6. WATER RESOURCES

6.1. Scope of Work

The study aimed at assessing the surface and groundwater resources within the ± 245 km^2 study area. The scope of work included:

- A status quo study, regarding quality and quantity of water resources.
- A site suitability assessment from a groundwater and surface water perspective.
- An evaluation of all monitoring data, hydro-chemical trend identification, and contamination assessment (coal stockyard, ash dams, etc.).
- Consideration of stormwater controls.
- Surface water availability and supply,
- Groundwater resources.

Due to the nature of the potential impacts, it was considered imperative to conduct a risk assessment regarding groundwater and surface water resources on the preferred site/s during the EIA phase.

6.2. Methodology

A risk assessment regarding groundwater and surface water resources were conducted based on Skivington's report (WRC report No. TT90/97) entitled "Risk Assessment for Water Quality Management" (1997).

The methodology followed is as follows: -

- A description of intention
- Hazard identification
- An estimation of the probability and magnitude of the consequences of the hazard
- A risk estimate
- A risk evaluation
- An overall risk assessment
- Risk management recommendations

The risk assessment is based on the existing Matimba power station, as the proposed new power station design has not yet been finalised. On this basis, it is deemed appropriate that the risks identified during this assessment and the proposed mitigation measures can be utilised for the proposed power station.

6.3. Overview of the Geology of the Area

Sediments and volcanics of the Waterberg Group and Karoo Supergroup underlie the study area. Table 6.1 presents the lithostratigraphy of the area.

Table 6.1: Lithostratigraphy

Age	Supergroup / Group	Formation	Alternative Name	Lithology
Jurassic	Karoo	Letaba	Letaba Formation	Basalt
Triassic		Clarens	Clarens Formation	Fine-grained cream-coloured sandstone
Triassic		Lisbon*	Elliot Formation	Red mudstone and siltstone
Triassic		Greenwich*	Molteno Formation	Red sandstone and conglomerate
Triassic		Eendragtpan*	Beaufort Group	Variegated shale
Permian		Grootegeluk*	Upper Ecca Group	Mudstone, carbonaceous shale, coal
Permian		Goedgedacht*	Middle Ecca Group	Gritty mudstone, mudstone, sandstone, coal
Permian		Swartrant*	Lower Ecca Group	Sandstone, gritstone, mudstone, coal
Permian / Carboniferous	Karoo / Dwyka	Wellington*	Dwyka Group	Mudstone, siltstone, minor grit
Carboniferous		Waterkloof*	Dwyka Group	Diamictite, mudstone
Mokolian	Waterberg	Mogalakwena	Mogalakwena Fm	Coarse-grained purplish brown sandstone

*Not yet approved by the South African Committee on Stratigraphy (SACS)

A veneer of quaternary (2 Ma) sandy soil covers the Waterberg Group sediments to the south of the study area.

Figure 6.1, a portion of the 1:250 000 geological map 2326 Ellisras, illustrates the study area geology. Figure 6.2 presents the structural geology within the study area, as provided by Mr. Leon Roux, Grootegeluk Coal Mine.

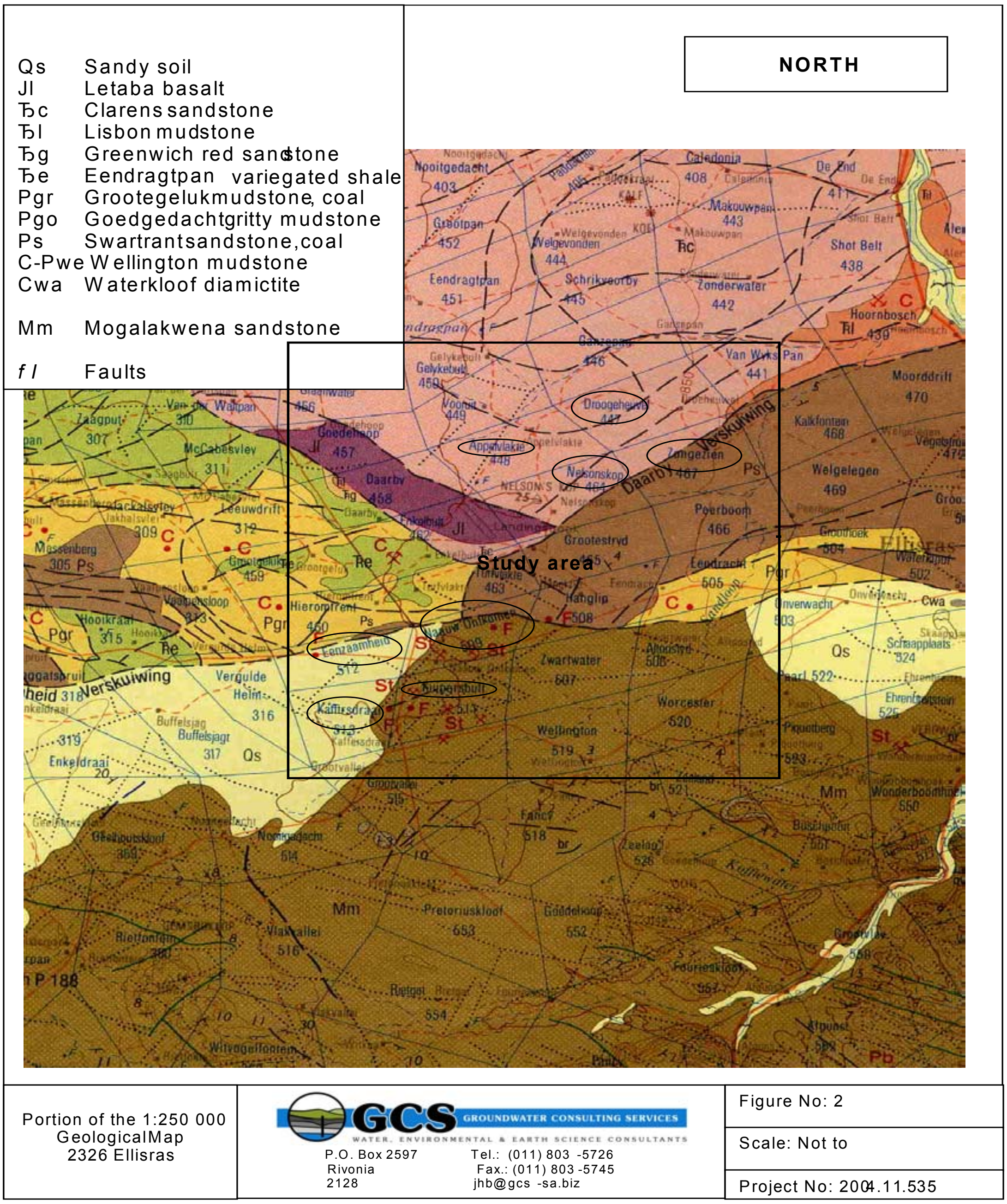
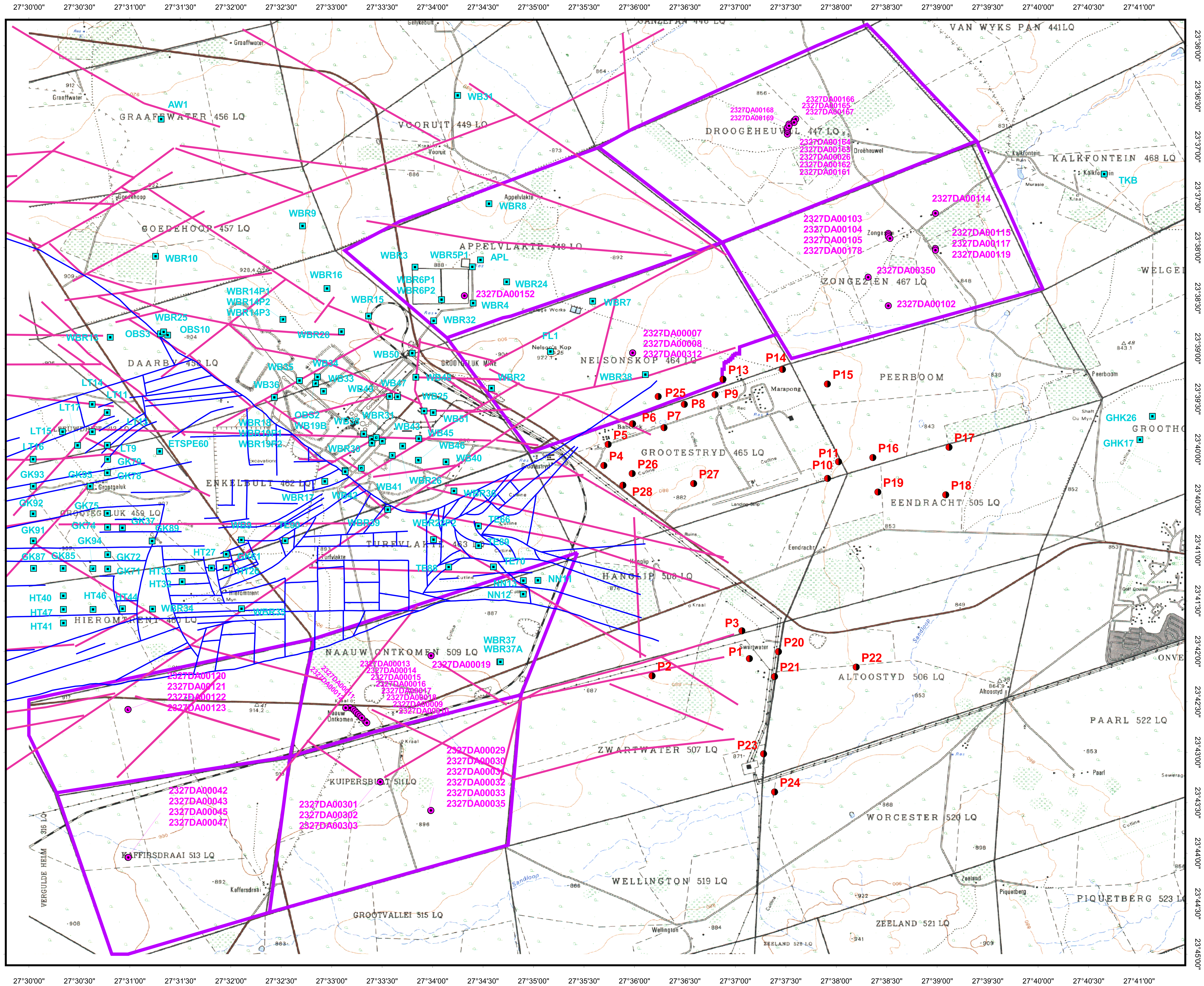


Figure 6.1: A portion of the 1:250 000 geological map 2326 Ellisras, illustrating the study area geology

Figure 6.2 – Structural geology within the study area

STRUCTURAL GEOLOGY WITHIN STUDY AREA



LEGEND:

- Grootegeluk boreholes
- Matimba boreholes
- NGDB boreholes on 8 farms
- Faults derived from boreholes
- Aeromagnetics Lineaments
- Farm boundaries (SG)
- Image: Wgs2327da_1981.tif

0.5 0 0.5 1 1.5 2 2.5 Kilometers

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Figure 3

6.3.1. Structural Geology

The study area falls within the Waterberg Coalfield, which comprises of a graben structure with the Eenzaamheid fault forming the southern boundary and the northern boundary is delineated by the Zoetfontein fault. Archaean granite rocks outcrop to the north of the Zoetfontein fault and sediments of the Waterberg Group outcrop to the south of the Eenzaamheid fault.

The study area is further subdivided by the Daarby fault, a major northeast then northwest trending fault. The Daarby fault has a down throw of 360 m to the north, at an angle of 50° to 60°.

Figure 6.3 is a north-south cross-section across the study area, indicating the faults, throws, and lithological contacts.

Associated minor faulting within the graben structure has been interpreted. Figures 6.4 and 6.5 present the identified and interpreted macros structures within the study area (Roux, 2001).

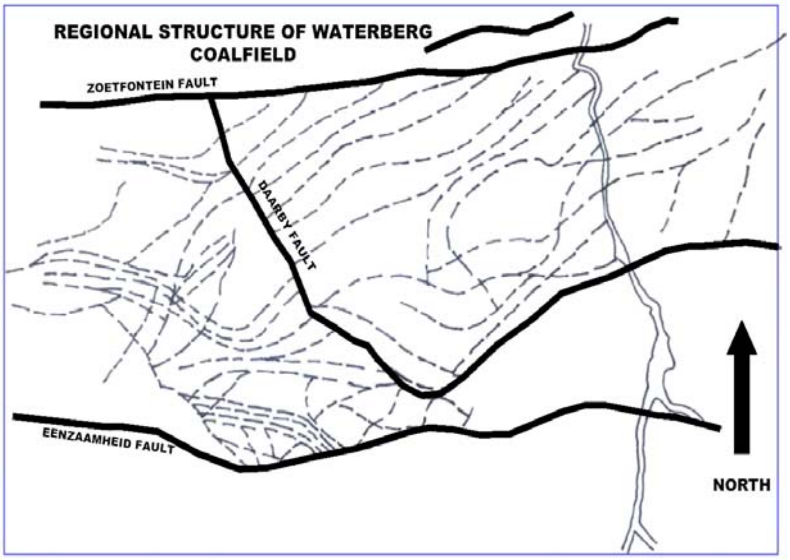


Figure 6.4: Faults and macro structures within the study area.

The geological structures can enhance the groundwater potential in the area by increasing the permeability and transmissivity of the host rock. Secondary processes, such as faulting and fracturing, can create secondary fractured rock aquifers.

