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Updated Groundwater Assessment for the Proposed Magdalena Opencast Extension

Report

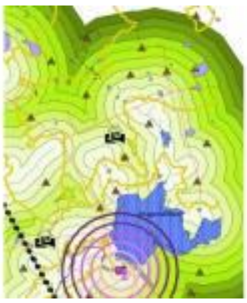
Version – Final

10 December 2013

Zinoju Coal (Pty) Ltd

GCS Project Number: 13-727

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EXECUTIVE SUMMARY

GCS (Pty) Ltd was contracted by Zinoju Coal (Pty) Ltd to conduct the Alleen 2 proposed opencast extension EMPR. This report will encompass the groundwater assessment for Magdalena Colliery which will be used to supplement the EMPR. The purpose of this report is to assess the potential changes to the groundwater quality and quantity in the vicinity of the new Magdalena opencast extension.

The DWA G4 guidelines (2008), specifically the source-pathway-receptor principles will be considered. The proposed opencast expansion will cover an area of approximately 0.62 km^2 and will be excavated to a depth of approximately 40 m. The entire project will last a period of approximately 4 years, during which time Forbes will mine the area using the opencast excavation, roll-over-method. This method compartmentalises the area so that a single section of the entire area is mined out and the following section is used as backfill to the previous section. In this way only a small area is exposed during any one time and each section should take approximately 1 month to complete.

During the excavation stage, the pit will be dewatered which will cause a cone of depression to form around the pit. Due to the hydraulic conductivity of the surrounding rock, this will take several years for normal flow to resume. During this time, oxidation of exposed sulphide minerals, mainly in the form of pyrite, will cause excess production of sulphate and iron to form. When sulphate is introduced to water, sulphuric acid forms. It is, therefore, important to reduce the exposure of sulphide bearing strata to the environment. This is best done during backfilling of the pit by ensuring that high risk geological strata are not exposed to oxygen through saturation of the material. This will be discussed in detail in the following sections.

The following concluding remarks can be made:

Hydrochemistry

- The available groundwater monitoring data shows that the current opencast workings have no adverse effects on the groundwater quality. However, the data for this area is limited and is based on one year worth of data at borehole GCS5 which is located immediately down gradient of the existing opencast workings.
- Data obtained for GCS5 as well as a community borehole located in the proposed expansion area indicates that the groundwater quality has a naturally high salt load with high conductivity, TDS and sodium present. This has been confirmed during previous studies which have shown naturally saline groundwater quality in this area.
- Both boreholes illustrate a sodium-bicarbonate water type, which was previously discovered during similar hydrocensus studies.

Acid Base Accounting

- The proposed pit will be excavated to a depth of approximately 40m through alternating beds of sandstone and shale. The sandstone forms the bulk of the geology, the upper ±30m, of the pit. The predominant shale layer is carbonaceous and closely associated with the upper coal seam. The shale and coal layers are, therefore, expected to contain a large amount of pyrite which is the key mineral in acid producing environments.
- The results of the ABA indicate that the shale and coal layers have a likely acid generating potential based on the NNP as well the NPR.
- The sandstone layer, which constitutes a large portion of the geology of the pit, has an uncertain (NNP) or possible (NPR) acid generation potential.
- The coal and shale layers, therefore, pose the greatest risk to groundwater quality. The bulk of the coal layer will be removed during mining which will reduce the risk of future acid generation in the pit.
- It is recommended that, during backfilling, the shale layer is put back into the pit first at the deepest section of the pit. Therefore, when water levels in the pit rise this section will be completely submerged and thus stop the oxidation process. The next section shows that groundwater levels are expected to rise approximately 15m from the base of the pit, once the pit has been backfilled, which means that the lower 15m of the pit will become saturated over time. This will help to reduce the acid generating potential of the shale.

Local Aquifer Characteristics

- Aquifer parameters (hydraulic conductivity / transmisssivity, piezometric levels, gradients, etc.) were obtained from the previous groundwater assessments and relevant literature. By making use of these values, a hydrogeological conceptual model for the mining area was developed.
- The water levels in this area are approximately 20 m below ground level. As such, it is expected that water levels will drop approximately 15 m at the receiving face of the pit during the operational phase. Once each section of the pit has been backfilled, normal flow will resume within that section over time.
- Analytical calculations indicate moderate groundwater movement (31 to 83 m in an easterly direction in one year, under steady state conditions). Any pollutants generated by the mining activities (SO_4 content usually) will therefore migrate according to these flow rates.

- However, it must be noted that de-watering activities, during the operational phase, will cause a cone of depression towards the opencast areas and groundwater flow tends to flow back towards these areas. This will limit mass transport to the surrounding aquifers during the operational phase. Mass transport can therefore increase after the rebound of water levels during the de-commissioning phase and after.

Impact due to dewatering

- The proposed opencast pit will be mined in sections using the roll over method. This will limit the extent of dewatering as the backfill material will accommodate recharge that will constitute a rise in static water level.
- Therefore, the extent of the simulated drawdown at the time of pit closure in 2018 is reduced by use of the roll over method. Groundwater levels are expected to drop by 5m at the center of the pit at the time of pit closure and rise further away from the pit. The drawdown simulations show that the cone of depression will have an extent of approximately 340m south, 697m east and 505m west of the pit.

Impact due to mass transport

- The simulated mass transport was modelled for mine closure in 2038, 50 years post closure and 100 post closure in order to examine the change in the zone of influence of the pit.
- At mine closure, the zone of influence is predicted to extend approximately 271m east of the pit. This increases to 549m 50 years post closure and 1.6km 100 years post closure at the greatest extent of the zone of influence.
- The sulphate concentrations within this zone are predicted to be above 200 mg/l. These concentrations will be highest at the pit and dissipate outwards.

Risk Assessment

- The risk assessment was determined based on estimated impact to the aquifer over time as well as risk to the receptors, in this case additional groundwater users.
- The risk assessment, in terms of groundwater, focuses on the risk that a specific activity will pose to the groundwater quantity and groundwater quality.
    - It is anticipated that a cone of depression will develop around the proposed opencast pit during the construction and operational phase of pit development. The extent of dewatering will be reduced by use of the Roll-Over Method. The cone of depression will also decrease over time, after the decommissioning phase, as water flow resumes normally within the rehabilitated pit.

- Long term poor water quality seepage is anticipated in the form of a sulphate plume.
- Stockpiles and discard dumps have already been established at the site. These areas may need to be enlarged to cope with the expansion. New pollution control dams will need to be constructed to cope with the additional volume of water. Dirty water runoff must be diverted to the PCD's and monitoring of these surface operations should continue quarterly.

Monitoring Program

- The current monitoring program does not include boreholes down gradient of the proposed opencast pit extension.
- It is recommended that two additional boreholes, GCS6 and GCS7 are drilled down gradient of the proposed opencast workings to a depth of 30m.
- These additional boreholes should be included into the monitoring programme before pit development commences so that changes in water quality from pre-construction to operational and closure phase can be assessed.

Recommendations

Groundwater Management Objectives

Construction Phase

To prevent contamination of surface water runoff from the opencast pit and infrastructure development.

Actions: Construction Phase

- Separate clean and dirty runoff and contain dirty water in adequately sized pollution control dams. Ensure that pollution control dams are adequately sized according to the specifications in DWAF's GN704 or other applicable regulations.
- Keep dirty areas as small as possible; and,
- Compact the base of dirty areas, like the ROM coal stockpile, workshops and oil and diesel storage areas to minimise infiltration of poor quality water to the underlying aquifers.
- Have oil/diesel spill kits on site (Spill Tech House, 604/608/610 Umbilo Road, Congella, KwaZulu-Natal, 4001, Tel: 0861 000 366, Tel: +27 (0)31 206 0919).
- Confirm groundwater and surface water monitoring protocol and plans. It is recommended that groundwater monitoring be conducted on a quarterly basis.
-

Operational Phase

To restrict the impact of polluted groundwater to the mining area and mitigate the loss of groundwater from the catchment.

Actions: Operational Phase

- Re-use groundwater seepage collected in the open pits to adequately sized pollution control facilities in the mining process.
- Keep dirty areas like the pollution control dam and coal stockpiles, workshops and oil and diesel storage areas as small as possible; and
- Contain poor quality runoff from dirty areas and divert this water to pollution control dam for re-use.
- Have oil/diesel spill kits on site (Spill Tech House, 604/608/610 Umbilo Road, Congella, KwaZulu-Natal, 4001, Tel: 0861 000 366, Tel: +27 (0)31 206 0919).
- Confirm groundwater and surface water monitoring protocol and plans. It is recommended that groundwater monitoring be conducted on a quarterly basis.

Groundwater Closure Objectives

- To negotiate and get the groundwater closure objectives approved by Government during the Decommissioning Phase of the project, based on the results of the monitoring information obtained during the Construction and Operational Phases of the project, and through verification of the numerical model constructed for the project;
- To continue the groundwater quality and groundwater level monitoring for a period of two to four years after mining ceases in order to establish post-closure groundwater level and quality trends. The monitoring information must be used to update, verify and recalibrate the predictive tools used during the study to increase the confidence in the closure objectives and management plans;
- To present the results of the monitoring programme to Government on an annual basis. The post-closure monitoring programme will be re-evaluated on an annual basis in consultation with Government;
- To negotiate mine closure with Government based on the results of the groundwater monitoring undertaken, after the two-four year post-closure monitoring periods.

Actions: Closure

- To close all mining pits according to the EMP;
- Update existing predictive tools to verify long-term impacts on groundwater, if required; and

- Present the results to Government on an annual basis to determine compliance with the closure objectives set during the Decommissioning Phase.

Technical Recommendations

The following technical aspects are recommended to ensure adequate follow ups and information gathering occurs. These are only generic and may be adjusted as mining commences. The main purpose is to ensure continuous improvement of the understanding of the hydrogeological environment:

- More ABA tests and leach test to be conducted during the construction of the open pits. As development progresses through the roof, seam and floor material samples can be collected.
- The numerical groundwater model is updated when changes in the mine plan and infrastructure plan occur.
- The numerical groundwater model be updated with new data and calibrated every two years during operations.
- Routine ABA and leach testing be conducted on coal discard and slurry material. This will assist with continuous impact and closure assessments,
- Water inflow in the open pit workings is sampled on a quarterly basis to understand water quality aspects.

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1 INTRODUCTION

1.1 Terms of Reference

GCS (Pty) Ltd was contracted by Zinoju Coal (Pty) Ltd to conduct the Alleen 2 proposed opencast extension EMPR. This report will encompass the groundwater assessment for Magdalena Colliery which will be used to supplement the EMPR.

The DWA G4 guidelines (2008), specifically the source-pathway-receptor principles will be considered. The proposed opencast expansion will cover an area of approximately 0.62 km^2 and will be excavated to a depth of approximately 40 m. The entire project will last a period of approximately 4 years, during which time Forbes will mine the area using the opencast excavation, roll-over-method. This method compartmentalises the area so that a single section of the entire area is mined out and the following section is used as backfill to the previous section. In this way only a small area is exposed during any one time and each section should take approximately 1 month to complete.

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1.2 Scope of Work

The main focus of this assessment will be to assess possible impacts on the groundwater environment. The main objectives of the groundwater assessment will be:

- Update the existing conceptual hydrogeological understanding of the area by including all newly available data.
- Conduct a hydrocensus of all additional groundwater users in the area. GRIP (Groundwater Resource Information Project) data will be used to locate additional users.
- Water samples will be collected from exploration boreholes to assess the pre-mining groundwater quality of the area.

- Collect fresh samples of the different strata from the existing opencast pit for Acid Base Accounting.
- Consider all new and updated water quality and water level data
- Apply all new data into the existing numerical groundwater model and update/calibrate the model accordingly
- Final reporting.

1.3 Area of Investigation

Magdalena Colliery is located approximately 22 km north of Dundee, within the Amajuba District Municipality in the KwaZulu-Natal Province, Figure 1-1. The Colliery is an existing Coal Mine Operation with an approved Environmental Management Programme Report (EMPR) and is operated by Zinoju Coal (Pty) Ltd. This site consists of abandoned underground workings, current underground workings, discard dump, rehabilitated opencast workings and un-rehabilitated opencast workings, Figure 1-2.

The proposed opencast workings will be situated on farm property, Alleen 2, immediately adjacent to the Forbes EMPR area which belongs to Ekhwesi Energy who have given Forbes permission to mine on their property.

