4.1.6 Geology

4.1.6.1 Regional Geology

The majority of the study area is underlain by Karoo Supergroup sedimentary rocks of the Vryheid and Volksrust Formations of the Ecca Group. These are largely comprised of sandstone, mudstone, shale, siltstone, and coal seams.

The available geological maps covering the study area did not indicate any major structural features such as faults or fractures. Limited tectonic activity is recognised within the study area, and the only evidence of secondary processes is outcrops of intrusive younger dolerite sills mapped in the Karoo sediments.

Four generations of dolerite intrusions are recognised within the study area, based on olivine or plagioclase content, alteration, and texture. The intrusive dolerite has produced large-scale de-volatilisation and structural displacement of the coal. These adverse geological conditions caused the closure of the Majuba Colliery in 1993. The litho-stratigraphy of the study area is presented in **Table 19** below.

Table 19: Litho-stratigraphy of the study area

Age	Supergroup	Group	Subgroup	Formation	Lithology
Jurassic					Dolerite
Permian	Karoo	Ecca		Volksrust	Mudstone, siltstone, shale
Permian	Karoo	Ecca		Vryheid	Sandstone, siltstone, shale, coal

4.1.6.2 Geology of the farm Roodekopjes 67HS

The general geology of the farm Roodekopjes 67HS from surface downwards is illustrated in **Figure 18**.

The B8 dolerite sill outcrops at surface on the site and averages in the order of 30 m thick. A sandstone and siltstone interval of between 5 and 25 m is followed by two to three stages of sill intrusion of the B4 dolerite totalling approximately 120 m in thickness.

Below this composite dolerite sill are sequences of sandstones, siltstones and mudstones containing minor coal seams. The main coal seams namely the Alfred and Gus seams are at an average depth of 280 m below surface.

They total about 5 m in thickness with a small parting between them that thickens and becomes more prominent towards the east.

Below this is a sequence of bioturbated siltstones, sandstone and mudstone with minor coal seams.

The B6 dolerite sill underlies the whole farm. This dolerite has indurated the coal and the coal seams volatile content is well below the required average for Majuba Power Station. The seam elevation and altitude for farm Roodekopjes is flat and consistent.

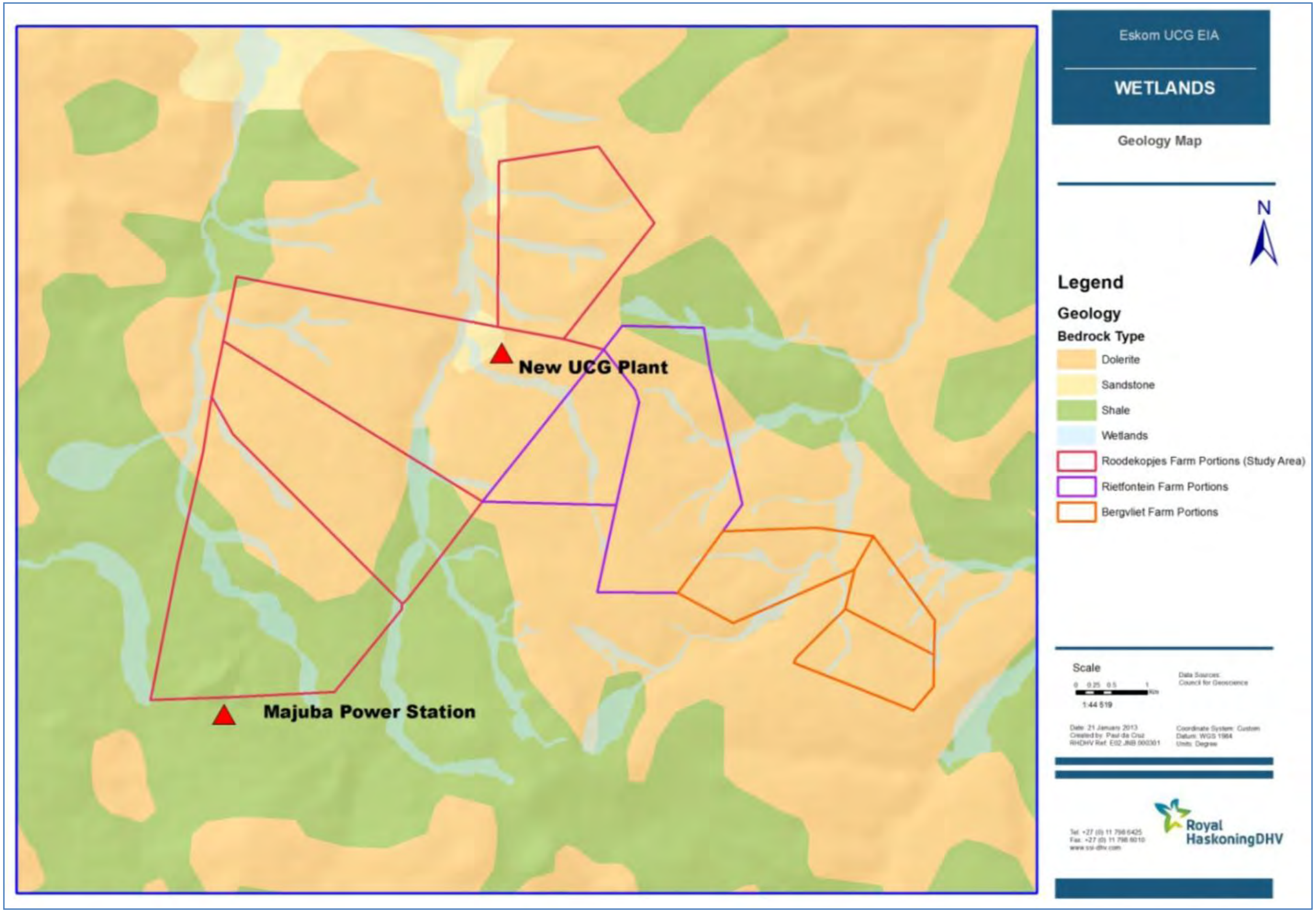


Figure 17: Study area geology

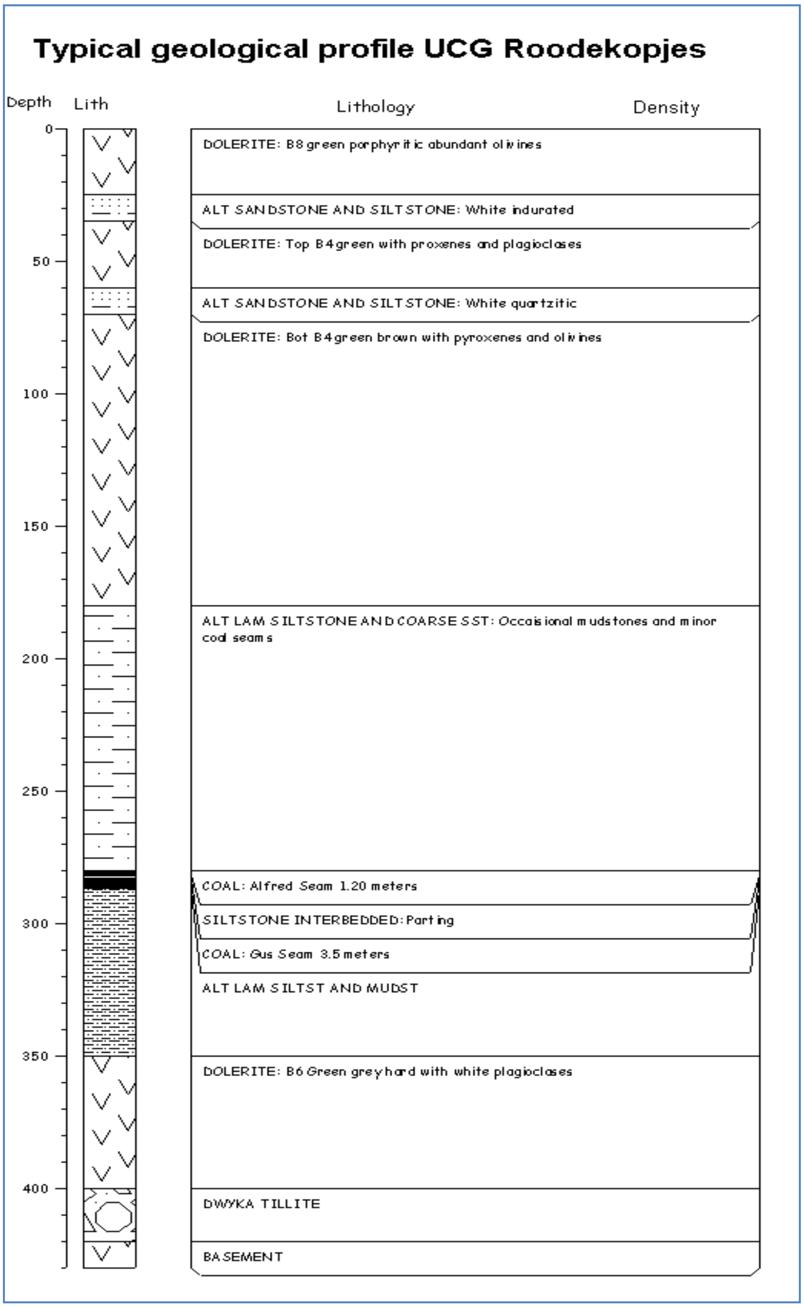


Figure 18: Typical geological profile of the farm Roodekopjes 67HS

4.1.6.3 Coal Seams

The two (2) main coal seams on the farm Roodekopjes 67HS are the Alfred and Gus seams.

The Alfred seam varies between 1 and 1.5 m in thickness. It often has contaminated coal and sandstone near the top. The coal is a dull bituminous coal, high in ash with some carbonaceous shale bands. The coal is slightly devolatilised as shown by the range of dry ash free volatiles.

The Gus seam is separated from the overlying Alfred seam by a shale parting of coaly shale that becomes thicker and more carbonaceous to the east. The Gus seam averages over 3.0 m in thickness and is divided into a poor shaly top half and a high quality bottom half. Again the coal shows signs of de-volatilisation.

4.1.7 Hydrogeology

The UCG site is underlain by Karoo sediments. These comprise out of inter-bedded sequence of sandstones, mudstones and coal seams.

The Karoo sequence is characterised by dolerite intrusions. At Majuba the sequence has been intruded by two dolerite sills. The upper sill, the B5, extends from approximately 70 m depth to about 170 m depth. The B6 sill lies about 50 m below the Gus coal seam (280 m below surface) at the Majuba UCG site.

A conceptual hydrogeological model was developed by Golder Associates Africa in 2010 and was updated in 2012 and is summarised below.

The conceptual model (**Figure 19**) distinguishes between four (4) distinct groundwater systems that are present at the UCG site.

4.1.7.1 Shallow Aquifer Unit

The shallow aquifer is found from surface to an average depth of 70 m below surface. This aquifer is present above the lower B4 dolerite sill and comprises weathered / fractured Karoo sediments and the upper B4 dolerite sill. Very low blow yields were encountered during drilling in this aquifer. The hydraulic conductivity ranges between 1.7 x 10^{-1} to 8.6 x 10^{-3} m/day. The groundwater piezometric levels vary between 17 and 35 m below surface and generally follow the topography.

The quality of the groundwater in the shallow aquifer is characteristic of recently recharged water and generally conforms to the SANS 241 Water Quality Guidelines for domestic use.

4.1.7.2 Intermediate Aquifer Unit

The previously defined intermediate aquifer zone is divided into an:

- *Intermediate upper aquifer zone*

  The intermediate upper aquifer zone (+/-70 to +/- 170 m) constitutes out of the top contact of the B5 dolerite sill. A hydraulic conductivity of $8x10^{-4}$ m/d was calculated for the intermediate upper aquifer zone.

- *Intermediate lower aquifer zone*

  The intermediate lower aquifer zone (+/-180 to +/- 270 m) constitutes bottom contact of the B5 dolerite sill including the sugary dolerite zone and the geological sedimentary units above the coal seam. Transmissivity values of the intermediate lower aquifer zone range from 0.1 to 0.9 m^2/d.

The SRK report of 1984[3] suggests hydraulic conductivity of $3x10^{-3}$ – $5x10^{-4}$ m/d for the average value across the aquifer and $3x10^{-4}$ – 5.5 m/d for the running (sugary) dolerite.

4.1.7.3 Coal Seam Aquifer Unit

The coal seam aquifer constitutes the fractured Gus coal seam and potential partings within the coal at depths between ± 280 and 284 m below surface. Groundwater levels measured in the deep monitoring boreholes range between 40 and 100 m below surface with recharge from overlying intermediate aquifer.

Golder confirmed the hydraulic conductivity as 10^{-4} m/day in 2007 and 10^{-5} m/day during 2012.

[3] ***Steffen Robertson & Kirsten, 1984**. Report CI.3936/3: Majuba Coal Mine. Hydrogeological, Hydrological and Environmental Study. Summary Report*

4.1.7.4 Lower Aquifer Unit

A lower aquifer is assumed to be present below the Gus coal seam at depths below 284 m below surface.

No information regarding piezometric levels hydraulic properties is available but it can be assumed the hydraulic conductivity will be low.

Table 20: Hydraulic Parameters of Groundwater Conceptual Model

Groundwater zone	Distribution	Depth	Hydraulic Parameters (Hydraulic Conductivity (K) /Transmissivity (T))	Properties
Shallow groundwater zone	Throughout Majuba area	0 – 70 m below surface	K = 1.7 x 10^{-1} m/day – 8.6 x 10^{-3} m/day (Slug test done during the current study)	• Highly weathered/fractured dolerite and Karoo sediments • Permeability generally decreases with depth • Groundwater piezometric surface generally follows the topography • High ground between watercourses generally constitutes recharge areas • Watercourses and springs are discharge areas
Intermediate upper groundwater zone	Throughout Majuba area. (may be compartmentalized through dykes)	70 – 120 m below surface	K = 8.0 x 10^{-4} m/day (Slug test done during the current study)	• Fractured dolerite • Permeability depends on the extent of fracturing • Recharge from overlying groundwater zone
Intermediate Lower groundwater zone	Throughout Majuba area. (May be compartmentalized through dykes)	180 – 270 m below surface	T = 0.1 to 0.9 m^2/d (Test pumping done during the current study)	• Fractured dolerite and Karoo sediments below the dolerite. • Discharge to local base level (Vaal River?)
Gus coal seam groundwater zone	Throughout Majuba area	280 – 284 m below surface	K = 1.0 x10^{-4} m/day to 1.0 x10^{-5} m/day	• Fractured coal and lithological partings within the coal seam • Groundwater levels approximately 100 mbgl during 2006-2007 and 40 – 60 mbgl in 2008 • Recharge from overlying groundwater zone • Discharge to local base level (Vaal River?)
Lower groundwater zone	Throughout Majuba area	284 m – unknown depth.	No information available	• Fractured dolerite and Karoo sediments below the Gus seam – Permeability depends on extent of fracturing - likely to be very low – Recharge from overlying groundwater zone – Discharge to regional base level (Vaal River?)

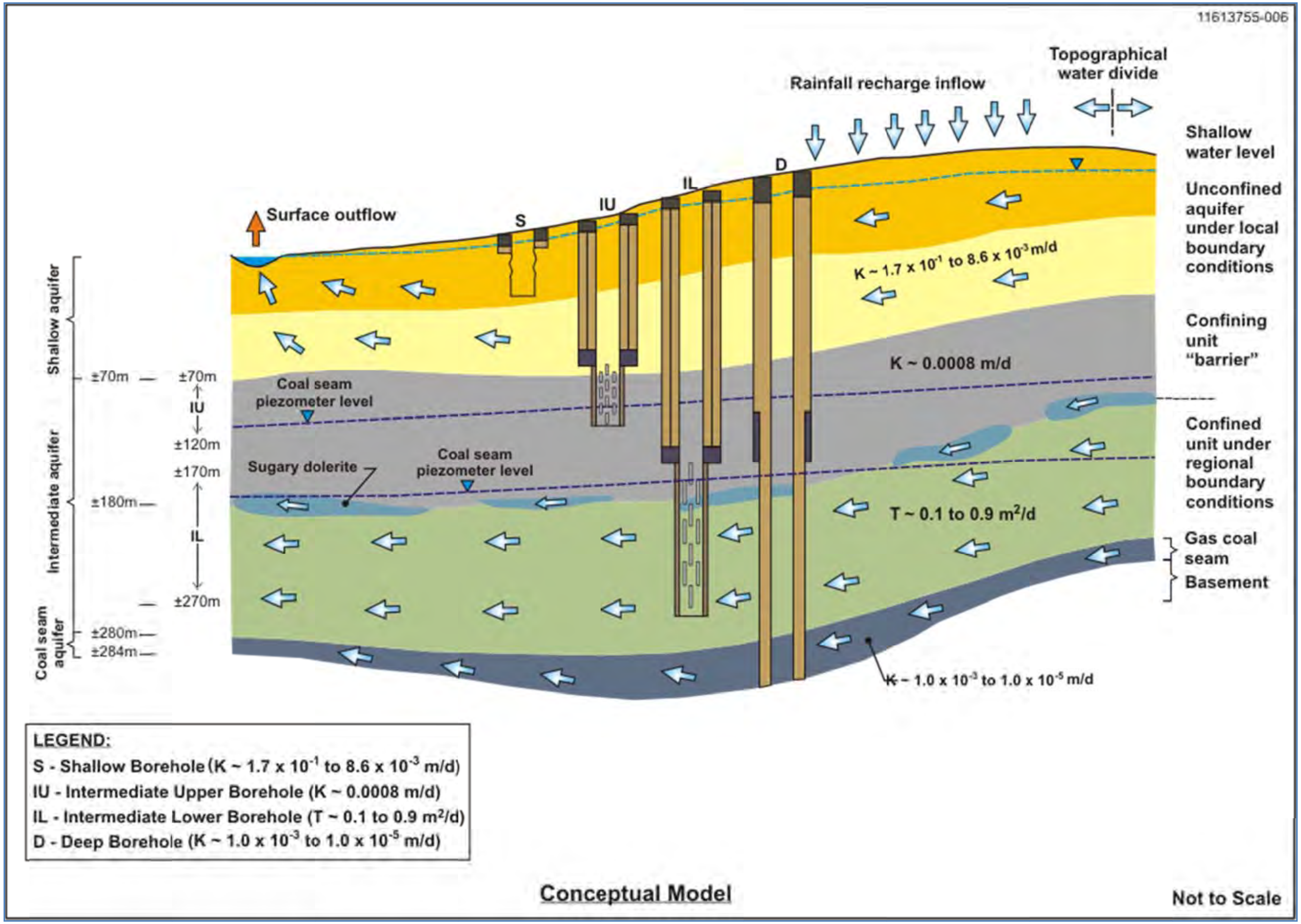


Figure 19: Conceptual hydrogeological model

The quality of the groundwater in the shallow aquifer unit is characteristic of recently recharged water and generally conforms to the SANS 241 Water Quality Guidelines for domestic use. There is a significant difference between the shallow aquifer unit and coal seam aquifer in terms of water levels and quality. This suggests that there is limited direct interaction between the two aquifers at the site although indirect interaction via the intermediate aquifer could occur. The saline character of the coal seam water does indicate a long underground flow path between recharge and discharge.

Groundwater hydrochemistry associated with the sediments is variable; the groundwater salinity associated with the formations in the study area can have electrical conductivity concentrations of < 250 up to 1,000 mS/m.

The sandstones of the Vryheid Formation of the Ecca Group can be massive and dense and have limited permeability and storage. It thus offers only moderate groundwater yield, especially in the absence of dolerite intrusions. Contacts between different rock lithologies and bedding planes within the sediments often yield groundwater. The contact zone between the dolerites and the sandstone lithologies can be high yielding. Fractured fault zones, especially if related to tensional stresses, are potentially rich targets for groundwater development. Groundwater occurs within the joints, bedding planes, and along dolerite contacts within the sediments (as recognised across the study area).

4.1.8 Hydrology

4.1.8.1 Drainage Context

The greater site straddles two quaternary catchments, both of which form part of the Grootdraai dam catchment of the Upper Vaal Water Management Area (WMA), C11J and C11E.

The area that is currently being assessed falls within catchment C11J, part of which is drained by the Witbankspruit, a stream that forms a tributary of the Upper Vaal River to the north of the site (the Witbankspruit flows from north to south across the site). All wetlands on the Roodekopjes site drain into the Witbankspruit.