Figure 6.3: Cross Section

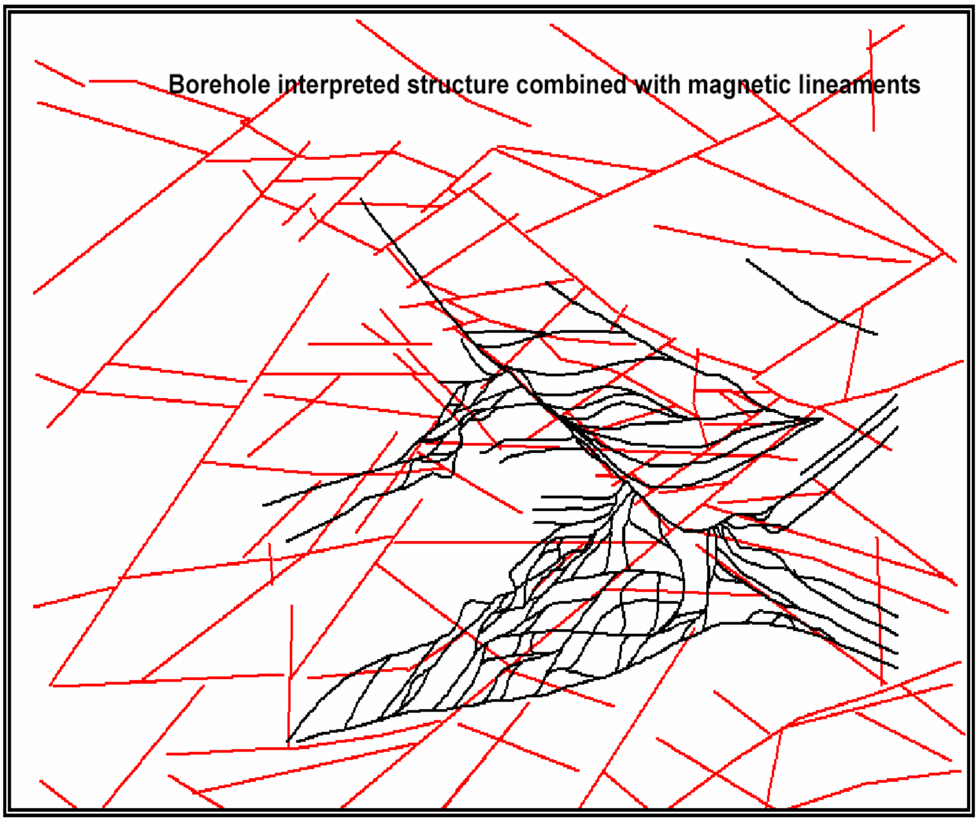


Figure 6.5: Macro structures and lineations interpreted from aerial magnetic data.

- *The Daarby Fault*

  The Daarby Fault is a major northeast then northwest trending fault, assumed to be a combination of two faults that have the same throw and throw directions.

  The down throw of 360 m to the north serves to bring the Grootegeluk Formation rocks to the south in contact with the younger Clarens Formation sandstone and Letaba Formation basalts in the north. Thus the fault divides the coalfield into a shallow (opencast) coal area to the south of the Daarby Fault, and a deep north coal area.

  Packer testing of a borehole drilled through the fault zone has shown the Daarby fault to be impermeable.

- *The Eenzaamheid Fault*

  The Eenzaamheid fault has a throw of 250 m to the north and the fault is near vertical (Figure 6.2). The fault brings the upthrown Waterberg Group sediments on the south side of the fault in contact with shallow coal on the northern side of the fault.

The permeability of the Eenzaamheid fault is not clearly understood, initial groundwater contours indicate that the fault was impermeable (Johnstone, 1989) and that dewatering at the mine did not impact on the Waterberg Group sediments to the south of the fault.

Subsequent groundwater modelling (Roux, 2003) indicates that plume migration will occur along the fault, indicating an increased transmissivity along the fault between the two geological units (Figure 6.6).

The groundwater model indicates that the Eenzaamheid fault has enhanced groundwater potential and could be targeted for groundwater resource development in the future. The fault can also act as a preferential flow path for groundwater and potential contamination. Any possible contaminant sources should not be constructed on the fault as the fault would facilitate the migration of contaminants off site, which could possibly impact on surrounding groundwater users.

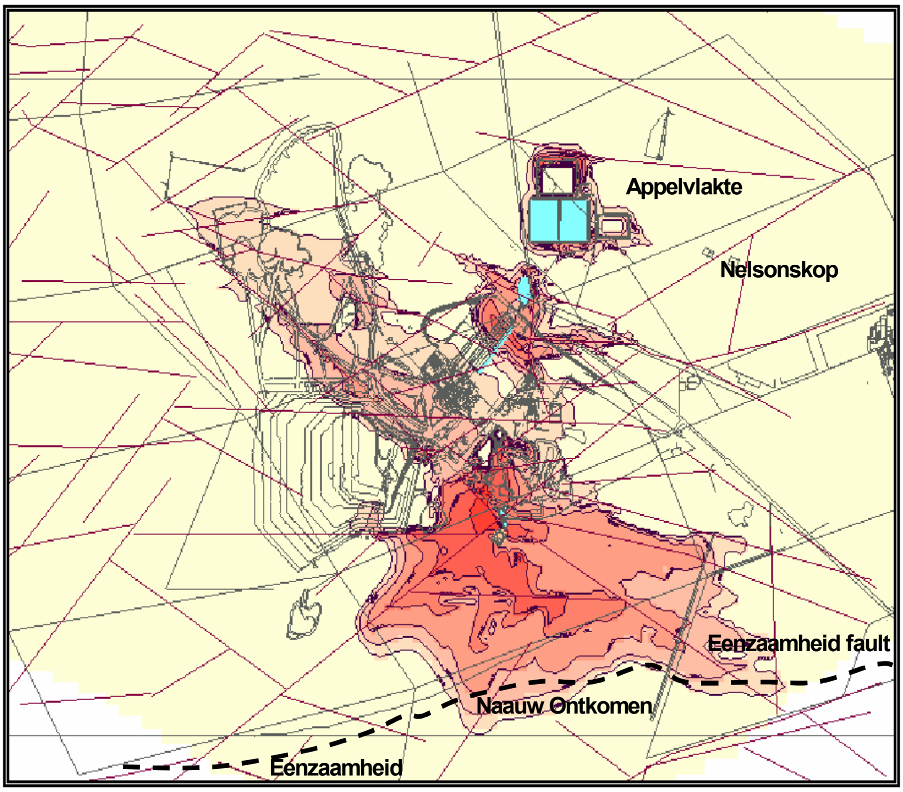


Figure 6.6: Plume migration along the Eenzaamheid Fault

- *Minor faulting*
  Associated step faults are identified within the area, especially where the Eenzaamheid and Daarby faults are in the closest proximity (± 2 km). The associated faults have varying strikes, throws, and throw direction (Figures

6.4 and 6.5). These faults have increased the in situ permeability of these rocks and influence the groundwater flow patterns.

Indications from exploration drilling are that the Daarby and Eenzaamheid faults are linked (on the farm Turfvlakte 463 LQ). This area also acts as a groundwater flow barrier as dewatering occurs within the Grootegeluk and Eendragtpan Formations, but not in the Swartrant Formation, as recognised from the groundwater modelling.

6.3.2. The Grootegeluk Coal Deposits

The Grootegeluk coal mine produces coking coal and middlings from the Grootegeluk and Goedgedacht Formations (Upper and Middle Ecca Group). The Grootegeluk Formation comprises intercalated shale and bright coal, with an average depth of 60 m. Coking and middlings grade coal are obtained from this formation. This coal is suitable for power generation, direct reduction, and formcoke.

Opencast mining occurs within the shallow coal, south of the Daarby Fault. Dewatering occurs which has led to the decline of the groundwater levels around the workings.

6.4. Regional Hydrogeology

The groundwater potential of the formations located in the study area are limited in their pristine state due to low permeability, storage, and transmissivity. Secondary processes, such as weathering, fracturing, etc., are required to enhance the groundwater potential.

Based on regional data, as compiled on the 1:500 000 hydrogeological map 2326 Polokwane, the following hydrogeological information is available for the formations on site:

Letaba Formation	-	Basic extrusive rocks (basalt)
	-	Intergranular and fractured aquifers
	-	Borehole yields 0,1 to 0,5 l/s
Clarens Formation	-	Argillaceous and arenaceous rocks
	-	Intergranular and fractured aquifers
	-	Borehole yields 0,1 to 0,5 l/s
Ecca Group	-	Upper and middle Ecca
(Grootegeluk)	-	Fractured aquifers
	-	Borehole yields 0,5 to 2,0 l/s

Ecca Group	-	Lower Ecca
(Swartrant)	-	Intergranular and fractured aquifers
	-	Borehole yields 0,5 to 2,0 l/s
Dwyka Group	-	Predominately arenaceous rocks
	-	Fractured aquifers
	-	Borehole yields 0,5 to 2,0 l/s
Waterberg Group	-	Predominantly arenaceous rocks
	-	Fractured aquifers
	-	Borehole yields 0,5 to 2,0 l/s

There are no artesian boreholes located within the study area. No large-scale groundwater abstraction occurs in the study area, even along the numerous faults.

The majority of the study area has electrical conductivity concentrations of between 70 and 300 mS/m. Incidents of groundwater with elevated fluoride concentrations (> 1,5 mg/l F) have been recorded.

6.4.1. Regional groundwater occurrence and aquifers

Based on the geology within the study area, the structural geology, and the geomorphology the following conditions can arise to enhance aquifer development within the study area:

- The fractured transition zone between weathered and fresh bedrock
- Fractures along contact zones between dykes and the host rocks due to heating and cooling of rocks involved with the intrusions
- Contact zones between sedimentary rocks of different types
- Contacts which may be open, enlarged, and loosened by weathering
- Openings on discontinuities formed by fracturing
- Faulting due to tectonic forces
- Stratigraphic unconformities
- Zones of deeper weathering
- Fractures related to tensional and decompressional stresses due to off-loading of overlying material
- Fault zones within the Karoo rocks

The sandstone of the Clarens Formation is characteristically massive and dense and has limited permeability and storage. It thus offers only moderate groundwater yield, especially in the absence of dolerite intrusions. 70% of boreholes drilled into the sandstone have yields < 3 l/s.

The groundwater potential of the fractured transitional zones between weathered and unweathered crystalline Letaba basalt rocks is good. Deeper fractures within the basalt, associated with faulting, have good groundwater potential.

Fractured fault zone, especially if related to tensional stresses, are potentially rich targets for groundwater development. The graben structures are associated with tensional stresses, thus the Eenzaamheid fault could be an area of increased groundwater potential. The Daarby thrust fault is impermeable.

Contacts between different rock lithologies and bedding planes within the sediments often yield groundwater. The contact zone between the basalt and the Clarens Formation sandstone can be high yielding.

Groundwater occurs within the joints, bedding planes, and along dolerite contacts within the Waterberg Group sediments. Groundwater potential is generally low in these rocks, with 87% of borehole yields < 3 l/s.

6.4.2 Hydrogeology of the Preferred Sites

Borehole information derived from the Department of Water Affairs and Forestry's (DWAF) national groundwater database (NGDB) and the monitoring data from the power station and Grootegeluk coal mine allowed for an assessment of the hydrogeology, aquifers, and water levels on each of the preferred sites and neighbouring sites.

Figure 6.7 shows the location of the boreholes. Unfortunately the NGDB borehole co-ordinates are not very accurate, and hence some of the boreholes plot in close proximity to one another. Each borehole record, however, provides individual geological and hydrogeological information.

The borehole information is presented in Table 6.2. Figures 6.8 and 6.9 present the borehole yields and static water level data, respectively.

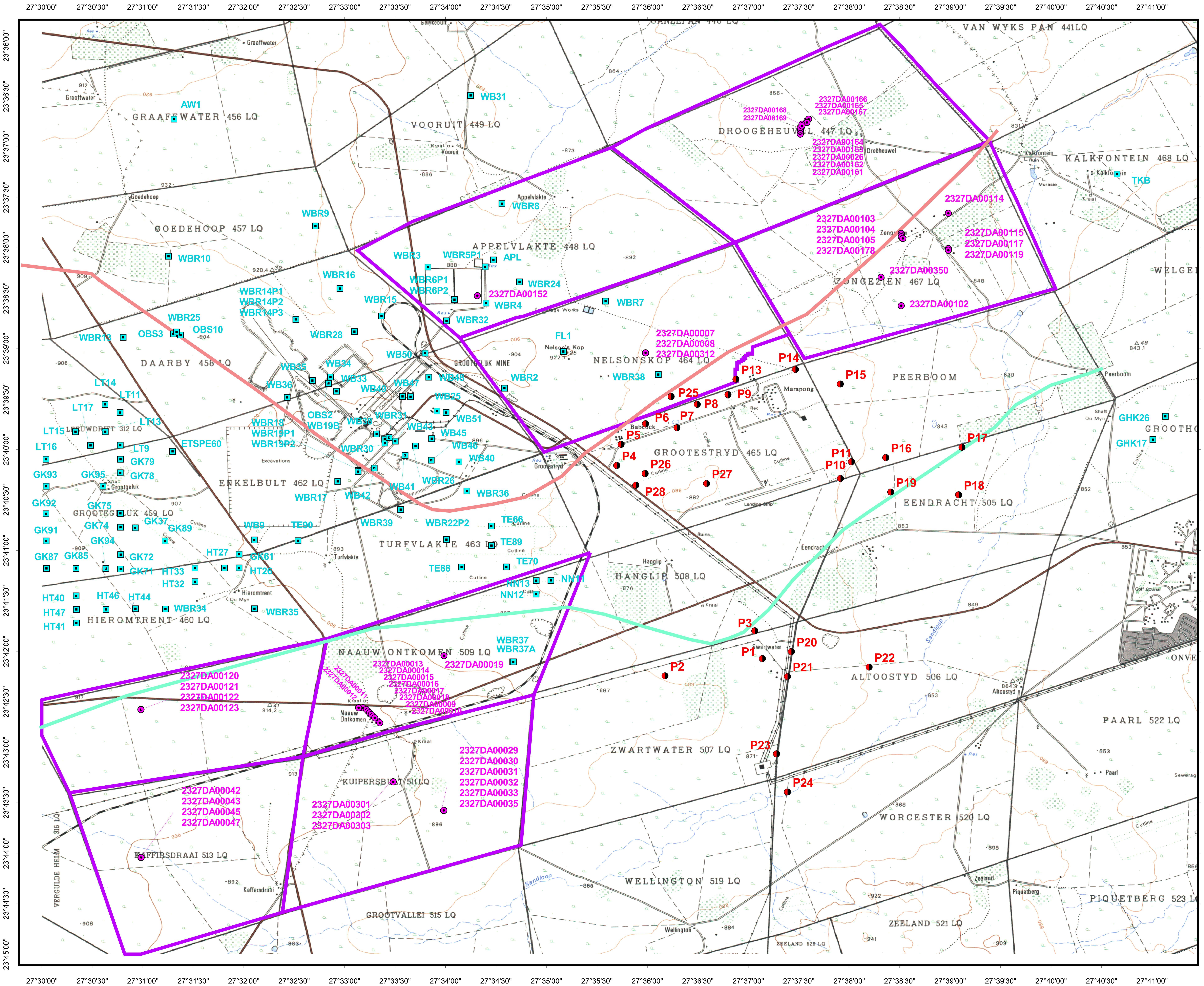
A summary of the borehole (drilling) records is as follows: -

- The majority of boreholes drilled on the candidate sites have very low sustainable yields.
- Only one borehole (41 records) has a yield > 1 l/s. This enhanced groundwater potential is as a result of secondary processes, possibly the faulting recognised on the farm Kuipersbult.
- Borehole depths are very variable. Deep drilling has occurred due to exploration (for coal) rather than for groundwater.