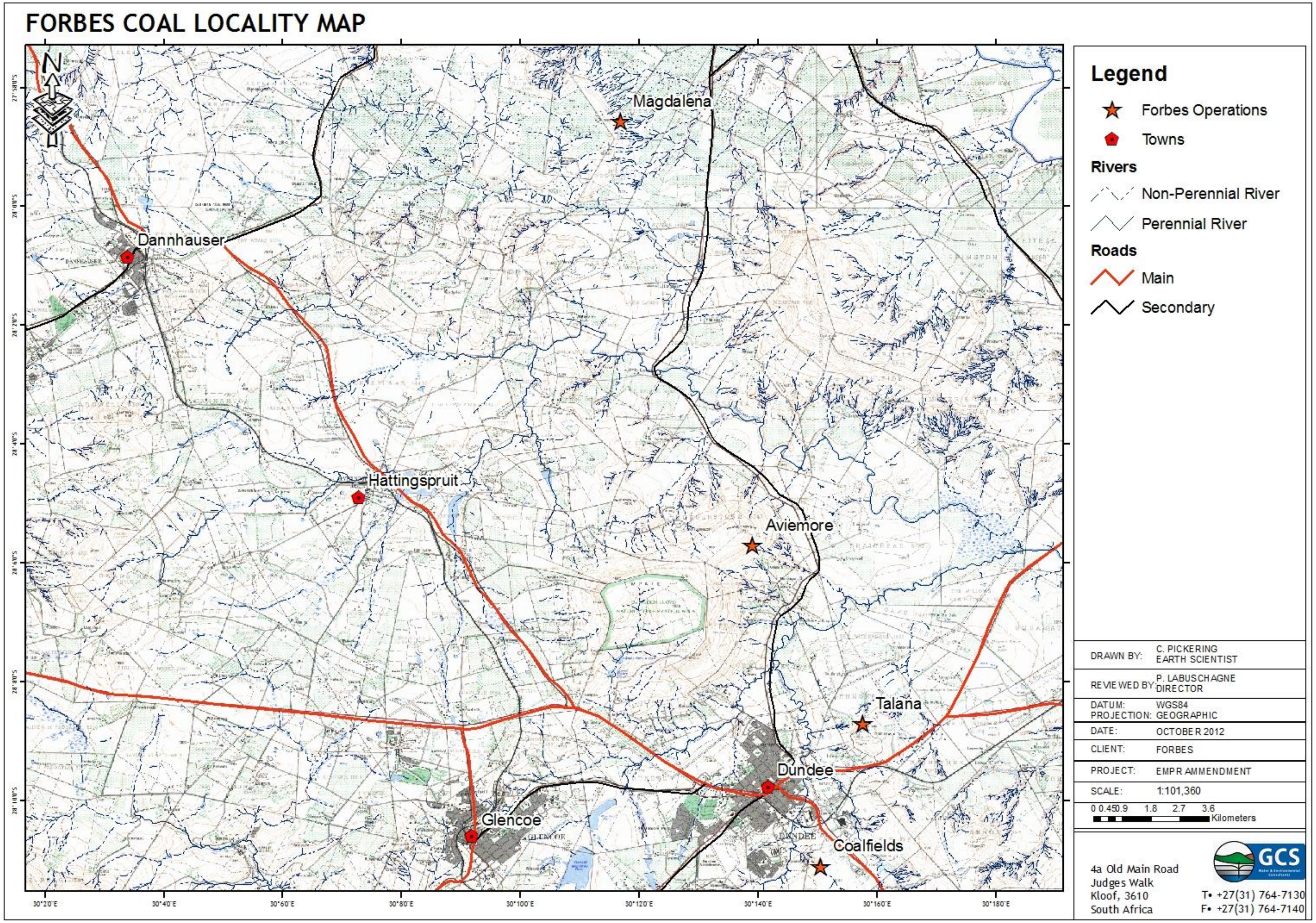

Figure 1-1: Forbes Operations Locality Map

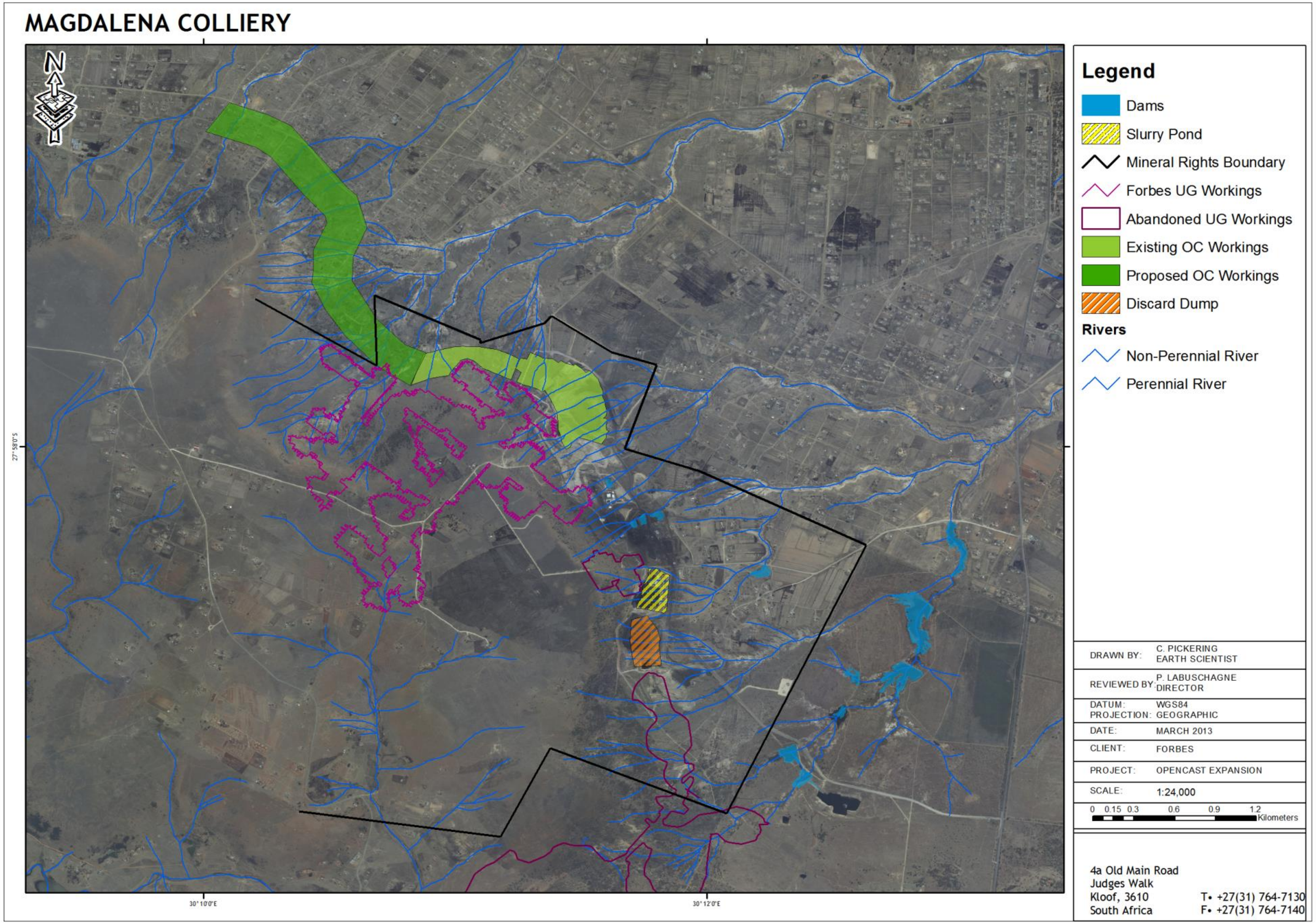

Figure 1-2: Magdalena Colliery mine operation

2 BACKGROUND INFORMATION

This section will supply background information on the Magdalena Colliery and the area surrounding the mine. This will be taken from the 2001 EMPR on Magdalena and will include information on the regional geology, surface water catchment characteristics and groundwater flow dynamics and chemistry.

2.1 Geology

Magdalena Colliery is underlain by sediments of the Vryheid Formation. The Vryheid formation, part of the Ecca Group, is represented by alternating beds of shale, mudstone and a variety of fine grained to gritty feldspathic sandstones, carbonaceous shales and coal.

Three coal seams; namely the Leader, Top seam and Bottom seam, occur within the region. Figure 2-1 indicates the extent of the Top seam as determined by regional geological drilling on the farms adjacent to Magdalena No. 7574.

Figure 2-2 shows the local geology of the area around Magdalena Colliery. This geology is discussed in more detail below.

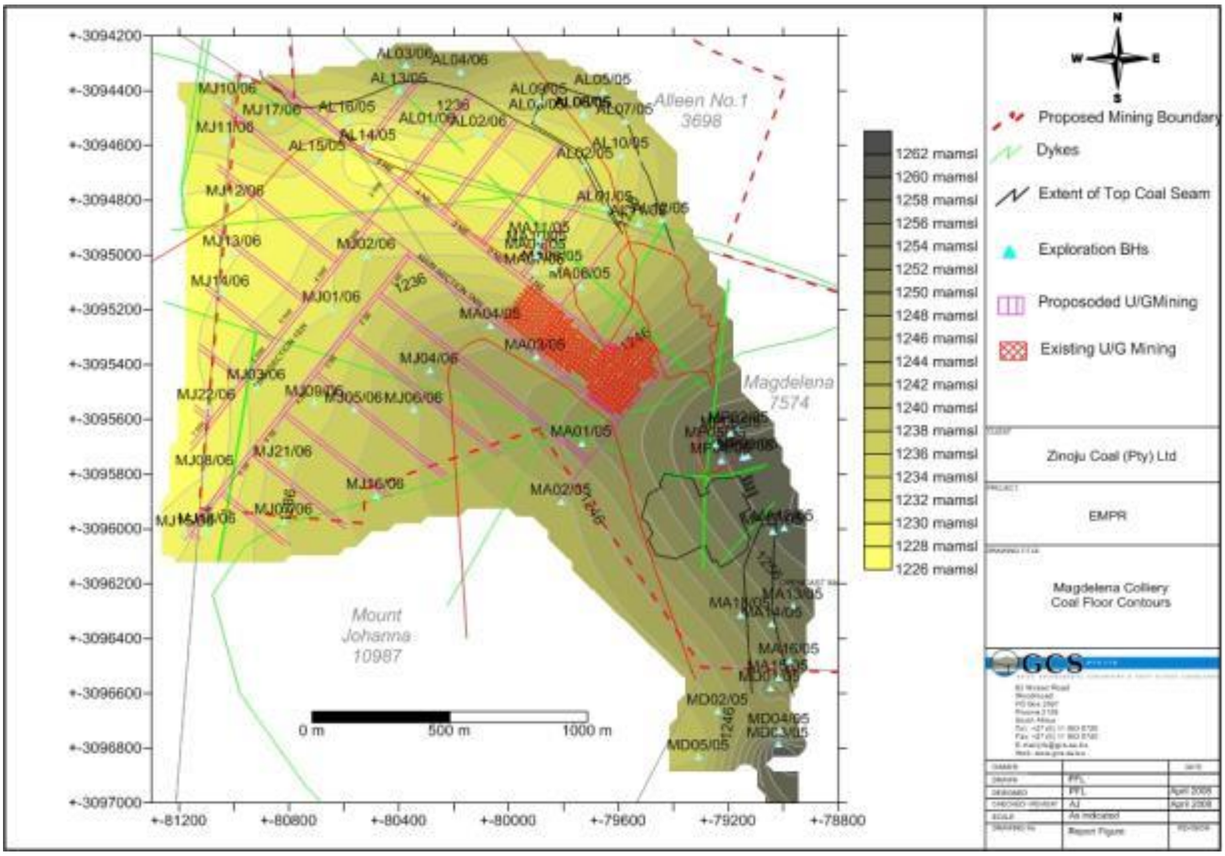

Figure 2-1: Regional Top seam extent

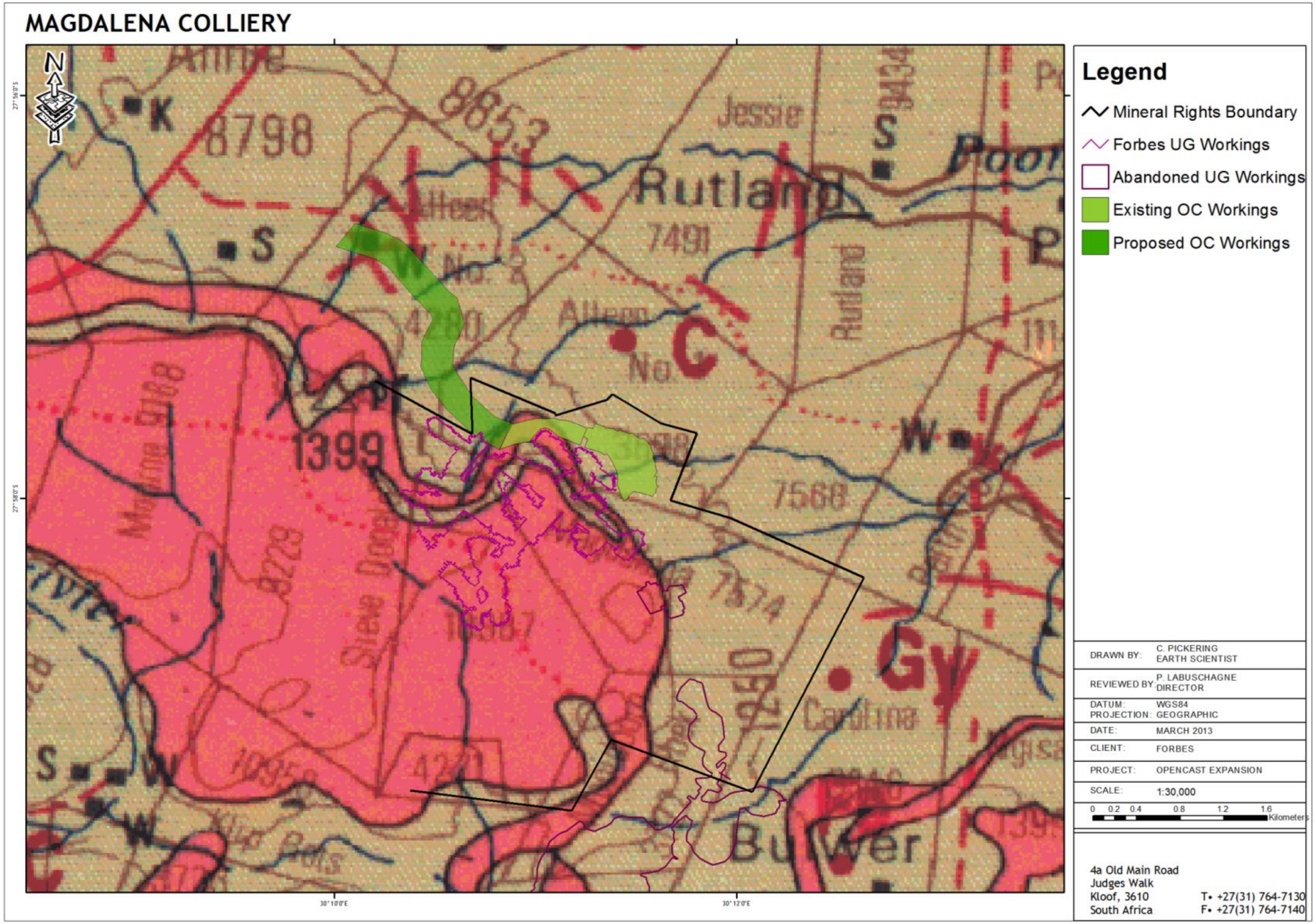

Figure 2-2: Local geology of the area around Magdalena Colliery

Coarse grained and gritty sandstones occur more frequently within the coal bearing strata, with overlying sediments generally being more argillaceous. Drilling proved the presence of 3 coal seams namely; the leader seam which occurs approximately 13 m – 18.5 m above the Top seam, and the Bottom seam occurring approximately 6 – 21 m below the Top seam. The parting between the Top and Bottom seam decreases in a northerly to north- westerly direction. Both the Top and Bottom seam are not uniform, but contain one or more partings of shale or sandstone. The Top seam has a seam thickness of 1.32 m to 4.38 m (average seam thickness on the farm Magdalena is 2.1 m). This coal is ranked as a low volatile bituminous coal. The total inter-seam partings have an average thickness of 0.19 m.

The bottom seam occurs at an average of 19.0 m below the Top seam on the farm Magdalena No. 7574. The parting between the Top and Bottom seam consists of medium to coarse grained sandstone.

The Bottom seam height ranges from 0.7 m to 2.04 m (average 1.00 m on the farm Magdalena No. 7574).

On Magdalena, the coal reserves are truncated by dolerite dykes to the north and south-east. These dykes were emplaced along pre-existing fault planes. The faulting gave rise to the formation of three distinct blocks. The block to the south- east has a 30 m displacement relative to the central block (mining area) whilst the block to the north was up-thrown by 12 meters.

2.1.1 Presence of Dykes, Sills and Faults

The Ingogo sill occurs approximately 60 meters above the Top seam on the farm Magdalena 7574. This dolerite sill attains a thickness of up to 76 meters. Due to its close proximity, the Top seam coal was devolatilised during emplacement, giving rise to a low volatile bituminous coal. Dolerite dykes within the area tend to follow pre-existing fault planes. These fault planes gave rise to vertical displacement of the coal seam.

2.2 Surface water

The Colliery falls within the upper catchments of the Poonaspruit and Bloubankspruit, which are non-perennial tributaries of the Buffalo River. All streams occurring within the vicinity of the proposed Magdalena Colliery area are seasonal, thus very little if any dry weather flow occurs.

2.3 Groundwater

2.3.1 Terminology

Confining layers are sometimes subdivided into aquitards, aquicludes and aquifuges. An aquifuge is an absolutely impermeable unit that will not transmit any water. An aquitard is a layer of low permeability that can store groundwater and also transmit it slowly from one aquifer to another. The term leaky confining layer is also applied to such a unit. Confined groundwater is found in a confined aquifer, unconfined groundwater is found in a water-table aquifer and perched groundwater is found in a perched aquifer (Fetter, 2001).

Permeability is the capacity of a rock for transmitting water. Materials, which do not allow water to pass through them, are impermeable. Sands and gravel, which have large pore spaces, are highly permeable; clays, on the other hand, are practically impermeable because pore spaces are extremely small and the water contained in them is virtually stationary.

Hydraulic Conductivity (K): Hydraulic conductivity is defined as the volume of water that will move through a porous medium in unit time under hydraulic gradient through a unit area measured at a right angle to the direction of flow. Hydraulic conductivity can have any units of Length/Time.

Transmissivity (KD or T): Transmissivity is the product of the average hydraulic conductivity (K) and the saturated thickness of the aquifer (D). Consequently, transmissivity is the rate of flow under a unit hydraulic gradient through a cross-section of unit width over the whole saturated thickness of the aquifer. Transmissivity has the units of $Length^2$/Time.

Storativity (S): The storativity of a saturated confined aquifer of thickness (D) is the volume of water released from storage per unit surface area of the aquifer per unit decline in the component of hydraulic head normal to that surface. In a vertical column of unit area extending through the confined aquifer, the storativity S equals the volume of water released from the aquifer when the piezometric surface drops over a unit distance. As storativity involves a volume of water per volume of aquifer, it is a dimensionless quantity.

2.3.2 Aquifer characteristics

At the site under investigation, the sedimentary rocks of the Ecca Group form the main water bearing strata. In the Ecca group, multi-layered aquifers are common, especially within the coalfields. It is however conceptualised as a single unit with interconnectivity between layers, as a worst-case scenario. The Dwyka Formation, which underlies the Ecca, normally has a very low permeability and can be considered as an aquitard. The base of the impacted zone can therefore be taken as the base of the coal seams. This will also be the maximum depth of mining and associated pollution sources.

Dolerite intrusions in the form of dykes and sills are common in the Karoo Supergroup, and are often encountered in this area. These intrusions can serve as both aquifers and aquifuges. Thick unbroken dykes will inhibit the flow of water, while the baked and cracked contact zones can be highly conductive. These conductive zones effectively interconnect the strata of the Ecca sediments both vertically and horizontally into a single, but highly heterogeneous and anisotropic (directionally dependent) zone on the scale of a typical mining activity.