The Upper Vaal WMA covers approximately 55,562 km^2 including parts of Gauteng, Mpumalanga, Free State and North West Provinces. It consists of the C1, C2 and C8 secondary drainage regions. The main rivers in the secondary drainage regions are listed in **Table 21**. There are three (3) large dams in the WMA: Grootdraai Dam, Vaal Dam and Sterkfontein Dam.

Table 21: Major catchments and rivers

Primary Catchment	Sub-catchment area	Quaternary catchments	Average gross area (km^2)
C	Wilge	C81A-M; C82AH; C83A-M	18,167
	Klip (Free State)	C13A-H	5,182
	Grootdraai	**C11A-L**	**7,995**
	Grootdraai to Vaal Dam	C11M; C12A-L	7,294
	Suikerbosrand	C12A-G	3,541
	Klip (Gauteng)	C22A-E	2,282
	Rietspruit	C22J and C22H	1,123
	Leeu / Taaiboschspruit	C22F; C22G; C22K	1,705
	Mooi	C23D-K	4,494
	Vaal Barrage to Mooi	C23A-C; C23L	3,239
	Wilge	C81A-M; C82AH; C83A-M	18,167

A small part of Roodekopjes property, and the Rietfontein and Bergvliet properties, fall within quaternary catchment C11E. The major rivers/streams in the area are the Skulpspruit (into which all wetlands located in this part of the site drain) and forms a tributary of the Rietspruit, itself a tributary of the Upper Vaal.

4.1.8.2 Water Users

The land-use in the area is primarily rural agricultural based, with an urban setting in the nearby town of Amersfoort:

a) Agriculture (covering the majority of the proposed development route);
b) Mixed urban use (in town approximately 7 km from proposed development area); and
c) Energy production (at Majuba Power Station opposite the proposed project area).

Amersfoort, Perdekop, Daggakraal, Siyasenzele and Ezamokuhle settlements falls under the management of the Pixley ka Seme Local Municipality in the Gert Sibande District Municipality.

The Pixley ka Seme Municipality serves as a Water Services Authority and Water Services Provider for the area. The Water Services Development Plan indicates that Amersfoort town main water source is the local dam (Amersfoort Dam) from where water is abstracted, purified and distributed. Amersfoort Dam is located on the Skulpspruit with a storage capacity of 0.992 million m^3 and a yield of 1.33 million m^3/annum. All water is abstracted from local resources.

The main water users in the area are therefore:

a) Urban related water users in the Pixley ka Seme Local Municipal area; and
b) Irrigation.

4.1.9 Wetlands

4.1.9.1 Study Area Biophysical Characteristics and how these relate to / affect Wetlands

- ***Geology***

The geological makeup of the area is important as it affects the geomorphological make-up of the landscape. This relates to the relative erodibility of the igneous (dolerite) rock as opposed to the sedimentary rock; dolerite is much more resistant to weathering than the sedimentary sandstones and weathers much more slowly. This has affected the landscape of the area in that the landscapes in the doleritic areas are slightly different from those in the areas of sedimentary geology. Where rivers and streams have to cross dolerite, in particular dolerite sills, the drainage has often cut relatively deep, narrow valleys into the landscape. This phenomenon is present to the west of the development site in the Palmietspruit valley where the river and its tributaries have cut relatively deeply incised valleys into the landscape.

Importantly, this has a critical bearing on the geomorphology of the drainage in this area as wetlands, where they exist are typically narrow, linear features that extend from valley bottoms up into the upper parts of valley heads. In certain areas underlain by dolerite geology, the valley bottom takes the form of a river channel rather than a wetland. In the tributaries of many of the larger streams in the area, wetlands in the higher valleys and valley heads are relatively narrow in width, many being less the 50 m wide. Wetland vegetation (see the ensuing sections for a description of wetland soils) is typically limited to the centre of the valley bottom into which a (stable) gulley has cut into the deep vertic soils.

This can be contrasted with wetlands on sandstone geology. The landscapes underlain by sandstone geology are typically shallower and less incised than those underlain by dolerite. As a result wetlands are typically wider, less channelised, and are much more likely to be characterised by areas of diffuse flow in which moribund vegetation often occurs. As soon as the wetland traverses dolerite, the wetland changes to become a much narrower wetland with limited patches of wetland soil and vegetation in the valley bottom.

It is important to note that all of the floodplain wetland units in the wider area (former study area) and on the revised development site occur on sandstone or shale geology. Many of the wider un-channelled valley bottom wetlands also occur in similar geology. These areas of sandstone or shale geology are typically surrounded by areas of dolerite geology and doleritic features such as dykes. The presence of these features is likely to be responsible for the formation of floodplain wetlands.

- ***Groundwater and Wetland Hydrology***

A report undertaken by Golder[4] for the study area around the first wells drilled (on the farm Roodekopjes) indicate that there are three (3) distinct aquifers in the study area; a shallow aquifer (from surface level to approximately 70 m), an intermediate aquifer and a much deeper aquifer. The shallow aquifer is of importance in a context of wetlands, as the other two aquifers are too deep to have any hydrological connectivity to the surface. This shallow aquifer is thought to occur across the study area[5].

The report by Golder further indicates that groundwater flow patterns in the shallow aquifer mimic the topography; i.e. groundwater flows were observed to be directed towards the Witbankspruit valley bottom and valley bottom tributary to the east. The study found that the piezometric groundwater level follows the topography; i.e. groundwater levels are deepest on interfluves and shallowest in valley bottoms. In the area in which boreholes were sampled the piezometric groundwater levels were observed to be between 17 and 35 m below the surface. This mimicry of groundwater flows and levels to terrain entails that groundwater discharge areas would primarily be located in valley bottoms. Importantly in this way the Golder report concurs with the observation in this study that groundwater discharge into wetlands occurs in the upper parts of valley bottoms and valley heads.

The Golder report also states that interfluves are groundwater recharge areas. The presence of vertic soils that occur across most of the study area may be a limiting factor in the recharge of groundwater into the ground. These soils are highly impermeable when wet, and thus preclude the vertical movement of rainwater into the ground, with much rainwater being directed as overland flow into the drainage systems, rather than sub-surface flow.

- ***Soils and Land Types***

As the majority of the study area is underlain by dolerite, most of this area is associated with highly vertic soils. In these areas there is homogeneity of soil type along the catena, with the vertic soils being uniformly present from crest to valley bottom, irrespective of location within the landscape or location within or outside of wetland areas. This is unusual, as many parts of the Highveld are characterised by a distinct sequence of soil forms from the valley bottom (in which wetlands are located) to the non-wetland mid-slopes and up to the crest. The wetland soil forms in the valley bottom are distinct from the other soil forms in the non-wetland areas around, and upslope of them, and this allows the wetland areas to be differentiated from the non-wetland parts of the landscape. This is not the case in many parts of the study area.

[4] ***Golder Associates; 2009***. *Majuba Underground Coal Gasification: February 2008 – March 2009. Report 11600-8209-1.*
[5] Ibid. *Footnote* 4.

Vertic soils are characterised by the presence of swelling and shrinking clays. They typically form where there is a distinct wet and dry period that affects the soils. These soils swell when they become saturated, and shrink again when they dry out, leading to characteristic 'cracking' on the surface of the ground (**Photograph 4**).

Photograph 4: Cracking on the surface of vertic soils

Vertic soils, even those that appear in wetlands, do not typically display redoximorphic features in the form of yellow or red / orange mottles. This is due to their high (alkaline) pH ≥8. Thus the usual soil wetness indicators do not apply to many of the wetlands in the study area.

- ***Drainage and Catchments***

All wetlands and rivers on the site drain into the Upper Vaal River. This factor is relatively important in a catchment management context as the Vaal River is critical in the supply of water to South Africa's most densely populated area and economic hub i.e. Gauteng.

4.1.9.2 Wetland Characteristics

- ***Wetland Hydrogeomorphic Forms***

There are a number of different types of wetlands in the study area, including a number of different wetland hydrogeomorphic forms; a classification system exists for different types of wetlands – a hydrogeomorphic-based classification system. The wetland hydrogeomorphic (HGM) approach to wetland classification which uses hydrological and geomorphological characteristics to distinguish primary wetland units has been used to classify wetland types in South Africa[6]. This approach has been used, and the classification system has been recently updated as part of the National Wetland Classification System for South Africa[7].

[6] ***SANBI; 2009:*** *Further Development of a Proposed National Wetland Classification System for South Africa, Primary Project Report. Prepared by the Freshwater Consulting Group (FCG) for the South African National Biodiversity Institute (SANBI).*

[7] Ibid. *Footnote 6.*

Under this classification system there are a number of different types of terrestrial (as opposed to marine) wetlands, some of which occur in the study area:

a) Channel
b) Channelled Valley-Bottom Wetland
c) Un-channelled Valley-Bottom Wetland
d) Floodplain
e) Hillslope Seep
f) Valleyhead Seep

The only wetland HGM units that have not been identified in the greater study area is the 'flat' wetland as well as the pan / depression wetland. A flat wetland is defined as a near-level wetland area (i.e. with little or no relief) with little or no gradient, situated on a plain or a bench in terms of landscape setting. Due to the undulating nature of the terrain in the study area, no flat or pan / depression wetlands have been found to occur.

The most common form of HGM form is the valley-bottom wetland, found in the numerous valley bottoms in the area. Most of these wetlands are naturally channelled, but importantly in a wetland functionality context, many are un-channelled and are characterised by diffuse (non-channelled) flow over the width of the wetland. The valleyhead seep wetland typically occurs at the head of valley bottoms where the terrain typically becomes steeper, rising out of the valley bottom. These HGM types are critical as they contain most of the seepage areas from which groundwater discharge is fed into the downstream wetlands / watercourses.

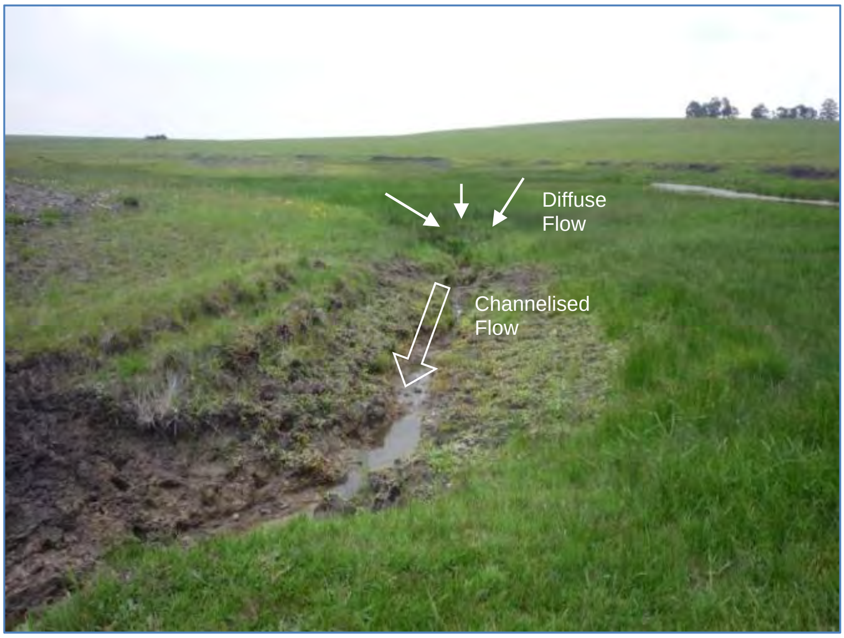
Floodplain wetlands are found exclusively on areas of sedimentary geology in the study area. These wetlands are important from a wetland functional point of view, as they have the ability to hold flood waters in depressions that would otherwise have flowed downstream and have a number of associated hydrological and ecological functions.

- ***Wetland Hydromophology (Hydrology and Geomorphological Processes)***

As described by the different hydrogeomorphic forms, different wetlands have different hydrological regimes. A key distinction can be made in terms of the surface hydrology of wetlands in the area, i.e. whether these are channelled or un-channelled. The majority of wetlands in the area contain some sort of channelled flow, sometimes in conjunction with diffuse flow. A large proportion of wetlands in the area are either valleyhead seep or valley bottom wetlands in which the bulk of the 'wetland habitat' (i.e. distinct wetland plant species and saturated area) occurs within the confines of a relatively narrow macro-channel. This is most common in doleritic areas of homogenous vertic soils across the catena. Flow within these wetlands is strongly channelled, or if diffuse, across a very narrow width of between approximately 20 and 40 m. Most of these types of wetlands appeared to be morphologically stable, i.e. they were relatively well vegetated and did not display excessive erosion in their bed or banks. Many of these wetlands displayed a relatively low 'scarp' erosion face at the top of the macro-channel bank.

Sub-surface flow is more complex, as this involves groundwater discharge. The vertic soils that predominate in the study area become relatively impermeable on becoming saturated. This means that sub-surface water is unlikely to move through the soils either vertically or on a horizontal plane (downslope), and the component of shallow sub-surface flow that it is an important component of the hydrological cycle in other parts of the Highveld is likely to be less important in this area (*pers comm.* Johan van der Waals). This would mean that water inputs to wetlands from upstream or the surrounding catchment during the wetter summer months would take the form of surface flows. Field assessments during, and immediately after a period of precipitation (on December 3, 2010 – rain had fallen in the area intermittently for roughly a 24-hour period) seemingly indicated this phenomenon. A significant degree of surface water run-off was noted, not only in wetland areas, but in the surrounding grassland. This has implications for the hydrology of wetlands, as the hydrograph is likely to show a distinct increase in flows during and immediately after periods of rainfall, with a concomitant fall once the rainfall event has stopped. This surface sheet wash / run-off is likely to enter many of the channelled wetlands and be transported down the system. Only in wetlands where significant areas of wide, un-channelled wetland habitat (especially those areas containing moribund vegetation), and in those wetlands which have significant depressions would this flow be attenuated for longer periods.

Erosion has been observed in one form or another in most of the wetlands in the study area. The most commonly encountered form of erosion is the headcut, with an associated gulley (donga) downstream of it. Headcuts were observed in many wetlands, in particular valleyhead seeps where a soil profile exists, where the presence of bedrock outcropping tends to preclude erosion.



Photograph 5: Example of a headcut eating up into an area of diffuse flow

There is also evidence that cattle are contributing to the retreat back of channel banks. In many areas cattle trampling was evident on banks down which they move to cross or access channels. This leaves the channels exposed and mobilises the sediment, allowing it to be washed down the channel as silt. There is thus much evidence to suggest that cattle are contributing to the channelization of wetlands.

- ***Wetland Hydrological Zonation***

The nature of the soils and the hydrology of wetlands affects the hydro-period (period of saturation of soils) of wetlands in the study area. The soil characteristics make it difficult for this classical zonation to be applied to wetlands in the study area. As discussed above, many wetlands are characterised by vertic soils across their width (and into the wetland catchment). The nature of vertic soils entails that these soils typically experience distinct seasonal periods of saturation and drying out. Under these conditions, very few of the wetlands could thus be considered to have permanently inundated / saturated zones.

The occurrence of typical obligate hydrophytes such as *Phragmites australis* and *Typha capensis* (which are typically found in the permanent wetland zone) in the study area appears to be limited to areas characterised by sedimentary geology which are typically devoid of vertic soils.

The hydro-period in wetlands in which vertic soils predominate could be described more accurately as predominantly seasonal, with the vast majority of the width of the wetland being seasonally inundated, with a very narrow temporary zone. In some wetlands the temporary zone may be absent as there is an abrupt transformation between the (seasonal) wetland zone and the surrounding grassland. This is especially true where there wetland habitat is confined to the bottom of a macro-channel.

- ***Wetland Vegetative Characteristics***

The study area lies in the south-eastern part of the Mpumalanga Highveld where the grassland biome is predominant. Grassveld vegetation thus characterises the entire study area. Wetlands in the study area are largely grass and forb-dominated.

Commonly occurring wetland grass species in the study area is presented in **Table 22**.

Table 22: Commonly occurring wetland grass species in the study area

Species	Hydrological zone / part of wetland
Agrostis lachnantha	Wetter areas (close to channels and in seepage zones)
Andropogon appendiculatus	
Andropogon eucomus	In seepage areas, especially sloping banks
Eragrostis plana	Across wetlands, especially in the drier parts of wetlands dominated by vertic clay soils
Helictotrichon turgidulum	Wetter areas (close to channels and in seepage zones)
Hemarthria altissima	Commonly inundated parts of valley bottoms, especially un-channelled valley bottoms
Imperata cylindrical	Seepage areas and river banks
Leersia hexandra	In seepage areas and in channel bottoms, especially in areas of standing water
Paspalum dilatatum	All parts of wetlands
Setaria sphacelata* var. *torta	Margins / drier peripheries of wetlands, or wetlands which are not regularly inundated
Themeda triandra	Margins / drier peripheries of wetlands, or wetlands which are not regularly inundated

In most wetlands where shallow water occurs, the grass *Leersia hexandra* was noted to be common, often forming large stands. This grass is important in a number of contexts as it forms the habitat for the Marsh Sylph butterfly (*Metisella meninx*) which is threatened in many parts of its range by habitat destruction.

The reed *Phragmites australis*, which is commonly encountered in many floodplain wetlands on the Highveld is not commonly encountered in many wetlands in the study area, in spite of the presence of suitable wetland habitat, especially within a number of valley bottom and floodplain wetlands. Where it is encountered, it typically occurs along the banks of rivers and streams, and in some cases in seepage areas.

The Vaal River Lily, *Crinum bulbispermum* occurs prominently in wetter inundated parts of wetlands and along stream banks. *Kniphofia fluviatilis* (River Poker) was found in a few wetlands in the study area.

Photograph 6: *Leersia hexandra* and a few *Crinum bulbispermum* specimens in a depression in the Witbankspruit floodplain wetland

4.1.10 Soils and Agricultural Potential

4.1.10.1 Land Type

The study area falls into the Ca2 land type (refer to the land type map of the study area – **Appendix J**).

A brief description of the land type is provided in **Table 23**.

Table 23: Characteristics of the Land Type Ca2

Soils	Land capability and capability and land use	Agricultural Potential
Landscape dominated by shallow yellow-brown apedal, distrophic soils in higher lying areas, variable depth bleached apedal soils in mid-slope positions and poorly drained structured soils of variable depth in low lying areas	Mainly dryland agriculture and extensive grazing	Medium to low except for lower lying areas that constitute wetlands

4.1.10.2 Soil Types

The topography of the broader site is undulating hilly and as such there are numerous low ridges and hills interspersed with drainage depressions and stream / drainage channels. The geology is dominated by dolerite (with inclusions of sandstone, grit and shale) leading to the dominance of shallow to moderately deep structured soils, often with vertic properties in lower lying areas and drainage depressions. These properties have far reaching implications for different land uses and aspects such as wetland delineation exercise as described in the sections that follow below.

The soils on the site can be grouped into three main categories or groups namely:

a) shallow and rocky soils on convex topography;
b) variable depth structured soils in flat terrain outside drainage depressions, and,
c) structured and swelling soils in drainage depressions (concave topography).

- ***Shallow and Rocky Soils on Convex Topography***

The area dominated by shallow and rocky soils is situated mainly on convex topography – that is rock outcrops, hills and ridges as well as vast areas making up the higher lying parts of the landscape.

The soils are predominantly of the Mispah (Orthic A-horizon / Hard Rock), Glenrosa (Orthic A-horizon / Lithocutanic B-horizon), shallow Arcadia (Vertic A-horizon / Unspecified – usually hard or weathering rock), Mayo (Melanic A-horizon / Lithocutanic B-horizon) and occasionally Milkwood (Melanic A-horizon / Hard Rock) forms. The texture of the A-horizons varies widely in that some are sandy (and sometimes bleached), some are clayey and some have very distinct structure.

During the survey it was found that there is very little predictability in the distribution of the different properties. This is a result of the varying geology as well as topography on the site.

Photograph 7: Shallow and rocky soils (rock outcrop)

- ***Variable Depth Structured Soils in Flat Terrain (Outside Drainage Depressions)***

The areas of flat terrain consist of a range of soils that vary from structured with swelling properties, to structured without swelling properties to sandy soil material overlying structured subsoils. The soils found in these areas do not occur in clear patterns and only a small degree of predictability is evident (as opposed to areas dominated by Plinthic Catena).