- Groundwater levels are variable due to the different piezometeric pressures associated with the units intersected during drilling
- Groundwater levels do not mimic the topography (which is very flat) as very shallow and very deep groundwater levels have been recorded on site. This is as a result of piezometeric differences, confined aquifers, artificial recharge, and geological structures.
- The average depth to groundwater within the Mogalakwena Formation sandstone is 25,6 m.
- The average depth to groundwater north of the Daarby fault (Clarens Fm) is 16,7 m.

Figure 6.7: All Boreholes

BOREHOLE POSITIONS



LEGEND:

■	Grootegeluk boreholes
●	Matimba boreholes
●	NGDB boreholes on 8 farms

Faults_manual_wgsdd.shp

∼	Daarby
∼	Eenzaamheid
∼	_
▭	Farm boundaries (SG)
Image	Wgs2327da_1981.tif

0.5 0 0.5 1 1.5 2 2.5 Kilometers

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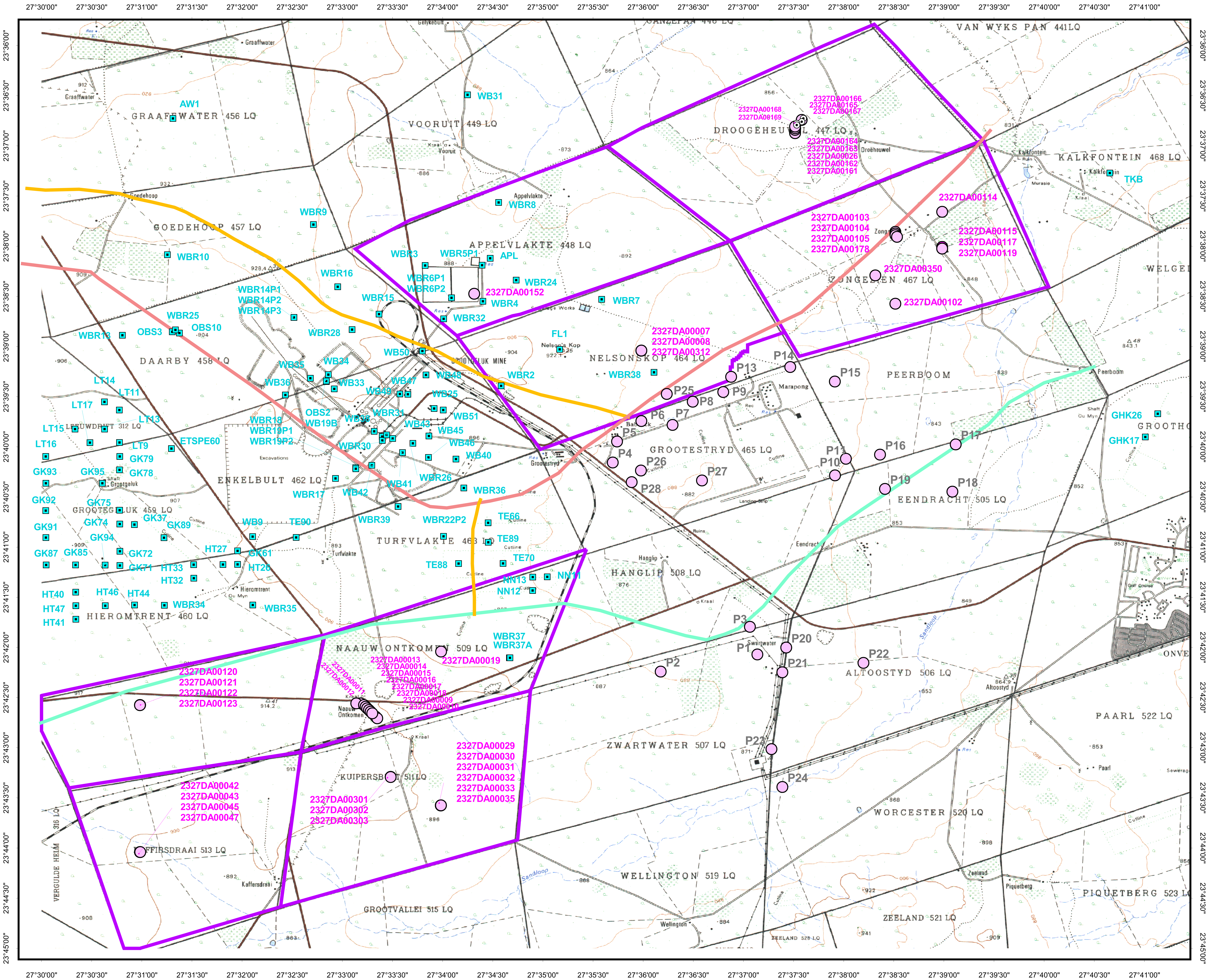
Figure 8

Table 6.2: Borehole information for the preferred and neighbouring sites

Borehole ID	Farm	Depth	Yield	Water level	Comment
2327DA00120	Eenzaamheid (Privately owned)	75 m	0.25 l/s	-	
2327DA00121		154 m	0.03 l/s	112.78 mbgl	
2327DA00122		400 m	0.06 l/s	77.42 mbgl	
2327DA00123		151 m	Dry	-	
2327DA00042	Kromdraai (Privately owned)	7 m	Dry	-	
2327DA00043		82 m	0.02 l/s	35.05 mbgl	
2327DA00045		400 m	0.85 l/s	1.83 mbgl	Confined piezometeric level
2327DA00042		152 m	0.07 l/s	32.92 mbgl	
2327DA00029	Kuipersbult (Privately owned)	153 m	0.01 l/s	22.86 mbgl	
2327DA00030		86 m	0.01 l/s	22.86 mbgl	
2327DA00031		137 m	0.07 l/s	48.77 mbgl	
2327DA00032		121 m	0.33 l/s	22.25 mbgl	
2327DA00033		77 m	0.01 l/s	18.29 mbgl	
2327DA00035		94 m	0.01 l/s	22.86 mbgl	
2327DA00301		79 m	3.2 l/s	-	Fault?
2327DA00302		15 m	0.05 l/s	3.35 mbgl	
2327DA00303		92 m	0.26 l/s	1.83 mbgl	
2327DA00009	Naauwontkomen (Ferroland / Kumba)	7 m	0.06 l/s	1.16 mbgl	
2327DA00010		4 m	0.15 l/s	1.62 mbgl	
2327DA00011		40 m	0.06 l/s	30.48 mbgl	
2327DA00012		34 m	0.63 l/s	21.34 mbgl	
2327DA00013		22 m	0.25 l/s	9.14 mbgl	
2327DA00014		100 m	0.98 l/s	10.36 mbgl	
2327DA00019		32 m	0.25 l/s	13.72 mbgl	
WBR37		-	-	14.2 mbgl	Grootegeluk monitoring hole
WBR37A		-	-	13.37 mbgl	Grootegeluk monitoring hole
NN12		-	-	49.96 mbgl	Grootegeluk monitoring hole

Figure 6.8: Borehole Yields

BOREHOLE YIELDS



LEGEND:

Only 2327DA00301 on Kuipersbult Yield>3 l/s

- Grootegeluk Boreholes
- < 1 l/s (Matimba boreholes)

Ngdb_8farms_boreholes_wgsdd.shp
- No Data
- < 1 l/s
- 1 - 2 l/s
- > 2 l/s

Faults_manual_wgsdd.shp
- Daarby
- Eenzaamheid
- Minor Faults
- Farm boundaries (SG)

0.5 0 0.5 1 1.5 Kilometers

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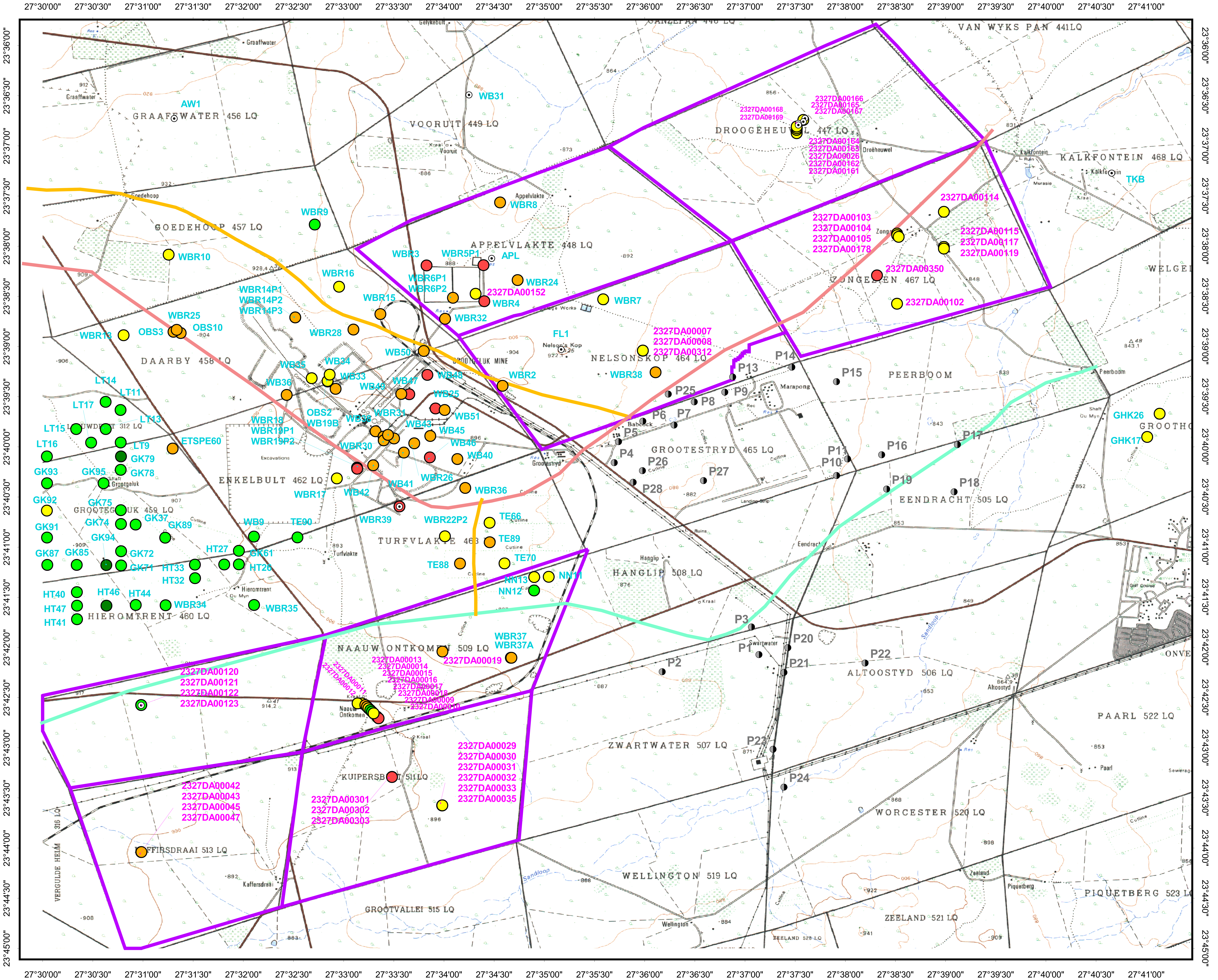
Figure 9

Figure 6.9: Static Water Levels

STATIC WATER LEVELS



LEGEND:

Grootegeluk Boreholes' Waterlevels <= 5m:

SITENAME	ZCOORD	WATERLEVEL	MBGL
WB25	895.30	890.57	4.73
WB46	894.11	890.37	3.74
WB47	896.72	891.91	4.81
WB48	896.02	891.77	4.25
WBR18	892.98	888.46	4.52
WBR19P2	892.90	888.66	4.24
WBR3	893.17	890.17	3.00
WBR39	891.02	886.26	4.76
WBR4	890.44	887.56	2.88
WBR5P1	886.57	884.23	2.34