From previous investigations in similar geological units, the saturated hydraulic conductivity of the Ecca Group was found to vary between 1×10^{-4} m/day. The degree of variance in the hydraulic conductivity is attributed to anisotropy of the hydraulic properties of the Karoo sediments. The above results fits well into this pattern, and can thus be considered as representative of this area. Dolerite intrusions are the main geological feature responsible for the formation of secondary aquifers in this area. Faulting occurs within the region but the fault planes have been infiltrated by dolerite dykes. Thus the down throw of the sediments along the dolerite dyke planes is attributed to pre-existing fault planes.

2.3.3 Unsaturated zone

The unsaturated zone in the study area is between 10 to 40 meters thick (based on static groundwater levels measured in August 2011), and consists of colluvial sediment underlain by residual sandstone/siltstone/mudstone of the Ecca Group, which becomes less weathered with depth. To a depth of about 3 m, the unsaturated zone consists of fine to medium grained clayey sand, followed by soft completely to moderately weathered Ecca sediments to a depth of 6.5 m on the lower slope. Upslope of this area, the soil depth decreases to approximately 2 meters underlain by a 1 meter decomposed sandstone layer followed by a competent sandstone layer.

2.3.4 Aquifer thickness

In the Ecca Group the base of the aquifer and impacted zone is taken as the base of the coal seams, ~150 m below surface at the deepest point. The maximum thickness of the aquifer in the Ecca Group must therefore be in the order of 24 m.

3 FIELD WORK

GCS conducted the hydrogeological assessments on the existing opencast pits and as such there is significant data available from previous field work already done on site. The objective of this study, therefore, is to update this data based on the location of the new extension.

GCS has been conducting water quality monitoring at Magdalena for 5 years, although monitoring was done by the mine from 1998, and as such has significant data on the water quality of the site, Figure 3-1. The groundwater quality at the current opencast pit is monitored at borehole GCS5. Surface water site MS5 monitors the downstream water quality.

As there are several additional groundwater users in the area, Figure 3-2 (from GRIP[1] data), it is important to establish the pre-mining groundwater quality at the pit extension area. Therefore, a hydrocensus of the area in a 1km buffer zone of the pit extension area was completed on 26 November 2013. GRIP data was used to locate these hydrocensus boreholes, however, many of the GRIP boreholes do not exist or have since been destroyed and therefore could not be found. Photos taken during this site visit are available in Appendix A.

The latest water quality data from the existing operations as well as the background pre-mining data for the extension will be discussed in Section 4.1.

Aquifer testing was done on several boreholes at Magdalena that were drilled in 2011; this data will be used to determine the aquifer properties in this area. This will be discussed in Section 4.3 below.

Rock samples from the opencast pit were collected on the 6th of November 2013 and submitted to Geostratum for Acid Base Accounting analysis. The results of this will be discussed in Section 4.4.

[1] Groundwater Resource Information Project (GRIP) is a borehole database of all known boreholes in South Africa which was started by the Department of Water Affairs in 2011.

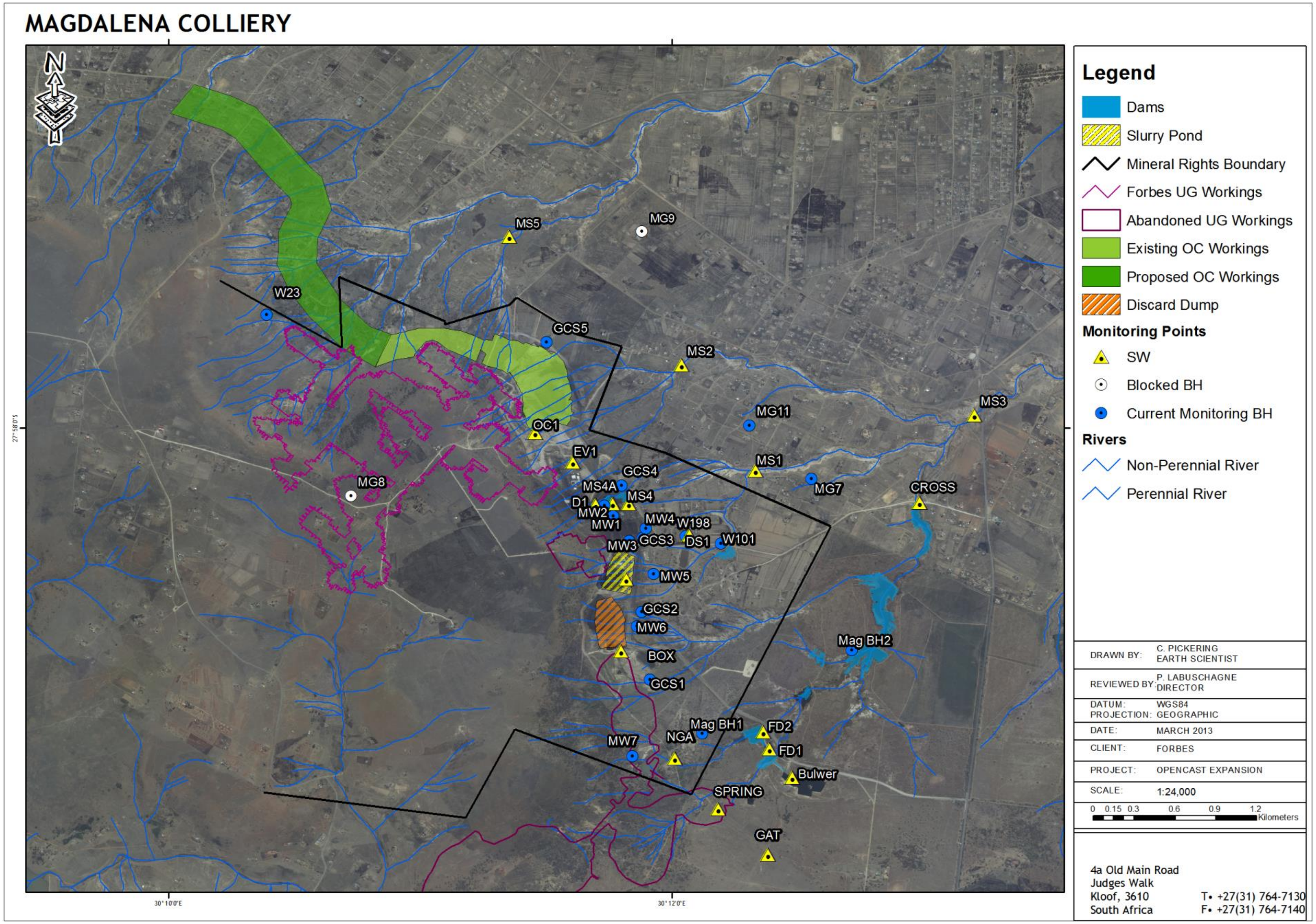

Figure 3-1: Magdalena surface and groundwater monitoring points

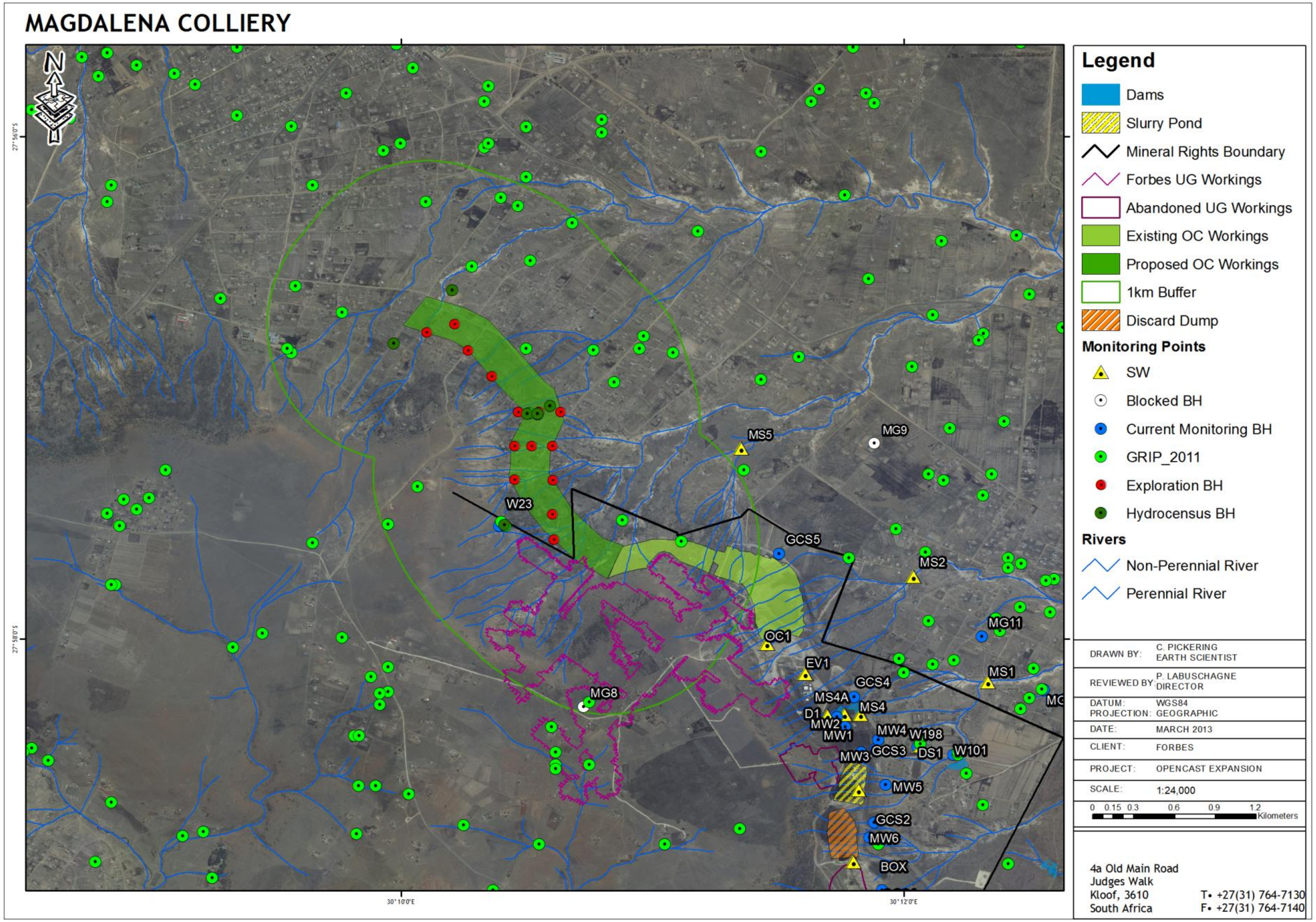

Figure 3-2: Map showing Magdalena monitoring points and GRIP hydrocensus boreholes

4 BASIC ASSESSMENT

4.1 Water Quality

This section will supply information on the groundwater and surface water quality in the vicinity of the existing opencast workings[2] as well as on pre-mining groundwater quality in the proposed expansion area.

4.1.1 Existing Water Quality Data

There is currently one borehole, GCS5, monitoring water quality down gradient of the existing opencast workings. Table 4-1 shows the 2013 monitoring data for GCS5 in comparison to both DWA (1996) Domestic Use Limits and the SABS SANS 241-1:2011 Drinking Water Standards. The DWA limits are more stringent than the SANS limits, therefore, if an element exceeds the SANS limits it also exceeds the DWA limits. Figure 4-1 shows the historical sulphate and pH time trend graph for this borehole. Figure 4-2 is a piper plot developed from all available data for GCS5.

Table 4-1: 2013 Groundwater quality at GCS5

		GCS5	MS2	DWA Codes	SANS Codes
		Groundwater	Surface Water		
DETERMINANT	**UNIT**	Aug-13	Jan-13		
Conductivity (EC)	mS/m	130	87.0	70	170
pH		7.66	7.12	6	5
				9	9.7
Total Dissolved Solids	mg/L	718	548	450	1200
Calcium	mg Ca/L	45.2	55.2	32	*n/s*
Chloride	mg Cl/L	80.4	4.76	100	300
Magnesium	mg Mg/L	27.3	36.8	30	*n/s*
Potassium	mg K/L	5.30	1.66	50	*n/s*
Sodium	mg Na/L	201	56.0	100	200
Sulphate	mg SO4/L	14.5	339	200	250
Aluminium	mg Al/L	<0.01	<0.01	0.15	0.3
Fluoride	mg F/L	1.08	0.355	1	1.5
Iron	mg Fe/L	<0.01	<0.01	0.1	2
Manganese	mg Mn/L	0.060	<0.01	0.05	0.5

This data shows that small variations in the sulphate concentrations are evident with stable pH conditions. Elevated conductivity, TDS and sodium are a result of the naturally saline water quality of the area.

The piper plot indicates that the water type is a sodium bicarbonate water with no evolution of chemistry towards a typical coal mine water quality. This data indicates no significant influence from the mining operations during the monitoring period.

[2] The elements shown here have been selected based on natural expected elements and indicator elements associated with coal mining. Indicator elements are TDS, EC, sulphate, pH and iron.

The surface water bodies around Magdalena are typically non-perennial streams that are dry for most of the year. There is currently one surface water monitoring point downstream of the existing opencast workings, MS5, which has not been sampled since 2010 as this stream is constantly dry.