Soil forms include Arcadia (Vertic A-horizon / Unspecified – usually hard or weathering rock), Sepane (Orthic A-horizon / Pedocutanic B-horizon / Unconsolidated material with signs of wetness) and Tukulu (Orthic A-horizon / Neocutanic B-horizon / Unspecified material with signs of wetness) soil forms with occasional occurrences of Glenrosa (Orthic A-horizon / Lithocutanic B-horizon), Klapmuts (Orthic A-horizon / E-horizon / Pedocutanic B-horizon), Hutton (Orthic A-horizon / Red Apedal B-horizon), Clovelly (Orthic A-horizon / Yellow-brown Apedal B-horizon), Westleigh (Orthic A-horizon / Soft Plinthic B-horizon), Avalon (Orthic A-horizon / Yellow-brown Apedal B-horizon / Soft Plinthic B-horizon) as well as the shallow soils listed earlier.

Photograph 8: Organic rich Orthic A-horizon of a Tukulu soil form on site

- ***Structured and Swelling Soils in Drainage Depressions (Concave Topography)***

The drainage depressions also exhibited certain degree of soil form variability but one of the constant characteristics is the presence of swelling properties in the soils. The swelling properties imply that most of the soils in lower lying areas are dominated by smectite clay minerals. These clay minerals impart characteristics to the soils that manifest in the form of cracks and slickensides (**Photograph 9**).

Photograph 9: Distinct slickenslides in the G-horizon of a Rensburg soil form

These soils are often associated with lime rich subsoil horizons that, when exposed, are characterised by copious amounts of lime nodules (concretions) (**Photograph 10**).

Photograph 10: Lime nodules associated with eroded and exposed G-horizons in under Vertic (and sometimes Melanic) A-horizons

Some of the soils had high clay contents without swelling properties indicating the presence of non-swelling 2:1 clay minerals. Even though the soils are dominated by similar clay minerals they vary in terms of soil form due to the variability in depth, rockiness and recently transported or eroded soil horizons / material.

The soil forms are, amongst others: Rensburg (Vertic A-horizon / G-horizon), Arcadia (Vertic A-horizon / Unspecified – usually hard or weathering rock), Mayo (Melanic A-horizon / Lithocutanic B-horizon), Milkwood (Melanic A-horizon / Hard Rock), Willowbrook (Melanic A-horizon / G-horizon), Katspruit (Orthic A-horizon / G-horizon), Dundee (Orthic A-horizon / Stratified Alluvium) and Mispah (Orthic A-horizon / Hard Rock).

4.1.11 Vegetation

The study site corresponds to the Grassland Biome, more specifically the Mesic Highveld Grassland as defined by Mucina and Rutherford (2006)[8]. This unit is found in the eastern, precipitation-rich regions of the Highveld. Grasslands of these parts are regarded 'sour grasslands'. The study area comprehends an ecological type known as the Amersfoort Highveld Clay Grassland. This grassland comprises undulating plains, with small scattered patches of dolerite outcrops.

The vegetation comprises of short, closed grassland, largely dominated by a dense *Themeda triandra* sward, often severely grazed. Overgrazing leads to invasion of *Seriphium plumosum*.

[8] ***Mucina, L. & Rutherford, M.C. (eds.). 2006****. The vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South African National Biodiversity Institute, Pretoria.*

Parts of this unit were once cultivated and these transformed areas are not picked up by satellite for transformation coverage; the percentage of grasslands still in a natural state may therefore be underestimated. The conservation status is regarded as 'Vulnerable'; none is formally protected.

The study area is situated within a part of the African Grasslands / Ekengela Initiative Transition Zone, rendering all areas of natural grassland sensitive (ENPAT, National Database, Biosphere). Some 25% of this vegetation type is transformed, predominantly by cultivation (22%).

The area is not suited to forestation. Silver and black wattle and *Salix babylonica* invade drainage areas.

4.1.12 Terrestrial Biodiversity Categories on a Local Scale

The mandate for conserving biodiversity lies with state agencies at national, provincial and local levels of government, forming part of a wider responsibility for the environment and the sustainable use of natural resources. Constitutional and national laws require these environmental issues to be dealt with in cooperative, participatory, transparent and integrated ways.

The MBCP[9] is the first spatial biodiversity plan for Mpumalanga that is based on scientifically determined and quantified biodiversity objectives. The purpose of the MBCP is to contribute to sustainable development in Mpumalanga.

The MBCP, maps the distribution of the Mpumalanga Province's known biodiversity into six (6) categories. These are ranked according to: i) ecological and biodiversity importance, and, ii) their contribution to meeting the quantitative targets set for each biodiversity feature.

The categories are:

a) Protected areas – already protected and managed for conservation;

b) Irreplaceable areas – no other options available to meet targets—protection crucial;

c) Highly Significant areas – protection needed, very limited choice for meeting targets;

d) Important and Necessary areas – protection needed, greater choice in meeting targets;

e) Ecological Corridors – mixed natural and transformed areas, identified for long term connectivity and biological movement;

f) Areas of Least Concern – natural areas with most choices, including for development; and

g) Areas with No Natural Habitat Remaining – transformed areas that do not contribute to meeting conservation targets.

The study area comprises three (3) of these categories (**Appendix K**), namely:

a) Important and Necessary;

b) Least Concern; and

c) No Natural Habitat Remaining.

Areas included in the '*Important and Necessary*' category represent significantly important areas of natural vegetation that play an important role in meeting biodiversity targets. This category comprises approximately 9.5% of the Mpumalanga Province.

[9] ***Lötter, M.C. & Ferrar, A.A. 2006****. Mpumalanga Biodiversity Conservation Plan.*

Biodiversity assets in landscapes categorized as '*Least Concern*' contributes to natural ecosystem functioning, ensuring the maintenance of viable species populations and providing essential ecological and environmental goods and services across the landscape. This category comprises approximately 25.5% of the Mpumalanga Province. Although these areas contribute the least to the achievement of biodiversity targets, they have significant environmental, aesthetic and social values and should not be viewed as wastelands or carte blanche development zones.

Areas of '*No Natural Habitat Remaining*' comprise approximately 35.8% of the Province. This category has already lost most of its biodiversity and ecological functioning.

4.1.12.1 Development Restrictions in Terms of the MBCP

The proposed development relates to 'Urban and Industrial Land Uses' (Land Use Types 14 – Underground Mining[10]) and is included in the category with other development types, such as Surface Mining, Urban & Business Development, Major Development Projects, Linear Engineering Structures and Water Projects & Transfers.

These six (6) land uses cause the greatest environmental impact and are almost completely destructive of natural vegetation and natural biodiversity. Where biodiversity persists, it is artificially maintained, generally supporting only opportunistic assemblages of plants and animals. Ecosystem processes are completely disrupted, heavily impacted or artificially maintained at high cost. These land uses not only produce the highest local impacts but also dominate the dispersed and cumulative impacts. They are the most destructive and wide-ranging, often spreading hundreds of kilometres from their source, especially along river systems. These land-use types also require special provision in land-use planning, impact assessment and mitigation.

Classification in terms of Underground Mining Restrictions place most of the study area within the '*Permitted*' category, with selected portions within the '*Restricted*' category. Specialist studies are therefore required to show that the proposed development will not add to existing cumulative impacts, regional degradation and habitat transformation and the loss of biodiversity on a local or regional scale.

4.2 Social Environment

4.2.1 Social

As mentioned in **Section 4.1.1**, the study area falls within the Pixley ka Seme Local Municipality (PKSLM). According to the Spatial Development Framework (SDF)[11] of the PKSLM, the current spatial pattern within the municipal area can be divided into seven (7) broad categories of land use, namely, urban land use, rural land use, mines and quarries, conservation areas, agriculture, tourism areas, and the transport network.

- **Urban land use**: The towns of Volksrust and Vukuzakhe are classified as major urban areas whereas Wakkerstroom, Daggakraal and Amersfoort are regarded as minor urban areas. An area such as Perdekop is regarded as a declining urban area.
- **Rural land use**: Agricultural activities seem to be dominating rural land use in the area, but most of these activities are regarded as subsistence farming.
- **Mines and quarries**: Operational mines are scattered throughout the PKSLM and include sand, dolerite and coal mining. Areas of coal mining are often also associated with energy generation activities.

[10] *Includes all underground mineral extraction and the surrounding 'footprint' of related development, which may include small areas for residential and industrial uses. It includes all waste dumps, settlement ponds and disposal sites both above and below ground.*

[11] ***Pixley ka Seme Local Municipality, 2010.*** *Pixley ka Seme Local Municipality SDF. Available at URL http://pixleykaseme.local.gov.za.*

- **Conservation areas**: The PKSLM is home to a number of important conservation and biodiversity areas, but it would appear if these areas are mostly confined to the southern parts of the municipal area, notably around Wakkerstroom. In addition to the conservation areas, the SDF also states that there are a number of natural heritage sites located around Wakkerstroom and Warburton.
- **Agriculture**: The SDF describes the majority of land within the PKSLM as "unimproved grassland" that is mostly used for stock grazing. Other land within the PKSLM is described as cultivated dry land used for crop cultivation (mostly maize).
- **Tourism**: The PKSLM falls within the Grass and Wetlands Tourism Region, which forms, what is called, a "birding paradise".
- **Transportation network**: The national road N11 traverses the municipal area and serves as an important north-south transportation link. In addition, several provincial roads also traverse the local area, including the R23, and portions of the R543. Apart from the road network, two railway lines pass through the PSLM, one being the main Johannesburg-Durban rail connection, the other a north-south rail passing through the towns of Amersfoort, Wakkerstroom and Volksrust.

Amersfoort is classified as a small urban centre. The town was initially established as a result of the coal mining in the area and has since, to a large extent, become dependent on the Majuba Power Station.

Approximately 12.8 km to the south-east of Amersfoort lies the town of Daggakraal, which is considered a very large urban settlement. It is believed that up to a third of the total population of the PKSLM resides in Daggakraal. Furthermore, Daggakraal (and most probably neighbouring Vlakplaats) is expanding at a rapid rate which is evident in the fact that the population increased from approximately 6,500 in 2001 to an estimated 38,000 people in 2009.

Even though the town has a range of social services, there is still a dire need for a range of diversified services to address the needs of Daggakraal's residents, including physical upgrades such as sanitation services, water reticulation and waste removal. The town is economically unsustainable as it has a very limited economic base which shows little to no growth during the past years – probably owing to the fact that the area is very inaccessible.

4.2.2 Air Quality

4.2.2.1 Identified Sensitive Receptors

A sensitive receptor for the purposes of the current investigation can be defined as a person or place where involuntary exposure to pollutants released by the proposed plant, can be expected to take place. For the purposes of this study, areas of development are identified as sensitive receptors.

Those receptors identified during the current study are listed as follows:

- Approximately 8 km north-east is the Amersfoort town;
- Approximately 6 km west are the Vlakplaats and Daggakraal communities; and
- Adjacent to surrounding livestock farms and associated farm houses.

4.2.2.2 Sources of Air Pollution

The following sources of air pollution have been identified in the study area:

- Stack, vent and fugitive emissions from the existing Majuba Power Station operations;
- Flaring and fugitive emissions at the UCG pilot plant operations;
- Agricultural activities on the surrounding farms;
- Vehicle entrained dust and exhaust emissions;
- Domestic fuel burning; and
- Veld fires.

4.2.2.3 Standards and Guidelines

Air quality Guidelines and Standards are generally only given for criteria pollutants. No such thresholds exist for the less common, toxic pollutants. In the absence of such guidance reference needs to be made to other health impact criteria such as effect screening levels (ESLs), reference exposure levels (RELs), inhalation reference concentrations (RfC) and unit cancer risk factors. The following information summarises the ambient air quality Standards available locally for various criteria pollutants under investigation during the current study.

Table 24: Air quality standards

Substance	10-minute maximum	1-hour maximum	8-hour maximum	24-hour maximum	Annual average
Inhalable Particulate Matter (PM10)				120 µg/m³ 75 µg/m³ (3)	50 µg/m³ 40 µg/m³ **(3)**
Sulphur Dioxide (SO_2) (1)	500 µg/m³	350 µg/m³		125 µg/m³	50 µg/m³
Nitrogen Dioxide (NO_2) (1)		200 µg/m³			40 µg/m³
Carbon Monoxide (CO) (1)		30 mg/m³	10 mg/m³		
Benzene (C_6H_6)					10 µg/m³ 5 µg/m³ (3)
Hydrogen Sulphide (H_2S) (2)		7 µg/m³ (30 mins)			
Ammonia (NH_3) (4)					100 µg/m³

Note:
(1) South African Standard
(2) WHO Guideline
(3) To come into effect 2015
(4) US EPA Guideline

- ***Particulate Matter***

Particulate matter (PM) is the collective name for the fine solid or liquid particles added to the atmosphere by processes at the earth's surfaces. PM includes dust, smoke, soot, pollen and soil particles. PM has been linked to a range of serious respiratory and cardiovascular health problems. The key effects associated with exposure to ambient particulate matter include: premature mortality, aggravation of respiratory symptoms, chronic bronchitis, decrease lung infection, and increased risk of myocardial infarction[12].

[12] ***USEPA, 1996.*** *Air Quality Criteria for Particulate Matter.*

- ***Sulphur dioxide***

Sulphur dioxide (SO_2) is the colourless gas which smells like burnt matches. It can also be oxidized to sulphur trioxide, which in the presence of water vapour is readily transformed to sulphuric acid mist. Sulphur dioxide can be oxidized to form acid aerosols and is also a precursor to sulphates which are one of the main components of respirable particles in the atmosphere. Health effects caused by exposure to high levels of sulphur dioxide include breathing problems, respiratory illness, changes in the lung's defences, and worsening respiratory and cardiovascular disease. People with asthma or chronic lung or heart disease are most sensitive to sulphur dioxide. Sulphur dioxide and nitrogen oxides are the main precursors of acid rains.

- ***Nitrogen dioxide***

Nitrogen dioxide (NO_2) has an irritating odour which transforms in the air to form gaseous nitric acid and toxic organic nitrates. Nitrogen dioxide plays a major role in atmospheric reactions that produces smog. Nitrogen dioxides can be a significant emission released from motor vehicles especially from poorly maintained vehicles and from diesel vehicles. Nitrogen dioxides can irritate lungs and lower resistance to respiratory infection and increases sensitivity to people with asthma and bronchitis. It can also damage trees and crops if it is transformed into nitric acid.

- ***Carbon monoxide***

Carbon monoxide (CO) is an odourless, colourless and toxic gas. At lower levels of exposure, CO causes mild effects that are often mistaken for the flu. These symptoms include headaches, dizziness, disorientation, nausea and fatigue. The effects of CO exposure can vary greatly from person to person depending on age, overall health and the concentration and length of exposure.

- ***Benzene***

Benzene is an aromatic hydrocarbon that is produced by the burning of natural products. It is a component of products derived from coal and petroleum and is found in gasoline and other fuels. Research has shown benzene to be a carcinogen (cancer-causing). With exposures from less than five years to more than 30 years, individuals have developed, and died from, leukaemia. Long-term exposure may affect bone marrow and blood production. Short-term exposure to high levels of benzene can cause drowsiness, dizziness, unconsciousness, and death.

- ***Hydrogen sulphide***

Hydrogen sulphide (H_2S) is a colourless gas, soluble in various liquids including water and alcohol. It can be formed under conditions of deficient oxygen, in the presence of organic material and sulphate. In industry, hydrogen sulphide can be formed whenever elemental sulphur or sulphur-containing compounds come into contact with organic materials at high temperatures. Hydrogen sulphide is formed, for instance, during coke production, in viscose rayon production, in waste water treatment plants, in wood pulp production using the sulphate method, in sulphur extraction processes, in oil refining and in the tanning industry. The lowest-adverse-effect level of hydrogen sulphide is 15 mg/m^3, when eye irritation is caused. In view of the steep rise in the dose-effect curve implied by reports of serious eye damage at 70 mg/m^3, a relatively high protection (safety) factor of 100 is recommended, leading to a guideline value of 0.15 mg/m^3 with an averaging time of 24 hours. A single report of changes in haem synthesis at a hydrogen sulphide concentration of 1.5 mg/m^3 should be borne in mind. In order to avoid substantial complaints about odour annoyance among the exposed population, hydrogen sulphide concentrations should not be allowed to exceed 7 µg/m^3, with a 30-minute averaging period. When setting concentration limits in ambient air, it should be remembered that hydrogen sulphide is emitted from natural sources in many places.

- ***Ammonia***

Ammonia (NH_3) is released to the atmosphere by natural processes such as the decay of organic matter and animal excreta, or by volcanic eruptions. It can also be released to the atmosphere by anthropogenic activities such as fertilizer use; spillage or leakage from storage or production facilities; or by loss from waste water effluents. Releases to water are usually due to effluent from sewage treatment plants or industrial processes, or run-off from fertilized fields or livestock areas. Soils usually obtain ammonia from natural or synthetic fertilizer application, animal excreta, decaying organic matter, or natural fixation from the atmosphere. In the atmosphere, ammonia can react with acidic substances in the air to produce ammonium aerosols, which can undergo dry or wet deposition.

The most important injurious effects of ammonia on humans are due to its irritative and corrosive properties. Exposures to ammonia as a gas cause chemical burns of the respiratory tract, skin, and eyes. Airway blockage and respiratory insufficiency may be lethal outcomes of exposure to anhydrous ammonia vapours or concentrated aerosols. Survival of the initial insult may be compromised by infections, scarring, and other complications that may develop days or weeks following inhalation or ingestion. Effects that have been observed in humans exposed to ammonia as a gas and ammonium salt aerosols have also been observed in animals. Hepatic and renal effects have also been reported in animals and humans; however, ammonia does not appear to be a primary liver or kidney toxicant[13].

Ammonia is an upper respiratory irritant in humans. Exposures to levels exceeding 50 ppm result in immediate irritation to the nose and throat; however, tolerance appears to develop with repeated exposure. Exposure to an air concentration of 250 ppm is bearable for most persons for 30 – 60 minutes. Acute exposure to higher levels (500 ppm) have been shown to increase respiratory minute volume. Accidental exposures to concentrated aerosols of ammonium salts or high concentrations of ammonia gas have resulted in nasopharyngeal and tracheal burns, airway obstruction and respiratory distress, and bronchiolar and alveolar oedema.

Chronic occupational exposure to low levels of airborne ammonia (<25 ppm) had little effect on pulmonary function or odour sensitivity in workers at some factories, but studies of farmers exposed to ammonia and other pollutants in livestock buildings indicated an association between exposure to pollutants, including ammonia, and an increase in respiratory symptoms (such as bronchial reactivity/hyper responsiveness, inflammation, cough, wheezing, or shortness of breath) and/or a decrease in lung function parameters.

The contribution of ammonia to these respiratory symptoms is unclear[14].

4.2.3 Micro-economic Status Quo

The current regional economic environment seems to be dominated by agriculture, and power generation, with towns in the area providing services and products to these industries and local residents providing labour to the industries or running related businesses. This is supported by information contained in the Pixley ka Seme Local

[13] ***USEPA, 2002.*** *Review of emission factors and methodologies to estimate ammonia emissions from animal waste handling.*
[14] Ibid. *Footnote 13.*

Municipality IDP[15] which indicated that agriculture and electricity provision both represented significant sectors in the local economy together with trade and manufacturing.

4.2.4 Regional Economic Indicators and Trends

4.2.4.1 Industry Profile

At a district level the economy is dominated by manufacturing and mining, indicating a strong focus on industrial activity in general. It is likely that other industries in the Gert Sibande District Municipality (GSDM) area are likely focused on delivering supporting services to these sectors. Details can be found in **Figure 20** below.