NGDB Waterlevels <= 5m:

SITE_ID	FARM	ORIG_SITE_	MBGL
2327DA00045	513	KAFFIRSDRAAI PTN. KAFFERSDRAAI	1.83
2327DA00302	511	KUIPERSBULT	3.35
2327DA00303	511	KUIPERSBULT	1.83
2327DA00009	509	NAAUW ONTKOMEN	1.16
2327DA00010	509	NAAUW ONTKOMEN	1.62

Matimba boreholes

Grootgeluk_boreholes_wgsdd.shp
- No Data
- 0 - 5 mbgl
- 5 - 18.9 mbgl
- 18.9 - 35.05 mbgl
- 35.05 - 77.42 mbgl
- 77.42 - 112.78 mbgl

Ngdb_8farms_boreholes_wgsdd.shp
- No Data
- 0 - 5 mbgl
- 5 - 18.9 mbgl
- 18.9 - 35.05 mbgl
- 35.05 - 77.42 mbgl
- 77.42 - 112.78 mbgl

Faults_manual_wgsdd.shp
- Daarby
- Eenzaamheid
- Minor

Farm boundaries (SG)

0.5 0 0.5 1 1.5 Kilometers

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Figure 10

6.4.3. Groundwater use

Limited groundwater abstraction occurs within the study area due to:

- Land use (primarily stock or game watering)
- Reticulated (piped) water is supplied to the area, either via the municipality, Eskom, or Grootegeluk Coal Mine
- Low sustainable borehole yields
- Variable hydrochemistry, high salinity areas
- Little or no domestic groundwater usage due to Mokolo Dam supply to the area

6.4.4. Ambient hydrochemistry

Groundwater quality data from the DWAF's national groundwater database provides an indication of the ambient groundwater quality in the study area. Only four boreholes have been sampled by the DWAF in the area, the sample points are on the farms:

- Nooitgedacht 403 LQ (15 km north of the power station, Clarens Fm sandstone)
- Waterkloof 502 LQ (10 km east of the power station, Swartrant Fm sandstone)
- Ehrenbreitstein 525 LQ (12,5 km southeast of the power station, Mogalakwena Fm sandstone)

Table 6.3 presents the ambient hydro-chemical data recorded in the study area, compared to the SANS:241 standards for drinking water quality.

Table 6.3: Ambient hydrochemistry

Tests	Units	SANS 241[1]	Nooitgedacht	Waterkloof	Waterkloof	Ehrenbreitstein
			14/06/1970	21/08/1970	21/08/1970	26/08/1970
PH	pH units	4 – 10	7.4	7.9	7.4	7.8
Nitrate	mg/l N	20	6.77	< 0.04	< 0.04	< 0.04
Fluoride	mg/l F	1.5	0.1	0.4	-	-
Sodium	mg/l Na	400	*692**	7	7	7
Magnesium	mg/l Mg	100	86	5	5	2
Sulphate	mg/l SO_4	600	*1 920**	< 4	< 4	< 4
Chloride	mg/l Cl	600	*37 630**	11	11	11
Calcium	mg/l Ca	300	*1 080**	14	14	6
EC	mS/m	370	*1 112.2**	13.3	13.3	7.2

* exceeds maximum allowable limits

The limited data indicates that the borehole sampled on the Farm Nooitgedacht, within the Clarens Formation rocks, has elevated concentrations of electrical conductivity, Na, Cl, SO_4, and Ca.

The hydrochemistry associated with the boreholes within the Swartrant and Mogalakwena Formations is good potable groundwater.

Fluoride was not recorded in the sample from the Farm Ehrenbreitstein, which is within the Mogalakwena Formation. These rocks contain elevated concentrations of fluorite (apatite and fluorspar), which can increase the fluoride concentrations within the groundwater.

6.4.5. Aquifer classification

Based on the available hydrogeological data the overall aquifer system within the study area can be classified as a Non-Aquifer System (Parsons, 1995[2]), where: -

- *Non-Aquifer System* occurs where the formations have negligible permeability and are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer as

[1] South African Bureau of Standards specifications for drinking water, maximum allowable limits, SABS 241 5th Edition, 2001
[2] WRC Report No. KV 77/95, A South African Aquifer System Management Classification, R. Parsons December 1995.

unusable. However, groundwater flow through such rocks, although imperceptible, does take place, and needs to be considered when assessing the risks associated with persistent pollutants.

Groundwater potential is enhanced along areas of secondary processes, such as faulting, fracturing, etc. allowing for the development of discrete minor aquifer systems, where: -

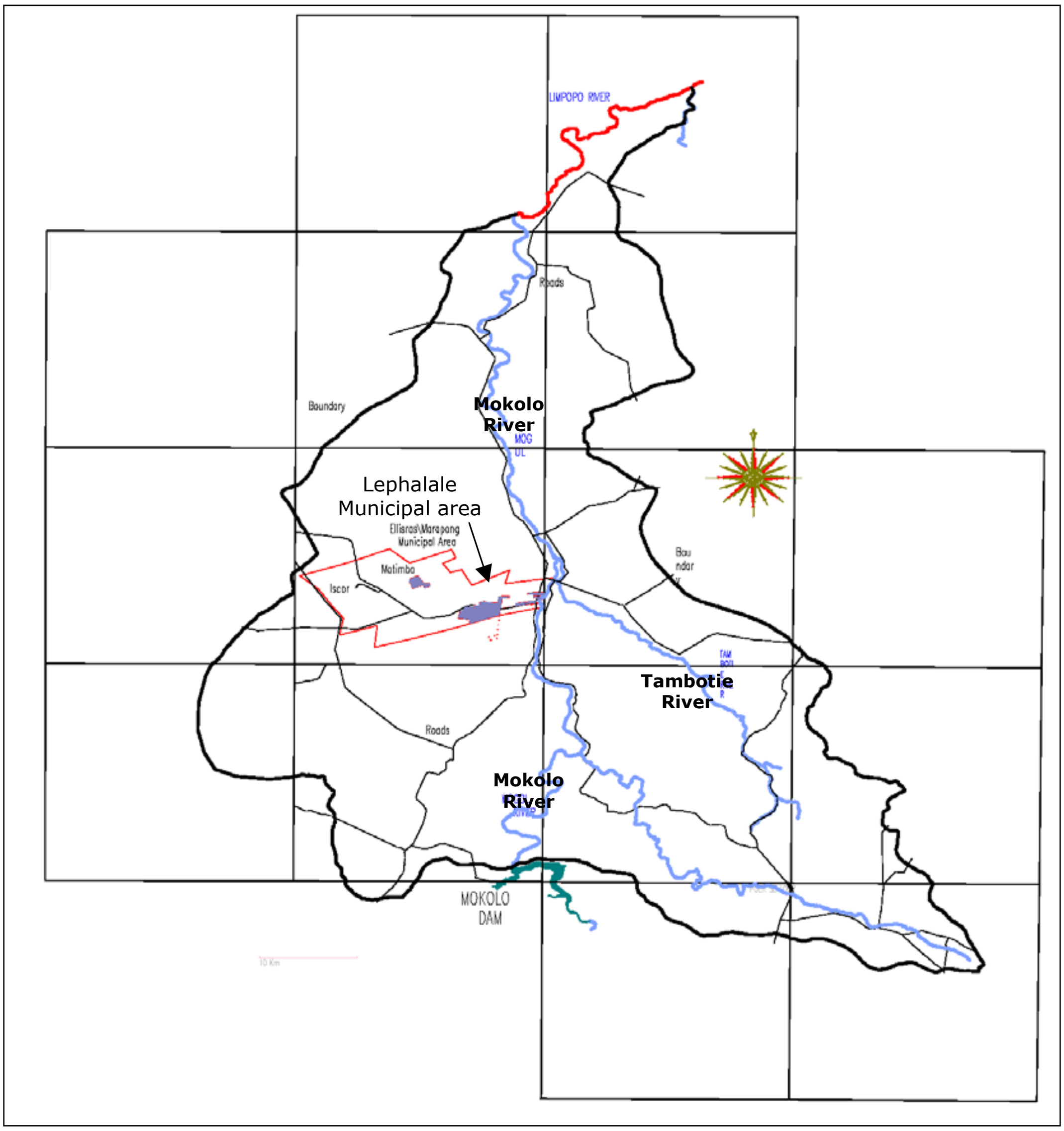
- A *Minor Aquifer System* comprises fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and in supplying base flow for rivers.

Based on the aquifer types present on site and the variable (high salinity) hydrochemistry a rating of the aquifer vulnerability indicates that limited to low levels of groundwater protection are required for these aquifers.

6.5. Surface Water Hydrology

The study area falls within the Mogol River Catchment, which drains into the Limpopo River to the north (Figure 6.10). The catchment covers an area of 8 387 km^2. The catchment stretches from the Waterberg Mountains though the upper reaches of the Sand River, and includes the Mokolo Dam and a number of small tributaries that join the main Mokolo River up to its confluence with the Limpopo River. The topography of the area is flat, varying between 900 and 922 m amsl[3]. The general topographical drainage system is poorly developed and drains in an easterly direction towards the Mogol River (810 m amsl), (Figure 6.11).

[3] The Nelson's kop is a prominent landmark at 922 m amsl; this hill is an inselberg (erosional relic) of the Clarens Formation sandstone.



The Mogol River Catchment	GCS GROUNDWATER CONSULTING SERVICES WATER, ENVIRONMENTAL & EARTH SCIENCE CONSULTANTS P.O. Box 2597 Rivonia 2128 Tel.: (011) -5726 Fax.: (011) 803745 jhb@gcsa.biz	Figure No: 11 Scale: As shown Project No: 2004.11.535

Figure 6.10: The Mogol River Catchment

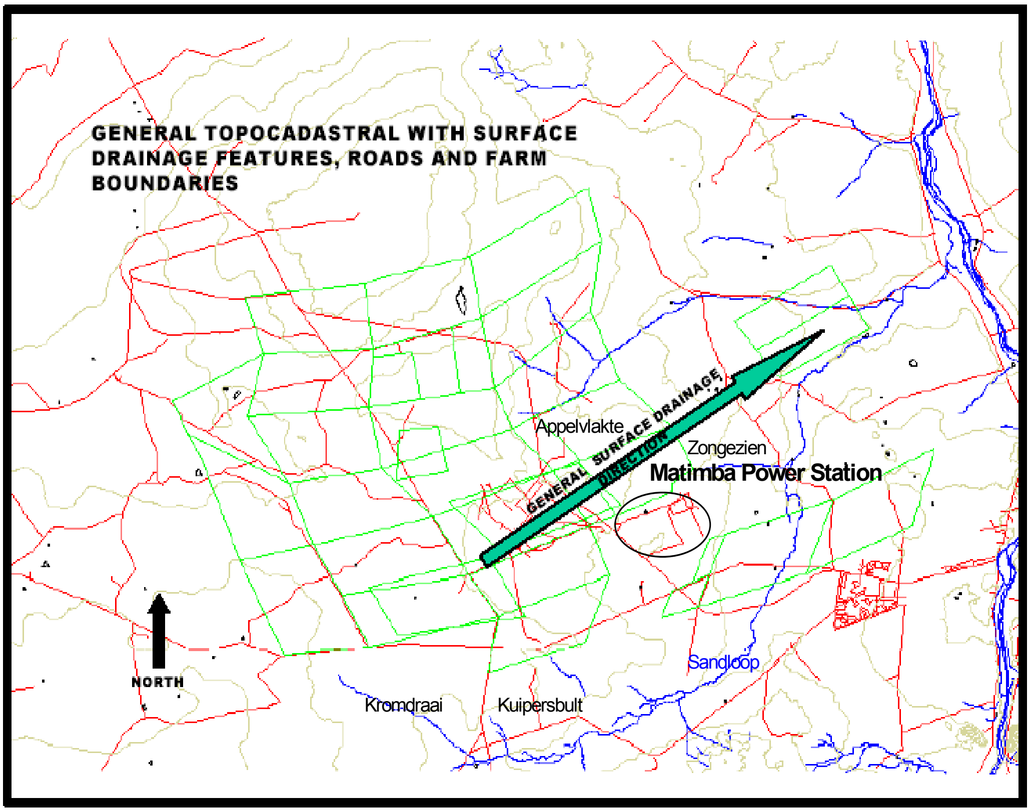


Figure 6.11: Surface drainage within the study area.

The drainage consists primarily of dry sandy gullies, such as the "Sandloop", located to the south and east of the existing Matimba Power Station.

The only recognisable drainage channels in the study area occur along the northern boundary of the farm Appelvlakte 448 LQ, through the center of Kromdraai 513 LQ, through the south of Zongezien 467 LQ, and through the northeastern section of Kuipersbult 511 LQ (refer to Figure 6.7).

The surface water drainage system is poorly developed due to:

- The flat topography (Power Station 880 mamsl to Mogol River 810 mamsl is 70 m over 15 000 m, gradient = 1:214)
- The sandy soil veneer, 1 m – 3 m of high permeable soil cover
- Low annual rainfall, 435 mm per annum (Weather Bureau, 29 year record 1961 – 1990)

Due to the absence of any well-defined or perennial surface water drainage courses within the study area, it is anticipated that the proposed power station and infrastructure will not have a direct impact, in terms of quantity (run off) or quality, on the surface water.

Currently, water use in the catchment broadly comprises (DWAF, 2005):

- 87% for agricultural activities.
- 13% for the industrial, mining, power generation and domestic water supply service sectors (municipalities).

