/a) will mean that water will not accumulate from day one in the rehabilitated area and therefore there will not be a driving head from day one;
    - There will be a time delay between trenching and when sufficient chemical reaction has taken place to oxidise the material which could lead to AMD conditions to form;
    - There will be a time delay between the rainwater accumulating in the rehabilitated material and sufficient leaching from the backfill material can take place to impact the water quality significantly;
- The plume migrating down gradient away from the trench area will impact on the upper reaches of the unnamed, non-perennial tributary to the Doringrivier. In total approximately 550 m of the length of the stream falls within the zone of influence of the migrating plume by the end of the life of mine. This equates to less than 1 % of the total length of the stream network that constitutes the tributary;
- The maximum expected salt load contribution to the stream is calculated to be 1.3 kg/day. This contribution will be for only a very short period of time, and will only occur after prolonged rainfall events where continuous recharge from rainfall can increase the groundwater level to near surface so that the groundwater can contribute to the stream flow volume through baseflow contribution. It is expected that this will not be a regular or even yearly occurrence due to the low rainfall in the area. In addition, any baseflow contribution to the stream will be diluted by surface runoff caused by the rainfall as the non-perennial stream will receive the majority of its flow volume from surface runoff during rainfall events;
- The total impact on the stream water qualities is expected to be intermittent and negligible due to the combined effect of:
    - The stream flow is non-perennial and the stream will mostly only flow during and shortly after rainfall events when surface sheet flow / runoff contributes the vast majority of the stream flows;
    - Prolonged and significant rainfall events are required to raise the groundwater level to near surface so that the aquifer can contribute poor quality seepage to the stream in the form of baseflow contribution;
    - The impacts length of the stream is less than 1 % of the total length of streams that constitutes the tributary;
- No privately owned and used groundwater supply boreholes are impacted; and
- The product stockpile will continuously be removed when the product is sold and transported off site. Rainfall in the area is low and intermittent and it is not expected that there will be significant seepage from the product stockpile towards the underlying aquifers. Therefore, the impact on the groundwater quality and surrounding environment from the product stockpile is expected to be low.

12.4.3. Decommissioning phase

12.4.3.1. Recovery of groundwater levels

- Because there were no impacts on the groundwater level during the operational phase, there is no recovery of groundwater levels.

12.4.3.2. Contaminant migration

- Contaminant migration similar to the operational phase will continue. Surface pollution sources will be removed; therefore, the plume concentrations can start to decrease. However, the decommissioning phase is expected to the short duration, therefore there will not be a notable change in contamination during this phase.

12.4.4. Long term post-closure phase

12.4.4.1. Groundwater level recovery

- Because there were no impacts on the groundwater level during the operational phase, there is no recovery of groundwater levels.

12.4.4.2. Decant potential

- The topographical elevation within the trench area ranges between 334 and 360 mamsl. With the trench being between 1.4 and 2.5 m deep, it is possible that decant can take place when the water level in the rehabilitated area rises due to rainfall recharge and a portion of the trench area is submerged to 334 m elevation; and
- However, using the hydraulic conductivity of the soil underlying the trench it is calculated that the rate of seepage into the underlying weathered material will exceed the rate of recharge into the rehabilitated material and therefore it is not expected that decant will take place.

12.4.4.3. Contaminant migration

- Contaminant migration away from the rehabilitated trench will continue in the post-mining environment. Natural attenuation through dilution with uncontaminated groundwater and recharging rainfall will mitigate the developing contaminant plume. Calculations show that the contaminant plume will migrate up to 250 m from the edge of the trench in a down gradient direction;
- The upper reaches of the unnamed, non-perennial tributary to the Doringrivier will be impacted by the developing contaminant plume. The plume migrating down gradient away from the trench area will impact on the upper reaches of the unnamed, non-perennial tributary to the Doringrivier. In total approximately 850 m of the length of the stream falls

within the zone of influence of the migrating plume by 100 years after the end of the life of mine. This equates to less than 1 % of the total length of the stream network that constitutes the tributary;