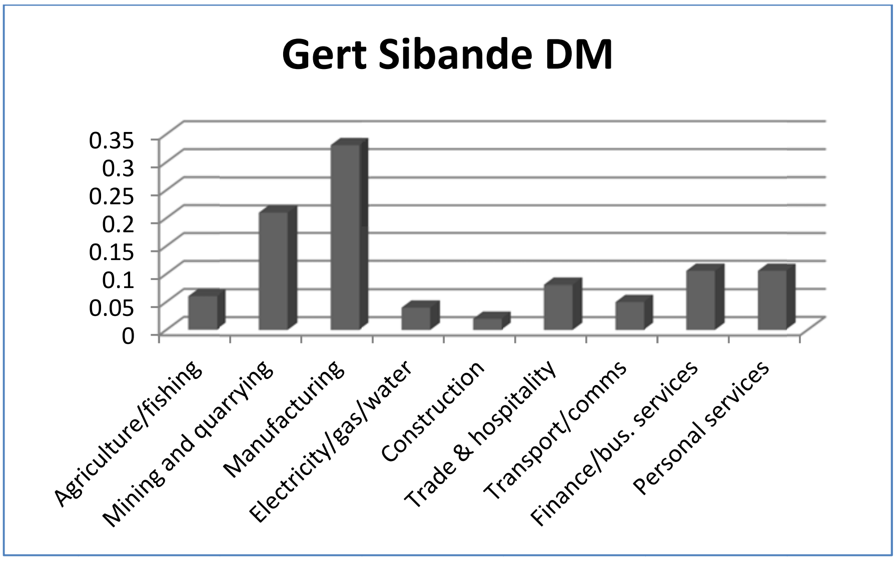


Figure 20: Industry sector contribution Regional GDP for the GSDM[16]

The information provided in the Gert Sibande Spatial Development Framework (SDF) indicates that majority of economic activity is located within the central and western areas of the District, towards Gauteng and the southern economic activity areas of the Nkangala District. Significantly, the town of Secunda dominates Gross Value Added (GVA) in Mpumalanga at 21.3%. All of the remaining areas making the largest contributions to the District GVA, except Piet Retief, are found within the central and western extents of the District.

The PKSLM area (comprising the Amersfoort and Volksrust centres) is an important agricultural hub, and activities in other industries probably support and serve the agricultural industry and those working in them.

Although tourism is seen as an important growth industry in the province and in the GSDM area, the PKSLM area does not seem to be particularly rich in features or infrastructure that could be utilised for tourism potential and tourism is unlikely to be seen as a viable alternative to agriculture.

4.2.4.2 Education Profile

The education profile in rural areas such as PKSLM remained similar from 2001 to 2007 with a minority of residents having matric and post-matric qualifications.

The summary of the education profile is given in **Table 25**. The data includes the total population in the PKSLM.

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[15] ***Pixley ka Seme Local Municipality, 2009 – 2012.*** *Pixley ka Seme Local Municipality IDP. Available at URL http://pixleykaseme.local.gov.za.*

[16] *Gert Sibande District Municipality (2010).*

Table 25: Education profile of the PKSLM

Education	2007	2001
No schooling	24.0%	35.3%
Some Primary	30.1%	19.4%
Complete Primary	5.2%	5.6%
Some secondary	25.2%	22.4%
Grade 12	9.3%	12.5%
Higher	6.2%	4.8%

As can be seen from the above, there has been a slight increase (1.4%) in the number of persons with a higher education and a 3.2% decrease in matriculants.

A significantly larger portion now has some primary schooling compared to the 2001 census, however, this may not result in a significant increase in the ability to fill jobs and derive income from skilled employment sectors. As a result employment will often require training and skills development in order to exploit the full potential of workers.

4.2.4.3 Local Employment

The number of employed and unemployed persons have increased from 2001 to 2007 indicating that a larger number of individuals are now economically active and are seeking employment. However, the employment situation remains largely unchanged with employment in the PKSLM being relatively low when compared to district, regional and national employment.

As recent economic growth has resulted in limited job creation, unemployment remains high especially in rural areas such as the project location. This increases the importance and potential positive local impact of large-scale infrastructure projects.

Table 26 below summarises the current employment statistics:

Table 26: Overview of employment

Labour Status	South Africa*	Mpumalanga Province	GSDM	PKSLM	
	2001	2007		2001	2007
Employed**	33.7%	40.1%	43.4%	25.1%	28.5%
Unemployed	24.0%	20.0%	21.6%	26.2%	31.9%
Not economically active	42.3%	39.9%	35.1%	48.0%	40.0%
Employment rate***	58.4%	66.7%	66.8%	49.3%	47.1%

Source: Community Survey 2007 and Census 2001
** Census 2001 data*
*** This is the percentage employed/unemployed of the entire working age population and should not be read as the unemployment rate, i.e. the not economically active population is included in this segment.*
**** In order to reflect a more accurate employment rate, the not economically active population has been excluded from this segment*

Table 27: Industry employment in PKSLM

Industry	PKSLM (2001)
Agriculture	20.5%
Mining	0.4%
Manufacturing	8.6%
Electricity	5.1%
Construction	4.5%
Trade	13.8%
Transport	2.6%
Financial	4.1%
Services	17.6%
Private households	0.5%
Other	17.9%
Undetermined	4.4%

Currently agriculture, services and trade are the biggest employers in the area, with some manufacturing employment taking place. The percentages given in **Table 27** provide further supporting evidence of the continued local dominance of the agricultural industry from 2001 to the present day. However, in the future the possibility of further industrial development may contribute to declining local employment in the agricultural industry if land-use patterns change.

4.2.4.4 Local Household and Personal Income

A regional and provincial income analysis is indicated in **Table 28** below:

Table 28: Monthly personal income in PKSLM[17]

Income	GSDM (2007)	PKSLM (2007)
No Income	51.0%	51.1%
R1 – R1,600	27.9%	39.0%
R1,601 – R25,600	20.2%	9.4%
R25,601+	0.9%	0.2%

At a municipal level more than half (51.1%) of the total population between 15 and 65 registered no income in 2007 followed by just over a third (39.0%) of those who earn an income of R1,600 or less per month. Figures for persons with no income are relatively consistent with district level results, however, income earners in PKSLM are likely to be poorer if the figures for those earning an income (i.e. earning above R1 a month) are considered.

The category percentages thus indicate low local income access, and local residents will benefit substantially from any development that is able to create income for more individuals. As income is related to skills and employment any recommendation applicable to education and employment will influence income.

4.2.4.5 Local Economic Feature of Importance

Interviews conducted with selected landowners indicate that it is likely that portions of the surrounding farms are being used for agriculture as the main activity.

[17] *Source: Community Survey 2007 and Census 2001. Note: Data is for persons from 15 to 65 years of age.*

Table 29: Examples of current land use activities in the surrounding farms

Farming Operation	Size	Activities
Koppieskraal Portion 9	327 ha	Agricultural, with 70% used for cattle and 30% cultivated agriculture. Carrying capacity of grassland is 3 ha per head of cattle. Maize is main crop but soya and cattle fodder also cultivated.
Palmietspruit Portion 3, Strydkraal Portion 8	1,230 ha	Land currently being rented to a tenant who is using it for cultivation agriculture. Regular crops are maize, soya and sunflower.
Strydkraal Portions 1, 3 and 6	1,185 ha	Agricultural, with 50% used for cattle and 50% cultivated agriculture. Carrying capacity of grassland is 3 ha per head of cattle. Currently farming 140 cattle and 1000 sheep. Maize and soya are both cultivated.
Tweedepoort Portions 2 and 4	684 ha	Agricultural, with 70% used for cattle and 30% cultivated agriculture. Carrying capacity of grassland is 2.5 ha per head of cattle. Maize is main crop but cattle fodder also cultivated.
Weiland Portion 8	400 ha	Agricultural, with 55% used for cattle and 45% for cultivated agriculture. Carrying capacity of grassland is 3 ha per head of cattle and 6 ha per sheep. Soya is main crop but cattle fodder also cultivated on 12 ha.
Bergvliet Portions 3,4,7,16-18	1,146 ha	Agricultural, with 100% used for cattle. Carrying capacity of grassland is between 2.5 ha and 3.5 ha per head of cattle depending on location. During social studies conducted in 2008 the owner indicated that the farming operation is not profitable, situation has improved by 2010.

4.2.5 Heritage – Larger Region

4.2.5.1 Rural Landscape

The rural landscape has always been sparsely populated and it was only during the last couple of hundred years that people, through the application of specific economic strategies, succeeded to occupy a section of the region for any length of time.

Archaeological sites in this area predominantly date to the Late Iron Age, although some sites dating to the Stone Age are also found in the larger region. Human occupation of the larger geographical region took place since Early Stone Age (ESA) times. This is evidenced by the scattered stone tools found in a secondary context (open surface material), where they have been exposed in gravel terraces by rivers and streams. Normally this material is viewed to have a low significance and the localities where they are found are referred to as “find spots” rather than sites. As this region was probably too cold and it does not have many rock shelters, occupation during Stone Age times remained low, resulting in very few sites dating to this period occurring in the region.

Iron Age people started to settle in southern Africa c. AD 300, with one of the oldest known sites at Silver Leaves, south east of Tzaneen dating to AD 270. However, Iron Age occupation of the eastern Highveld area (including the study area) did not start much before the 1500s. Some sites dating to the Late Iron Age is known to exist to the north west of the study area. As this was a period signified by high stress levels, people tended to settle in towns, usually located on hill tops for protection. The villages were laid out in a complex manner and different areas were demarcated by stone walled enclosures.

4.2.5.2 Farmsteads

Farmsteads are complex features in the landscape, being made up of different yet interconnected elements. Typically these consist of a main house, gardens, outbuildings, sheds and barns, with some distance from that labourer housing and various cemeteries. In addition, roads and tracks, stock pens and windmills complete the setup.

By the early 19th century white settlers took up farms. An investigation of the Title Deeds of most of the farms under consideration indicated that they were surveyed as early as the 1860s, implying that they would have been occupied by colonists since then.

Many farmsteads and even houses in Amersfoort were destroyed during the Anglo Boer War. As a result most structures date to the period after that. The architecture of these farmsteads can be described as eclectic as they were built and added to as required over a period of time. In some cases outbuildings would be in the same style as the main house, if they date to the same period. However, they tend to vary considerably in style and materials used.

4.2.5.3 Cemeteries

Apart from the formal cemeteries that occur in municipal areas (towns or villages), a number of these, some quite informal, i.e. without fencing, occur sporadically all over. Many also seem to have been forgotten, making it very difficult to trace the descendants in a case where the graves are to be relocated. Most of these cemeteries, irrespective of the fact that they are for landowner or farm labourers (with a few exceptions where they were integrated), are family orientated. They therefore serve as important 'documents' linking people directly by name to the land.

4.2.5.4 Infrastructure and Industrial Heritage

In many cases, this aspect of heritage is left out of surveys, largely due to the fact that it is taken for granted. However, the land and its resources could not be accessed and exploited without the development of features such as roads, bridges, railway lines, electricity lines and telephone lines.

4.2.5.5 Urban landscape

The urban landscape in the region includes a number of small towns, of which Amersfoort is the closest to the study area. The study area *per sé* does not contain any section that can be classified as an urban environment.

4.2.5.6 Palaeontology

By their nature coals are plant-rich. Good quality coals do not preserve the anatomy of the original plant matter, but the shales between the sequences do. Here it is possible to find well preserved *Glossopteris* leaves, roots and inflorescences, lycopod and sphenophyte stems, ferns, cordaitaleans and early gymnosperms. A Phase 1 assessment has shown that no vertebrae fossils are likely to be found but fossil plants are likely to be encountered. This type of flora is common and of little scientific interest.

It is therefore recommended that a responsible person (geologist, environmental officer, or other) regularly monitors the excavations, removes and collects fossil material that is found. The fossils should then be given to an institute that is recognised by SAHRA as a repository for fossils.

4.2.5.7 Noise

The *noise climate* (ambient noise condition) in the Amersfoort area is quiet and is representative of a rural (farming) noise district (SANS 10103).

There are a number of major noise sources in the area namely the existing Majuba Power Station, the traffic on the main roads, coal trucks transporting coal to Majuba Power Station and the coal supply railway line to the power station.

The noise sensitive sites / areas are Amersfoort town (approximately 12 km from the Majuba Power Station) and various farmhouses and farm labourer residences in the surrounding area (on farms Palmietspruit, Strydkraal, Tweedepoort, Koppieskraal, Rietfontein, Weiland, and, Bergvliet).

4.2.5.8 Traffic

There are a number of major roads and secondary roads servicing the study area.

These include:

a) National Road N11, which links Amersfoort to Volksrust, is aligned in a north-south direction through the eastern sector of the study area.

b) Road P48/2 (Route R35), which links Amersfoort to Morgenzon, is aligned in an east-west direction through the north-eastern sector of the study area.

c) Road P97/1 which links Amersfoort to Perdekop, is aligned in a north-east to south-west direction through the western sector of the study area. It passes 4 kilometres to the north-west of the Majuba Power Station.

d) Road D2514, which links from Road P97/1 to National Road N11, is aligned in a north-west to south-east direction through the central portion of the study area. It is the main access road to Majuba Power Station.

e) Road D284, which links from Road D2514 to National Road N11, is aligned in a south-west to north-east direction through the central portion of the study area. It is the main access road to Majuba Colliery (no longer in public operation).

4.2.5.9 Visual

4.2.5.10 Landscape Structural Components

The study area is located in a rural part of south-eastern Mpumalanga, between the nearby town of Amersfoort to the north and the regional centre of Volksrust to the south. The study area's visual environment is based on a number of physical factors, including the topography, vegetation, land-use, and presence of the built environment.

In a wider context, the south-eastern Mpumalanga Highveld is largely flat to undulating, forming part of the high-lying interior plateau (Highveld) that occurs in the north-eastern interior of South Africa. The Great Escarpment that forms the edge of the interior plateau is located to the south of the study area in the vicinity of the town of Volksrust, with prominent hills such as the historical Amajuba Mountain forming part of the escarpment that separates the high-lying Highveld plateau from the lower-lying areas with KwaZulu-Natal around Newcastle.

The flat to undulating topography is largely due to the underlying geology – the south-eastern Highveld is largely underlain by the Karoo Supergroup, comprising largely of sedimentary rocks such as sandstone and shale. The presence of this geology and the way in which it weathers gives rise to largely flat to gently undulating topography. However another geological factor has played an important part in the geological evolution of the landscape in the study area, i.e. the large-scale intrusion of the sedimentary sequences by igneous (volcanic) rock in the form of dolerite. Large parts of the study area are comprised of this dolerite intrusion.

Dolerite is a harder rock less prone to weathering, and thus it forms the higher-lying prominent parts of the landscape such as ridges and interfluves, e.g. the Graskop koppie located to the south of the study area close to the N11 highway.

As it occurs within this interior plateau, the topography of the study area is gently undulating, with streams and wetlands draining shallow valley bottoms. The northern parts of the study area (closer to the town of Amersfoort) that are underlain by dolerite are generally a little more incised than the flatter areas underlain by sedimentary geology in the south (i.e. around the Majuba Power Station), although the revised development site is not as deeply incised as the valley of the Palmietspruit located just to the west.

Photograph 11: Very gently sloping terrain in an area of sedimentary geology on the Rietfontein site

The climate and underlying soils have determined the nature of the natural vegetation in the study area. The nature of the climate – i.e. summer rainfall with cold winters characterised by much frost occurrence, and the presence of fire as driving factor entail that the south-eastern Highveld is naturally characterised by grassland vegetation. Natural woody vegetation typically only occurs on ridges where the presence of outcropping rock provides the woody vegetation enough protection from fires to be able to survive.

The study area is thus characterised by short, open grassland which gives rise to wide vistas over the gently undulating terrain. Due to the nature of the land-use as described below, much of this natural grassland still exists over the wider study area. In small areas, particularly around farmsteads or in small woodlots, groves of exotic trees (in particular eucalyptus) have historically been established. The widespread presence of vertic clay soils as described below has precluded the wider establishment of trees in the study area.

The predominant land-use and economic activity in the wider area is livestock (cattle) farming. In much of the study area the nature of the soils (strongly vertic clay soils that are characterised by strong swelling and shrinking properties) precludes the growth of crops, but in small areas crops are grown. As such most of the area in which livestock rearing occurs is comprised of natural grassland.

There is a strong industrial component to the study area, with the Majuba Power Station located on the boundary of the revised development site. The power station is comprised of a number of massive structures including three cooling towers, the power station building itself and two (2) very tall stacks. In the power station complex there are other buildings / infrastructure such as raised conveyors belts and a large ash dump.

Due to its massive bulk, the Majuba Power Station (**Photograph 12**) is visually very prominent across the study area, with most localities within the study area and its immediate surrounds being able to see the power station. The power station thus dominates views within the study area, especially within a 5 km radius.

There is a significant amount of associated infrastructure present, in particular a number of high voltage power lines that link the power station with the wider electricity grid. A number of such power lines radiate out from the power station to the east and to the west.

Coal is supplied to the power station by truck traffic, and there is an almost constant supply of coal trucks travelling to and from the power station along the power station access road from the R35 (Morgenzon-Amersfoort Road), and (to a lesser degree) along the Perdekop Road to the west.

Photograph 12: Majuba Power Station

There are other aspects of the built environment within the study area, including the disused coal mine at Bergvliet west of the N11 (comprising of headgear and a number of buildings) as well as the concentration of structures within the small town of Amersfoort to the north-east, and within the settlement of Daggakraal to the east. Rural farmsteads are dotted across the study area, although many of these are disused / abandoned.

There is an existing gas field on the Roodekopjes property although this is not typically visible as it is located on Eskom-owned property (Roodekopjes) onto which access is largely limited to the general public.

A number of other aspects of typical rural infrastructure are located in the study area, such as smaller power lines and phone lines, windmills and communication towers on certain higher-lying areas.

5 PUBLIC PARTICIPATION

5.1 Aims of the Public Participation Process

The primary aims of the public participation process are:

- To inform interested and affected parties (I&APs) and key stakeholders of the proposed application and environmental studies;

- To initiate meaningful and timeous participation of I&APs;
- To identify issues and concerns of key stakeholders and I&APs with regards to the application for the development (i.e. focus on important issues);
- To promote transparency and an understanding of the project and its potential environmental (social and biophysical) impacts (both positive and negative);
- To provide information used for decision-making;
- To provide a structure for liaison and communication with I&APs and key stakeholders;
- To assist in identifying potential environmental (social and biophysical) impacts associated with the proposed development;
- To ensure inclusivity (the needs, interests and values of I&APs must be considered in the decision-making process);
- To focus on issues relevant to the project, and issues considered important by I&APs and key stakeholders; and
- To provide responses to I&AP queries.

5.1.1 Consultant with Competent Authorities

The competent authorities issuing decisions regarding the project as well as consultation to date are presented in below. Linked information is provided in **Appendix B**.

Table 30: Competent authorities and other relevant authorities associated with the project

Authority	Role	License / Approval	Consultation to date
Department of Environmental Affairs (DEA)	Competent Authority for integrated Environmental Authorisation process	Waste Management License and Environmental Authorisation	• Pre-application meeting • S24G application submission • Draft EIAR submitted on 21 October 2013
Department of Mineral Resources (DMR) – Mpumalanga Region	Competent Authority for mining right application process	Mining Right	• Prospecting licences • Draft EIAR submitted on 21 October 2013
Department of Water Affairs (DWA)	Competent Authority for Integrated Water Use License process	Integrated Water Use License	• Pre-directive issued on 22 November 2012 • IWULA submitted on 31 January 2013 • Follow-up meeting with DWA on 06 February 2013
Mpumalanga Department of Economic Development, Environment and Tourism (MDEDET)	Commenting Authority for integrated Environmental Authorisation process		• Notification of parallel S24G process • Draft EIAR submitted on 18 October 2013
SAHRA – Mpumalanga Region	Heritage Authority	Approval indicating that the application fulfils the requirements of the relevant heritage resources authority as described in Chapter II, Section 38(8) of the NHRA, Act 25 of 1999	• Notification of parallel S24G process • Final comment received on 15 November 2013

5.1.2 Consultation with other Relevant Authorities and Key Stakeholders

Consultation with other relevant authorities and key stakeholders was undertaken via telephone calls, written correspondence, and where appropriate, personal visits to specifically identified I&APs, in order to actively engage these stakeholders from the outset and to provide background information about the proposed project (refer to **Appendix E** for proof of notification).

The following authorities and key stakeholders have been consulted with to date as part of the parallel EIA process. As the same I&AP database is being used for the S24G process, by default the following stakeholders will be contacted in connection with the application process at hand. Note that consultation will in some cases take the form of focus group meetings with the relevant authority (e.g. Pixley ka Seme LM).