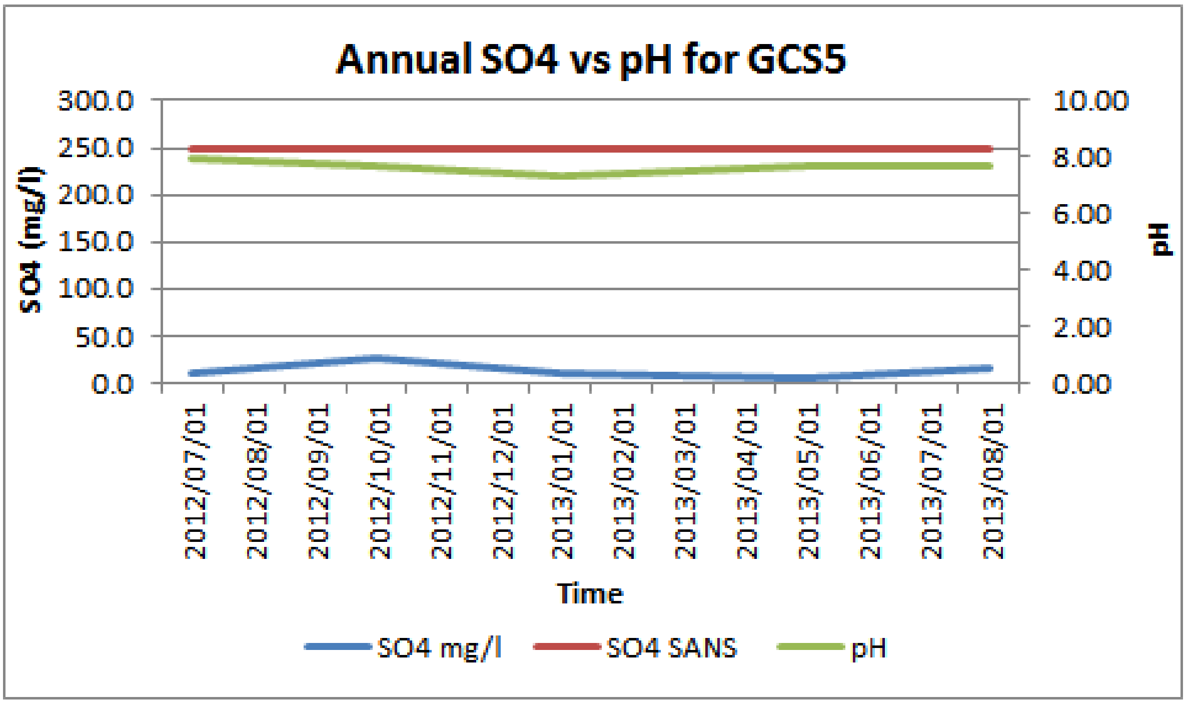

Figure 4-1: Sulphate vs pH time trend graph for GCS5

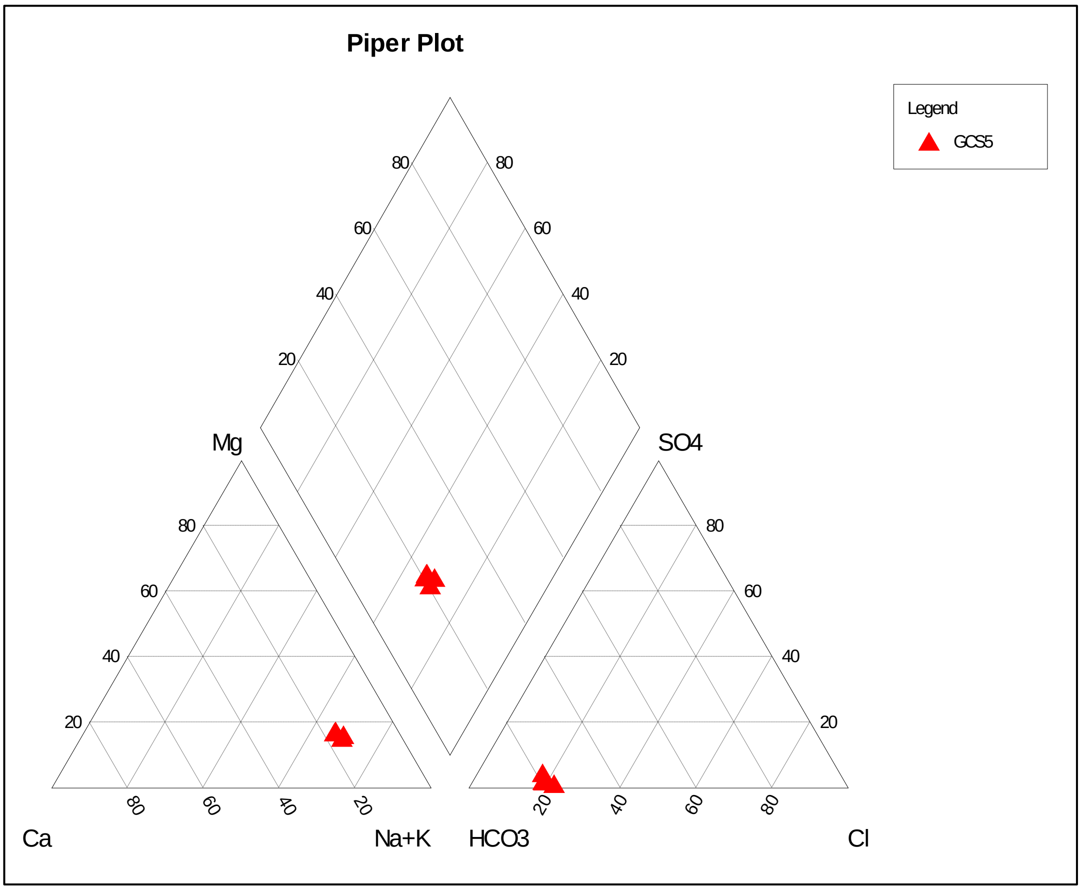

Figure 4-2: Piper plot for GCS5

4.1.2 Hydrocensus Water Quality

Four boreholes, situated within a 1km buffer zone of the proposed opencast expansion area, were visited on 26 November 2013 as part of a hydrocensus. Three of the community boreholes were dry and one had water. Table 4-2 shows the field data collected for these boreholes and Figure 3-2 shows the locations of these points. Table 4-3 shows the chemistry data for community borehole MGH1 compared to the DWA and SANS standards.

Table 4-2: Hydrocensus field data

Borehole ID	Latitude	Longitude	Water Level (mbgl)	Comments
MGH1	-27.95908	30.17355	Hand pump	Sampled
MGH2	-27.94352	30.1701	Hand pump	Dry
MGH3	-27.94707	30.1662	Hand pump	Dry
MGH4	-27.95173	30.17575	Hand pump	Dry

Table 4-3: Hydrocensus chemistry data

		MGH1	DWA Codes	SANS Codes
		Groundwater		
DETERMINANT	**UNIT**	Nov-13		
Conductivity (EC)	mS/m	64.6	70	170
pH		8.06	6	5
			9	9.7
Total Dissolved Solids	mg/L	363	450	1200
Calcium	mg Ca/L	36.3	32	*n/s*
Chloride	mg Cl/L	12.4	100	300
Magnesium	mg Mg/L	15.4	30	*n/s*
Potassium	mg K/L	8.46	50	*n/s*
Sodium	mg Na/L	74.9	100	200
Sulphate	mg SO4/L	<0.01	200	250
Aluminium	mg Al/L	<0.01	0.15	0.3
Fluoride	mg F/L	0.334	1	1.5
Iron	mg Fe/L	0.270	0.1	2
Manganese	mg Mn/L	<0.01	0.05	0.5

The chemistry data for the hydrocensus borehole represents the pre-mining water quality. This data shows that elevated conductivity, TDS and sodium are evident, which is typical of this area. This is further confirmed by the piper plot for MGH1, Figure 4-3, which plots the chemistry data as a sodium-bicarbonate water type similar to GCS5.

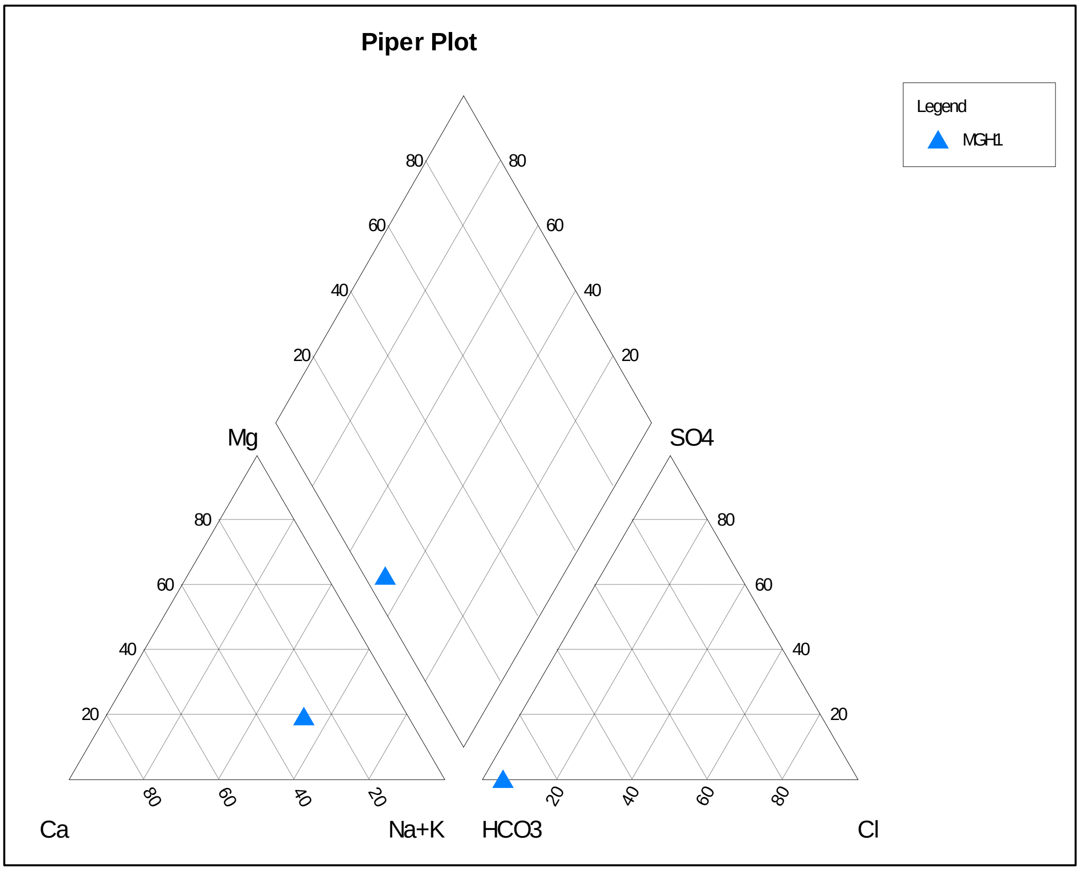

Figure 4-3: Piper plot for MGH1

4.1.3 Water Quality Summary

- The groundwater data for the existing opencast workings indicates no significant influence from the mine. Sulphate and metals remain low with consistently neutral pH.
- Both the existing data and the hydrocensus data show elevated conductivity, TDS and sodium as a result of the naturally saline water quality of the area.
- The groundwater of this area is classified as a sodium-bicarbonate water type.

4.2 Water Flow Direction

Figure 4-4 shows the local groundwater flow directions at Magdalena. It appears as though groundwater flow directions are typically in an easterly direction.

Figure 4-5 illustrates the correlation between topographical elevation and water level elevation; this graph shows a 90% correlation. This shows a strong correlation between topography and groundwater elevation.

It is fair to assume that an aquifer has developed within the upper weathered strata above the dolerite sill because the sill acts as an aquiclude. However, connections to lower aquifer systems could occur through cracks and fractures within the lower more permeable rock formations.

It is further fair to assume that the upper aquifer will not be influenced by underground mine de-watering due to the separation of the top weathered aquifer system and the lower fractured rock aquifer system by the dolerite sill and also by solid impermeable rock.

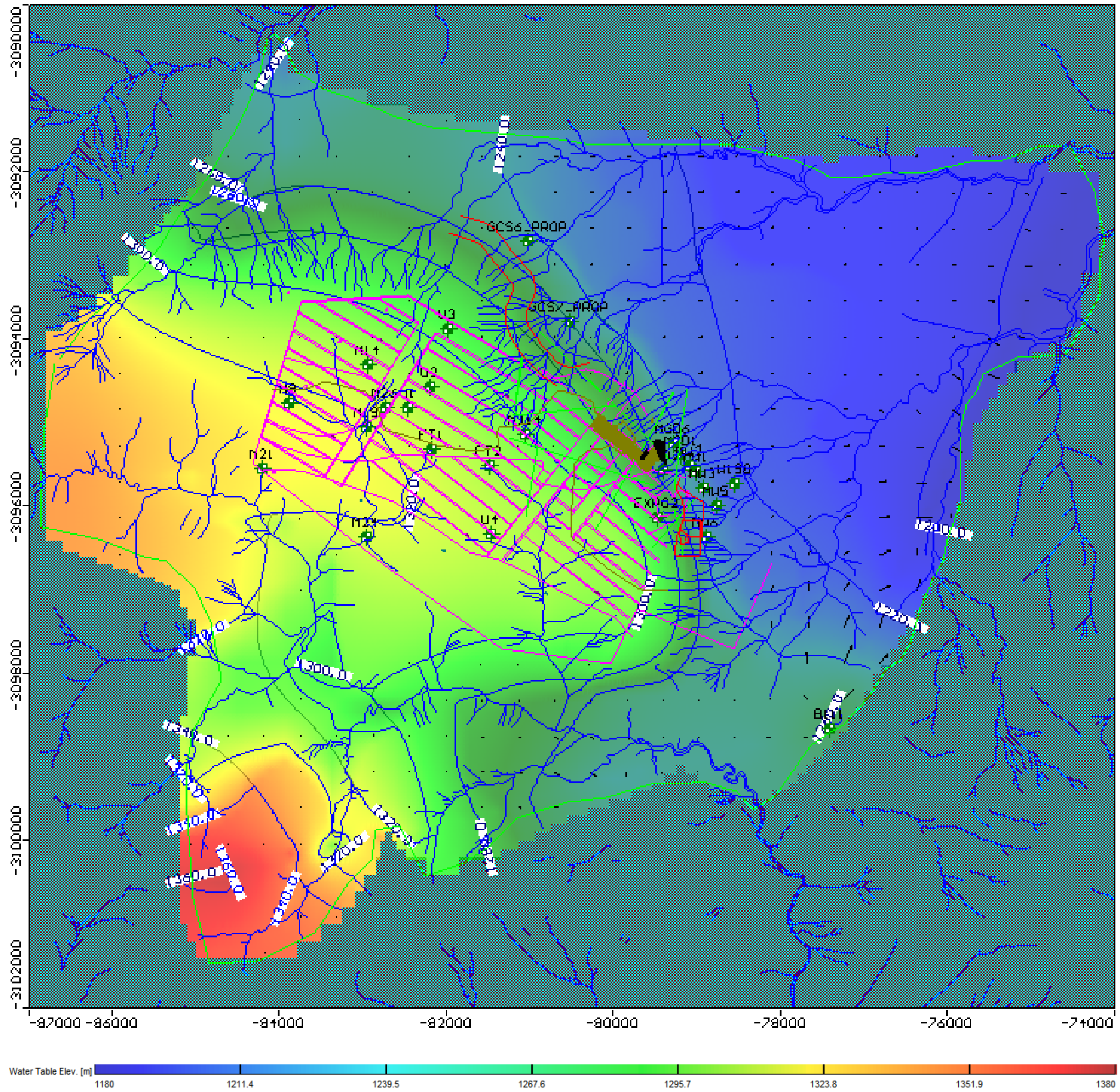

Figure 4-4: Water level elevation contour map

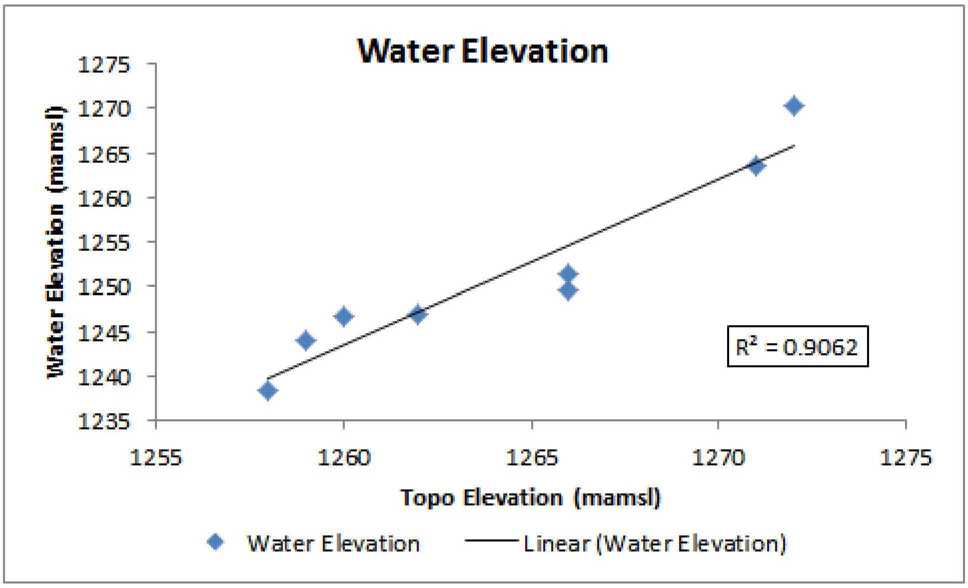

Figure 4-5: Water level elevation vs topographical elevation

4.3 Water Quantity

The impact on groundwater quantity (during the operational phase) is due to dewatering of aquifers at the receiving face of the opencast workings. A cone of depression will form due to the fact that groundwater seeping into the opencast mine will be pumped out in order to ensure safe and dry working conditions. It is important to note that the draw down cone created by the opencast workings will most likely affect both the upper perched aquifer and deeper fractured aquifer.

The contact of the dolerite sill with the surrounding Karoo formations acts as a preferential flow path, transporting water from the perched aquifer along the strike and dip of this contact. In places where this contact outcrops, the water daylights in the form of springs. The bottom of the contact zone acts as a hydraulic divide between the two aquifers. Therefore the two aquifers are not in hydraulic contact. It must be noted that other minor perched zones also exist due to the layered nature of sandstone/dolerite and shale layers.

Flow rate

The calculation of the flow rate of the groundwater is vital for the dewatering of the aquifer and for the delineation of the cone of depression. The average flow velocity can be calculated, using the following equation.

$$v = \frac{Ki}{\theta} \text{...} \textit{Equation 1}$$

Where: *v=flow velocity*

K=hydraulic conductivity

θ=porosity (a standard porosity of 20% for sandstones will be used)

i =probable average hydraulic gradient

$i = \frac{h1-h2}{l}$ ……………………………………………………………………….Equation 2

The hydraulic conductivity as well as the hydraulic gradient of the region are calculated in Table 4-5 and Table 4-6.

In an attempt to quantify the saturated hydraulic conductivity of the layered aquifer in the Ecca Group, slug tests were done in the five new boreholes. Table 4-4 below gives borehole construction details of the new boreholes drilled on site in 2011 that have been used to calculate flow velocity.