- The maximum expected salt load contribution to the stream is calculated to be 1.6 kg/day. This contribution will be for only a very short period of time, and will only occur after prolonged rainfall events where continuous recharge from rainfall can increase the groundwater level to near surface so that the groundwater can contribute to the stream flow volume through baseflow contribution. It is expected that this will not be a regular or even yearly occurrence due to the low rainfall in the area. In addition, any baseflow contribution to the stream will be diluted by surface runoff caused by the rainfall as the non-perennial stream will receive the majority of its flow volume from surface runoff during rainfall events;
- The total impact on the stream water qualities is expected to be intermittent and negligible due to the combined effect of:
    - The stream flow is non-perennial and the stream will mostly only flow during and shortly after rainfall events when surface sheet flow / runoff contributes the vast majority of the stream flows;
    - Prolonged and significant rainfall events are required to raise the groundwater level to near surface so that the aquifer can contribute poor quality seepage to the stream in the form of baseflow contribution;
    - The impacts length of the stream is less than 1 % of the total length of streams that constitutes the tributary;
- No privately owned and used groundwater supply boreholes are impacted.

12.5. Reasoned professional opinion

It is recommended that the project be authorized. This recommendation is based on:

- The impact assessment shows that there will be no impact on the groundwater levels in the area. No privately owned boreholes will be impacted by a groundwater level;
- Contaminant migration away from the trench does not impact on private groundwater users;
- The impact on the stream water quality is expected to be limited.

12.6. Conditions for authorisation

There are no conditions for authorisation, except commitment to optimal management and monitoring of the expected impacts as described in Sections 9 and 10 of this report.

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APPENDIX A:

GROUNDWATER BOREHOLE LOGS

Date drilled	29-May-18
Borehole number	KAN1
South	-3 430 484
East	-4 860
Borehole depth	20 m
SWL	Dry
Depth	**Lithology**
1	
2	Light grey gypsum
3	
4	
5	Brown clay
6	
7	
8	Light grey gypsum
9	
10	
11	
12	
13	
14	Brown, weathered gritstone
15	
16	
17	
18	
19	Grey gritstone
20	

Date drilled	29-May-18
Borehole number	KAN2
South	-3 428 733
East	-4 238
Borehole depth	20 m
SWL	Dry
Depth	**Lithology**
1	
2	White gypsum
3	
4	
5	
6	
7	
8	Brown clay
9	
10	
11	
12	
13	Greenish grey weathered clayey
14	shale. Grading over to more competent
15	with depth.
16	
17	
18	Greenish grey shale
19	
20	

Date drilled	29-May-18
Borehole number	KAN3
South	-3 427 285
East	-2 302
Borehole depth	20 m
SWL	Dry
Depth	**Lithology**
1	Light brown overburden
2	
3	Brown clay
4	
5	Yellow clay
6	
7	
8	Light brown clay
9	
10	
11	Greenish, light brown clay
12	
13	
14	
15	Greenish grey clay, grading over to more
16	competent wit depth.
17	
18	
19	Greenish grey shale
20	

Date drilled	30-May-18
Borehole number	KAN4
South	-3 429 493
East	-2 693
Borehole depth	20 m
SWL	Dry
Depth	**Lithology**
1	
2	Light grey gypsum
3	
4	
5	
6	
7	
8	
9	
10	Light brown clay to bottom
11	
12	
13	
14	
15	
16	
17	Some moisture in clay, but not enough
18	to wet sample.
19	
20	

APPENDIX B:

GROUNDWATER CHEMICAL ANALYSIS CERTIFICATES

aquatico Laboratories (Pty). Ltd.

ilac-MRA sanas Testing Laboratory T0685

Test Report Page 1 of 1

Client: Future Flow Cc
Address: 8 Victoria Link, Route 21 Corporate Park, Irene, 0062
Report no: 53348
Project: Future Flow