According to the Internal Strategic Perspective (Report WMA 01/000/00/0304 available at www.dwaf.gov.za) presently, water availability and water use in the catchment are in balance. However, within the provisions of the National Water Act (Act 36 of 1998) as stipulated in the National Water Resources Strategy, there is a need to meet the water requirements of the Reserve (Basic Human needs and Ecological requirements) in terms of both water quantity and quality. When this requirement is determined and imposed on the current water supply system, presently there would be insufficient water to maintain the required balance. The area has been earmarked as a growth node by the provincial government and plans are in place to increase the water resource to assist with development in the area (Limpopo Province Development Blueprint Vision 2020). It is anticipated that water demand will increase with new developments proposed in the Mokolo Catchment, such as new or expanded mining activities, new power stations and other developments. Refer to Appendix J for a graphical interpretation of the above paragraph.

The supply of additional water from the already stressed catchment is likely to have an impact on the downstream surface water users.

6.5.1. Current surface water supply

Matimba Power Station currently receives its water from the Mokolo dam on the Mogol River (Figure 6.10). Apart from supplying the Matimba Power Station, the Mokolo dam also supplies the Grootegeluk Coal Mine, Lephalale town, and various settlements and farmers in the area.

The Mokolo River drains the southwestern part of the Limpopo Water Management Area and has various tributaries. Of these tributaries, the Sand River and the Grootspruit, originate in the Waterberg mountain range and flow into the Mokolo River upstream of the Mokolo Dam. Other tributaries are the Tambotie River, Poer se Loop, and the Rietspruit River that join the Mokolo River downstream of the Mokolo Dam. The altitude varies from 1 700 m from the origin to 790 m at the confluence of the Mogol River with the Limpopo River.

The availability of the surface water resulted in extensive irrigation development. This development has been enhanced by the construction of Mokolo Dam, which was developed mainly to support mining and power generation development. The associated infrastructure development was undertaken by Kumba Resources and Eskom.

- The Mokolo Dam forms part of a Regional Water Supply Scheme supplying drinking water to Lephalale and irrigation water along the Mokolo River. The Mokolo Regional Water Supply Scheme comprises of the Mokolo Dam (gross capacity 146 million m^3, firm yield 27,1 million m^3/a at 99,5% assurance level) located in the middle reaches of the Mokolo River. The storage capacity of the Mokolo Dam is significantly less than the mean annual run-off in the Mokolo River, 240,4 x 10^6 m^3/year.

The dam was constructed to assure water supply to the Matimba Power Station (allocation 6.5 million m^3/a), Grootegeluk coal mine (allocation 5.6 million m^3/a), Lephalale and adjacent urban water users (allocation 3.9 million m^3/a) and irrigation of an area of 2 000 ha (allocation 10,4 million m^3/a, at a lower level of assurance).

Raw water is drawn from the dam and pumped through a 700 mm diameter steel pipeline to Lephalale via a balancing dam at Wolwefontein, some 40 km from Mokolo Dam. Part of the water is treated in a 17 Ml/d raw water treatment works before being delivered through a 450 mm diameter pipeline to Lephalale.

Raw water is drawn from the balancing dam and delivered to Grootegeluk mine and Matimba Power Station. Eskom treats water for own use and also delivers potable water to the adjacent village of Marapong.

Irrigation water is released from Mokolo Dam into the Mokolo River where it is abstracted by riparian irrigators as required.

Based on discussions with the Department of Water Affairs and Forestry (DWAF, *pers comm.*) regarding the allocation of water from the Mokolo Dam, the current allocation is as follows:

- Mokolo Irrigation Board Allocation 10,4 million m^3/annum
- Kumba Resources Coal Mine Allocation 17,2 million m^3/annum. From this allocation, Kumba supplies water to a number of users, including Lephalale Municipality, Marapong and 6.5 million m^3/annum for Eskom Matimba

These volumes differ slightly from the Mokolo Regional Water Supply Scheme. Although the water system is in balance, DWAF indicated that the current system was already stressed due to the fact that there are no additional volumes of water from the Mokolo Dam that could be allocated for use.

- *Power station water use (based on current Matimba Power Station)*
  Water consumption at the dry cooled power station is in the order of 0,1 to 0,2 l/kWh (litres per unit of electricity produced). The average water use is 0,12 l/kWh sent out. The power station is capable of generating 3 990 MWh with an Energy Availability Factor (EAF) of 94%[4]. The current water use at Matimba Power Station is 3,3 million m^3/annum of a possible allocation of 6.5 million m^3/annum. (*pers comm* Heine Hoffman Eskom, 2005). Although Matimba Power Station has not used the remainder of its allocation DWAF is currently unable to assure that is available. DWAF is currently undertaking a validation and verification study in conjunction with a hydrology study to ascertain the legal status of all water uses and the current yield of the water supply system.

  The power station requires an assured reliable water source in order to generate sufficient energy to meet its demands. The DWAF provides the water at an assurance of 99,5% i.e. the probability of system failure occurring only once in 200 years. Eskom has made a provisional water use licence application to DWAF for the abstraction of 6 Mm3/annum for the first phase and the possible increase to 12 Mm3/annum for a six unit 4800 MW dry cooled power station.

- *Current surface water demand and future capacity*
  At present the only source of water to the existing power station is the Mokolo Dam. Should an additional power station be built, then the demand on the dam will be increased and DWAF will be required to provide an assured water supply. Figure 6.12 illustrates the percentage storage within the dam. Current levels within the dam (May 2005) are at 89%. The storage within the dam dropped to 60% of full storage capacity during March 2004. The Mokolo Dam forms part of the quotas from Government Water Schemes in accordance with Section 56 of the Water Act, 1956 and specific allocations have been made to household and stock watering (quota 0,057 x 10^6 m^3/a) as well as the municipality (quota 0,465 x 10^6 m^3/a). The potential surface water resources within this area are nearly fully developed (the scheme is stressed) with major dams and a host of smaller dams existing in the area. Only the upper Lephalala River and Mokolo River have significant potential for surface water development in terms of the physical requirements for surface water storage infrastructure.

[4] The power station produces full capacity 94% of the time.

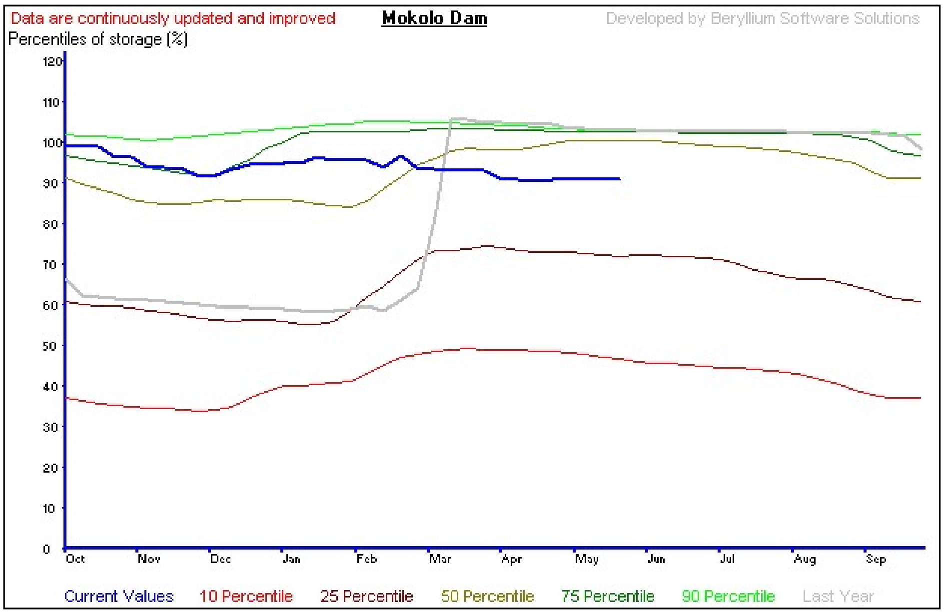


Figure 6.12: Mokolo Dam storage volumes

Table 6.4: Mokolo Dam specifications and water use allocations

Mokolo Dam	Quaternary catchment	Gross capacity	MAR	Required yield	Firm yield	Households	Irrigation	Matimba	Kumba
		$10^6 m^3$	$10^6 m^3/a$						
Allocation	A42F	146.0	240.4	28.6	27.1	1.0	10.4	7.3	9.9
Quota						0.522	-	-	-

6.5.2. DWAF studies

- *Background*

  The Department of Water Affairs and Forestry (DWAF) initiated a stakeholder consultation process in the Lephalale area in December 2003 to discuss future developments that were anticipated and the concomitant water requirements. At this time, the inflow to the Mokolo Dam was low and fears developed that the dam would not be able to yield enough water in the event of moving into a period of prolonged low rainfall. This led to DWAF identifying a series of planning studies that would culminate in defining the water use and the availability of water. These studies are as follows:

  Validation and Verification study:

  This is to verify the water use of each water user and then validate the information. Satellite images, aerial photographs and registered water use information will be used to determine actual water use. This study will validate how much water is currently being used by the different use sectors and verify the lawfulness of the water users and determine the existing lawful water use. This information will assist DWAF with the evaluation and issuing of licences as the current allocations that have been granted under the old Water Act are still valid.

Progress:

* A rapid assessment model was used to look at the water registration. The results were made available for public comment in January 2006.
* The validation process will be completed at the end of March 2006.
* The verification process will follow the validation process and it will not affect the progress of other parallel studies because it is mostly a legal process.
* Focus group meetings have been held for different categories of water users (Irrigation farmers, Local Municipalities, etc). Two public meetings have taken place to promote access to information and transparency. This allows the project to be open to public scrutiny.
* This study is expected to be completed in May 2006.

Hydrology Study:

This investigation is aimed at providing DWAF with an updated understanding of how much water (yield) is presently available in the catchment. This work will be based on the analysis of historical rainfall patterns, streamflow, ground and surface water resources. The study will also analyse the performance of the Mokolo Dam under different water abstraction scenarios. This study will provide valuable information to the validation and verification study on existing lawful water uses and the potential of the catchment to support new developments and new water uses.

Progress:

* The collection and analysis of the rainfall data is complete. Where rainfall information was not available, patching was applied during the analysis of data.
* The stream flow data analysis is in progress and patching will also take place in the task.
* The WRSM2000 needs to be calibrated for both the rainfall and stream flow data. Simulation of flows and testing of scenarios will follow this process.
* Diagrams will be developed for the stream flow for each of the quaternary catchments.
* The study program is on schedule and will be completed by December 2006.

Water Conservation and Water Demand Management Study:

Water conservation means "minimising water losses and/or wastage and the use of water in an efficient and effective way". Water Demand Management is the adoption and implementation of action plans to influence the demand for, and use of water by consumers. While it is recognised that some sectors in the Mokolo River Catchment are already practicing Water Conservation and Water Demand Management, additional efforts are required to realise additional water conservation and efficient use of this valuable resource. The outcomes of this study will feed into the updated hydrology and systems models (reduced demand) as well as into validation and verification (via improved efficiencies). This is a study to assess the potential to implement further water conservation and water demand management initiatives in the area. This study will be completed by end of March 2006.

Pre-feasibility and Feasibility Studies:
This study will determine the feasibility of raising the Mokolo Dam Wall and/or transfer of water from the Crocodile (West) catchments. The pre-feasibility for an augmentation option was identified prior to Eskom's intent of developing the new power station due to the requirements of the catchment. (DWAF, 2005). As a pre-emptive measure DWAF motivated by Eskom's future capacity expansion plan in the Mokolo catchment initiated a reconnaissance study to evaluate the options with regard to abstraction and pipeline routes for a water transfer scheme from the Crocodile West to Mokolo Catchment. The purpose of this study is to identify and estimate the cost for various options for transfer pipeline routes from the Crocodile West/Marico WMA to the balancing dams at the end of the existing rising main from Mokolo Dam (Limpopo WMA). The study has been undertaken at a reconnaissance level of detail and is expected to be completed in March 2006

A public participation process for these studies was held on 19, 20, 21 July 2005 and was well received (refer to Appendix Ma). This served as a pre-cursor for future Environmental Impact Assessments that may arise as a result of the outcome of these studies. DWAF will continue this public consultation as the studies progress.

Eskom was part of the initial stakeholder consultation process, and have submitted preliminary water use figures to DWAF, which included water use for a second dry cooled power station in the future. Following the completion of the pre-feasibility phase of proposed new power station in early 2005, Eskom engaged DWAF in bi-lateral discussions regarding future development and water requirements in the Lephalale region. The discussions have covered the following issues, and proceed on a monthly basis:

* Information sharing regarding the progress of each party – DWAF with regards to the water studies and future water supply development and Eskom in terms of future generation expansion and water requirements.
* Establishing a memorandum of agreement/understanding to enable future co-operation with regards to resource sharing and funding requirements

* Undertakings required for achieving milestones in future planning e.g. fast-tracking completion dates for studies.

6.5.3. Possible water augmentation sources

The estimated water requirement for the proposed power station is 4 – 6 million cubic meter of water for the first 2400MW installed then ramping up to 8 to 12 million cubic metres of water for a 4800 MW power station.

The current water supply systems and possible future augmentation of this area is represented in Fig 5.6.4. In order to augment the current volumes of water available in the catchment, the following water supply schemes are being considered:

- *Option 1: Augmentation from Crocodile West/Marico Catchment*

  This entails the supply of 45 million m^3/annum from the Crocodile (West) and Marico catchment to the Lephalale area in the Limpopo Catchment. A detailed study has been conducted in the Crocodile (West) and Marico catchment, which makes provision for 45 million m^3/annum of water to be made available to the Limpopo catchment via an inter-basin transfer. **Both the Internal Strategic Perspective of the Crocodile West/Marico (ref: WMA03/ 000/00/0303; S5.4 available on www.dwaf.gov.za) (the executive summary is included in Appendix M b) and the National Water Resource Strategy (available on www.dwaf.gov.za) earmarks this 45 million m^3/annum for the possible development of a new power station in the Limpopo Water Management Area. In addition to this, the Crocodile (West) River Return Flow Study (PWMA 03/000/00/0604) indicates that there was a return flow of 359 million m^3/a estimated for the year 2001 from both the urban and irrigation sectors, to the catchment. (please refer to Appendix M c for an executive summary of this report).**

  In the event that the augmentation scheme from the Crocodile West and Marico Catchment area is implemented, the inter basin transfer would terminate at the Wolwefontein Balancing Reservoirs. This is however still subject to further DWAF feasibility studies, which could indicate an end-point of the new pipeline closer to the end-user sites. If necessary, existing water supply infrastructure would then need to be further upgraded.