Table 4-4: Borehole construction details

BH No.	Co-ordinate South	Co-ordinate East	Borehole Depth (m)	Plain Steel Casing (m)	Water Strikes (m bgl)	Static Water Level (m bgl)	Coal Seam (m bgl)
MAGCGS 1	-27.98337	30.19860	50	0 - 24	26	14.42	30 – 33
MAGCGS 2	-27.97883	30.19805	50	0 - 18	Seepage	16.012	26 – 28
MAGCGS 3	-27.97392	30.19811	50	0 - 18	Seepage	7.37	28 – 30
MAGCGS 4	-27.97064	30.19671	50	0 - 24	26 & 36	4.71	22 – 25
MAGCGS 5	-27.96109	30.19173	50	0 - 24	26	18.82	31 - 33

Table 4-5: Hydraulic Conductivity Calculation

Borehole Number	Hydraulic conductivity (m/day)	Transmissivity (m^2/day)	Geological Summary
MAGGCS 1	0.26	9.25	Sand/Mudstone/Sandstone/Shale Coal at 31 m
MAGGCS 2	0.29	9.6	Sand/Mudstone/Sandstone/Shale Coal at 26 m
MAGGCS 3	0.83	10	Sand/Mudstone/Sandstone/Shale Coal at 28 m
MAGGCS 4	1.42	63.6	Sand/Mudstone/Sandstone/Shale Coal at 25 m
MAGGCS 5	0.06	1.79	Sand/Mudstone/Sandstone/Shale Coal at 31 m
Average for Ecca Sediments	***0.57***		

From previous investigations in similar geological units the saturated hydraulic conductivity of the Ecca Group was found to vary between 1 x 10^{-1} and 8 x 10^{-4} m/day. The degree of variance in the hydraulic conductivity is attributed to anisotropy of the hydraulic properties of the Karoo sediments. The above results fit well into this pattern, and can thus be considered as representative of this area.

Table 4-6: Hydraulic Gradient Calculation

	MW3- MW4	MW2-GCS4	GCS4-MG11	AVG
h1	1272	1273	1265	
h2	1260	1265	1232	
h1-h2	12	8	33	
L	150	185	946	
I	0.08	0.04	0.03	**0.05**

Table 4-7: Flow Velocity Calculation

	MW3- MW4	MW2-GCS4	GCS4-MG11
m/day	0.228	0.114	0.0855
m/year	83.22	41.61	31.2

The hydraulic conductivity and the hydraulic gradient of the region are known parameters. By making use of these values, a flow velocity ranging between 0.0855 m/day and 0.228 m/day was estimated. This means that groundwater is estimated to travel about 31 to 83 m in one year through the Ecca sediments under steady state conditions, Table 4-7. Groundwater movement along dolerite intrusions is expected to flow at rates of approximately 75 m/year and more.

Any pollutants generated by the mining activities (SO_4 content usually) will therefore migrate according to these flow rates. However, it must be noted that de-watering activities, during the operational phase, will cause a cone of depression towards the opencast areas and groundwater flow tends to flow back towards these areas. This will limit mass transport to the surrounding aquifers during operations. Mass transport can therefore increase after the rebound of water levels once the project has been completed.

The above illustrates that groundwater movement in the Ecca sediments is slow to moderate, compounded by the relatively planar topography. It must be remembered that the results obtained from permeability tests only represent the characteristics of the aquifer in the vicinity of the boreholes tested.

4.4 Acid Base Accounting

In order to estimate the acid generation potential of material at the Magdalena opencast pit, three geological samples were collected from sandstone, shale and coal in the existing opencast pit (refer to Photo 4 in Appendix A) and sent for preliminary geochemical 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 tailings in order to predict post-mining water quality. 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 acid 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) as shown below:

Net neutralisation potential NNP = NP – AP

Neutralisation potential ratio $NPR = \frac{NP}{AP}$

Below are two tables showing the comparison ranges.

Table 4-8: Net neutralising potential (NNP)

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

Table 4-9: Neutralisation potential ratio (NPR)

$NPR = \frac{NP}{AP}$	Acid generating potential
< 1	Likely
1 - 2	Possible
2 - 4	Low
> 4	Unlikely

4.4.1 Results

Acid Base Accounting

The ABA testing results are summarised in Table 4-10.

Table 4-10: Acid base accounting results (kg/t CaCO3 where applicable)

Sample ID	Depth (m)	Type	Paste pH	Total %S	AP CaCO3 kg/t	NP CaCO3 kg/t	NNP CaCO3 kg/t	NP/AP
SS	0-20	Sandstone	6.97	0.007	0.22	0.38	0.17	1.76
Shale	20-28	Shale	5.60	1.899	59.33	28.58	-30.75	0.48
Coal	28-30	Coal	6.79	1.099	34.33	3.31	-31.02	0.10

4.4.2 Discussion

- The results indicate that the shale and coal layers have a likely acid generating potential based on the NNP as well the NPR. The sulphur content is highest in the shale and the pH paste test resulted in a more acidic pH. However, the coal layer had a lower NNP as well as a lower NPR.
- The sandstone layer, which constitutes a large portion of the geology of the pit, has an uncertain (NNP) or possible (NPR) acid generation potential. The sulphur content of this layer is low and the pH paste test resulted in a neutral pH.
- The coal and shale layers, therefore, pose the greatest risk to groundwater quality as both these geological units have a likely acid generation potential.
- The bulk of the coal layer will be removed during mining, therefore, this will lower the risk of future acid generation in the pit.
- It is recommended that, during backfilling, the shale layer is put back into the pit first at the deepest section of the pit and compacted. Therefore, when water levels in the pit rise this section will be completely submerged and thus stop the oxidation process. This will help to reduce the acid generating potential of the shale.

5 THERORETICAL CONCEPTUALISATION

The coal seam that will be mined out during opencast mining is approximately 40 m below ground surface which will be the maximum depth of the highwall. The overlying rock consists mainly of mudstones and sandstones which will be used as the backfill material. Groundwater levels closest to the current opencast mine workings are approximately 21 mbgl. The original water strike observed in the five new boreholes drilled in 2011 was at 26 mbgl which indicates a deeper fractured aquifer at this depth. Figure 5-1 shows a cross section of the relative position of the coal seam, topography and water level. The coal seam is therefore below the expected groundwater level in this area.

As a result, the groundwater level will most likely drop by approximately 15 m at the receiving face of the opencast workings. This will result in a cone of depression extending outwards from the opencast workings. However, as each strip of the opencast mining operation will take about two weeks to mine and backfill and the groundwater in this area has a low hydraulic conductivity, the extent of the depression will be small.

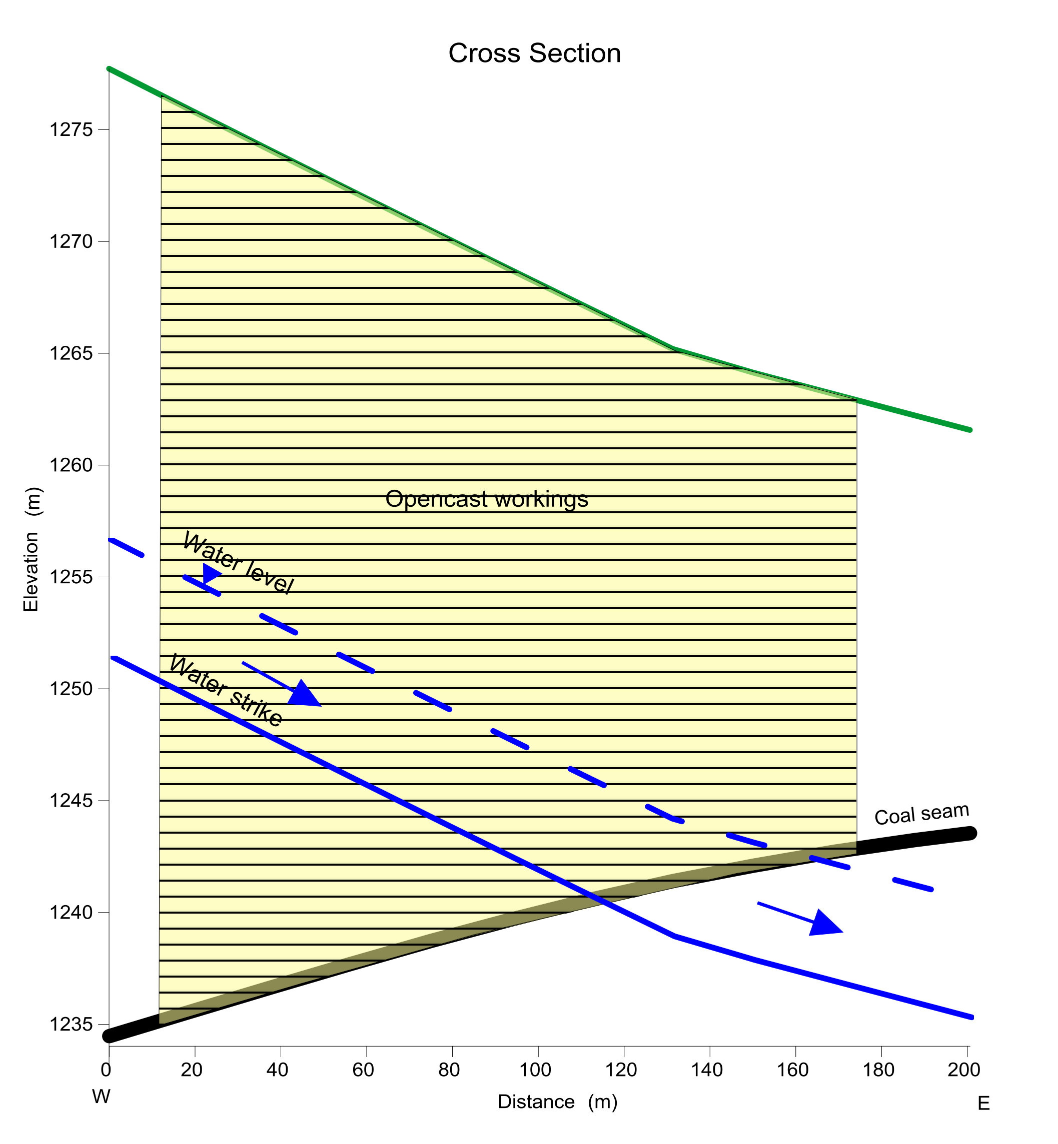

Figure 5-1: Cross section showing coal floor elevation and topography of the proposed area

6 IMPACT ASSESSMENT

6.1 Methodology

The existing groundwater flow and mass transport model[3], which was developed in Visual MODFLOW by GCS in 2008, was applied to assess the groundwater impacts of the proposed extension to the opencast workings.

[3] *The flow and contaminant transport model was constructed using version 4.2 of the Visual MODFLOW software developed by Waterloo Hydrogeologic Inc. (Waterloo, Ontario CANADA, 2007). The model is based on the conceptual model developed from the findings of the desktop and the baseline investigations.*

In order to investigate the behaviour of aquifer systems in time and space, it is necessary to employ a mathematical model. It simulates steady and non-steady flow in an irregularly shaped flow system in which aquifer layers can be confined, unconfined, or a combination of confined and unconfined. Flow from external stresses, such as flow to boreholes, aerial recharge, evapotranspiration, flow to drains, and flow through riverbeds, can be simulated.

A groundwater flow and transport model was developed for the Magdalena Colliery in order to demonstrate:

a) The effects of dewatering during the mining operations, particularly to simulate the drawdown cone that will be generated by the dewatering. This will assist in identifying the zone of influence,
b) The rise in groundwater levels after mine closure, and
c) The impacts that the mining operations will have on groundwater quality in the area (after mining has ceased).

The following mine progress plan, Figure 6-1, was used in the model. The opencast extension area is indicated.

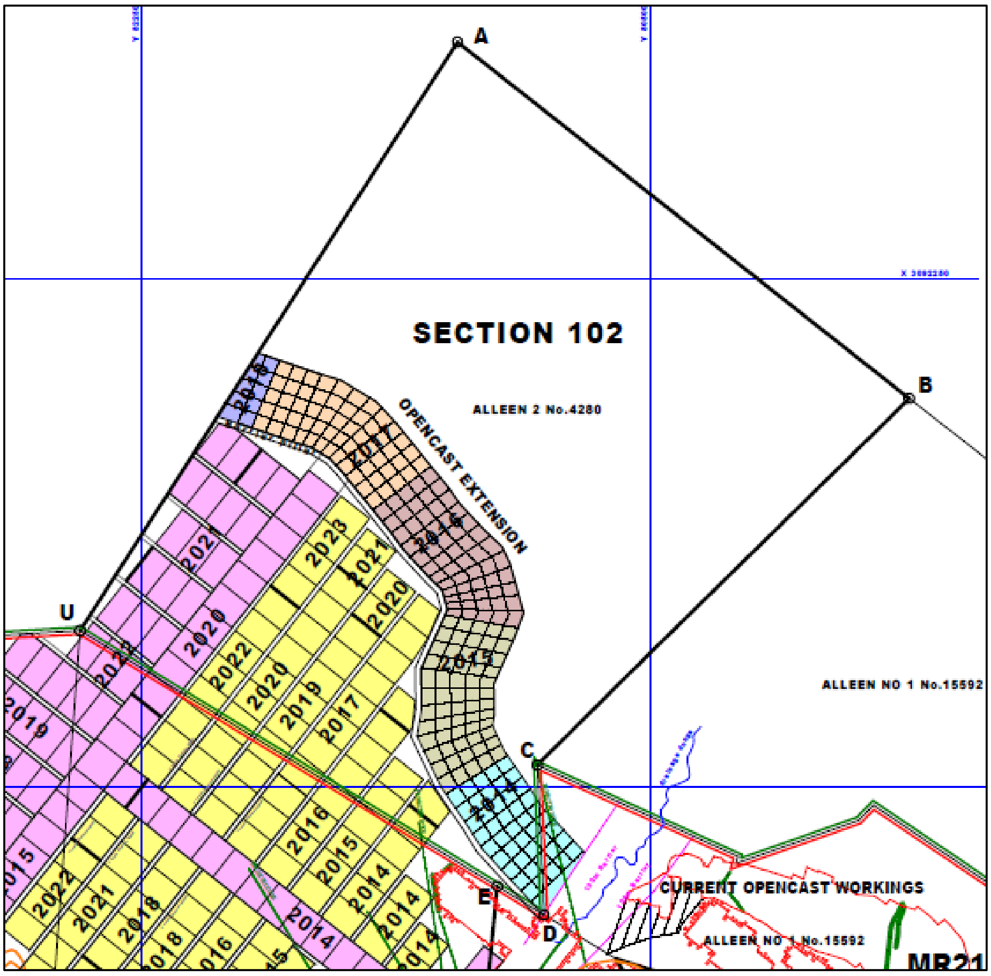

Figure 6-1: Mine progress plan

6.2 Impacts Assessment

6.2.1 Groundwater Quantity and Zone of Influence

Figure 6-2 illustrates the potential water level drawdown around the proposed opencast extension at the time of pit closure in 2018; according to the mine progress plan, Figure 6-1. This model assumes that the opencast area will be mined to below the coal floor and that groundwater will be lowered to at least this elevation.

Groundwater levels are expected to drop by 5m at the center of the pit at the time of pit closure and rise further away from the pit. The drawdown simulations show that the cone of depression will have an extent of approximately 340m south, 697m east and 505m west of the pit.

6.2.2 Recovery

After the proposed area has been mined out and backfilled, the ideal situation would be to return the area to its natural state. In this case, the backfill must be compacted so that a 1-3% recharge is achieved (this is expected recharge for Karoo Sediments). Should recharge exceed this, the water level will rise and decant may occur.

Figure 6-3 and Figure 6-4 show the predicted change in head and drawdown over time modelled for two theoretical boreholes, GCS6 and GCS7 (indicated on Figure 6-2), respectively. These graphs show that GCS7 will reach a peak drawdown of 3.22m at the end of 2015 and GCS6 will reach a peak drawdown of 0.9m at the end of 2022. After this, water levels are expected to start recovering.

6.2.3 Groundwater Quality- Transport Modeling

The mass transport model has been modelled for mine closure, 50 years post closure and 100 years post closure, refer to Figure 6-5, Figure 6-6 and Figure 6-7.