Date of certificate: 08 June 2018
Date accepted: 01 June 2018
Date completed: 08 June 2018
Revision: 0

Lab no:			30227	30228	30229	30230
Date sampled:			01-Jun-2018	01-Jun-2018	01-Jun-2018	01-Jun-2018
Sample type:			Water	Water	Water	Water
Locality description:			KH01	KH03	KH15	KH09
Analyses	**Unit**	**Method**				
A pH @ 25°C	pH	ALM 20	7.80	7.83	7.70	7.72
A Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	560	538	463	497
A Total alkalinity	mg CaCO3/l	ALM 01	112	146	113	146
A Chloride (Cl)	mg/l	ALM 02	2649	2277	1576	1600
A Sulphate (SO_4)	mg/l	ALM 03	512	984	726	674
A Nitrate (NO_3) as N	mg/l	ALM 06	2.72	2.79	4.59	0.919
A Ammonium (NH_4) as N	mg/l	ALM 05	0.046	0.033	0.038	0.035
A Orthophosphate (PO_4) as P	mg/l	ALM 04	<0.005	<0.005	<0.005	<0.005
A Fluoride (F)	mg/l	ALM 08	1.10	0.561	0.720	2.56
A Calcium (Ca)	mg/l	ALM 30	211	263	252	271
A Magnesium (Mg)	mg/l	ALM 30	194	177	184	160
A Sodium (Na)	mg/l	ALM 30	1272	1272	700	833
A Potassium (K)	mg/l	ALM 30	17.1	8.27	5.19	10.0
A Aluminium (Al)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002
A Iron (Fe)	mg/l	ALM 31	<0.004	<0.004	<0.004	<0.004
A Manganese (Mn)	mg/l	ALM 31	0.001	<0.001	<0.001	<0.001
A Chromium (Cr)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003
A Copper (Cu)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002
A Nickel (Ni)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002
A Zinc (Zn)	mg/l	ALM 31	0.054	0.067	0.032	0.213
A Cobalt (Co)	mg/l	ALM 31	<0.003	<0.003	<0.003	0.003
A Cadmium (Cd)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002
A Lead (Pb)	mg/l	ALM 31	<0.004	<0.004	<0.004	<0.004
A Total hardness	mg CaCO3/l	ALM 26	1325	1385	1386	1335
A Bicarbonate alkalinity	mg CaCO3/l	ALM 26	112	145	112	146

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative test report ; The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

M. Swanepoel
Technical Signatory

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APPENDIX C:

WASTE CLASSIFICATION AND ABA ANALYSIS CERTIFICATES

WATERLAB

WATERLAB (PTY) LTD

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CERTIFICATE OF ANALYSES
ACID – BASE ACCOUNTING
EPA-600 MODIFIED SOBEK METHOD

Date received: 2018-06-01
Project number: 1000

Report number: 74913

Date completed: 2018-06-20
Order number: CAB. 17. 036 – Geochem

Client name: Future Flow Groundwater and Project Management Solutions
Address: Postnet Suite #71, Private Bag X8, Elarduspark, 0047
Tel: —
Facsimile: 086 695 3846

Contact person: Martiens Prinsloo
Email: martiens@ffgpm.co.za
Cell: 083 633 4949

Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification			
	KAL 2 Croon	KAL 2 Calc	KAL 4	KAL 4
Sample Number	31846	31847	31848	31848 D
Paste pH	7.7	8.2	8.3	8.3
Total Sulphur (%) (LECO)	0.75	1.06	5.34	5.34
Acid Potential (AP) (kg/t)	23	33	167	167
Neutralization Potential (NP)	27	52	67	67
Nett Neutralization Potential (NNP)	3.65	18	-100	-100
Neutralising Potential Ratio (NPR) (NP : AP)	1.16	1.56	0.399	0.400
Rock Type	II	II	I	I

*** Negative NP values are obtained when the volume of NaOH (0.1N) titrated (pH: 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 – 2.5 Any negative NP values are corrected to 0.00.**