- *Option 2: Raising the Mokolo Dam Wall*

  DWAF have investigated the possible raising of the Mokolo Dam wall. The design and construction of the dam is such that it is possible to raise the wall to provide additional storage capacity. The dam wall may be raised by some 15 m to have an ultimate storage capacity of about 303 x 10^6 m^3. The possibility of raising the dam wall will depend largely on the results obtained from the validation and verification and the hydrology and yield analysis studies. In order to supply additional water from the Mokolo Dam, the existing infrastructure would need to be upgraded.

The Mokolo River is a tributary of the Limpopo River, which is an international shared watercourse. In order to raise the dam wall, approval from the Limpopo co-basin states such as Botswana, Zimababwe and Mocambique is required. These international basin sharing agreements tend to be long and time consuming.

Depending on the outcome of the hydrology studies, raising the dam wall may not be the optimum solution to augment the water supply system for the future needs of the Lephalale area. For Eskom, this option is also not strategically optimal since it increases Eskom's risk due to the resultant dependency of two power stations on a single water source (Mokolo Dam).

- *Option 3: Development of Borehole fields*

  Borehole fields with a capacity of 30,7 x 10^6 m^3/year could be developed in the Mokolo River catchment.

6.5.4. Water Supply to the Proposed Power Station from current water infrastructure

From the existing Matimba Power Station a water supply pipeline would need to be constructed to the proposed power station site. This pipeline could use the existing ash conveyor servitude southwards towards the ash dump on the farm Zwartwater. At the point where the Steenbokpan crosses the ash conveyor servitude, it is proposed that the pipeline turns westwards following the Steenbokpan road to the proposed new power station on the farm Naauwontkomen. A new servitude (approximately 2.5 kilometres long and 20 meters wide) would have to be obtained for this purpose. The proposed Eskom water Supply System is illustrated in Figure 6.13.

In light of the future water developmental needs for the Lephalale area, option one provides a practical solution as an augmentation option as this would provide access to water without the need for a lengthy international treaty and provide water from a different water management area thus reducing risk of non-supply. Consideration should be given to the various water uses at the proposed power station, and synergistic water uses between the mine(s) and the power stations could be considered.

6.6. Existing Matimba Power Station

In order to determine the possible impacts the proposed new power station will have on the water resources, an assessment of the existing Matimba Power Station has been compiled.

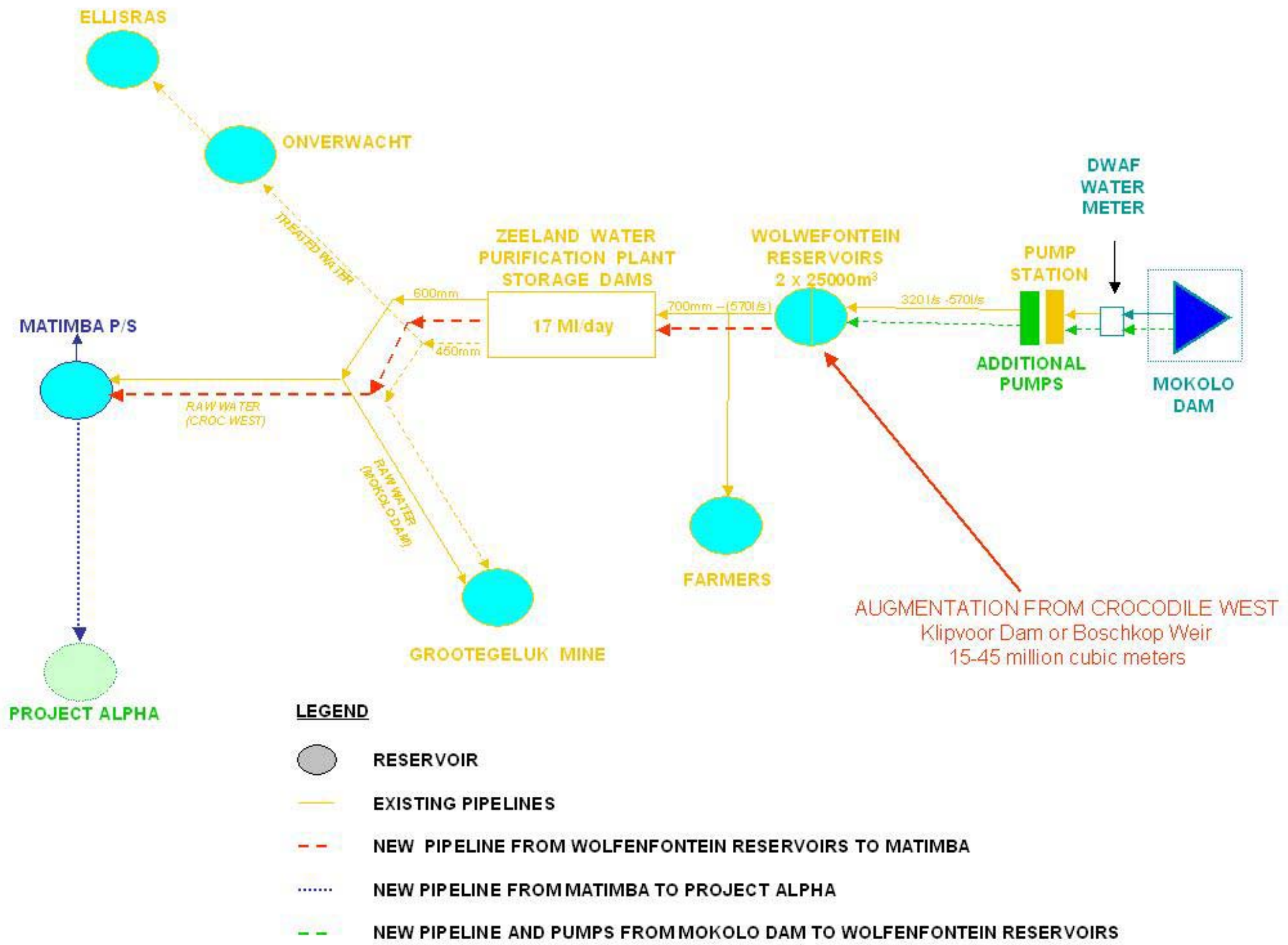


Figure 6.13: The proposed Eskom water Supply System

6.6.1. Power station infrastructure

The possible sources of contamination or infrastructure that may impact on the groundwater or surface water are:

The coal stockpiles	Potential acid generation area
The raw water dam	Source of artificial recharge to the groundwater
The sewage plant and dams	Irrigation of effluent may impact on groundwater
Treated (de-ionized) water system	Brine added to fly ash for deposition on ash dump
Evaporation dams (x2)	Source of "poor" quality artificial recharge
Recovery (dirty water) dams (x4)	Overflow and irrigation may impact on groundwater
Bunker fuel oil	Oil enters water and requires treatment
Ash dump	Source of "poor" quality artificial recharge
Ash dump toe dam	Source of artificial recharge
Solid waste site	Source of leachate or poor quality water

6.6.2. Power station geology and hydrogeology

Swartrant Formation sediments, comprising sandstone, gritstone, mudstone, and coal underlie the power station and all its facilities, except the ash dump. A thin layer of soil followed by weathered sediments overlies these rocks. Weathering occurs to a depth of 15 to 25 m and is permeable to water movement. Below the weathered zone is an impermeable layer of black shale.

Contaminants from surface will penetrate the weathered and fractured sediments. Lateral deflection of contaminant migration takes place along the top of the shale.

The ash dump is underlain by Waterberg Group sandstone, which has recrystallised and fully oxidised. Approximately 3 m of permeable sandy soil covers ± 4 m of weathered sandstone. Red hard competent sandstone is intersected below the shallow weathering.

The majority of the 26 monitoring boreholes (Figure 6.8 labeled P1 to P28) drilled and constructed at the power station and the ash dump were dry. Blow-out yields in the successful boreholes did not exceed 500 l/hr. Water strikes in the Karoo sediments ranged from 11 to 29 m, and the water strikes in the Waterberg Group ranged from 14 to 39 m.

These sediments are recognised to be poor aquifers with water moving through the rocks at very low rates. These rates are very low due to the low permeabilities of the rocks and the very low regional groundwater gradients. The groundwater gradients, which mimic the surface water gradients, are to the east at an average gradient of 1:250.

6.6.3. Power station monitoring

Eleven monitoring boreholes have been monitored at Matimba Power Station since 1987. The monitoring shows some degree of groundwater quality deterioration with time. In 2004, an additional 15 new monitoring boreholes were drilled and constructed to further assess the pollution plumes.

- *Water level monitoring*

  Groundwater level depths, before the establishment of the power station, were in the range of 15 m to 20 m below surface.

  The power station infrastructure, including run-off dams, dirty water dams, coal stockpile, the ash dump and toe dam, provided areas of artificial recharge. The water levels on site have risen by more than 10 m in certain areas due to the seepage into the ground. Groundwater contamination can occur as a result of poor quality water recharging the underlying aquifers.

  An examination of water level monitoring data from the Grootegeluk Coal Mine indicates the same rise in groundwater levels to the north of the Daarby fault as a result of the slimes dams in the area (on the Farm Appelvlakte).

  Examination of the rise in groundwater levels and the hydraulic response of the aquifer in areas away from the artificial recharge points, known as the equalisation reaction, provide an indication of the hydraulic characteristics of the aquifer. The localised nature of the groundwater mounds around the recharge points and the limited zone of influence suggests low regional permeabilities within the Karoo and Waterberg sediments.

  The groundwater level data indicates interconnectivity between the power station water infrastructure and the aquifers over a relatively small area, and that groundwater contamination could occur but would migrate at a very slow rate. Pollution plume modelling, conducted by the Institute for Groundwater Studies (IGS) from the University of the Free State, indicate that the rate of plume migration is retarded, due to indirect flow paths along fractures and cracks in the rock and because of chemical reactions and ionic bonding.

  Groundwater level monitoring generally indicates that deeper water levels are recorded away from the power station and infrastructure. It is concluded that the hydraulic response due to artificial recharge is localised.

- *Hydrochemistry*

  After 17 years of groundwater monitoring by Eskom, most of the 11 original monitoring boreholes have shown some degree of groundwater quality deterioration. Based on these data pollution plume(s) modelling was conducted and predictions regarding migration were made.

Based on DWAF requirements, an additional 15 monitoring boreholes were drilled and constructed to further assess the pollution plumes.

The new monitoring boreholes were drilled to a depth of 40 m and geological records indicate that the strata at 40 m were impermeable.

Down-the-hole hydrochemical logs were recorded for each of the new boreholes. Variations in vertical hydrochemistry were recorded. The variations are as a result of the sediments naturally containing salts, which is a result of:

* The drilling has exposed the impermeable shale to water, which allows for the release of salts into the groundwater (natural pollution of the borehole)
* Natural salinities in the groundwater are high due to the dry climate. Long residence time of the groundwater would allow for high concentrations of almost all macro constituents to occur.

Based on the vertical stratification within the monitoring boreholes and the recognised protocol to stratified sampling (DWAF), all 26 monitoring boreholes were sampled in January 2004. The sampling and data analysis was undertaken by IGS.

Table 6.5 presents the current hydrochemistry within the monitoring boreholes at the power station.

The groundwater monitoring and pollution plume mapping conducted by IGS indicates the following:

* Borehole P1 located on the northeast edge of the ash dump is the only monitoring point to have low pH and elevated sulphate concentrations with time (possible AMD[5]). According to IGS, this is a local phenomenon that cannot currently be explained.
* Groundwater within boreholes P2 to P11 indicates some degree of groundwater quality deterioration. The rise in the salt content of the groundwater is due to seepage from surface sources and also because of the dissolution of salt from the previously unsaturated impermeable zone. The increase in salinity is, therefore, a combination of artificial recharge of

[5] Acid mine drainage – low pH and elevated sulphate concentrations in groundwater due to the oxidisation of sulphides

poor quality (saline) surface water sources and the mobilisation of salts in the exposed impermeable zones in the boreholes.

* A contaminant plume has been identified associated with the ash dump, boreholes P2, P3, P20, P21, P23, and P24. The plume is recognized to migrate to the northeast. P22 located down gradient of the ash dump and plume has not yet been impacted on. Plume migration predictions indicate it will take between 50 and 100 years to alter the hydrochemistry in borehole P22 (IGS, 2004).
* P12 is lost as it was drilled into a fault and collapsed.
* P13, P14, P15, and P25 have been drilled to cover the coal stockyard and associated dirty water dams. Water levels in these holes are shallower than 10 m, suggesting the hydraulic response from water in these areas has already resonated through these boreholes. Due to the naturally elevated salinity within the groundwater, there is insufficient information to determine whether or not pollution has migrated through any of these sites (IGS, 2004).
* P16, P17, P18, and P19 were constructed down gradient of the surface water run-off dams[6]. Shallow groundwater in P16 indicates possible seepage or leaks from the dams. A contamination plume has been recognised and modelled migrating east / southeast from these dams.
* Borehole P18 is down gradient of the surface water run-off dams. The groundwater within this borehole, drilled into a zone of deeper weathering (38 m), has elevated concentrations of most macros constituents. These concentrations are significantly higher than the regional background values. Additional information is required to determine the source of the salinity.
* Boreholes P26, P27, and P28 were constructed within the power station security fence to monitor possible sources of surface contamination from the solid waste area and the coal stockyard. Borehole P26, located closest to these areas, has the highest salinity. Additional monitoring (quality) data is required to determine whether the salinity originates from pollution sources or it is natural.