This model represents the worst case scenario and assumes no mitigation measures have been implemented. At mine closure in 2038 (20 years after pit closure), the zone of influence is predicted to extend approximately 271m east of the pit. This increases to 549m 50 years post closure and 1.6km 100 years post closure at the greatest extent of the zone of influence. The sulphate concentrations within this zone are predicted to be above 200 mg/l (the DWA Domestic Use Standard). The sulphate concentration will be greatest at the pit and dissipate outwards.

The extent of this zone of influence can be reduced by implementing certain mitigation measures. These measures are discussed in the following section.

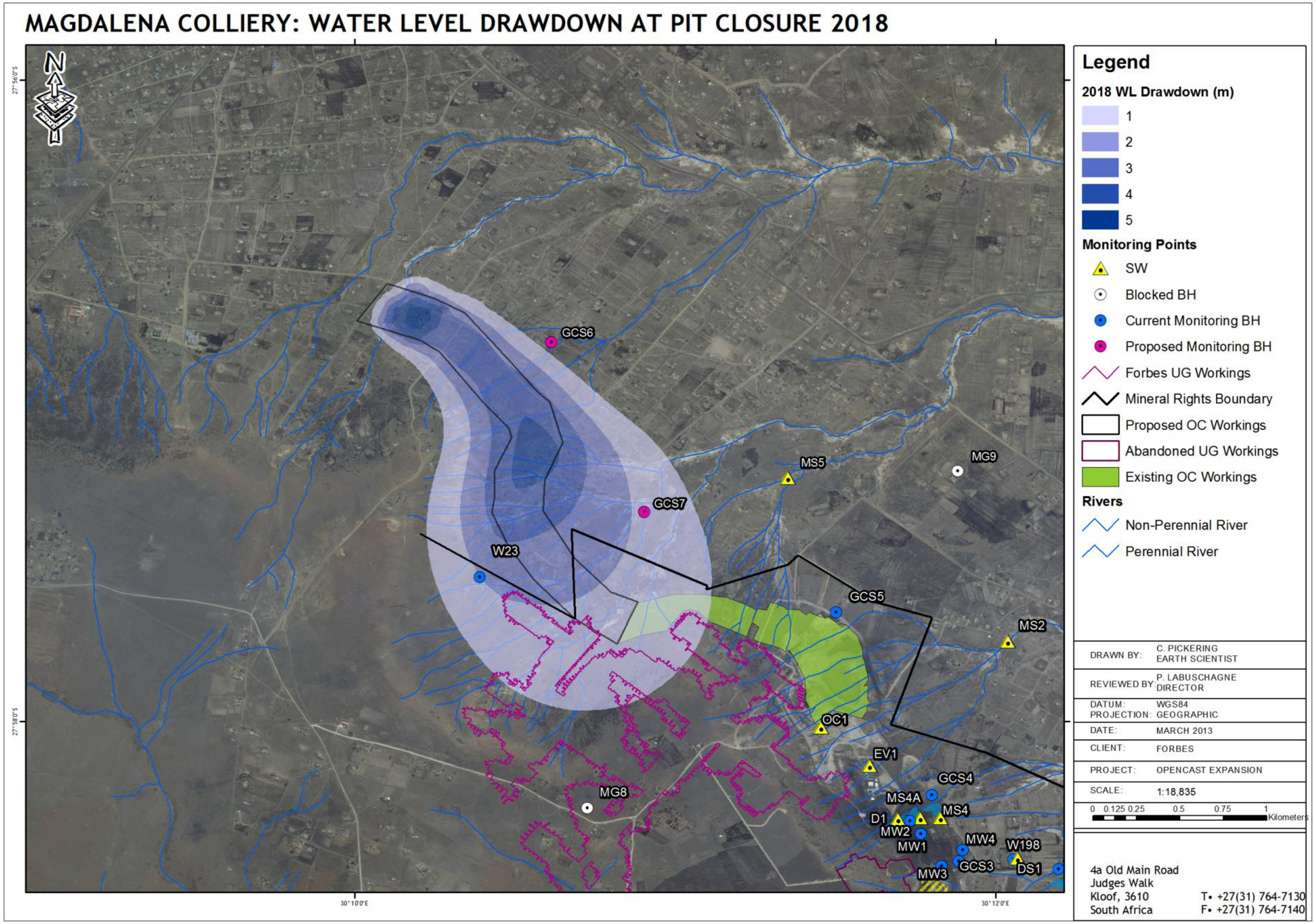

Figure 6-2: Potential water level drawdown at pit closure in 2018

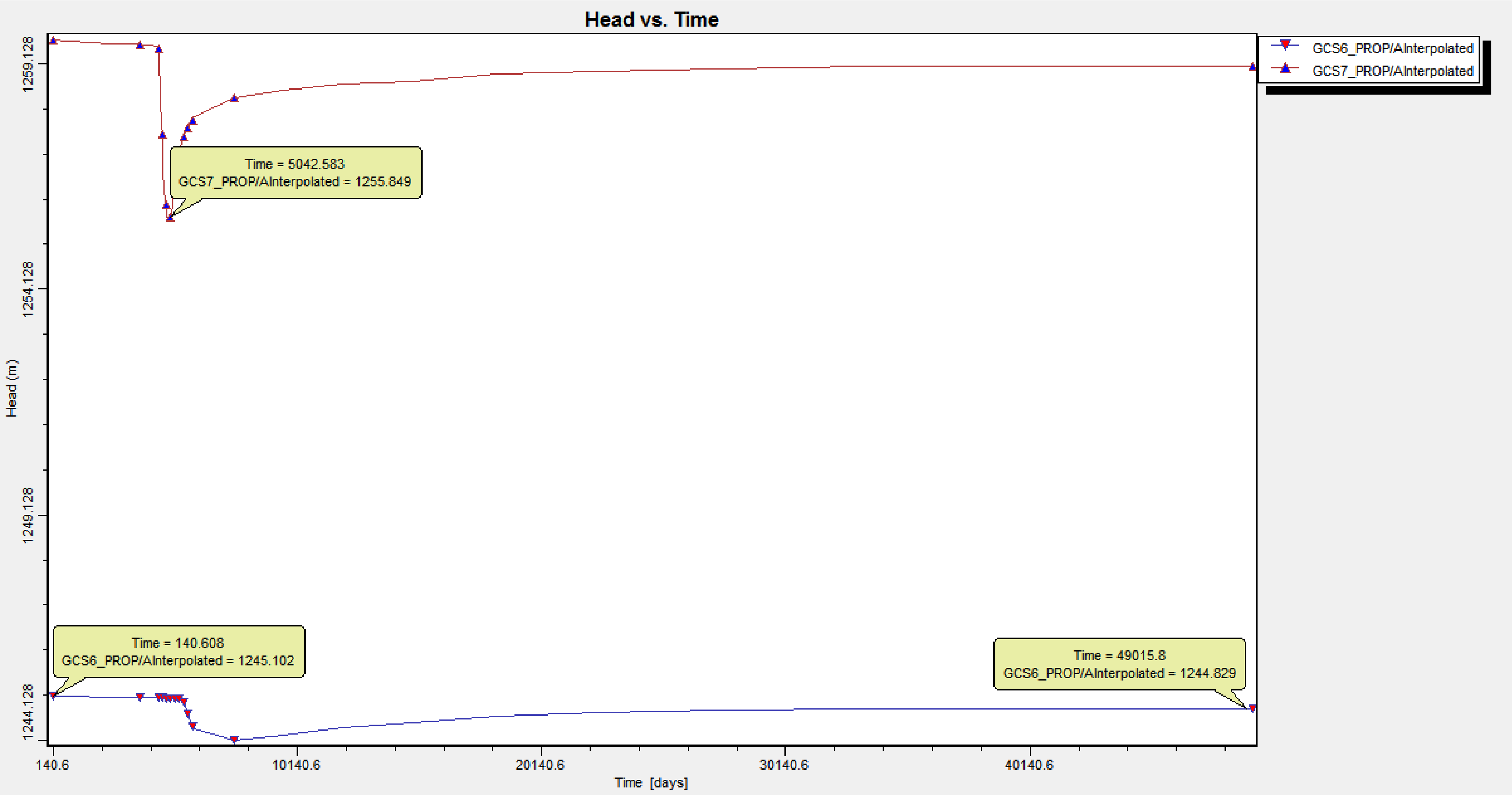

Figure 6-3: Head vs. Time Graph

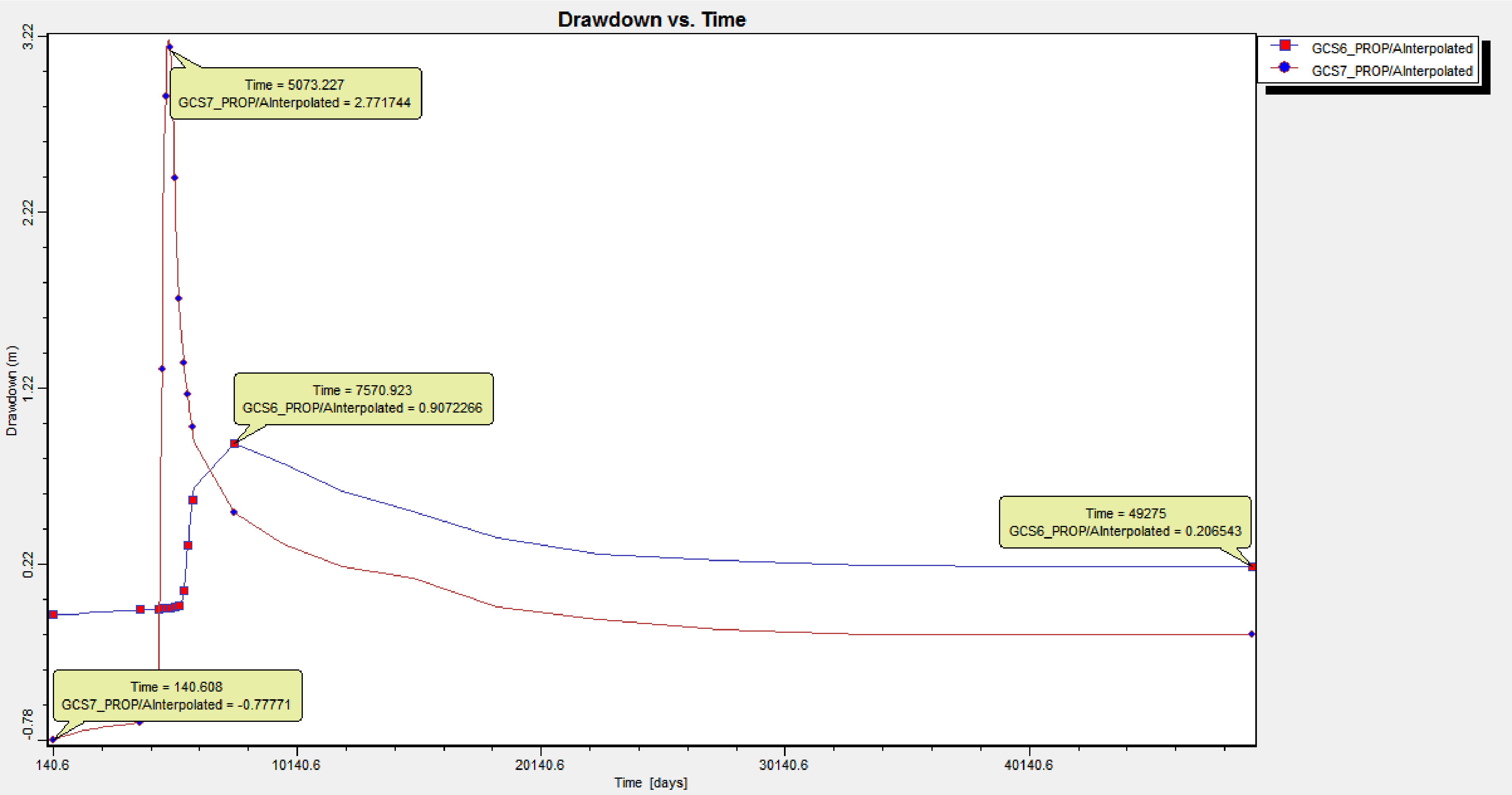

Figure 6-4: Drawdown vs. Time Graph

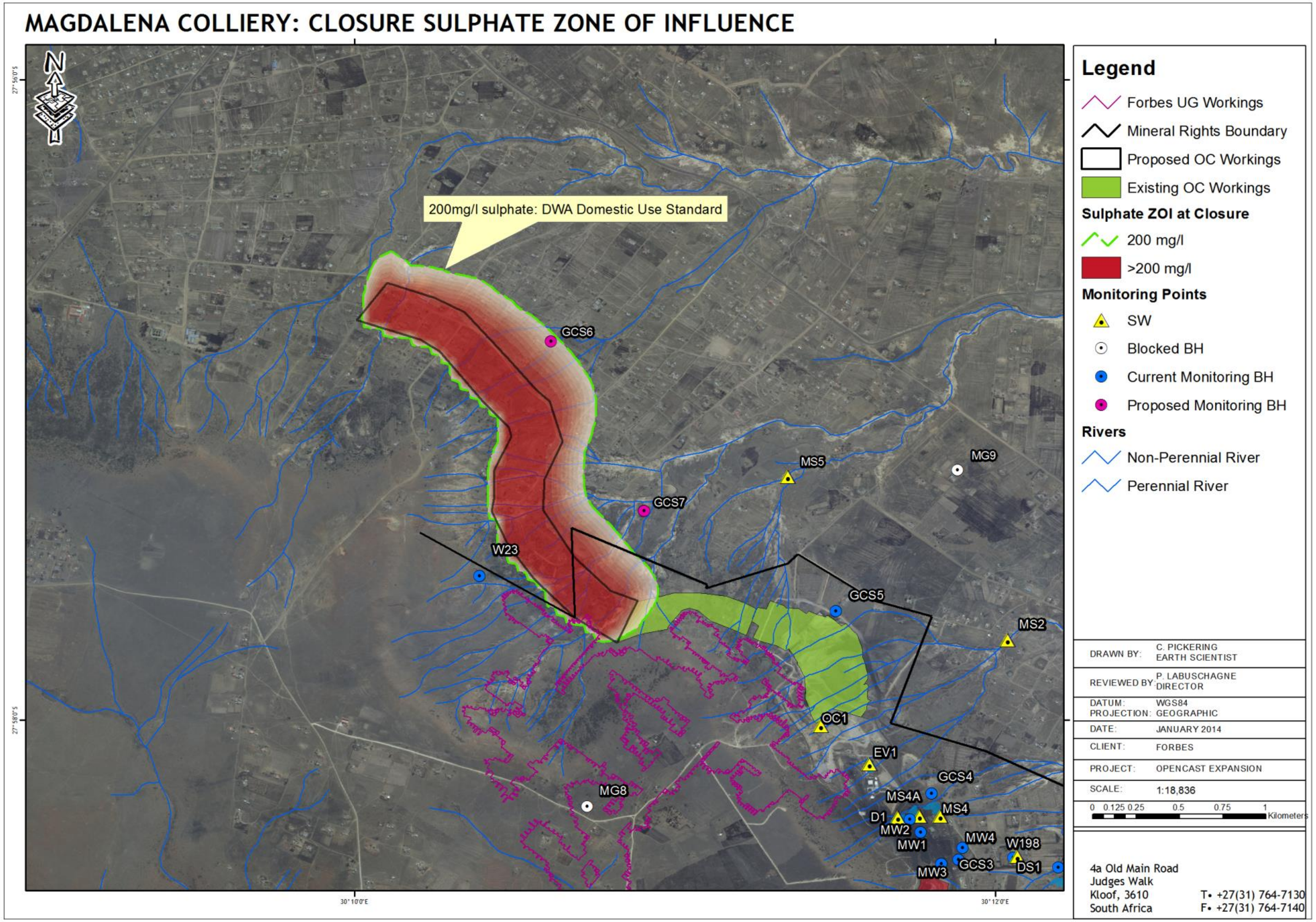

Figure 6-5: Potential sulphate zone of influence for proposed opencast extension at mine closure