- National and Provincial Government:
  - Department of Agriculture, Forestry and Fisheries;
  - Department of Labour;
  - Department of Public Enterprises;
  - Department of Trade and Industry;
  - Mpumalanga Department of Agriculture, Rural Development and Land Administration;
  - Mpumalanga Department of Health;
  - Mpumalanga Public Works, Roads and Transport;
  - Mpumalanga Department of Human Settlements; and
  - Mpumalanga Department of Social Development;
- Pixley ka Seme Local Municipality and Gert Sibande District Municipality;
- Ward councillors;
- South African Heritage Resource Association (SAHRA) – Mpumalanga office;
- Mpumalanga Tourism and Parks Agency;
- Neighbouring property owners / landowners;
- Farmers Associations; and
- Environmental interest groups and NGOs.

5.1.3 Advertising

Advertisements on the availability of the EIAR for public comment and public meeting was placed in the Volksrust Recorder (25 October 2013) and the Star (23 October 2013) newspapers.

5.1.4 Identification of Interested and Affected Parties

I&APs and key stakeholders were identified during the parallel EIA process of the wider UCG project. The identification of I&APs and key stakeholders was revisited during this process and any I&APs that wish to now register will be given the right to register for both the S24G and ongoing EIA process. This is indicative of the fact that the public participation process is a continuous process that runs throughout the duration of any environmental investigation (or combination of such investigations).

5.1.5 I&AP Database

All I&AP information (including contact details), together with dates and details of consultations and a record of all issues raised is recorded within a comprehensive database of I&APs (refer to **Appendix E**). This database has been updated on an on-going basis throughout the project, and will act as a record of the communication / involvement process.

5.1.6 Issues Trail

All issues, comments and concerns raised during the public participation process to date will be compiled into an Issues Trail that is attached to the final EIAR.

5.1.7 Public Review of the Draft Environmental Impact Assessment Report

The draft EIAR, will be made available for public review for a 40 day review period. Hard copies of the report will also be made available for review at the following public places:

- Volksrust Public Library, Cnr Joubert & Laingsnek Street, Volksrust;
- Amersfoort Public Library, Cnr Plein & Bree Street, Amersfoort;
- UCG Mine Site Offices, Majuba Colliery, Bergvliet, Amersfoort;
- Office of Royal HaskoningDHV, 78 Kalkoen Street, Monument Park, Pretoria; and
- Royal HaskoningDHV website (http://www.rhdhv.co.za/pages/services/environmental/current-projects.php).

5.1.8 Public and Authority Review of the Draft Environmental Impact Assessment Report

The draft EIAR was also submitted to the DEA, DMR, DWA, and, MDEDET simultaneously. A 40 calendar day period was allowed for this review process.

I&APs registered on the project database will be notified of the availability of this report by correspondence (i.e. letters, emails, flyers, radio announcement). All I&AP notifications are attached in **Appendix E**.

The draft document was available for review from 18 October to 30 November 2013.

During the review period, meetings with I&APs and stakeholders were held in the greater Amersfoort area.

- 19 November 2013 – Public meeting, eZamokuhle Community Hall, Amersfoort, 17h00 – 18h30; and
- 20 November 2013 – Focus Group Meeting, Old Bergvliet Mine Building, Majuba, 07h30 – 08h30.

The Issues Trail for the Rectification process, including all comments from the public to date of direct relevance to the rectification process and the minutes of the above mentioned meetings is included in the Public Participation Appendix (**Appendix E**).

5.1.9 Public and Authority Review of the Final Environmental Impact Assessment Report

In order to give effect to regulation 56(2) of the EIA Regulations (2010), before submitting the final EIAR to the DEA, the EAP must give registered I&APs access to, an opportunity to comment on the report in writing within 30 days. This review period will be run across 06 December 2013 and through to 24 January 2014. The availability of the document will be made known to the I&APs and will be available via the RHDHV website, or in hardcopy on request.

5.1.10 Authority Review and Decision-making

After the public review period, all relevant comments received from the public were considered and included into the final EIAR. This final document (the document at hand) shall be submitted to DEA for final review and decision-making.

5.1.11 Environmental Authorisation

On receipt of the environmental authorisation for the project, I&APs registered on the project database will be informed and its associated terms and conditions by correspondence.

6 SPECIALIST FINDINGS AND RECOMMENDATIONS

The findings and recommendations of the specialists and reports of specialised processes have been incorporated in this chapter.

The following studies have been undertaken as part of this and the parallel EIA processes (i.e. Pilot Plant Phase 1 and 2 investigations):

- Geology (**Appendix F**);
- Hydrogeology (**Appendix F**);
- Hydrology (**Appendix G**);
- Wetlands (**Appendix H**);
- Freshwater Ecology (**Appendix I**);
- Soils and Agricultural Potential (**Appendix J**);
- Biodiversity (**Appendix K**);
- Waste (**Appendix L**);
- Social (**Appendix M**);
- Air Quality (**Appendix N**); and
- Heritage and Palaeontology (**Appendix O**).

6.1 Geology

Note that this section refers dominantly to future expansion of the UCG process based on outcomes of the Pilot Plant Phase 1 covered so far. It is provided for completeness although it does not have specific reference to Gasifier 1's (Pilot Plant Phase 1) future fate, as it indicates the fact that the phases form an ongoing research process with the results obtained informing the next steps taken.

6.1.1 Geological Studies

The following geological studies (conducted by Eskom personnel) are completed:

1. A Geological report of Gasifier 1 (Pilot Plant Phase 1) is in progress. This report is an overview of the geological characteristics of the G2 panel area, with the following objectives in mind:
   - Mineral Resource Calculation of the Gus coal seam in the G2 Panel Area.
   - An interpretation of the geological structure of the G2 Panel, Majuba UCG Gasifier One Area.
   - Illustrate the general geological environment of the identified mining area and to highlight conditions to be considered for gasifier design and development.
   - Summarised Gus seam coal quality results.
   - Complete drilling, geological and wireline logging results and provision of a consolidated database.
2. Desktop study of opening-mode fractures in coal seams (coal cleat):

   The aim of this desktop study is to establish a method of capturing and mapping in-situ data with regards to fractures within the Gus coal seam. Geophysical / wireline logging techniques will be approached, together with orientated drill core. Confirmation pending on scheduled diamond core prospecting programme of 2013.

   Cleat orientation mapping is critical to determine the maximum principal compressive horizontal stress direction for UCG exploration and exploitation, which in turn controls the direction of maximum gas or water flow though coal beds.

3. Geophysical exploration methods to be trailed: Review:

   Numerous geophysical exploration methods are conducted at various mineral exploration projects. At Majuba, historical data from a Gravity Survey and an Aeromagnetic Survey in the Majuba area was conducted in the early 1990's. The shortcomings of these surveys were mainly due to the fact that the overlying dolerite sills served as a "shield / barrier". Dolerites were both magnetic and non-magnetic, if any dyke originated from an underlying sill, it could not be detected from the Aeromagnetic survey. The abovementioned methods are not suitable for detecting dykes (in seam) in the Majuba area.

   In seam seismics, cross-hole seismics, electric resistance tomography and seismic refraction methods are currently being investigated for feasibility.

4. Recommendations from previous geological studies to be implemented, where applicable, during future proposed prospecting (drill core availability):

   Numerous recommendations have been documented in various Geological reports of the Majuba area. The aim of this exercise is to implement the relevant recommendations, especially regarding sampling and recovery of drill core. Detailed descriptions of core, as well as dolerite sampling strategies should be looked at. Adoption of several recommendations regarding drilling, logging, sampling, reporting and communication is crucial. Raw coal analysis of all subordinate seams within the Coal Zone should also be considered.

5. Coal resource calculations:

   In order to establish a measured resource, a borehole spacing grid of 350 m, as per SAMREC code and SANS10320 is recommended. This would be applicable to identify potential target areas for erecting gasifiers with proven reserve status. At the current Gasifier 1 area, a measured resource have already been established.

6. Comparing coal quality results with wireline logs (Natural gamma, density):

   The viability to use density and gamma information to predict coal quality is currently being examined. This involves comparing coal quality analyses of cored samples of the Gus coal seam (a complete proximate and ultimate analyses of the entire Gus seam) and then comparing results with the geophysical signature on the wireline logs. This is an on-going study pending on core availability and wireline (density) information.

7. Prediction of dolerite activity:

   Upon completion of coal analyses, a Dry Ash Free Volatile Matter calculation should be conducted. This will confirm whether the seam (results) have been exposed to heat from the dolerite (establish the devolatilised nature of the coal seam, if present). Short comings from previous coal percussion drill cuttings results have been regarded as unreliable.

6.1.2 UCG Rock Mechanics Monitoring

A new Time Domain Reflectometry (TDR) system has been proposed at Gasifier 2 (the parallel EIA process) based on findings from Gasifier 1 (the project at hand). Key learning points from the previous TDR installation were incorporated into the design of the new system.

6.1.2.1 Shortcomings of the previous monitoring system

A number of shortcomings have been identified in the previous monitoring system. The system has not yielded much data since it was installed in 2006.

The main shortcomings of both the TDR and wire extensometer system were:

- The limited number of monitoring boreholes in relation to the unknown location, profile and extent of the gasification cavity.
- The location of the assigned boreholes in relation to the location of the cavity. The location was not in the direct path of the initial burn but rather to the side. Therefore, the predicted caving above the cavity would have been a pseudo-convex shape (Gothic arch) and any offset of the monitoring boreholes from the centre of the cavity would have negatively affected the effectiveness of the monitoring system.
- The depth of the boreholes – the boreholes terminated approximately 10 m above the coal seams, there were concerns of gas leakage through the holes. The physical location, extent or envisage size of the cavity could not be predicted with certainty at that stage of the project and therefore it was not known if this 10 m proximity above the seam would be adequate or not.

As a consequence of the location and depth, the extensometer system cannot detect current deformation and movement of the immediate strata above the cavity.

6.1.2.2 Tracking UCG Cavity Growth

Understanding the growth of the cavity is important from a Process and Rock Engineering point of view. The information obtained from a system of tracking UCG cavity growth can be used to determine the size and shape of the gasification chamber. A number of geophysical techniques that can be used to track the UCG cavity were investigated. A Microseismic Monitoring system was identified as the most suitable technique to track the UCG cavity growth. Eskom UCG has currently purchased the microseismic monitoring system, already installed at Gasifier 1 (see **Figure 21**).

- **Microseismic monitoring system**

A micro seismic system works by using geophones to detect microseismic activity from locations of brittle fracturing within the rock mass. Brittle fracturing in rocks produces seismic waves with low frequencies. It is expected that there will be fracturing as the gasification process takes place. This fracturing will mainly occur at the “boundary” of the gasification cavity. Some fractures will also be formed away from the gasifier. Locations of such fractures will be used to estimate the height of failure above the gasification cavity.

The system can also be used to determine fracture orientation during Aquasplitt™. It is important to know when goafing occurs as well as the size of the cavity at the time of goafing. This information will be used to validate the analytical and numerical methods. Back analysis can also be performed to determine “correct” input parameters for the models. As a result the numerical and analytical methods will represent reality more accurately. It will also be possible to determine if goafing poses any significant risks to the process.

The monitoring system comprises of four dedicated boreholes equipped with two geophones per borehole. In addition to the microseismic monitoring boreholes a similar setup was completed for the piezometer boreholes, equipped with multiple geophones per borehole. During any activity (drilling, linking, Aquasplitt™, etc.) at Gasifier 2, seismic activity will be recorded, this data will be interpreted and incorporated into the Geological Model.

- **Subsidence**

Subsidence beacons will be installed to verify baseline information with regards to any movement of the ground surface area in and around the Gasifier 2 area prior to any events.

6.1.3 Recommendations

Ongoing geological and rock monitoring programmes are required to ensure that a high level of geological certainty, reliability and assurance is achieved and maintained. The existing geological database should be continuously updated when new geological data is acquired. Record should be kept of all changes that are made over time.

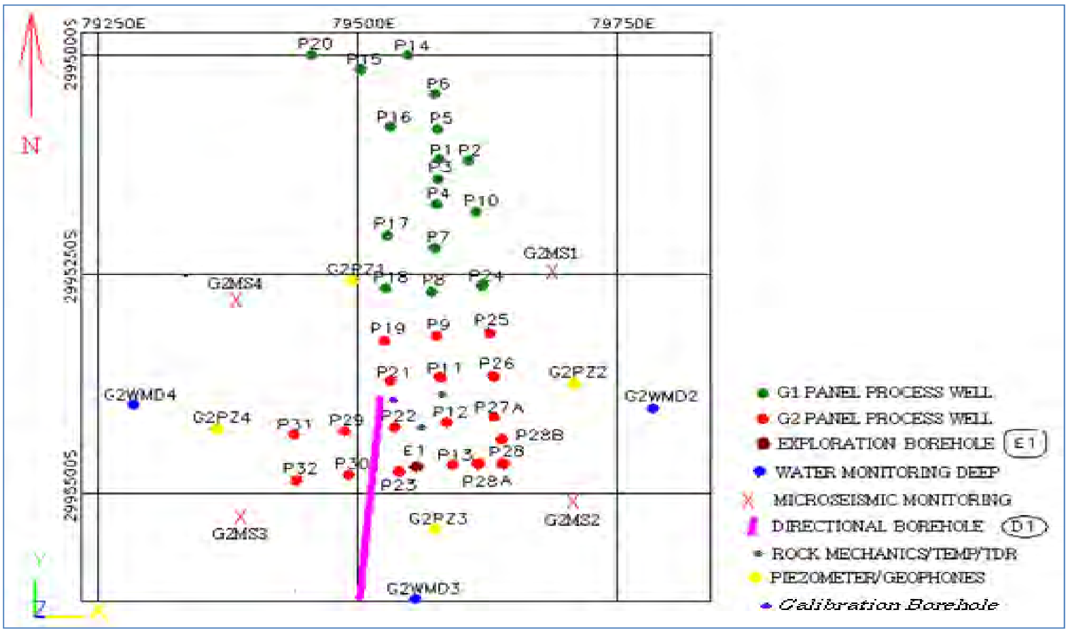

Figure 21: Borehole monitoring layout at Majuba UCG Gasifier 1 (Pilot Plant Phase 1)

6.2 Hydrogeology

Groundwater and surface water sampling programmes have been conducted at Majuba UCG since 2006. A monitoring procedure was developed in 2009 by Golder[18] for Eskom. **Figure 22** shows the distribution of groundwater and surface water monitoring points.

The recently drilled boreholes around the future proposed gasifier 2 (should it be approved) are constructed to monitoring the different aquifer units. These are not active operational boreholes at this time, but merely serve as monitoring points for the Pilot Plant Phase 1 in terms of potential contamination from the now-dormant gasifier process. Specifically the existing boreholes are as follows:

- **Shallow** – all WMS boreholes monitoring the shallow aquifer (± 40 m deep);
- **Intermediate upper** – all WIU boreholes monitoring the upper contact with the dolerite sill (± 120 m deep);
- **Intermediate lower** – all WIL boreholes monitoring the bottom contact of the dolerite sill (± 170 m deep); and
- **Deep** – all WMD boreholes monitoring the Gus coal seam (± 280 m deep).

The aim of the sampling is to monitor the quality of the surface and the groundwater lying within the Gus coal seam about 280 m below surface and the shallow aquifer at 30 m below surface. It is known that UCG processes can a pose potential pollution risk to groundwater although it depends mainly on local hydrogeological conditions.

The aim of the monitoring is thus to monitor and analyse the extent of the (potential) groundwater pollution originating from UCG processes. Groundwater pollution is caused by the diffusion and penetration of contaminants generated by underground gasification processes towards surrounding strata and the possible leaching of underground residue by natural groundwater flow after gasification.

Typical organic pollutants include phenols, benzene, minor components such as Polycyclic Aromatic Hydrocarbon (PAHs) and heterocyclics. The natural groundwater flow after gasification through the coal seam is attributable to the migration of contaminants.

The extent and concentration of the groundwater pollution plume depend primarily on groundwater flow velocity, the degree of dispersion and the adsorption and reactions of the various contaminants. The adsorption function of coal and surrounding strata make a big contribution to the decrease of the contaminants over time and with the distance from the burned cavity.

[18] **Ibid.** *Footnote* 4.

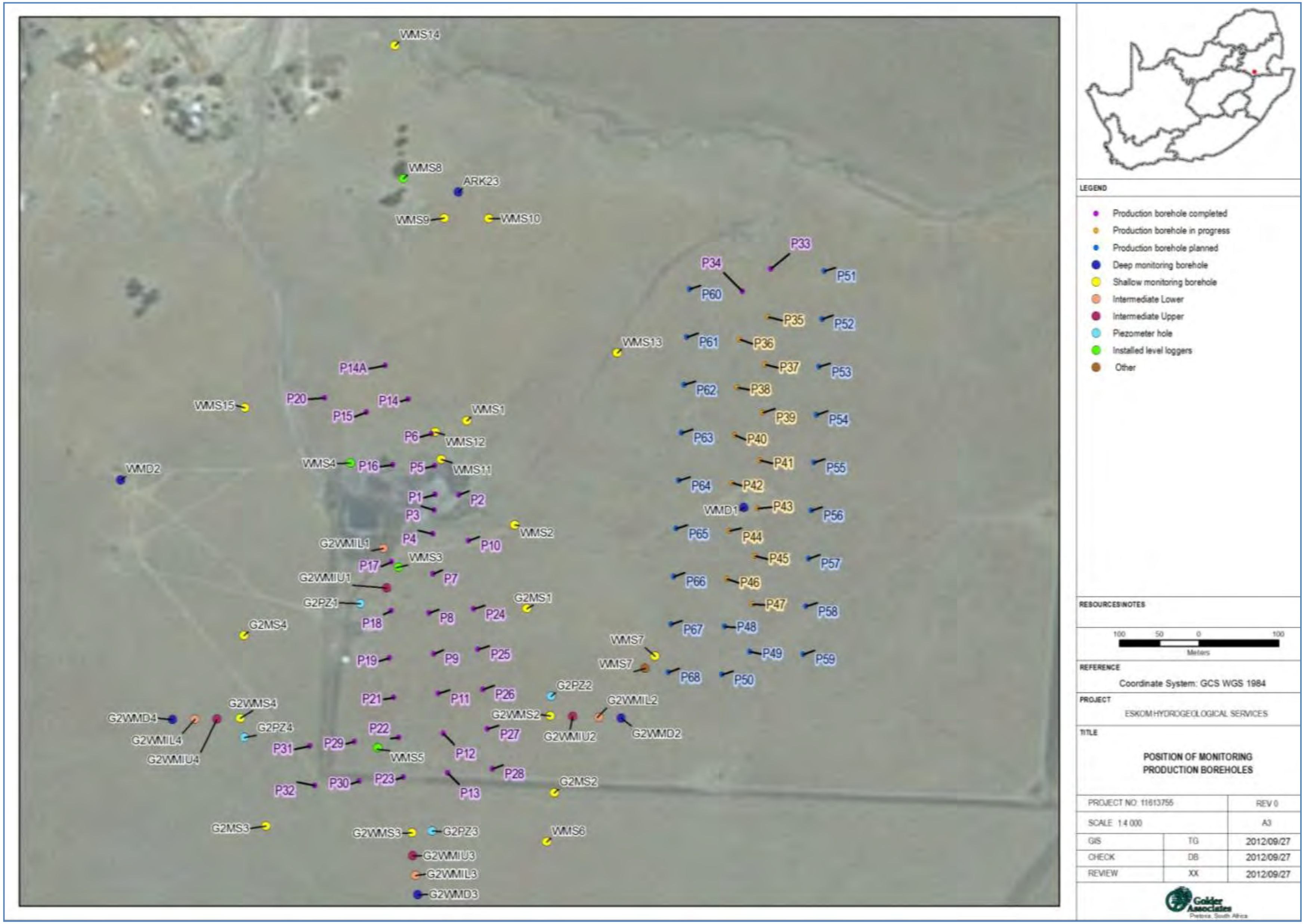

Figure 22: Position of boreholes and monitoring points

6.2.1 Groundwater Sampling

Groundwater samples were collected at fifteen (15) shallow monitoring boreholes (WMS1 – WMS15) and two (2) deep monitoring boreholes (WDM1 and WDM2). The positions of the monitoring boreholes together with the production boreholes are indicated in **Figure 22**.

Shallow monitoring boreholes WMS7, WMS9 and WMS10 were drilled in June 2010 and sampling for WMS9 and WMS10 started during June 2010 and for WMS7 during July 2010.