Please refer to Appendix (p.2) for a Terminology of terms and guidelines for rock classification

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Facsimile: 086 695 3846
Contact person: Martiens Prinsloo
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APPENDIX: TERMINOLOGY AND ROCK CLASSIFICATION

TERMINOLOGY (SYNONYMS)

- Acid Potential (AP) ; *Synonyms*: Maximum Potential Acidity (MPA)
  Method: Total S(%) (Leco Analyzer) x 31.25
- Neutralization Potential (NP) ; *Synonyms:* Gross Neutralization Potential (GNP) ; *Syn*: Acid Neutralization Capacity (ANC) (The capacity of a sample to consume acid)
  Method: Fizz Test ; Acid-Base Titration (Sobek & Modified Sobek (Lawrence) Methods)
- Nett Neutralization Potential (NNP) ; *Synonyms:* Nett Acid Production Potential (NAPP)
  Calculation: NNP = NP – AP ; NAPP = ANC – MPA
- Neutralising Potential Ratio (NPR)
  Calculation: NPR = NP : AP

CLASSIFICATION ACCORDING TO NETT NEUTRALISING POTENTIAL (NNP)

If NNP (NP – AP) < 0, the sample has the potential to generate acid
If NNP (NP – AP) > 0, the sample has the potential to neutralise acid produced

Any sample with NNP < 20 is potentiall acid-generating, and any sample with NNP > -20 might not generate acid (Usher *et al*., 2003)

ROCK CLASSIFICATION

TYPE I	Potentially Acid Forming	Total S(%) > 0.25% and NP:AP ratio 1:1 or less
TYPE II	Intermediate	Total S(%) > 0.25% and NP:AP ratio 1:3 or less
TYPE III	Non-Acid Forming	Total S(%) < 0.25% and NP:AP ratio 1:3 or greater

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CLASSIFICATION ACCORDING TO NEUTRALISING POTENTIAL RATIO (NPR)

Guidelines for screening criteria based on ABA (Price *et al.*, 1997 ; Usher *et al.*, 2003)

Potential for ARD	Initial NPR Screening Criteria	Comments
Likely	< 1:1	Likely AMD generating
Possibly	1:1 – 2:1	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides
Low	2:1 – 4:1	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP
None	>4:1	No further AMD testing required unless materials are to be used as a source of alkalinity

CLASSIFICATION ACCORDING TO SULPHUR CONTENT (%S) AND NEUTRALISING POTENTIAL RATIO (NPR)

For sustainable long-term acid generation, at least 0.3% Sulphide-S is needed. Values below this can yield acidity but it is likely to be only of short-term significance. From these facts, and using the NPR values, a number of rules can be derived:

1) Samples with less than 0.3% Sulphide-S are regarded as having insufficient oxidisable Sulphide-S to sustain acid generation.
2) NPR ratios of >4:1 are considered to have enough neutralising capacity.
3) NPR ratios of 3:1 to 1:1 are consider inconclusive.
4) NPR ratios below 1:1 with Sulphide-S above 3% are potentially acid-generating. (Soregaroli & Lawrence, 1998 ; Usher *et al.*, 2003)

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CERTIFICATE OF ANALYSES

Digestion AS 4439.3

Date received:	**2018/06/01**	**Date completed:**	**2018/07/09**
Project number:	**1000** **Report number: 74913**	**Order number:**	**CAB. 17. 036 – Geochem**
Client name:	**Future Flow Groundwater and Project Management Solutions**	**Contact person:**	**Martiens Prinsloo**
Address:	**Postnet Suite #71, Private Bag X8, Elarduspark, 0047**	**Email:**	**martiens@ffgpm.co.za**
Telephone:	---	**Cell:**	**0836334949**