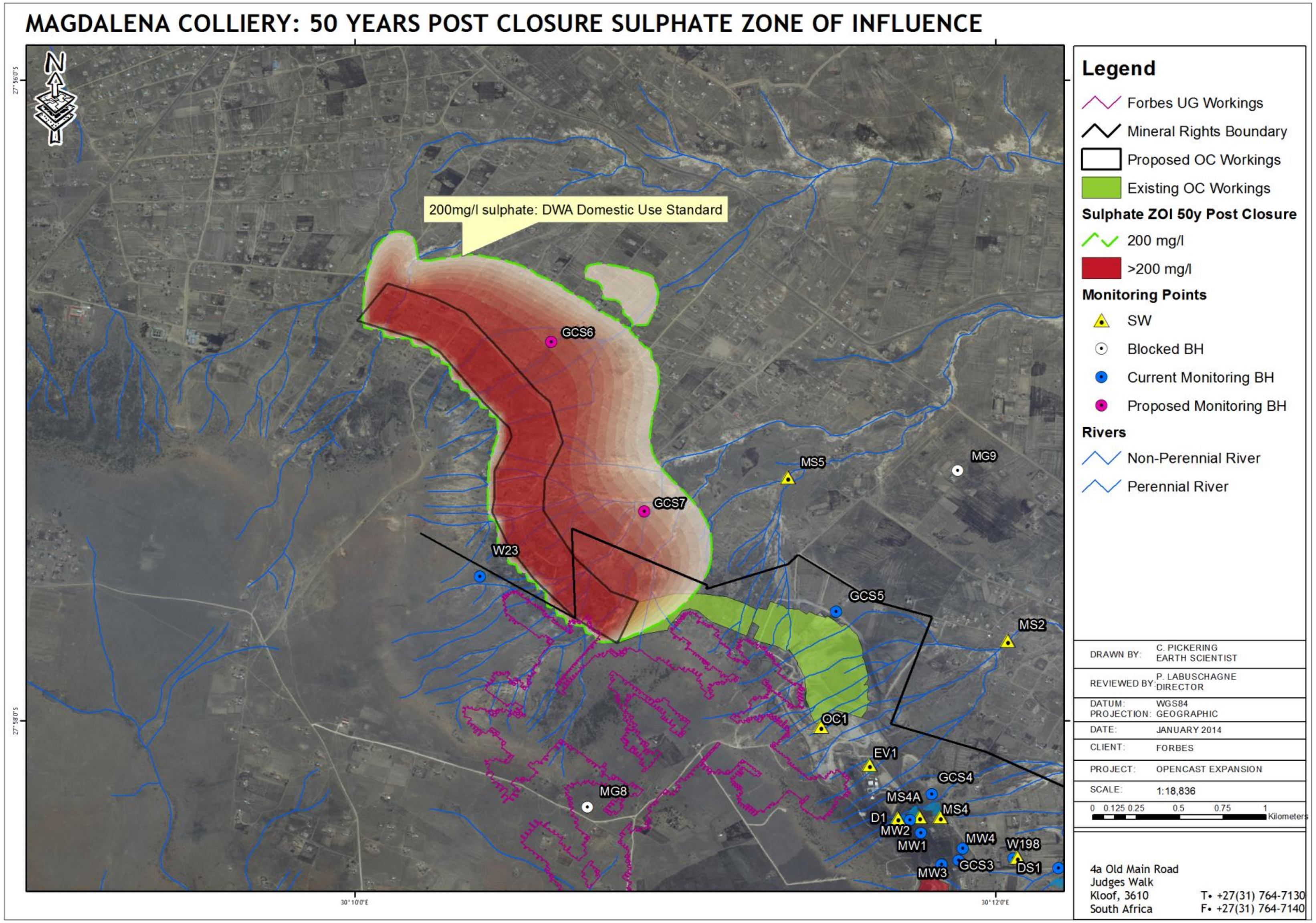

Figure 6-6: Potential sulphate zone of influence for proposed opencast expansion 50 years post closure

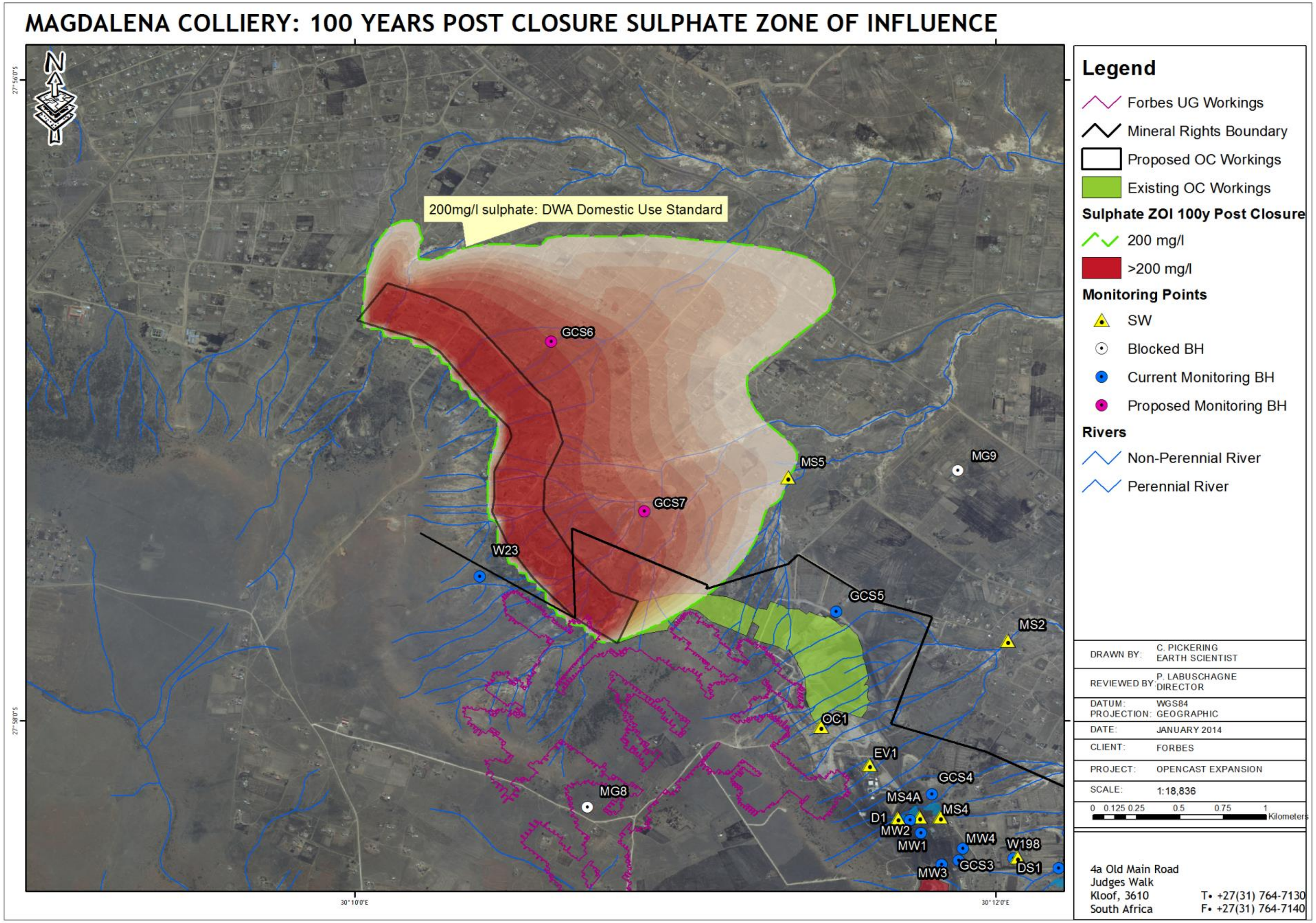

Figure 6-7: Potential sulphate zone of influence for opencast expansion 100 years post closure

7 RISK ASSESSMENT

7.1 Groundwater Impact Assessment

The impact assessment will focus on groundwater quantity and quality issues over the life-cycle of the proposed mining activity which, for an opencast pit, will be construction, operational, closure and post closure. It is important to understand the previous sections which dealt with gathering of basic information and impact prediction while reading the next section on risk assessment.

Table 7-2, Table 7-3 and Table 7-4 detail the findings of the risk assessment for the construction, operational and decommissioning/closure phases of the project. Table 7-1 shows the risk rating tables that are used to calculate risk.

Table 7-1: Risk rating table

Status of Impact	
+: Positive (A benefit to the receiving environment)	
N: Neutral (No cost or benefit to the receiving environment)	
-: Negative (A cost to the receiving environment)	
Magnitude:=M	***Duration:=D***
10: Very high/don't know	5: Permanent
8: High	4: Long-term (ceases with the operational life)
6: Moderate	3: Medium-term (5-15 years)
4: Low	2: Short-term (0-5 years)
2: Minor	1: Immediate
0: Not applicable/none/negligible	0: Not applicable/none/negligible
Scale:=S	***Probability:=P***
5: International	5: Definite/don't know
4: National	4: Highly probable
3: Regional	3: Medium probability
2: Local	2: Low probability
1: Site only	1: Improbable
0: Not applicable/none/negligible	0: Not applicable/none/negligible

The maximum value that can be achieved is 100 Significance Points (SP). Environmental effects were rated as follows:

Significance	***Environmental Significance Points***	***Colour Code***
High (positive)	>60	H
Medium (positive)	30 to 60	M
Low (positive)	<30	L
Neutral	0	N
Low (negative)	>-30	L
Medium (negative)	-30 to -60	M
High (negative)	<-60	H

Table 7-2: Construction Phase risk assessment

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION							NO-GO ALTERNATIVE	ENVIRONMENTAL SIGNIFICANCE OF NO-GO ALTERNATIVE						
		M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP
CONSTRUCTION PHASE ACTIVITIES: SITE PREPARATION, FOOTPRINT CLEARANCE, PIT DEVELOPMENT AND WASTE HANDLING																								
GROUNDWATER																								
Impact on groundwater quantity	**Construction** - Pit construction and blasting	6	2	2	4	40	-	M	Keep mining areas small and dewater for as short a duration as possible	4	4	2	4	40	-	M								
	Diversion of watercourses-reduction in groundwater infiltration	2	4	1	2	14	-	L	None required- impact is low and watercourse diversion is necessary	2	4	1	2	14	-	L								
Impact on groundwater quality	**Footprint Clearance** - exposure of soil will create an easy conduit for dirty water infiltration	2	2	1	4	20	-	L	Prevent seepage of dirty water to the aquifer	2	2	1	2	10	-	L								

Table 7-3: Operational Phase risk assessment

POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION							NO-GO ALTERNATIVE	ENVIRONMENTAL SIGNIFICANCE OF NO-GO ALTERNATIVE						
		M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP
OPERATIONAL PHASE ACTIVITIES: SITE PREPARATION, FOOTPRINT CLEARANCE, PIT DEVELOPMENT AND WASTE HANDLING																								
GROUNDWATER																								
Impact on groundwater quantity	**Construction** - Pit construction	6	4	2	4	48	-	M	Keep mining areas small and dewater for as short a duration as possible	4	4	2	4	40	-	M	None required- Impact to additional groundwater users is minimal. Groundwater levels are low in this area, most community boreholes are already dry							
Impact on groundwater quality	**Dust suppression**	4	4	1	2	18	-	L	None required- impact is low	4	4	1	2	18	-	L								
	Pit Backfilling- Roll over method	10	4	2	4	64	-	H	Backfill pit correctly- geology with the highest acid generation capacity must be placed at the bottom of the pit and compacted	8	4	2	4	56	-	M	None required- Geology will have the greatest influence of groundwater quality down gradient of the site. Few groundwater users exist. Quarterly monitoring must be done to monitor the plume development.							
	Pollution Control Dams	10	4	2	4	64	-	H	Line dams	0	1	1	2	4	-	L								
	Formation of stockpiles	8	4	1	4	52	-	M	Divert dirty water runoff to PCD, prevent infiltration to aquifer, compact base of stockpile	6	4	1	3	33	-	M								
	Coal transport via haulage roads to Coalfields	4	4	2	2	20	-	L	Clean spillages regularly	2	2	2	2	12	-	L								

Table 7-4: Decommissioning/ Closure phase risk assessment

POTENTIAL ENVIRONMENTAL IMPACT	APPLICABLE MINE AREA	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION							ACTION PLAN	FREQUENCY	PERSON
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP			
DECOMISSIONING and CLOSURE ACTIVITIES: PIT BACKFILL AND REHABILITATION OF DISTURBED AREAS																				
GROUNDWATER																				
Impact on groundwater quantity	Opencast pit	**Residual dewatering cone of depression**	6	3	2	4	44	-	M	No mitigation measure required- cone of depression will decrease over time until original water levels are achieved	2	3	1	2	12	-	L	Compact pit so that a 3-5% recharge value is achieved. Monitoring groundwater levels quarterly to assess change in cone of depression over time	Quarterly	Groundwater Consultant
Impact on groundwater quality	Opencast pit	**Long term plume development**	6	3	2	4	44	-	M	Groundwater monitoring down gradient of the pit to monitor plume development. Mitigation measures should be implemented during the operational phase	2	3	1	2	12	-	L	Backfill pit correctly to reduce risk of long term plume development. Drill two new monitoring boreholes down gradient of the pit. Sample boreholes quarterly.	Quarterly	Groundwater Consultant

7.2 Risk Assessment Summary

The risk assessment, in terms of groundwater, focuses on the risk that a specific activity will pose to the groundwater quantity and groundwater quality.

7.2.1 Construction Phase

- The construction phase of the opencast extension will entail site preparation and clearance for mining.
- Low risk construction phase activities include removing topsoil and diversion of watercourses. Watercourses are typically dry but will feed into the groundwater during summer rainfall months. Removal of topsoil will create a sink for infiltration of dirty water runoff to the underlying aquifer.
- Excavation of overburden material by blasting poses a medium risk as this will increase the fracturing at the receiving face of the pit. This will result in increased seepage into the pit which will need to be pumped to the PCD's.

7.2.2 Operational Phase

- Pit dewatering will continue during the operational phase which will create a cone of depression around the opencast pit.
- Once the overburden has been removed the coal seam will be exposed. This will need to be transported via haulage roads to the stockpile area. Transportation via the haulage road poses a low risk to groundwater quality as spillages will be small. The risk can be furthered reduced by cleaning any spillages that occur.
- The coal stockpiles pose a medium risk as the coal has a high acid generation potential. The base of the stockpile should be compacted to reduce seepage to the underlying aquifer. Dirty water runoff from the stockpile must be diverted to the PCD's.
- The PCD's pose a high risk to groundwater quality as all polluted runoff will be diverted to these dams. However, the risk can be reduced significantly by lining these dams. Lining the PCD's will result in a low risk.
- Backfilling the opencast pit will also pose a high risk to groundwater quality as the geology, most significantly shale, has an acid generation potential and high sulphur content. The risk to groundwater quality will be reduced if the shale is put back into the pit first and compacted.

7.2.3 Decommissioning/ Closure Phase

- The cone of depression created during the operational phase will reduce over time as natural groundwater ingress and flow regime resumes.
- Long term sulphate plume development is anticipated.

8 GROUNDWATER MONITORING PROGRAMME

The monitoring programme at Magdalena is conducted on a quarterly basis and includes all the surface water and groundwater monitoring points mentioned in Section 4 of this report.

GRIP data shows that there are 13 boreholes down gradient of the proposed extension area, however, most of these could not be found during the hydrocensus investigation. Most community boreholes in this area are shallow, hand pumped boreholes that are usually dry. Therefore, it is recommended that two boreholes are drilled down gradient of the proposed expansion area to at least 30m (the main water strike being at 20-26m) to ensure a consistent sample. The proposed location of these boreholes are shown in Figure 8-1.

8.1 Groundwater Objectives

- To continue the groundwater quality and groundwater level monitoring.
- To present the results of the monitoring programme to The Department of Water Affairs on an annual basis. The post-closure monitoring programme will be re-evaluated on an annual basis in consultation with DWA.

8.2 Monitoring: Groundwater

Groundwater monitoring will be undertaken to establish the following:

- The impact of mine dewatering on the surrounding aquifers. This will be achieved through monitoring of groundwater levels in the monitoring boreholes. If private boreholes are identified within the zone of impact on groundwater levels, these will be included in the monitoring programme.
- Groundwater quality trends. This will be achieved through sampling of the groundwater in the monitoring boreholes.