The water quality analytical results are compared to the South African drinking water standards, SANS 241 of 2011 which provides the minimum assurance necessary that the water is deemed to present an acceptable health risk for lifetime consumption (this implies an average consumption of 2ℓ of water per day for 70 years by a person that weighs 60 kg). It is noted that SANS 241: 2011 standards do not have limits for magnesium, potassium, and calcium. In absence of standards in SANS 241: 2011 for these determinants, the SANS241: 2005 standard was used.

The Dutch standard was used to compare the organic chemical results and is listed in Appendix A of the Hydrogeology Report (**Appendix F**). These guidelines have been developed for the protection of drinking water and aquatic systems and are therefore considered appropriate for all water samples collected from the Majuba UCG site.

6.2.2 Incidents during the Monitoring Period

Two known incidents since commencement of the groundwater monitoring are noted:

- Surface diesel spillage occurred in early 2008 near shallow monitoring borehole WMS4.
- Production borehole P5 gas leak (**Figure 23**):
  - The incident occurred during May to September 2011.
  - The leak occurred in production borehole P5 due to casing failure and syngas leakage. It was detected in shallow monitoring boreholes WSM11 and WMS9 (drilled to depths of 25 and 18 m below ground level respectively). WSM11 and WMS9 are located approximately 10 and 100 m downstream, respectively from P5.
  - The gas migrated along the annulus of the casing until it reached the inferred fracture zone within the shallow dolerite sill above the groundwater table. It potentially migrated along the fracture within the unsaturated zone towards the north where it came in contact with groundwater near borehole WMS9.
- Eskom implemented air sparging as well as flushing of the soil and shallow aquifer system with clean water to remediate the impacted area successfully during September 2011 to November 2011.

An investigation was done to establish the root cause of the casing failure in the production well and to establish the nature, depth and severity of the casing failure in order that the well can be successfully repaired and permanently sealed off.

The monitoring results indicate that the contamination area is less than five hectares (5 ha), which is less than 2% of the localised aquifer.

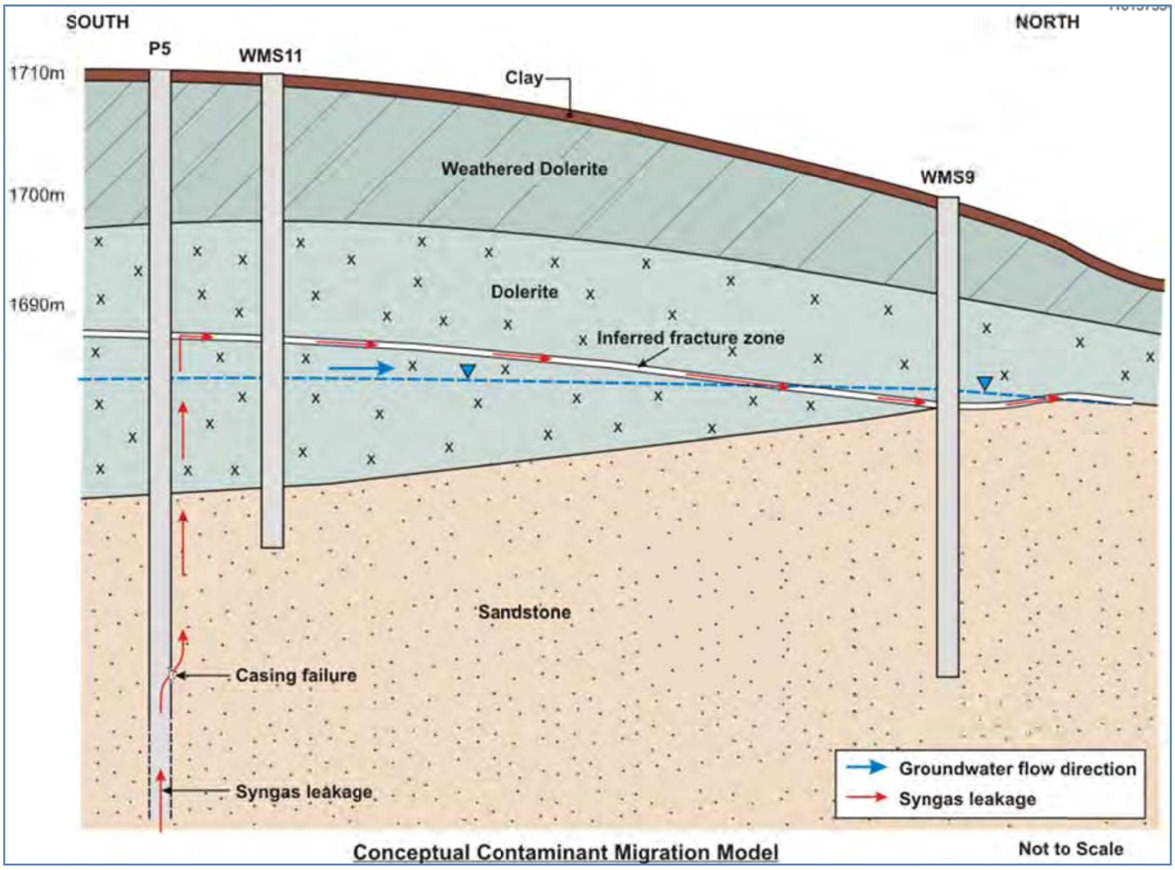

Figure 23: Conceptual contaminant migration model[19]

- ***Chemical composition of the potential contamination***

The condensate produced by the UCG process contains organic compounds typically found in the Gasoline Range organics (GRO's), some Polyaromatic Hydrocarbons (PAHs), Phenols and BTEX (Benzene, toluene, ethylene, xylene).

As part of the early detection water monitoring system, the following organic compounds were analysed on a monthly basis and the discussion included in **Section 6.2.4**:

- BTEXMN – Benzene, toluene, ethyl benzene, m+p-Xylene, o-xylene, 1, 3, 5 trimethyl benzene, 1,2,4 trimethyl benzene, Naphthalene, MTBE and TAME.
- PHENOL – Phenol, 2 chlorophenol, 2 nitrophenol, 2, 4 dichlorophenol, 2, 6 dichlorophenol, 2 methylphenol (o-cresol), 3- and 4-methylphenol (m+p cresol), 2, 4 dimethylphenol, 2, 4, 6 trichlorophenol, 2,4,5 trichlorophenol, 4-chloro-3-methylphenol, 2,3,4,6 tetrachlorophenol and pentachlorophenol.
- PAHs – Naphthalene, acenaphthene, acenapthylene, fluorine, phenanthrene, anthracene, pyrene, benzo(a)anthracene, crysene, benzo(k+b)fluoranthrene, benzo(a)pyrene, benzo(g,h,i)perylene, dibenz(a,h)anthracene, indeno(123-cd)pyrene.

The major components in the raw produced UCG condensate are as follow according to concentration (parts per billion (µg/l).

- Phenol: 3,200,000

[19] Golder Associates, 2013. Eskom Majuba Groundwater Monitoring Report. Report No. 11613755-11623-1.

- 4-methyl-phenol: 620,000
- 2-methyl-phenol: 220,000
- Benzene: 18,000
- Naphthalene: 29,000
- Toluene: 2,000

It has been confirmed by analyses that the major components are present in some of the water monitoring wells at significantly reduced levels.

6.2.3 Inorganic Groundwater Quality

6.2.3.1 Synopsis of Shallow Aquifer Quality Trends

With the exception of boreholes WMS1, WMS7 and WMS11; total dissolved solids, sodium and chloride were reported low below SANS 241:2011 standards for all shallow aquifer boreholes throughout the monitoring term (2010 to August 2012).

High TDS was recorded for boreholes WMS1, WMS7 and WMS11 throughout the monitoring term. Similarly, the elevation of Ca, Mg, Na, Cl, F, NO_3, SO_4, were observed during specific times during monitoring in many of the boreholes but especially WMS1, WMS7 and WMS11. Most of the trace metals analysed was reported below the lab detection limit.

Trace metals including Zn, Mn, Al, B, Ba, and Li were detected in shallow aquifer water samples. There seem to be an increasing trend (although at low concentrations) of trace metals and this trend needs to be observed over time, to apply precautionary measures if the problem persists.

From the data collected it is evident that the elevated levels of inorganic species in the groundwater are likely caused by dissolution of minerals associated with the Ecca Group sedimentary formations. However, geochemical characterisation will be required to unequivocally state that this is the case. It is further suspected that the gasification processes (changes in temperature and pressure) may enhance the dissolution to result in elevated salinity and trace metal content. These processes can be investigated by advanced geochemical modelling.

The incident at P5 where there was a leakage and the subsequent remediation efforts of air sparging and water flooding; may also be related to the increase in contaminants. However, the quality of the water that was injected in the process void was not known (i.e. no base level for comparison).

The shallow aquifer water was characterised by plotting relative major anion and cation concentrations on a Piper diagram. The basis of piper plots is percentage plotting of cations and anions in separate triangles. The intersection of lines extended from the ion points to the central rectangular field gives a point representing a type of water. The disadvantage of Piper diagrams is that it excludes parameters such as NO_3, TDS, and Si in water characterisation.

The shallow aquifer water all plots in the centre to the left section of a diamond field, **Figure 24**, indicating no dominant cation but with the majority of samples being bicarbonate anion dominant. WMS11 water plots in the upper centre of a diamond field, showing enrichment of chloride relative to bicarbonate.

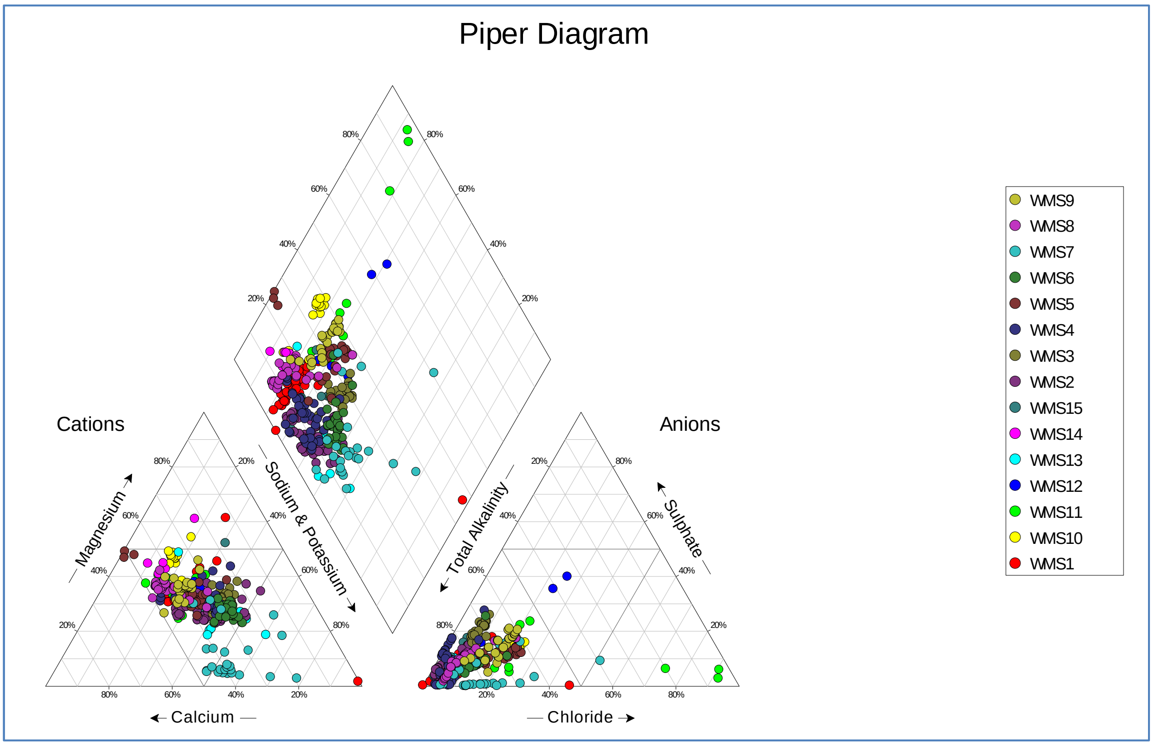

Figure 24: Piper diagram shallow aquifer water characterisation (2010 to 2012)[20]

6.2.3.2 Synopsis of Deep Coal Seam Aquifer Water Quality Trends

The dominating ions in deep aquifer water include Sodium, Chloride and Bicarbonate, resulting to high Total dissolved solids. Other cations present include Calcium, and Magnesium. Nitrates, Fluoride and sulphates are also present in low concentrations. The elevated levels of trace metals such as Mn, Fe, As, Se, Ba, Li, Mo and Sr are also present in deep aquifer groundwater. There is an increase in most of these trace metals during the July 2012 sampling event. The source of this is unknown need to be confirmed observed over time.

The hydrochemical data discussed above was plotted on Piper and Stiff diagrams to characterise deep aquifer groundwater and to establish the groundwater types. Piper diagram presents the cations and anions (as milliequivalent per litre) percentages as plotted in two triangular diagrams and both cations and anions extrapolated onto the central diamond field. This enables the water types and source of ions present in the water to be identified.

The water quality trends for deep coal seam shows elevated concentrations of TDS, sodium and chloride in both boreholes WMD1 and WMD2. The samples plot in a predominantly Na-Cl-bicarbonate section of the diamond field (**Figure 25**). The high salt levels are typical what is expected of deep coal seam water, however a geochemical characterisation of the host rock will be valuable to determine whether the elevated chemical parameters measured in the groundwater is caused by natural mineralisation or from external sources e.g. hydro-linking injection water.

[20] Ibid. *Footnote 19.*

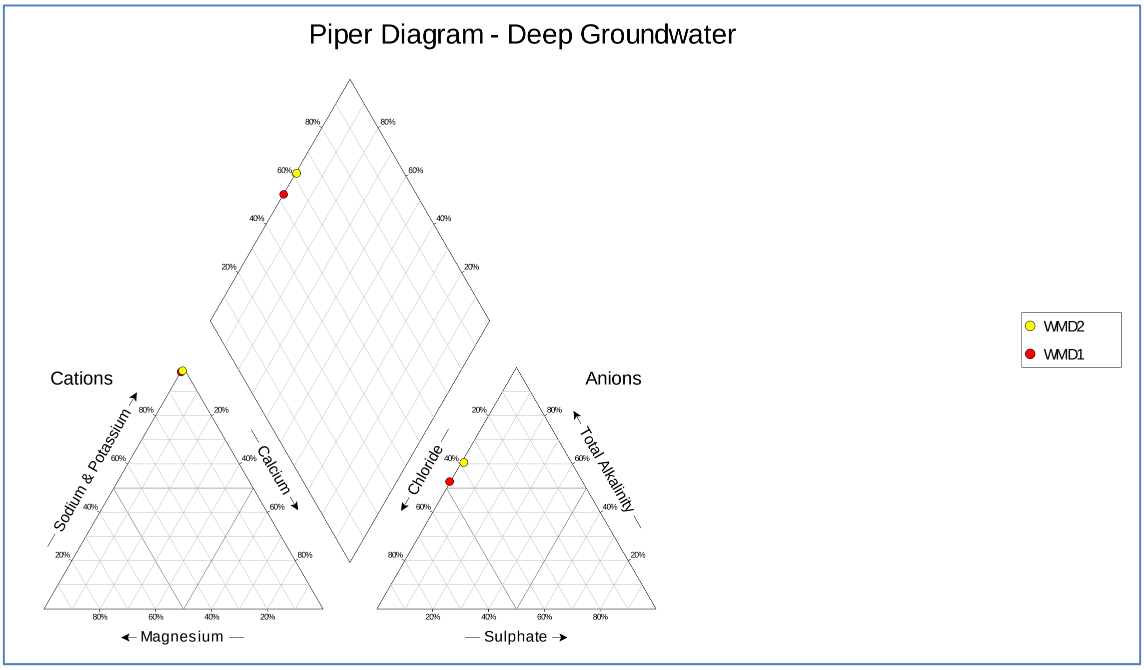

Figure 25: Piper diagram – deep coal seam aquifer[21]

6.2.4 Synopsis of Hydrocarbon Results

From the currently available organic sampling results, it is confirmed that boreholes WMS1, WMS2, WMS4, WMS7, and WMS9 are contaminated with organic pollutants. The source of contamination is related to the UCG processes on site. These boreholes are located downstream (with exception of WMS7) from where the incident in 2011 happened in P5. The contaminants were at the highest levels recorded in the time period between August 2010 and November 2011. This indicates that the leakage from P5 may have started earlier than the recording of the incident in May 2011.

Levels of contaminants decreased and stabilised in the next year, but an increase in concentrations are observed in the last part of the monitoring period – August 2012. The major contaminants of concern are volatile compounds BTEX and phenol as well as PAH contaminants especially naphthalene. The concentrations at which these contaminants are found are above the Dutch intervention levels, which would imply that it poses a risk to the environment and that intervention/remediation is required.

The two deep monitoring boreholes WMD1 and WMD2 remain consistent and mostly unaffected by the hydrocarbon contamination.

6.2.5 Groundwater Levels

Groundwater level measurements forms part of the groundwater monitoring programme implemented on site by Eskom. The water level monitoring seeks to explore the water level fluctuation and response to site activities. In this case both shallow and deep aquifer water levels were monitored.

[21] Ibid*. Footnote 19.*

6.2.5.1 Shallow Aquifer Water Levels

The shallow aquifer water level data trends are included in **Figure 26**. The shallow aquifer monitoring boreholes and latest water level data are listed in **Table 31**.

It should be noted that water level data reported may not be the true representation of the static water level condition on site but that of the site during the field measurements. Site activities such as water injection in attempt to clean the aquifers, pumping as well as abstraction requirement for hydrolinking affect the natural water level condition.

Table 31: Shallow aquifer groundwater levels

BH_ID	Date	Lat	Long	Elevation (mamsl)	SWL (mbgl)	SWL (mamsl)
WMS1	05/09/2012	-27.06447	29.80257	1681.4	34.2	1647.3
WMS10	05/09/2012	-27.06219	29.80282	1695.7	19.4	1676.3
WMS11	05/09/2012	-27.06490	29.80228	1709.3	26.6	1682.7
WMS12	06/09/2012	-27.06459	29.80221	1708.8	5.6	1703.2
WMS13	05/09/2012	-27.06370	29.80427	1695.7	24.9	1670.8
WMS14	05/09/2012	-27.06023	29.80176	1679.0	4.0	1675.0
WMS15	05/09/2012	-27.06432	29.80006	1708.5	26.0	1682.5
WMS2	05/09/2012	-27.06564	29.80311	1680.2	37.4	1642.8
WMS3	05/09/2012	-27.06612	29.80180	1685.1	28.3	1656.8
WMS4	05/09/2012	-27.06494	29.80125	1704.3	26.1	1678.2
WMS5	05/09/2012	-27.06816	29.80156	1689.3	1.8	1687.5
WMS6	05/09/2012	-27.06922	29.80347	1688.6	34.9	1653.7
WMS7	05/09/2012	-27.06712	29.80470	1712.1	5.2	1706.9
WMS8	05/09/2012	-27.06173	29.80185	1678.0	38.4	1639.7
WMS9	05/09/2012	-27.06218	29.80232	1696.6	19.8	1676.8

6.2.5.2 Shallow Aquifer Piezometric Surface and Groundwater Flow Direction

Groundwater levels in shallow aquifer boreholes are generally deep ranging between 20 and 39 mbgl. This was measured in the majority of boreholes during the monitoring in September 2012. However, in the vicinity of the stream located to the north of the site and the areas where there are no activities taking place especially to the south of the Gasifier 1 and the proposed future Gasifier 2, shallower water levels (1 to 20 mbgl) was measured.

The shallower levels were measured in boreholes WMS5, WMS7, WMS10, WMS12 and WMS14 and WMS5 (**Figure 26**).

The deeper groundwater levels were measured in boreholes WMS1, WMS11, WMS13, WMS15, WMS3, WMS2, WMS4, and WMS6; located in the vicinity of the production wells. There is an increase in water levels observed from September 2011 to November 2011 (**Figure 27**) and are due to water injected during the remediation of the P5 incident.

The water level data were used to prepare the groundwater piezometric and flow direction map. The flow direction across the study area is from the south to the north towards the stream located to the north of the site, as illustrated on **Figure 28**. In general, groundwater flows from the higher topographic area to the lower lying area, following the topographic gradient as expected.