The borehole positions, P1 to P28, are presented on Figure 6.7.

[6] Clay and concrete lined recovery dams and canals, complete with oil traps and separators. Used as a source of irrigation water

Table 6.5: Chemistry results for the Matimba power station monitoring holes (January 2004)

Elements	P1	P2	P3	P4	P5	P6	P7	P9	P10	P11	P13	P13	P14	P14
Depth (m)	10	30	13	14	15	13	13	9	6	6	10	29	10	33
pH	3.56	6.77	6.96	6.24	7.18	7.61	7.21	7.83	6.84	6.63	7.25	7.42	7.17	7.32
EC (mS/m)	270	380	97	153	68	345	293	169	67	81	184	192	147	144
Al (mg/l)	33.941	0.035	0.053	0.178	0.111	0.039	0.049	0.055	0.04	0.086	0.039	0.03	0.048	0.135
B (mg/l)	12.197	2.806	0.233	0.247	0.193	0.511	0.303	0.192	0.115	0.126	0.285	0.293	0.2	0.186
Ba (mg/l)	0.065	0.163	0.072	0.086	0.538	0.138	0.174	0.107	0.141	0.175	0.188	0.115	0.132	0.132
Be (mg/l)	0.005	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Br (mg/l)	0.54	0.67	0.13	2.71	0.32	2.83	2.5	0.2	0.45	0.19	0.95	1.03	0.8	0.8
Ca (mg/l)	250	142	43	33	44	90	56	48	26	33	97	104	28	28
Cd (mg/l)	0.003	0.005	0.003	0.003	0.002	0.005	0.004	0.001	0.001	<0.001	0.001	0.001	0.002	0.002
Cl (mg/l)	33	945	21	356	72	645	427	49	109	31	153	171	274	255
Co (mg/l)	0.059	<0.005	<0.005	<0.005	<0.005	<0.005	0.009	<0.005	<0.005	0.015	<0.005	<0.005	<0.005	<0.005
Cr (mg/l)	0.026	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cu (mg/l)	0.091	0.115	0.121	0.112	0.107	0.108	0.106	0.101	0.099	0.104	0.107	0.106	0.1	0.098
F (mg/l)	1.21	1.44	0.73	0.26	0.28	1.97	1.44	5.56	0.16	0.67	0.28	0.15	0.86	0.87
Fe (mg/l)	0.224	0.084	4.532	5.664	1.576	0.136	1.446	1.097	0.638	10.933	2.427	1.75	0.098	0.778
K (mg/l)	60.6	41	11.4	4.1	0.5	3.1	12.5	1.6	1.7	2.7	12.4	13.6	1.6	1.7
Li (mg/l)	0.021	0.086	0.015	0.131	0.009	0.028	0.319	0.026	0.016	0.001	0.19	0.212	0.031	0.034
Mg (mg/l)	83	114	31	31	26	146	51	72	15	17	56	57	23	24
Mn (mg/l)	1.431	0.577	0.577	0.122	0.082	0.015	0.462	0.272	0.186	1.164	0.218	0.184	0.118	0.131
Mo (mg/l)	<0.003	<0.003	<0.003	0.006	<0.003	0.020	0.012	0.01	0.007	<0.003	0.005	<0.003	0.012	0.012
Na (mg/l)	219	456	109	237	69	458	550	244	96	119	257	278	252	243
Ni (mg/l)	0.157	0.016	0.01	0.011	<0.01	<0.01	0.01	<0.01	<0.01	0.015	<0.01	<0.01	0.01	0.013
NO_2 (as N)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NO_3 (as N)	7.52	26.25	0.04	0.09	11.84	28.65	<0.045	<0.045	0.22	0.15	0.06	<0.045	6.16	4.89
Pb (mg/l)	0.05	<0.015	<0.015	0.023	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	0.023
PO_4 (mg/l)	0.21	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.7	0.68
Se (mg/l)	0.086	0.009	<0.006	<0.006	<0.006	0.006	0.007	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
SO_4 (mg/l)	1371	310	346	64	6	284	169	520	14	210	93	103	28	27
Sr (mg/l)	1.76	1.419	0.392	0.292	0.392	1.209	0.675	0.652	0.21	0.192	0.846	0.879	0.245	0.246
V (mg/l)	<0.01	<0.01	<0.01	<0.01	0.022	0.053	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.013	0.013
Zn (mg/l)	0.113	0.075	0.077	0.469	0.08	0.06	0.075	0.061	0.073	0.072	0.069	0.063	0.066	0.112

Red values exceed the SABS 241 maximum allowable limits for Drinking Water (SABS, 2001)

Table 6.5 cont.: Chemistry results for the Matimba power station monitoring holes (January 2004) (Page 2)

Elements	P15	P15	P16	P16	P17	P17	P18	P18	P19	P20	P20	P21	P21	P22
Depth (m)	10	29	10	24	27.5	37	39	31	33	18	33	30	15	39.5
pH	6.76	6.94	7.14	7.3	7.53	7.66	6.76	6.67	7.43	7.12	7.83	6.34	6.41	6.39
EC (mS/m)	79	88	106	109	135	200	917	911	115	48	43	158	159	448
Al (mg/l)	0.062	0.055	0.052	0.063	0.071	0.072	0.302	0.046	0.042	0.077	0.061	0.12	0.174	0.048
B (mg/l)	0.152	0.177	0.211	0.227	0.301	0.348	0.384	0.38	0.223	0.199	0.169	6.428	6.399	0.504
Ba (mg/l)	0.194	0.22	0.211	0.416	0.152	0.098	0.085	0.115	0.247	0.059	0.068	0.062	0.067	0.436
Be (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Br (mg/l)	0.55	0.82	0.72	0.9	0.24	1.21	8.56	8.2	0.82	0.49	0.43	1.16	1.19	6.04
Ca (mg/l)	31	39	31	40	48	28	951	955	51	29	25	141	142	301
Cd (mg/l)	0.001	<0.001	0.001	0.001	0.001	0.002	0.004	0.006	0.002	<0.001	<0.001	<0.001	<0.001	0.004
Cl (mg/l)	162	172	185	192	99	258	2234	2265	195	38	32	30	33	1305
Co (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.016	0.015	<0.005	0.006	0.006	0.023	0.030	0.006
Cr (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cu (mg/l)	0.088	0.077	0.104	0.094	0.111	0.099	0.091	0.101	0.077	0.047	0.047	0.068	0.057	0.077
F (mg/l)	0.18	0.42	0.95	0.89	1.55	1.51	<0.01	<0.01	0.71	1.68	1.82	2.84	2.94	0.17
Fe (mg/l)	2.692	4.845	0.077	0.746	0.069	0.104	10.341	4.734	4.721	4.614	4.55	39.24	42.001	0.116
K (mg/l)	2.7	3.6	1.8	2.9	28.7	20.7	62	60.3	3.4	10.2	10.3	30	31.1	46
Li (mg/l)	0.011	0.039	0.007	0.017	0.023	0.037	0.353	0.341	0.066	0.003	0.004	0.009	0.009	0.076
Mg (mg/l)	16	19	20	20	42	23	568	569	21	15	14	70	73	67
Mn (mg/l)	0.68	0.816	0.156	0.295	0.186	0.084	2.846	2.706	0.632	0.604	0.57	2.772	2.691	2.297
Mo (mg/l)	0.008	0.011	0.064	0.07	0.185	0.54	<0.003	<0.003	0.007	0.006	0.005	<0.003	<0.003	<0.003
Na (mg/l)	115	118	164	160	189	372	500	504	163	51	40	90	94	441
Ni (mg/l)	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.017	0.016	<0.01	0.016	0.01	0.036	0.044	0.017
NO_2(as N)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NO_3(as N)	0.06	<0.045	4.61	1.77	6.19	0.09	0.83	0.05	0.05	0.05	<0.045	0.03	0.16	16.93
Pb (mg/l)	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	0.057	<0.015	<0.015	<0.015	<0.015	0.039	0.043	<0.015
PO_4 (mg/l)	0.51	1.62	0.4	0.63	3.99	1.25	<0.1	<0.1	<0.1	4.06	0.82	<0.1	<0.1	<0.1
Se (mg/l)	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
SO_4 (mg/l)	6	3	11	12	44	68	1888	1881	16	16	11	805	825	161
Sr (mg/l)	0.204	0.26	0.245	0.341	0.463	0.272	4.099	4.068	0.319	0.13	0.1	1.412	1.236	6.686
V (mg/l)	<0.01	<0.01	<0.01	<0.01	0.037	0.021	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn (mg/l)	0.07	0.047	0.073	0.066	0.079	0.079	0.084	0.075	0.057	0.047	0.05	0.049	0.074	0.218

Red values exceed the SABS 241 maximum allowable limits for Drinking Water (SABS, 2001)

Table 6.5 cont.: Chemistry results for the Matimba power station monitoring holes (January 2004) (Page 3)

Elements	P23	P24	P24	P25	P25	P26	P27	P27	P28
Depth (m)	34	11	30	19	27	8	8	16	19
pH	7.08	6.78	7.00	6.43	6.50	7.49	6.91	7.03	6.91
EC (mS/m)	314	35	39	128	130	326	96	94	137
Al (mg/l)	0.032	4.213	0.22	0.058	0.042	0.058	0.084	0.05	0.079
B (mg/l)	0.698	0.097	0.104	0.284	0.291	0.522	0.073	0.065	0.226
Ba (mg/l)	0.227	0.492	0.028	0.125	0.121	0.157	0.27	0.215	0.145
Be (mg/l)	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Br (mg/l)	2.45	0.43	0.53	0.74	0.82	2	0.48	0.55	1.58
Ca (mg/l)	133	4	6	38	37	47	19	16	33
Cd (mg/l)	0.002	0.004	<0.001	0.002	0.001	0.004	0.002	0.001	0.002
Cl (mg/l)	478	40	42	174	184	455	207	210	187
Co (mg/l)	0.008	0.008	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cr (mg/l)	<0.005	0.014	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cu (mg/l)	0.061	0.102	0.024	0.112	0.077	0.091	0.073	0.019	0.083
F (mg/l)	0.41	2.84	0.75	0.63	0.65	1.52	0.48	0.86	1.1
Fe (mg/l)	2.229	10.427	0.23	2.298	3.695	0.128	0.442	0.052	3.609
K (mg/l)	38.8	11.3	11.7	2.9	2.6	26.2	2.5	2.2	4.9
Li (mg/l)	0.08	0.008	0.006	0.054	0.055	0.123	0.002	0.002	0.018
Mg (mg/l)	57	1	1	43	44	86	22	21	34
Mn (mg/l)	1.389	0.58	0.068	0.247	0.218	0.156	0.044	0.035	0.268
Mo (mg/l)	0.019	<0.003	0.021	0.004	0.007	0.029	<0.003	<0.003	0.006
Na (mg/l)	473	67	71	182	177	589	139	137	222
Ni (mg/l)	0.01	0.034	<0.01	<0.01	0.011	<0.01	0.011	0.01	<0.01
NO_2 (as N)	<0.01	<0.01	<0.01	<0.01	<0.01	0.75	<0.01	<0.01	<0.01
NO_3 (as N)	0.06	<0.045	<0.045	0.18	0.23	1.49	8.35	11.46	0.2
Pb (mg/l)	<0.015	0.124	<0.015	<0.015	<0.015	0.022	<0.015	<0.015	<0.015
PO_4 (mg/l)	2.12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Se (mg/l)	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
SO_4 (mg/l)	533	17	19	31	28	106	38	39	28
Sr (mg/l)	1.835	0.227	0.092	0.376	0.366	0.694	0.158	0.145	0.331
V (mg/l)	<0.01	0.033	<0.01	<0.01	<0.01	0.017	<0.01	<0.01	<0.01
Zn (mg/l)	0.096	0.295	0.012	0.086	0.102	0.106	0.09	0.074	0.067

Red values exceed the SABS 241 maximum allowable limits for Drinking Water (SABS, 2001)

6.6.4. Impact Assessment Regarding Existing Matimba Power Station

Based on the available data the following conclusions are made:

- Borehole yields and groundwater potential within the power station study area are very low.
- Water levels in the boreholes adjacent to the power station and infrastructure are elevated by 5 – 10 m because of infiltration (artificial recharge from water use on site).
- Artificial recharge from the power station infrastructure is impacting on the groundwater.
- The hydraulic response in the aquifer is much faster than that of the spread of contaminants (water rise in the boreholes but there is no associated increase in salinity), the elevated water levels are thus not an indication of contamination rather recharge.
- Groundwater quality is very variable and generally high in salinity. The source of salinity is difficult to establish as it can either be naturally occurring salt (released from impermeable shale exposed during drilling) or derived from pollution sources at the power station.
- Modelled pollution plumes have only extended over small areas / distances due to the non-aquifer system, low groundwater gradients, and limited rainfall recharge.
- Persistent sources of contaminants can alter the hydrochemistry, causing an increase in dissolved solids and metals.

6.7. Preferred Site Study

The site suitability, for the development of a power station and infrastructure, on the nominated preferred sites was assessed based on hydrogeological criteria[7].

The existing power station, associated waste (ash, brine, water) infrastructure, coal stockpiles, and dams are recognised to have had an impact on the local hydrogeology, either by enhanced recharge and/or by altering the hydrochemistry within the aquifer(s).