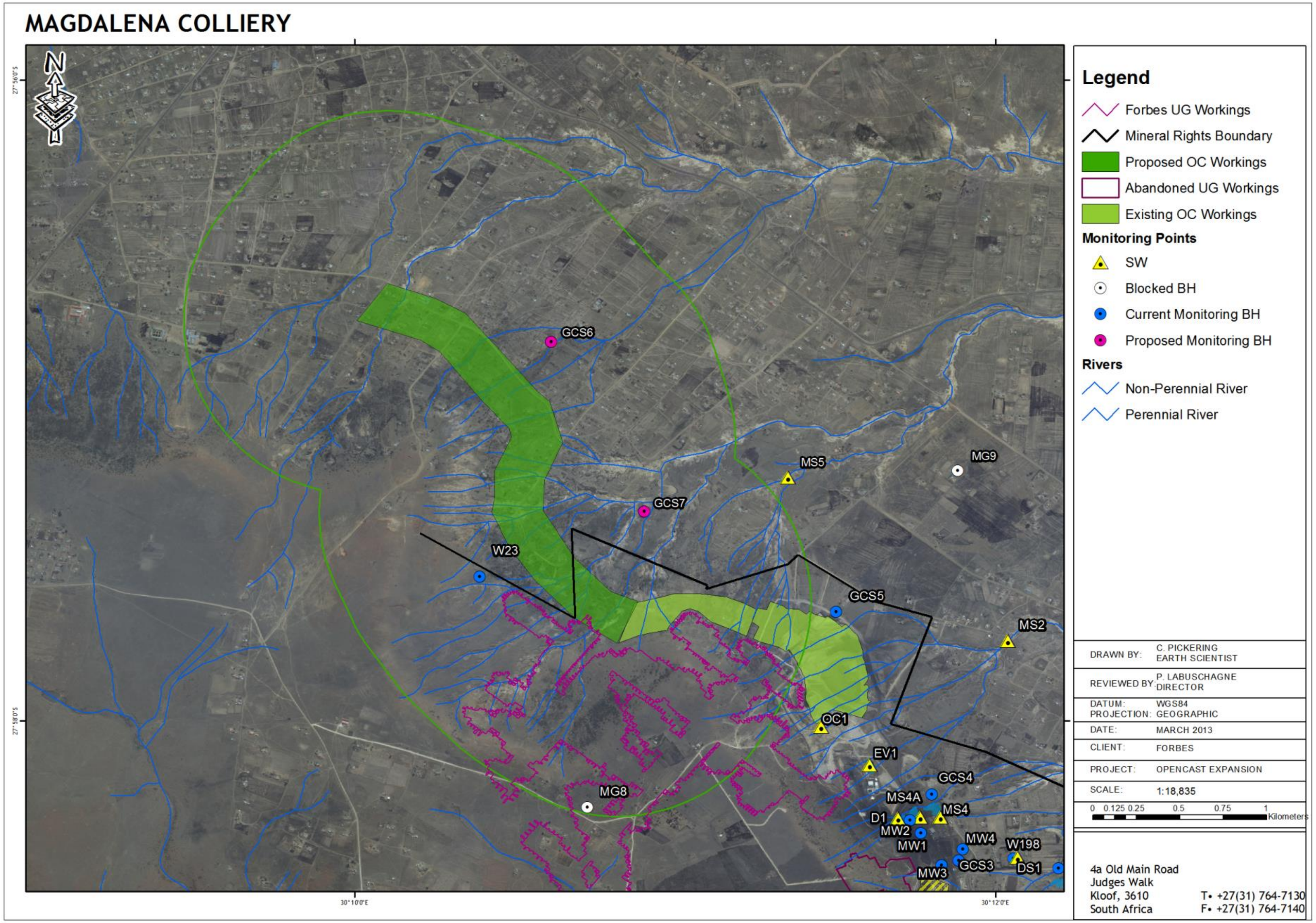

Figure 8-1: Proposed groundwater monitoring boreholes

9 CONCLUSIONS

The following concluding remarks can be made:

9.1 Hydrochemistry

- The available groundwater monitoring data shows that the current opencast workings have no adverse effects on the groundwater quality. However, the data for this area is limited and is based on one year worth of data at borehole GCS5 which is located immediately down gradient of the existing opencast workings.
- Data obtained for GCS5 as well as a community borehole located in the proposed expansion area indicates that the groundwater quality has a naturally high salt load with high conductivity, TDS and sodium present. This has been confirmed during previous studies which have shown naturally saline groundwater quality in this area.
- Both boreholes illustrate a sodium-bicarbonate water type, which was previously discovered during similar hydrocensus studies.

9.2 Acid Base Accounting

- The proposed pit will be excavated to a depth of approximately 40m through alternating beds of sandstone and shale. The sandstone forms the bulk of the geology, the upper ±30m, of the pit. The predominant shale layer is carbonaceous and closely associated with the upper coal seam. The shale and coal layers are, therefore, expected to contain a large amount of pyrite which is the key mineral in acid producing environments.
- The results of the ABA indicate that the shale and coal layers have a likely acid generating potential based on the NNP as well the NPR.
- The sandstone layer, which constitutes a large portion of the geology of the pit, has an uncertain (NNP) or possible (NPR) acid generation potential.
- The coal and shale layers, therefore, pose the greatest risk to groundwater quality. The bulk of the coal layer will be removed during mining which will reduce the risk of future acid generation in the pit.
- It is recommended that, during backfilling, the shale layer is put back into the pit first at the deepest section of the pit. Therefore, when water levels in the pit rise this section will be completely submerged and thus stop the oxidation process. The next section shows that groundwater levels are expected to rise approximately 15m from the base of the pit, once the pit has been backfilled, which means that the lower 15m of the pit will become saturated over time. This will help to reduce the acid generating potential of the shale.

9.3 Local Aquifer Characteristics

- Aquifer parameters (hydraulic conductivity / transmisssivity, piezometric levels, gradients, etc.) were obtained from the previous groundwater assessments and relevant literature. By making use of these values, a hydrogeological conceptual model for the mining area was developed.
- The water levels in this area are approximately 20 m below ground level. As such, it is expected that water levels will drop approximately 15 m at the receiving face of the pit during the operational phase. Once each section of the pit has been backfilled, normal flow will resume within that section over time.
- Analytical calculations indicate moderate groundwater movement (31 to 83 m in an easterly direction in one year, under steady state conditions). Any pollutants generated by the mining activities (SO_4 content usually) will therefore migrate according to these flow rates.
- However, it must be noted that de-watering activities, during the operational phase, will cause a cone of depression towards the opencast areas and groundwater flow tends to flow back towards these areas. This will limit mass transport to the surrounding aquifers during the operational phase. Mass transport can therefore increase after the rebound of water levels during the de-commissioning phase and after.

9.4 Impact due to dewatering

- The proposed opencast pit will be mined in sections using the roll over method. This will limit the extent of dewatering as the backfill material will accommodate recharge that will constitute a rise in static water level.
- Therefore, the extent of the simulated drawdown at the time of pit closure in 2018 is reduced by use of the roll over method. Groundwater levels are expected to drop by 5m at the center of the pit at the time of pit closure and rise further away from the pit. The drawdown simulations show that the cone of depression will have an extent of approximately 340m south, 697m east and 505m west of the pit.

9.5 Impact due to mass transport

- The simulated mass transport was modelled for mine closure in 2038, 50 years post closure and 100 post closure in order to examine the change in the zone of influence of the pit.
- At mine closure, the zone of influence is predicted to extend approximately 271m east of the pit. This increases to 549m 50 years post closure and 1.6km 100 years post closure at the greatest extent of the zone of influence.
- The sulphate concentrations within this zone are predicted to be above 200 mg/l. These concentrations will be highest at the pit and dissipate outwards.

9.6 Risk Assessment

- The risk assessment was determined based on estimated impact to the aquifer over time as well as risk to the receptors, in this case additional groundwater users.
- The risk assessment, in terms of groundwater, focuses on the risk that a specific activity will pose to the groundwater quantity and groundwater quality.
  - It is anticipated that a cone of depression will develop around the proposed opencast pit during the construction and operational phase of pit development. The extent of dewatering will be reduced by use of the Roll-Over Method. The cone of depression will also decrease over time, after the decommissioning phase, as water flow resumes normally within the rehabilitated pit.
  - Long term poor water quality seepage is anticipated in the form of a sulphate plume.
  - Stockpiles and discard dumps have already been established at the site. These areas may need to be enlarged to cope with the expansion. New pollution control dams will need to be constructed to cope with the additional volume of water. Dirty water runoff must be diverted to the PCD's and monitoring of these surface operations should continue quarterly.

9.7 Monitoring Program

- The current monitoring program does not include boreholes down gradient of the proposed opencast pit extension.
- It is recommended that two additional boreholes, GCS6 and GCS7 are drilled down gradient of the proposed opencast workings to a depth of 30m.
- These additional boreholes should be included into the monitoring programme before pit development commences so that changes in water quality from pre-construction to operational and closure phase can be assessed.
- The available water quality data shows that the current opencast workings have no adverse effects on the groundwater quality. However, the data for this area is limited and is based on one years worth of data at borehole GCS5 which is located immediately down gradient of the existing opencast workings.
- Data obtained for GCS5 as well as a hydrocensus borehole located in the proposed expansion area indicates that the groundwater quality has a naturally high salt load with high conductivity, TDS and sodium present.
- Both boreholes illustrate a sodium-bicarbonate water type.

10 RECOMMENDATIONS

10.1 Groundwater Management Objectives

10.1.1 Construction Phase

To prevent contamination of surface water runoff and infiltration into groundwater from the opencast pit and infrastructure development.

Actions: Construction Phase

- Separate clean and dirty runoff and contain dirty water in adequately sized pollution control dams. Ensure that pollution control dams are adequately sized according to the specifications in DWAF's GN704 or other applicable regulations.
- Keep dirty areas as small as possible.
- Compact the base of dirty areas, like the ROM coal stockpile, workshops and oil and diesel storage areas to minimise infiltration of poor quality water to the underlying aquifers.
- Have oil/diesel spill kits on site (Spill Tech House, 604/608/610 Umbilo Road, Congella, KwaZulu-Natal, 4001, Tel: 0861 000 366, Tel: +27 (0)31 206 0919).
- Confirm groundwater and surface water monitoring protocol and plans. It is recommended that groundwater monitoring be conducted on a quarterly basis.

10.1.2 Operational Phase

To restrict the impact of polluted groundwater to the mining area and mitigate the loss of groundwater from the catchment.

Actions: Operational Phase

- Re-use groundwater seepage collected in the open pits to adequately sized pollution control facilities in the mining process.
- Keep dirty areas like the pollution control dam and coal stockpiles, workshops and oil and diesel storage areas as small as possible.
- Contain poor quality runoff from dirty areas and divert this water to pollution control dam for re-use.
- Have oil/diesel spill kits on site (Spill Tech House, 604/608/610 Umbilo Road, Congella, KwaZulu-Natal, 4001, Tel: 0861 000 366, Tel: +27 (0)31 206 0919).
- Confirm groundwater and surface water monitoring protocol and plans. It is recommended that groundwater monitoring be conducted on a quarterly basis.

10.1.3 Closure Phase

- To negotiate and get the groundwater closure objectives approved by Government during the Decommissioning Phase of the project, based on the results of the monitoring information obtained during the Construction and Operational Phases of the project, and through verification of the numerical model constructed for the project.
- To continue the groundwater quality and groundwater level monitoring for a period of two to four years after mining ceases in order to establish post-closure groundwater level and quality trends. The monitoring information must be used to update, verify and recalibrate the predictive tools used during the study to increase the confidence in the closure objectives and management plans.
- To present the results of the monitoring programme to Government on an annual basis. The post-closure monitoring programme will be re-evaluated on an annual basis in consultation with Government.
- To negotiate mine closure with Government based on the results of the groundwater monitoring undertaken, after the two-four year post-closure monitoring periods.

Actions: Closure

- To close all mining pits according to the EMP.
- Update existing predictive tools to verify long-term impacts on groundwater, if required.
- Present the results to Government on an annual basis to determine compliance with the closure objectives set during the Decommissioning Phase.

10.2 Technical Recommendations

The following technical aspects are recommended to ensure adequate follow ups and information gathering occurs. These are only generic and may be adjusted as mining commences. The main purpose is to ensure continuous improvement of the understanding of the hydrogeological environment:

- More ABA tests and leach test be conducted during the construction of the open pits. As development progresses through the roof, seam and floor material samples can be collected.
- The numerical groundwater model be updated when changes in the mine plan and infrastructure plan occur.
- The numerical groundwater model be updated with new data and calibrated every two years during operations.
- Routine ABA and leach testing be conducted on coal discard and slurry material. This will assist with continuous impact and closure assessments,
- Water inflow in the open pit workings is sampled on a quarterly basis to understand water quality aspects.

11 REFERENCES

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- DEPARTMENT OF WATER AFFAIRS AND FORESTRY 1996. South African Water Quality Guidelines, Volume 1, Domestic Use. DWAF, Pretoria.
- Fetter, C.W. (2001). Applied Hydrogeology (4th ed.), Prentice-Hall, Upper Saddle River, New Jersey.
- SABS (2001). South African Standard Specification Drinking Water. SABS 241 Edition 5.
- Groundwater Resources Information Project Database (2011). Department of Water Affaires and Forestry, Pretoria, South Africa.
- Weaver, J.M.C. (1992). Groundwater sampling a comprehensive guide for sampling methods. Water Research Commission Report No. TT54/92

APPENDIX A

Photolog

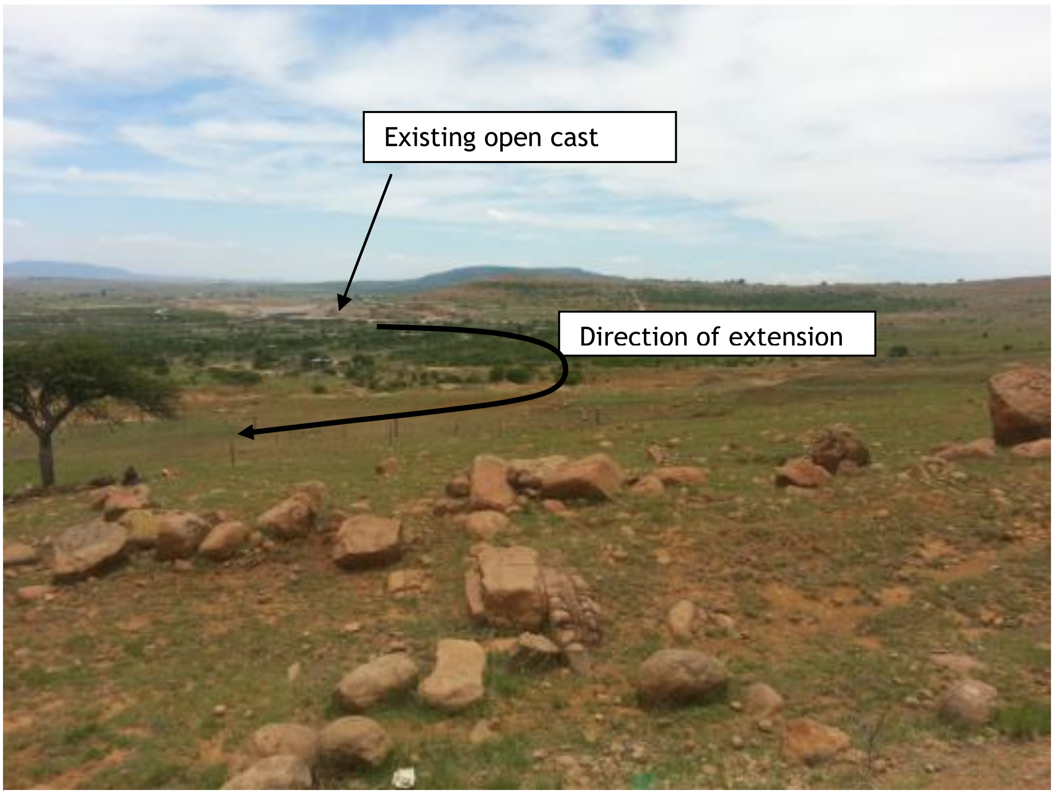
Photo No: 1	
Description: MGH1 with hand pump fitted.	
Photo No: 2	
Description: Proposed opencast extension area	

Photo No: 3	
Description: Dry river bed	
Photo No: 4	
Description: Geology of existing opencast pit where ABA samples were taken	