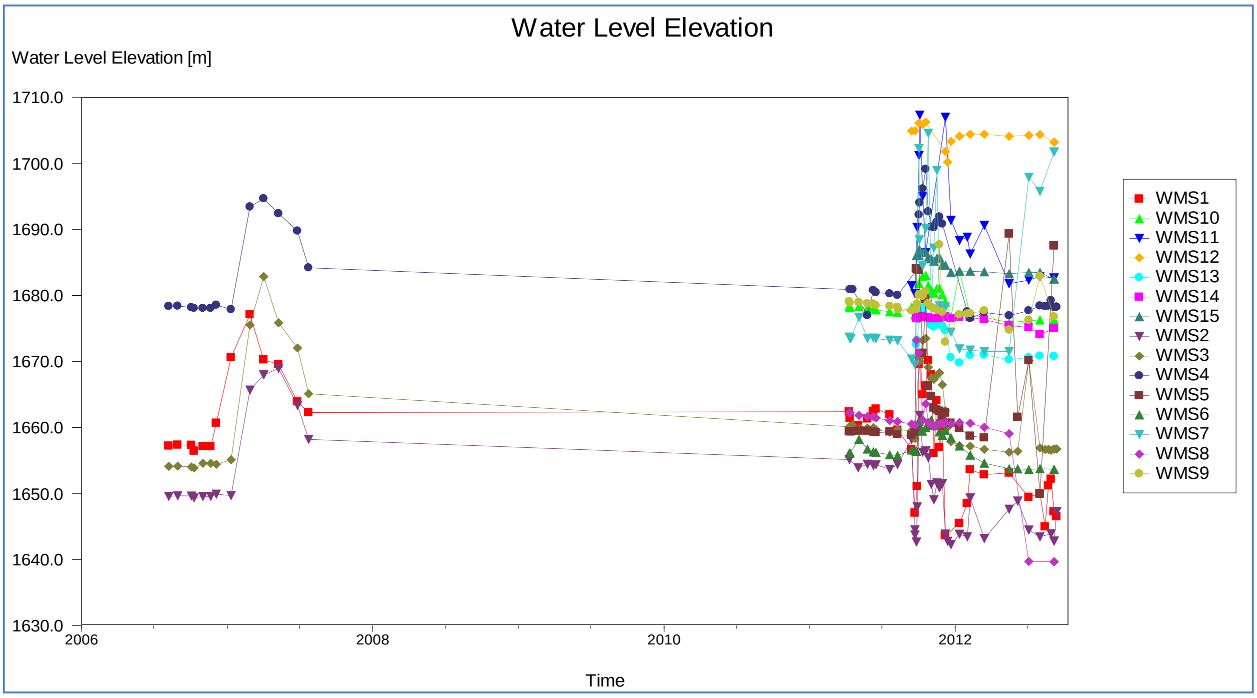

Figure 26: Shallow Aquifer Water Levels (2006 to 2012)[22]

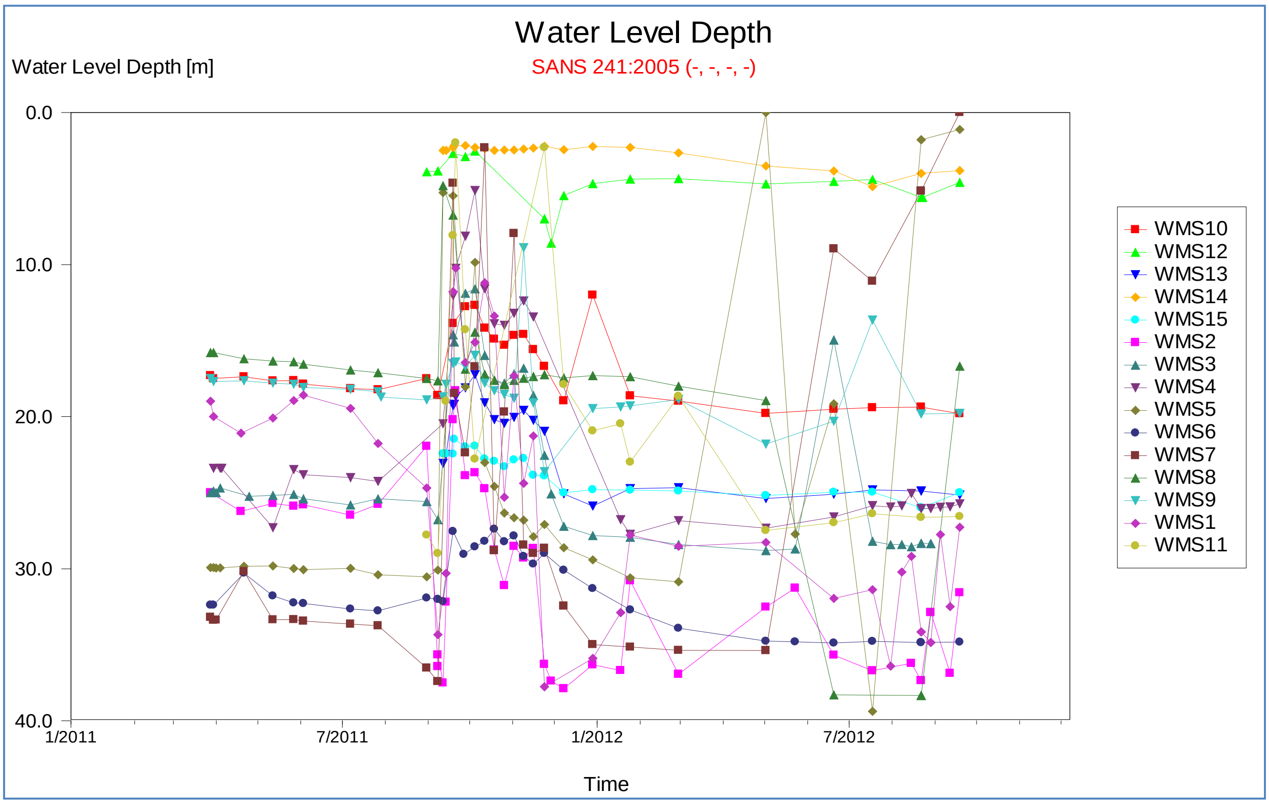

Figure 27: Shallow Aquifer Water Level Depth (2011 to 2012)[23]

[22] Ibid. *Footnote 19.*
[23] Ibid. *Footnote 19.*

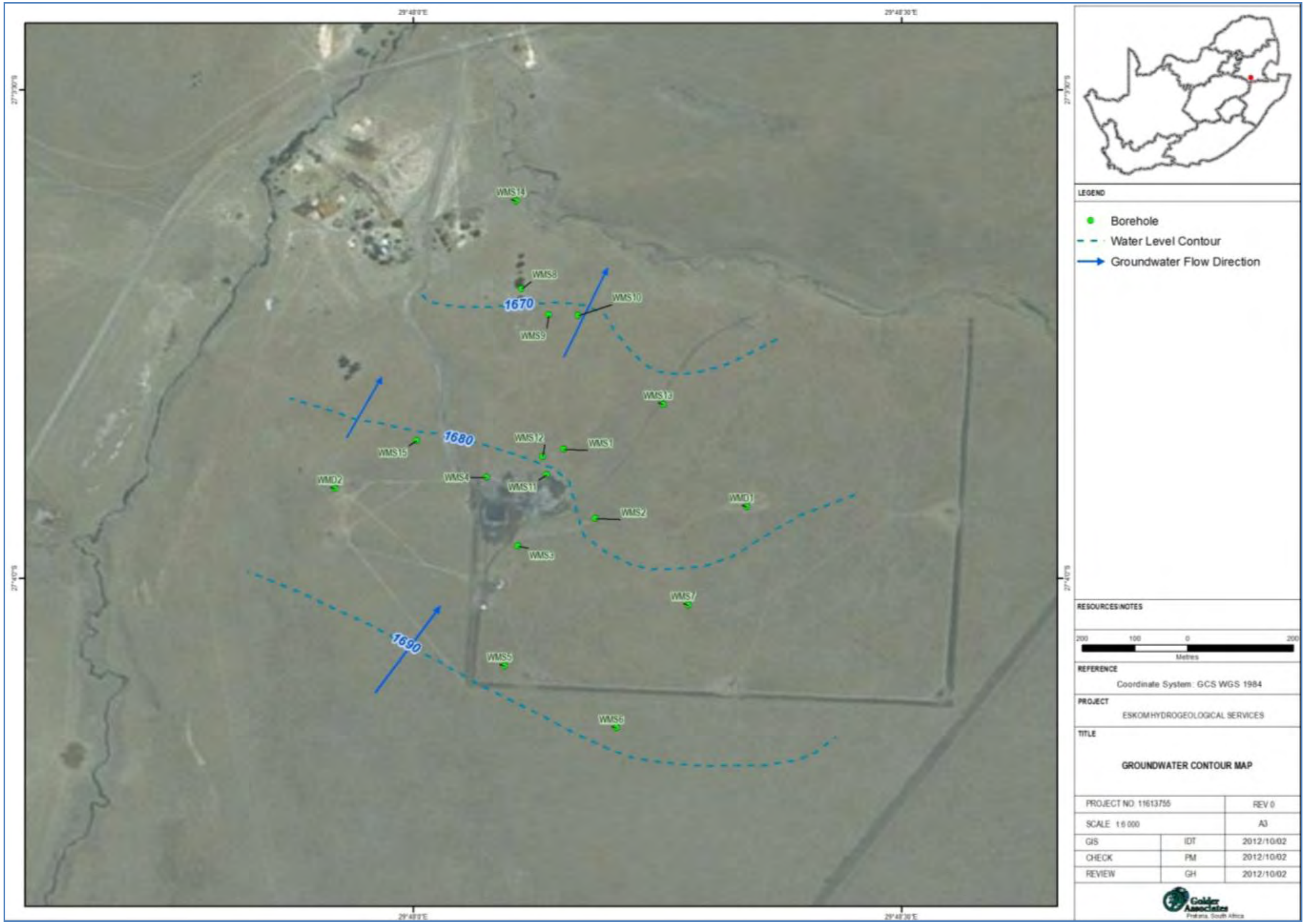

Figure 28: Groundwater piezometric level and flow direction map for the shallow aquifer (July 2012)

6.2.5.3 Deep Aquifer Water Levels

The deep aquifer water levels show an increasing trend since monitoring started to the last available water level in September 2012, **Figure 29**. Both boreholes were artesian flowing due to pressure in the system since the beginning of the year in 2012. As a result, similar groundwater flow direction pattern as in the shallow aquifer is noticed for the deep aquifer, and the groundwater flow is from south to the north, towards the east west flowing stream to the north of the site.

The latest deep coal seam water level data is included in **Table 32**.

Table 32: Deep coal seam water level

BH_ID	Date	Lat	Long	Elevation (mamsl)	SWL (mbgl)	WL_mamsl
WMD1	01/08/2012	-27.06545	29.80570	1679.1	0.0	1679.1
WMD2	01/08/2012	-27.06514	29.79866	1682.9	0.0	1664.5

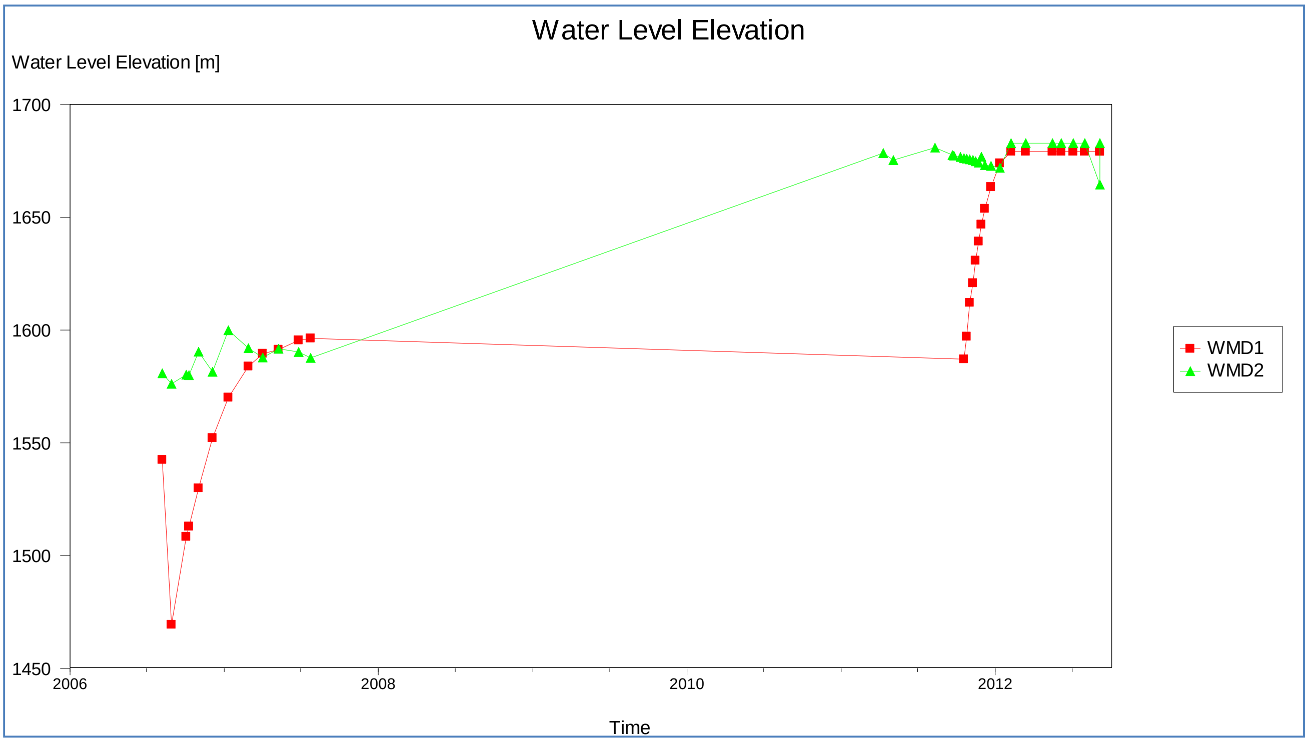

Figure 29: Deep coal seam water levels

6.2.6 Potential Impacts

Table 33: Potential groundwater impacts with respect to UCG project

Aspect	Key Environmental Issue / Potential Impact
Construction	
Shallow groundwater contamination	• Spillage of fuels, lubricants and other chemicals. • Construction equipment, vehicles, workshop and wash bay areas will be a likely source of pollution as a non-point source. • Lack of provision of ablutions that may lead to the conducting of 'informal ablutions. It is noted that to date the site has not experienced this and the behaviour of the staff on site is not likely to change at this time.

Aspect	Key Environmental Issue / Potential Impact
Operations	
Impact on shallow groundwater level	• Lowering of the shallow groundwater level in farmers' boreholes – note that as the Guss seam used is approximately 280 – 300 m below surface and thus this impact is deemed unlikely.
Impact on shallow groundwater quality	• Contamination of the shallow groundwater quality.
Impact on shallow groundwater quality	• Failure of production borehole casings – the design / type of casings used is deemed critical.
Impact on the coal seam water level	• The gasification process consumes groundwater and an impact on the coal seam water level is expected. This water is below commonly used water resources.
Impact on the coal seam water quality	• The gasification process may impact on the quality of the coal seam groundwater, it is however noted that the water in the coal seam is of poor quality due to contact with the coal seam.
Irrigation of condensate and potential impact on shallow groundwater quality	• The condensate recovered from the gas treatment plant and gas pipeline is pumped into a process water dam (12,000 m^3). The dam is lined and has monitoring wells in place to provide an early warning system. UCG condensate from gasifier unit 1 has been piped to this dam. The condensate will be treated to a quality suitable to either: o Support local irrigation activities; o Re-inject the water into the coal seam aquifer; or o Purify to Majuba raw water quality requirements. • Golder[24] indicated potential quality for the irrigation water as having very high concentrations of sulphate (1,520 mg/l); fluoride (141 mg/l) and chloride (413 mg/l).
Overflow from contaminated storage dams causing an impact on the shallow groundwater quality	• As a safety precaution, a dam with sufficient capacity will be constructed in order to cater for down-time of the UF water treatment plant. Overflow of contaminated water from ponds may therefore have a negative impact on the shallow groundwater quality.
Leaks from pipelines	• Leaks of untreated water from pipelines may occur and impact on the shallow groundwater quality – note that to date no significant leaks have occurred and contamination checks indicate no localised pollution from the system.
Decommissioning/Closure	
Impact on the coal seam water level	• After the gasification process has shut down the impact on the coal seam water level will remain during the water level recovery period.
Impact on the coal seam water quality	• The gasification process may impact on the quality of the coal seam groundwater that will remain after closure – as indicated above the water quality to start would have been poor.

6.2.7 Groundwater Management Recommendations

Groundwater level and quality monitoring is an essential management tool and is strictly required for the validity of a water use licence. Water quality monitoring provides early warning signs about the status of the resource and it allows the development of mitigation strategies to be implemented when necessary.

The water resources (surface and groundwater) monitoring should continue at the Eskom UCG site and the following should be considered:

- Consistency in water sampling and groundwater level measurement dates is missing and should be established to allow data comparison. All the points (surface and groundwater sampling points) must be

[24] ***Golder Associates; 2013.*** *Management Plan for the disposal of condensate water by irrigation. Report Number 11613755-11857-2.*

sampled consistently and analysed within the same sampling period to allow the establishment of seasonal variation and influence of site activities to groundwater levels and quality.

- The sampling procedure as detailed in Golder report 11600-8209-1[25] should be followed and sample contamination should be prevented at all cost by using the appropriate sampling equipment, bottles and latex gloves when necessary.
- The groundwater abstraction and injection records are essential and must be kept, to allow the establishment of the response of an aquifer to either pumping or aquifer recharge. This data would enable the explanation of groundwater level fluctuation occurrences, i.e. occasional water level drawdown and recoveries.
- The quality of water injected into the aquifer must also be analysed to allow the comparison of the injected water quality and groundwater analytical results. Similarly, the quality of water used during hydro-linking is essential and must be recorded for the same reason. Data on the volume and duration of injection must also be recorded.
- The proactive management and monitoring of fuel storage tanks is needed on site, and should include fuel spillage control, management and remediation. This will reduce the likelihood of incidents recurring.
- Surface water quality monitoring is very important in tracing the influence of the site activities to the quality of surface water resources and must continue in all surface water monitoring points (upstream, downstream, Witbankspruit and process water dam).
- The duration gap of groundwater and surface water quality data analysis and reporting should be reduced from 2 (two) years to at least 6 (six) months. This will allow reporting on the status of the water system half yearly and will allow Eskom to respond to the recommendations, so as to implement necessary controlling measures.

6.3 Hydrology

There are four surface water monitoring points (**Figure 30**) on site. The surface water was sampled consistently throughout the monitoring period from four points shown in **Figure 30**:

- The Witbankspruit (2010 data only);
- Upstream at a non-perennial stream (2010 – 2012);
- Downstream at a non-perennial stream (2010 – 2012); and
- The cooling water dam (2010).

The samples were collected by Eskom personnel and chemical analysis was done by the UIS laboratory. The analytical results from the surface water samples are compared against the Resource Water Quality Objectives (RWQOs) set out in **Table 34** or against the water quality guidelines[26] for irrigation and aquatic systems where RWQOs are not available.

[25] Ibid. *Footnote* 4.