Analyses	KAL 2 Croon		KAL 2 Calc		KAL 4				
Sample Number	31846		31847		31848		TCT0 mg/kg	TCT1 mg/kg	TCT2 mg/kg
Digestion	HNO3 : HF		HNO3 : HF		HNO3 : HF				
Dry Mass Used (g)	0.25		0.25		0.25				
Volume Used (mℓ)	100		100		100				
Units	mg/ℓ	mg/kg	mg/ℓ	mg/kg	mg/ℓ	mg/kg			
As, Arsenic	0.013	5.20	0.012	4.80	0.015	6.00	5.8	500	2000
B, Boron	0.124	50	0.069	28	0.133	53	150	15000	6000
Ba, Barium	0.763	305	2.80	1120	1.10	440	62.5	6250	25000
Cd, Cadmium	0.016	6.40	0.008	3.20	0.011	4.40	7.5	260	1040
Co, Cobalt	<0.025	<10	<0.025	<10	<0.025	<10	50	5000	20000
Cr_{Total}, Chromium Total	0.298	119	0.287	115	0.330	132	46000	800000	N/A
Cu, Copper	0.075	30	0.057	23	0.035	14	16	19500	78000
Hg, Mercury	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	0.93	160	640
Mn, Manganese	1.30	520	0.561	224	0.882	353	1000	25000	100000
Mo, Molybdenum	<0.025	<10	<0.025	<10	<0.025	<10	40	1000	4000
Ni, Nickel	0.069	28	0.026	10	0.037	15	91	10600	42400
Pb, Lead	0.037	15	0.045	18	0.036	14	20	1900	7600
Sb, Antimony	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	10	75	300
Se, Selenium	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	10	50	200
V, Vanadium	0.170	68	<0.025	<10	0.081	32	150	2680	10720
Zn, Zinc	0.206	82	0.070	28	0.083	33	240	160000	640000
Inorganic Anions	mg/ℓ	mg/kg	mg/ℓ	mg/kg	mg/ℓ	mg/kg			
Cr(VI), Chromium (VI) Total [s]	—	<5	—	<5	—	<5	6.5	500	2000
Total Fluoride [s] mg/kg	—	785	—	574	—	347	100	10000	40000

[s] = subcontracted

UTD = Unable to determine

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PRELIMINARY CERTIFICATE OF ANALYSES

EXTRACTIONS AS 4439.3

Date received:	**2018/06/01**	**Date completed:**	**2018/07/10**
Project number:	**1000** **Report number: 74913**	**Order number:**	**CAB. 17. 036 – Geochem**
Client name:	**Future Flow Groundwater and Project Management Solutions**	**Contact person:**	**Martiens Prinsloo**
Address:	**Postnet Suite #71, Private Bag X8, Elarduspark, 0047**	**Email:**	**martiens@ffgpm.co.za**
Telephone:	---	**Cell:**	**0836334949**

Analyses	KAL 2 Croon	KAL 2 Calc	KAL 4				
Sample Number	31846	31847	31848				
TCLP / Borax / Distilled Water	Distilled Water	Distilled Water	Distilled Water				
Ratio*	1:20	1:20	1:20				
Units	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	LCT0 mg/l	LCT1 mg/l	LCT2 mg/l	LCT3 mg/l
As, Arsenic	<0.001	<0.001	<0.001	0.01	0.5	1	4
B, Boron	0.393	0.114	0.516	0.5	25	50	200
Ba, Barium	<0.025	0.045	<0.025	0.7	35	70	280
Cd, Cadmium	<0.003	<0.003	<0.003	0.003	0.15	0.3	1.2
Co, Cobalt	<0.025	<0.025	<0.025	0.5	25	50	200
Cr_{Total}, Chromium Total	<0.025	<0.025	<0.025	0.1	5	10	40
Cr(VI), Chromium (VI)	<0.010	<0.010	<0.010	0.05	2.5	5	20
Cu, Copper	<0.025	<0.025	<0.025	2.0	100	200	800
Hg, Mercury	<0.001	<0.001	<0.001	0.006	0.3	0.6	2.4
Mn, Manganese	<0.025	<0.025	<0.025	0.5	25	50	200
Mo, Molybdenum	<0.025	<0.025	<0.025	0.07	3.5	7	28
Ni, Nickel	<0.025	<0.025	<0.025	0.07	3.5	7	28
Pb, Lead	<0.010	<0.010	<0.010	0.01	0.5	1	4
Sb, Antimony	<0.001	<0.001	<0.001	0.02	1.0	2	8
Se, Selenium	0.003	0.003	0.001	0.01	0.5	1	4
V, Vanadium	<0.025	<0.025	<0.025	0.2	10	20	80
Zn, Zinc	<0.025	<0.025	0.052	5.0	250	500	2000
Inorganic Anions	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**				
Total Dissolved Solids*	1440	2358	2568	1000	12 500	25 000	100 000
Chloride as Cl	147	23	110	300	15 000	30 000	120 000
Sulphate as SO4	826	1394	1432	250	12 500	25 000	100 000
Nitrate as N	0.2	0.1	<0.1	11	550	1100	4400
Fluoride as F	0.9	1.0	<0.2	1.5	75	150	600
pH	7.8	8.0	8.0				