[26] ***Department of Water Affairs and Forestry, 1996.*** *South African Water Quality Guidelines series.*

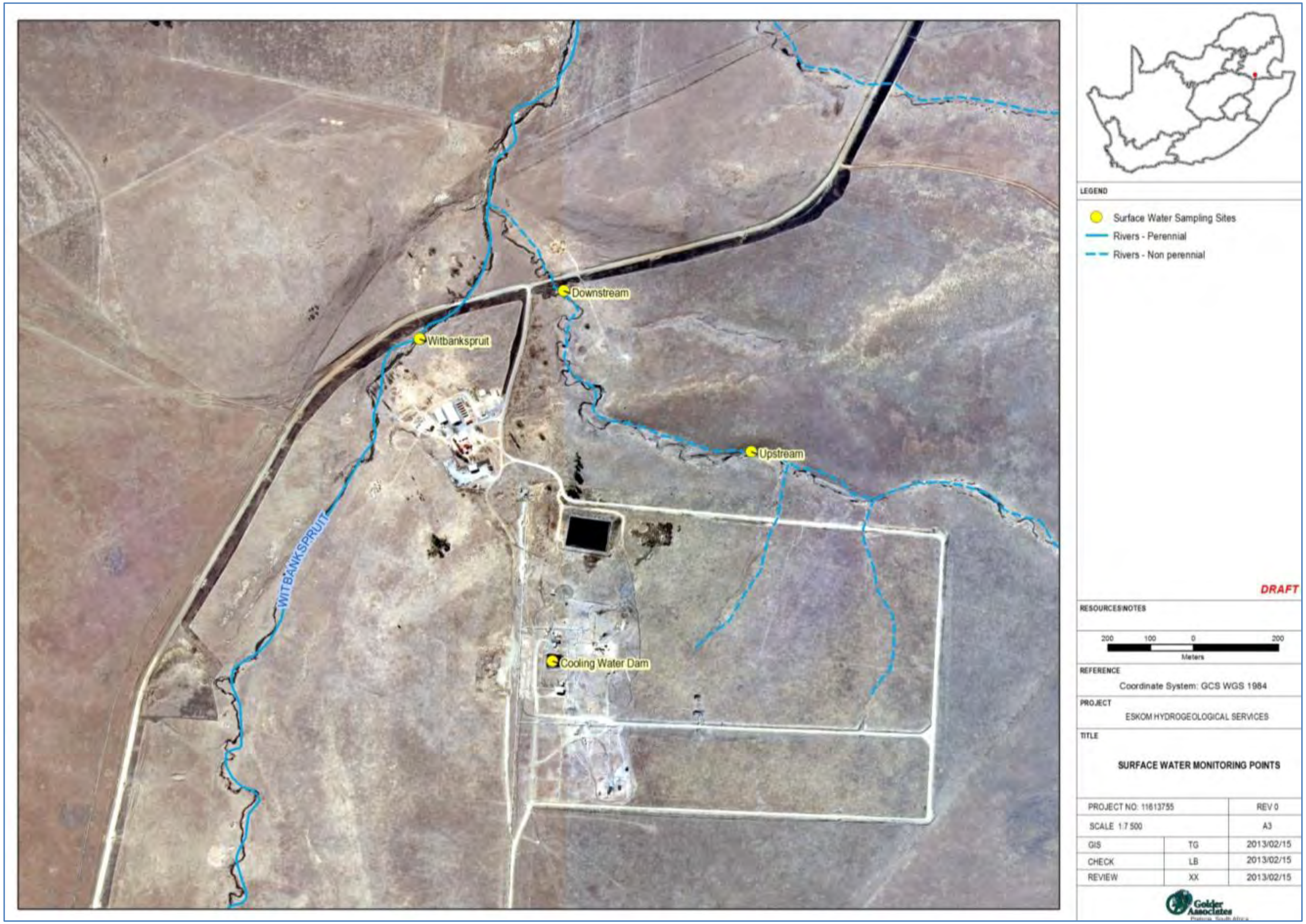

Figure 30: Surface water monitoring points

Table 34: Resource Water Quality Objectives: Grootdraai catchment

Variable	Unit	Ideal	Acceptable	Tolerable	Unacceptable
Conductivity	mS/m	< 10	10 – 15	15 – 25	> 25
Alkalinity ($CaCO_3$)	mg/l	< 20	20 – 45	45 – 75	> 75
pH	pH units				< 6.4 & > 8.5
Phosphate (PO_4)	mg/l	< 0.05	0.05 – 0.08	0.08 – 1	> 1
Sulphate (SO_4)	mg/l	< 10	10 – 20	20 – 30	> 30
Nitrate (NO_3)	mg/l	< 0.05	0.05 – 0.25	0.25 – 0.50	> 0.50
Ammonia (NH_4)	mg/l	< 0.02	0.02 – 0.5	0.5 – 1	> 1
SAR		< 4	4 – 8	8 – 12	> 12
Chloride (Cl)	mg/l	< 10	10 – 15	15 – 20	> 20
Chemical Oxygen Demand (COD)	mg/l	< 10	10 – 15	15 – 25	> 25

6.3.1 Chemical Water Quality

The average values are compared against the acceptable level RWQOs available (**Table 34**) or against the stricter of the water quality guidelines[27] for aquatic, irrigation or domestic water use.

Figure 31 indicates that there is an impact from the site with average TDS at the upstream monitoring point at a concentration of 127 mg/l and 257 mg/l at the downstream site. The same is noted for the average sulphate concentration of 25 mg/l and 37 mg/l at the respective up and downstream sites (**Figure 32**).

The sampling also indicates increases at the downstream site of alkalinity, calcium, chloride and nitrate.

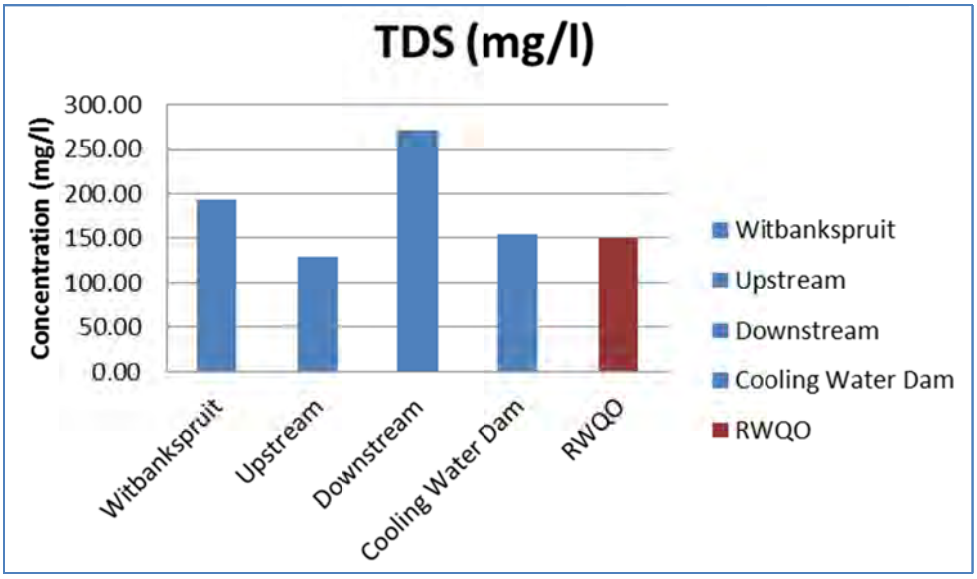

Figure 31: Average TDS concentration at the four (4) surface water sampling points

[27] Ibid. *Footnote 26.*

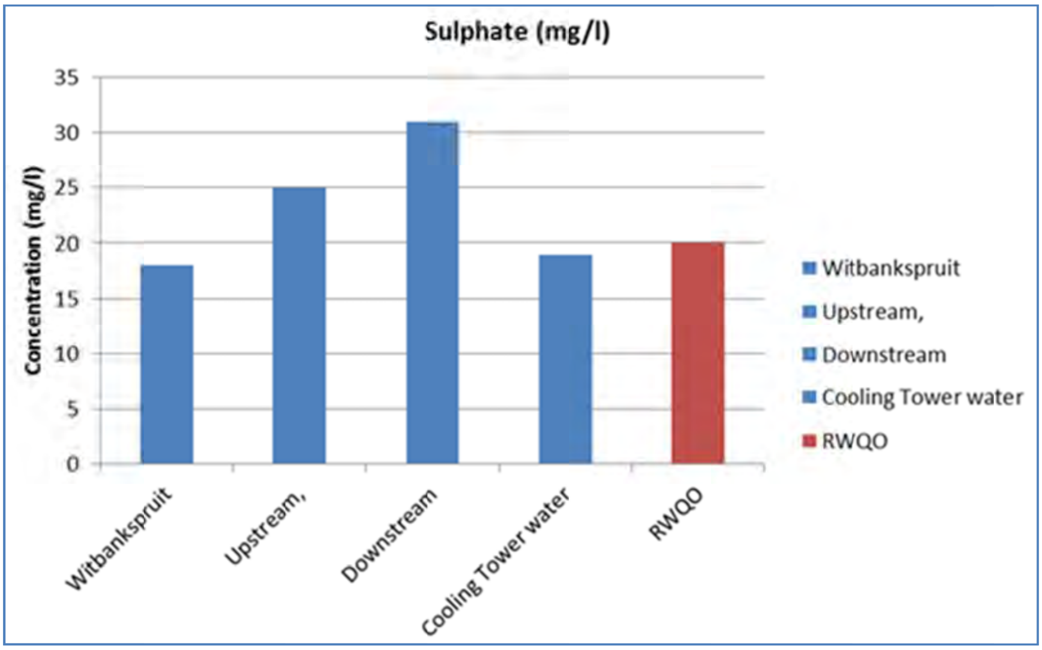

Figure 32: Average sulphate concentration at the four (4) sampling points

6.3.2 Water Quality Trends

6.3.2.1 Witbankspruit

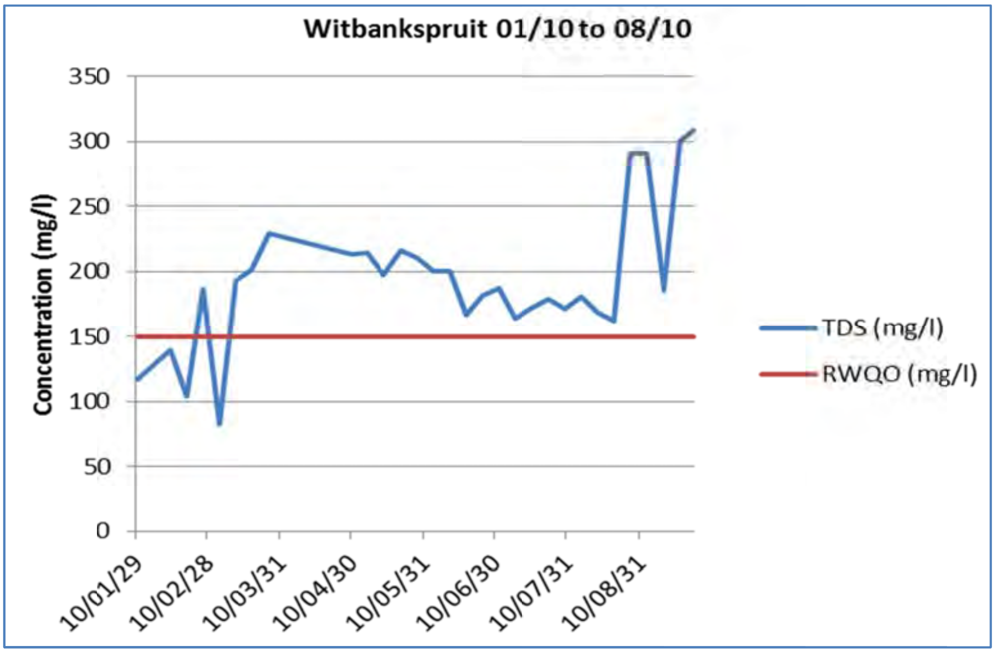

Figure 33: Witbankspruit TDS trends for the period January 2010 to August 2010

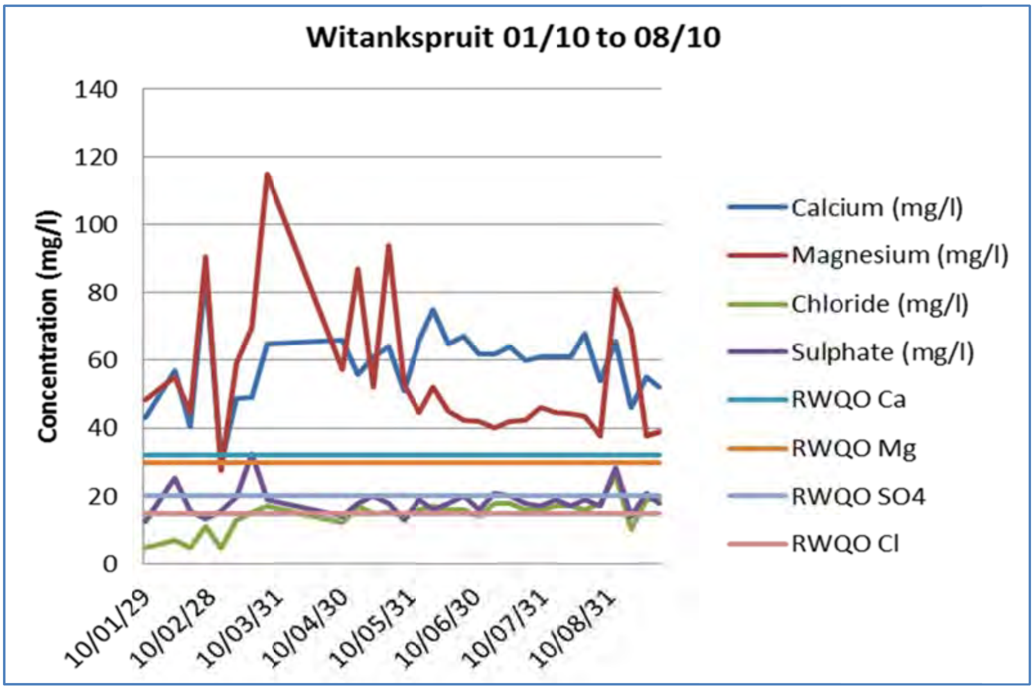

Figure 34: Witbankspruit water quality trends for the period January 2010 to August 2010

6.3.2.2 Upstream Sampling Site

Water quality for the period January 2010 to August 2010 indicated that the stream is being impacted on by upstream activities, very likely from overflows from the process water dam located east of Majuba Power Station (**Figure 35**).

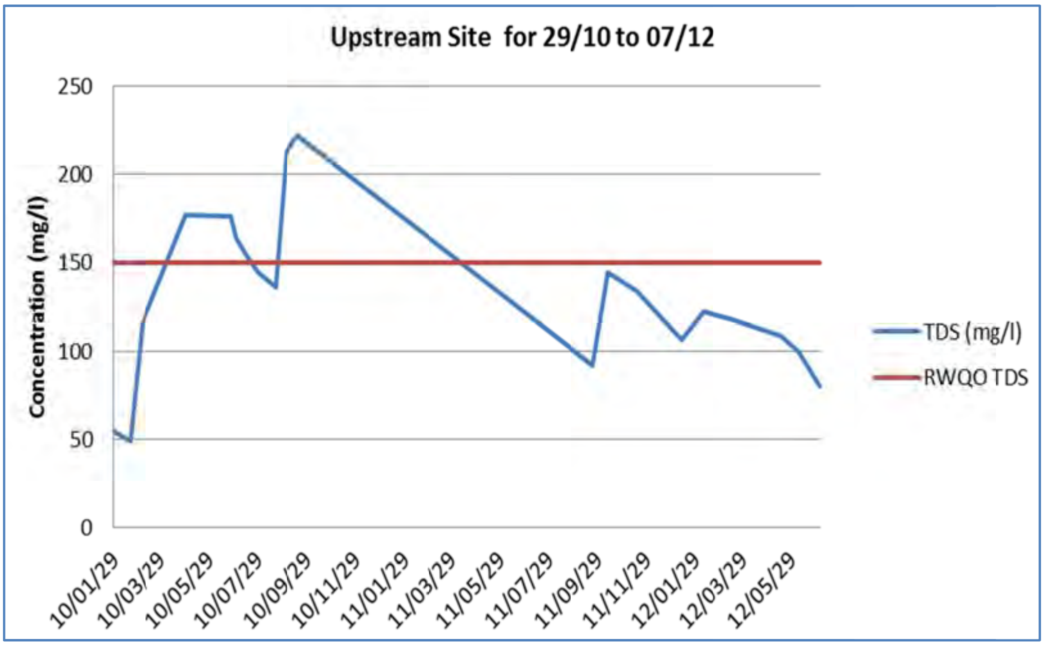

Figure 35: Upstream TDS trends for the period January 2010 to July 2012

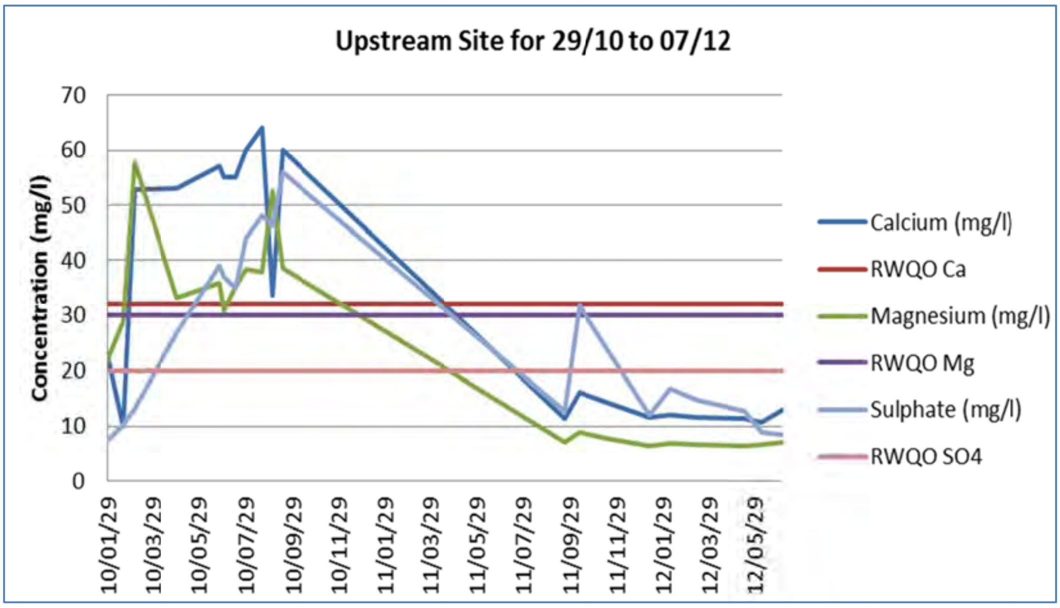

Figure 36: Upstream water quality trends (calcium, magnesium and sulphate) for the period January 2010 to July 2012

The water quality at the upstream site has improved considerably since May 2011. This would indicate that amongst other factors, the mitigation measures in operation are halting further contamination, as well as potentially reducing background contamination.

6.3.2.3 Downstream Sampling Site

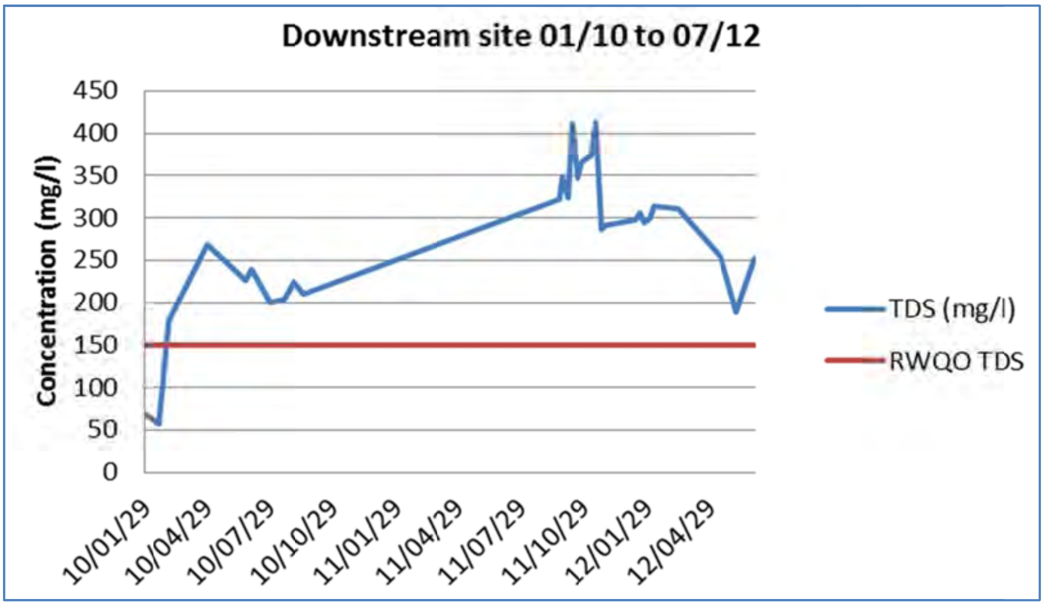

Figure 37: Downstream TDS trends for the period January 2010 to July 2012