[s] = Subcontracted

***Please note:**
1. The sample
2. A moisture
3. In cases wh
   Moisture c
4. The results

S. Laubscher
Assistant Geochemistry Project Manager

APPENDIX D:

CURRICULUM VITAE

PERSONAL DETAILS

NAME:	Martiens Prinsloo
DATE OF BIRTH:	14 January 1976
NATIONALITY:	South African
MARITAL STATUS:	Married

ACADEMIC QUALIFICATIONS

Year	Qualification & Institution
2008	MBA: Graduate School of Business, University of Cape Town
2005	M.Sc. (Geohydrology): University of the Free State (Bloemfontein)
1997	B.Sc. (Hons) (Geohydrology): University of the Free State (Bloemfontein)
1996	B.Sc. (Earth Sciences): University of Pretoria

PROFESSIONAL REGISTRATION AND AFFILIATIONS

Registered Professional Natural Scientist S.A. (SACNASP Reg. No. 400248/04)
Groundwater Division of the Geological Society of South Africa (Membership no. 234)
International Association of Hydrogeologists (IAH membership no. 122757)
International Mine Water Association (IMWA membership no. 1121)

OTHER COURSES

Course	Institution
FeFlow (2009)	DHI WASY (Johannesburg)
Geochemical and reactive transport modelling – PHREEQC, MT3DMS and PHT3D (2006)	University of the Western Cape (Cape Town)
Model sensitivity analysis, data assessment, calibration and uncertainty evaluation (2006)	USGS (Cape Town)
Contaminant Site Risk Assessment and Groundwater Modelling (2004)	Waterloo Hydrogeologic Inc. (Johannesburg)
Groundwater Modelling Course (2002)	Summer University of Bremen (Germany)

EMPLOYMENT HISTORY

Date	Company & Position
July 2008 - Present	Future Flow Groundwater & Project Management Solutions cc Founding Member
January 2013 – September 2017	AquaStrata Laboratories (Pty) Ltd (ISO17025 / SANAS accredited testing laboratory) Founding Member
Feb 2007 – June 2008	GCS (Pty) Ltd Manager: Water Resources Unit
Jan 2006 – Jan 2007	GCS (Pty) Ltd Manager: Mining & Modelling Sub-Unit (part of Water Resources Unit)
Apr 2002 – Dec 2005	GCS (Pty) Ltd Hydrogeological modeller / Senior hydrogeologist
Sept 2000 – Mar 2002	GCS (Pty) Ltd Field hydrogeologist
Feb 1998 – Aug 2000	Council for Geoscience Scientific Officer - Hydrogeology

SCIENTIFIC EXPERIENCE

Mining related hydrogeology:

- Hydrogeological investigations for various types of mines including: coal, gold, platinum, nickel, copper, cobalt, uranium, heavy mineral sands and diamond. Work experience range from field data collection to data analysis, chemical characterisation, acid base accounting and waste classification, numerical flow and contaminant transport modelling, water balance calculations and compilation of reports;
- Groundwater monitoring and audit reports. The evaluation of groundwater level fluctuation and water quality data. The compilation of monthly, quarterly and annual monitoring reports;
- Groundwater monitoring well field designs. The siting and design of monitoring boreholes for the assessment of the influence of mining activities on the regional groundwater environment;
- Groundwater investigations and numerical modelling of both fractured rock and primary aquifers;
- Hydrogeological assessments for both opencast and underground mines;
- Water supply for mining activities;
- Mine dewatering assessments and dewatering program designs; and
- Tailings and waste storage facility site selection and impact assessments.

Groundwater resource assessment and development:

- Water supply studies and well field design ranging from rural water supply (hand pump) to large scale water supply for construction and irrigation projects (4 000 m^3/hr);
- Assessment of geological controls, geophysical exploration methods and the quantification of groundwater exploitation potential in complex and problematic terrain;
- Hydrogeological mapping investigations and catchment resource analysis; and
- Regional hydrogeological and chemical investigations involving reconnaissance investigations, geophysical surveys, drilling and test pumping for the planning and development and utilisation of groundwater resources in Southern Africa.

Waste disposal management:

- Environmental Impact Assessments for the manufacturing and petroleum industries. Experience includes field data collection, hydrogeological and chemical data analysis and report compilation;
- Environmental Impact Assessments and site suitability assessments for waste disposal sites (including HH classified sites); and
- Characterisation and numerical modelling of contaminant plume migration.

Energy:

- Conventional coal powered power stations, including underground coal gasification: Site selection and risk assessment, environmental impact assessments, geochemical characterisation of fly ash disposal facilities, and impact mitigation;
- CSP and PV renewable energy: Site selection and risk assessment and environmental impact assessments;
- Bio-mass-to-energy (various energy sources from plant matter to biological waste products): Site selection and risk assessment and environmental impact assessments;
- Hydropower: Impact and risk assessment.

COUNTRIES WORKED IN

Australia, Burkina Faso, Democratic Republic of the Congo (DRC), Ivory Coast, Lesotho, Madagascar, Mali, Mozambique, Namibia, Senegal, South Africa, Tanzania, Zambia, and Zimbabwe.

LANGUAGE PROFICIENCY

English and Afrikaans – Speak, read, write.

TEACHING

- Part time lecturing at the University of Johannesburg (2001 – 2005): Civil Engineering Course – Hydrogeology.
- Ad hock lecturing at the University of the Witwatersrand (2007 – 2008): Postgraduate / Industrial Masters Course: Coal mining extraction and exploitation – Groundwater contaminant transport modelling;
- Annual course lecturing at the University of Pretoria (2009, 2011 – 2018): Postgraduate course: Groundwater Numerical Modelling.

PAPERS AND PUBLICATIONS

- Prinsloo, M.J. (2004). "Characterisation of the dolomitic aquifer in the Copperbelt Province, Northern Zambia". Waternet / WARFSA Symposium, Windhoek, Namibia.
- Prinsloo, M.J. (2006). "Prediction of mine inflow volumes". Mine Water Conference, Johannesburg, South Africa.
- Prinsloo, M.J. (2006). "Prediction of the impact that coal mines have on the environment". Waterberg Coalfield Conference, Lephalale, South Africa.
- Prinsloo, M.J. (2006). "Ruashi Phase II hydrogeological investigation". Mining Review Africa, Issue 2, 2006.
- Wilke, A.R. & Prinsloo, M.J. (2009). "Overview of Malian Geohydrology with focus on Mining Projects and their influence on the environment". GSSA GWD: Groundwater Conference, Somerset West, South Africa.
- Prinsloo, M.J. (2011). "Using groundwater modelling to facilitate your mining operations". Strategic Water Drainage Summit 2011 – Optimising Water Usage and Minimising Impact on Water Quality in Mining Operations. Johannesburg, South Africa.

CONTACT DETAILS

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