In order to assess the preferred sites from a groundwater perspective an assessment of each site has been conducted based on the following criteria:

- The *threat* posed by the power station and infrastructure
- The *barrier* between the power station and the groundwater resources
- The groundwater *resource*

[7] This methodology is a modification of the Waste – Aquifer Separation Principle approach, Jolly and Parsons WRC Report No. 485/1/94, June 1994

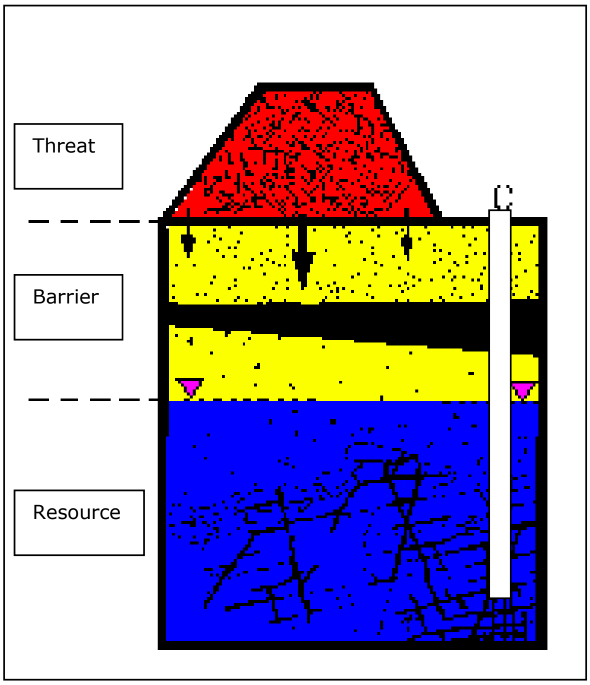


Figure 6.14: The assessment criteria to determine site suitability from a groundwater perspective.

The vulnerability of the groundwater and risk to the current groundwater users (or future use) is then examined. The site suitability assessments have been conducted using available data.

6.7.1. Threat factor

The threat to the groundwater resources posed by the proposed power station and associated infrastructure has been identified based on the existing Matimba Power Station, existing ancillary infrastructure, available groundwater monitoring data, and the recognition of potential sources of contamination.

These include:

- The coal stockpiles, a potential source of acid generation and sulphate.
- Areas of artificial recharge, which include the raw water dam and the ash dump toe dam.
- Areas of artificial recharge with poor quality water, which are recognised as the sewage plant and dams, the evaporation dams, and the ash dump (including brine deposits from the de-ionised water system).
- Recharge and contamination from the recovery / surface water run-off dams, through seepage, spillage, and overflow.
- Bunker fuel oil storage. Potential of oil entering the surface water run-off dams and the associated treatment required.

- Potential surface water contamination from the solid waste site (if required at the proposed new power station).

Monitoring reports for Matimba Power Station indicate that the groundwater quality has deteriorated with time and pollution plumes have developed within the immediate areas surrounding the various infrastructures on site.

It is, therefore, recognised that the threat of the proposed power station and infrastructure will be the same for each site and will comprise of:

- Artificial recharge causing an increase in groundwater levels, change in groundwater flow patterns and gradients.
- Artificial recharge of poor quality water causing an increase in salinity in the groundwater.

The threats can be managed and mitigated once the power station and infrastructure design has been finalised.

6.7.2. Barrier factor

The unsaturated zone represents the barrier between the proposed power station and infrastructure and the groundwater. It is within this zone that attenuation will occur. The attenuation processes can include chemical precipitation, adsorption, dilution, dispersion, and biodegradation.

Attenuation is a set of complex and often inter-related processes governed by a number of factors. The modelling of attenuation processes is hence extremely difficult. It is therefore necessary to assess the time taken for poor quality water to migrate through the unsaturated zone, from the surface contaminant source to the groundwater level.

The travel time through the unsaturated zone is dependent on the depth of the groundwater and the porosity and permeability of the unsaturated material. Preferential pathways, such as faults, fractures or weathering, can increase the travel time and reduce the attenuation.

The vulnerability of the groundwater is determined by assessing the unsaturated zone at each of the candidate sites. Farms with identified geological structures, which may act as preferential pathways for contaminant movement from surface to groundwater, are identified as less suitable.

6.7.3. Resource factor

The groundwater resource at each farm was assessed to determine the significance of the groundwater in terms of current and potential use.

The resource assessment identifies both the current groundwater usage and hydrochemistry, and the groundwater potential for possible future use.

6.7.4. Site Suitability Assessment

As the threat to each of the farms is the same, an assessment of the barrier and resource factors was conducted for each of the two farms and their two neighbouring farms. Table 6.6 presents the suitability assessment.

Based on the assessment of the barriers and groundwater resources at each of the sites, it is established that the farms that are underlain by the Waterberg Group have the least vulnerable groundwater due to: -

- Deep groundwater levels, longer travel time and attenuation.
- Limited geological structures, apart from the Eenzaamheid Fault, and limited development of secondary aquifers.
- Low yielding boreholes with limited groundwater resource development potential.

The site suitability assessment confirmed that the farms Eenzaamheid (south of the Eenzaamheid Fault) and the farm Naauwontkomen are suitable for the construction of the power station and ancillary infrastructure. It is envisaged that the proposed power station and all other infrastructure including the ash dam can be constructed on these two farms. However, should additional area be required then a portion of the farm Kromdraai is proposed as being suitable for use.

Table 6.6: Site suitability assessment

Farm	Threat	Barrier	Resource	Comments
Eenzaamheid 512 LQ	Artificial recharge causing an increase in groundwater levels, change in groundwater flow patterns and gradients Poor quality recharge causing an increase in salinity	Very deep groundwater (77 – 113 m) Waterberg Group sandstone, ± 3 m of permeable soil covers ± 4 m weathered sandstone. Red hard competent sandstone Grootegeluk FM rocks north of Eenzaamheid fault No sills or dykes	Low borehole yields, dry to 0.25 l/s Aquifer potential enhanced along Eenzaamheid fault Current abstraction for stock watering only Groundwater can contain elevated concentrations of fluoride	No surface drainage Could be impacted on by plume migration from Turfvlakte[8] along the Eenzaamheid fault
Kromdraai 513 LQ	Artificial recharge causing an increase in groundwater levels, change in groundwater flow patterns and gradients Poor quality recharge causing an increase in salinity	Groundwater levels 32 – 35 mbgl Shallow groundwater in deep (400m) hole as a result of piezometeric pressure Waterberg Group sandstone, with fault on eastern boundary	Very low borehole yields, dry to 0.07 l/s Yield of deep hole enhanced to 0.85 l/s Fluorspar on site may impact on groundwater quality	Non-perennial tributary draining through center of farm Wind pump at farm house, possible domestic use Linear features from API identified on site

[8] Irrigation with poor quality water was conducted by Grootegeluk on this farm, poor quality groundwater has resulted and is modelled to migrate south towards the Eenzaamheid fault

Table 6.6 cont.: Site suitability assessment (Page 3)

Farm	Threat	Barrier	Resource	Comments
Kuipersbult 511 LQ	Artificial recharge causing an increase in groundwater levels, change in groundwater flow patterns and gradients Poor quality recharge causing an increase in salinity	Groundwater levels range between 18 and 48 mbgl Shallow groundwater levels were measured in two boreholes, < 4 mbgl These may be related to a fault recognised in the sediments Waterberg sandstone Stone aggregate mining is recognised to occur on Kuipersbult	The boreholes have typically low yields, 0.01 to 0.33 l/s The highest borehole yield recorded in the study, 3.2 l/s, was measured on Kuipersbult – fault related Fluorspar and mining on site may impact on groundwater quality	Small drainage line along southwest boundary Linear features from API identified on site
Naauwontkomen 599 LQ	Artificial recharge causing an increase in groundwater levels, change in groundwater flow patterns and gradients Poor quality recharge causing an increase in salinity	Variable groundwater levels due to complex geology Shallow groundwater associated with Karoo rocks and faults Deep groundwater levels 30 – 50 m associated with Waterberg sediments Stone aggregate mining occurred on the farm	Borehole yields are low, however, faulting has enhanced the groundwater potential Yields range from 0.06 to 0.98 l/s No groundwater abstraction on farm Poor quality groundwater from irrigation at Turfvlakte impacts on farm and along fault	No surface drainage Old quarries / borrow pits on site

6.8. Risk Assessment

6.8.1. Description of intention

It is the intention to construct an additional power station and infrastructure adjacent to the Matimba Power Station, outside of Lephalale. A risk assessment was compiled to determine the various threats posed by the proposed power station and infrastructure on the water resources. The risk assessment aimed at providing information regarding the management of recognised risks and allowing for the optimum management to mitigate these risks.

6.8.2. Hazard identification

The hazards identified with the existing power station and associated infrastructure are related to the use of water in the power generation process, the creation and storage of poor quality water and waste, and its impact on the groundwater and surface water environments.

These hazards include: -

- Poor quality water stored on site recharging the groundwater
- Artificial recharge impacting on groundwater
- Solid waste site (Eskom is most likely to use Municipal waste site)
- Seepage below the ash dump
- Poor quality surface water on site
- Sewage facilities
- Fuel (bunker) oil
- Surface water supply
- Coal stockyard

6.8.3. An estimation of the probability and magnitude of the consequences of the hazard(s)

The probability (P) and magnitude (M) of the consequences of any or all of the identified hazards occurring has been estimated.

This exercise allows for the development of the correct management plan to be developed to ensure that the operation or process failure at the proposed power station and infrastructure that can lead to the hazard occurring is addressed. The correct management plans can reduce the possible negative impacts on the water resources in the study area.

Table 6.7 provides a summary of the identified hazards, the consequences of the hazard becoming a reality, the probability of the hazard occurring, and the magnitude of these consequences.

Please note: The following values represent the various probabilities and magnitudes: -

PROBABILITY	SCORE	MAGNITUDE
High	5	Severe
Medium	3	Moderate
Low	1	Mild
Negligible	0	Negligible

Table 6.7 – Hazards, consequences, probability and magnitude

Hazard	Consequences	Probability (P)	Magnitude (M)
Hazard 1 Poor quality water entering the groundwater	An alteration in the ambient groundwater quality. Contamination can move off site and impact on other users.	**Medium (3):** Poor quality recharge will occur through permeable soil and weathered material	**Moderate (3)** The cost of groundwater clean up is expensive. The plume migration is however localised
Hazard 2 Artificial recharge to groundwater	Groundwater mounds created adjacent to raw water dams, alteration in groundwater flow patterns Mobilisation of salts with infiltration	**Medium (3):** Artificial recharge will occur through permeable soil and weathered material	**Negligible (0):** Very limited zone of impact, very localised changes to groundwater
Hazard 3 Poor quality run off from solid waste site	Contaminated run off water can recharge groundwater	**Low (1):** Limited rainfall run off over small area. Area managed to prevent ponding of poor quality water	**Negligible (0):** Limited volumes of poor quality water
Hazard 4 Seepage below ash dump	Contaminated water can alter the groundwater quality. The contaminated groundwater can impact on other users.	**High (5):** Existing ash dump is unlined and is recognised to impact on groundwater a new dump would have the same impact if unlined Initial ash disposal will have high seepage rates, ash contains 10 –12 % moisture	**Moderate (3):** The cost of groundwater clean up is expensive. The plume migration is however very slow Attenuation and dilution will occur and the slow travel times (attenuation) will reduce the threat.
Hazard 5 Poor quality surface water on site	Rainfall will form “dirty” runoff within the site and can leave site Ponding of poor quality can recharge groundwater	**Low (1):** Surface water controls, separating clean and dirty water, to be implemented Stormwater controls to be put in place	**Mild (1):** Small volumes of poor quality surface water generated and limited drainage channels Flat topography can allow ponding to occur

Table 6.7 – Hazards, consequences, probability and magnitude (Page 2)

Hazard	Consequences	Probability (P)	Magnitude (M)
Hazard 6 Poor quality water associated with the sewage facilities	Seepage, spills or overflow can enter the groundwater and alter the hydrochemistry.	**Low (1):** Correctly designed and managed facility	**Mild (1):** The cost of groundwater clean up is expensive. Little or no groundwater use
Hazard 7 Fuel (bunker) oil in water migrating off site	Oil in the recovery / surface water run-off dams, can overflow and add hydrocarbons to soil and groundwater	**Medium (3):** Oil is collected from existing recovery dams	**Mild (1):** Limited volumes of oil in the water, overflow during rainfall events can occur
Hazard 8 Insufficient water supply	Insufficient water supply will impact on Eskom's ability to produce power which will impact on the quality of life and the economy	**Low (1):** Current DWAF allocation is assured Plans to augment surface water supplies	**Severe (5):** Impacts on local and regional economy Negative impact on the economy
Hazard 9 Coal stockyard	Seepage from the wet coal can recharge the groundwater Acid mine drainage (AMD) can occur associated with the coal	**Medium (3):** Wet coal is stockpiled on bare ground, no lining. A new coal stockpile will be required for the proposed power station. If unlined will have the same impact Temporary piles reduces constant contaminant source	**Moderate (3):** 1.2 million ton stockpile, < 37 mm size thus low permeability
Hazard 10 Reduction in catchment water (indirect impact)	Additional water supply to the proposed power station can impact negatively on downstream users due to reduced river flow	**Medium (3):** An increase in the Mokolo Dam capacity will influence the river flow	**Moderate (3):** DWAF supply strategy to the catchment includes augmentation of water from the Crocodile (west) and Marico catchment

6.8.4. A risk estimate

An estimation of risk for each hazard can be calculated based on the combination of the probability of the hazard occurring and the magnitude of the consequences of such a hazard becoming a reality.

The risk (R) is the product of the probability (P) and magnitude (M) of the given consequence.

A risk value for each hazard is calculated for comparison in order to determine the most serious hazard or threat.

The water risk assessment has identified an unlined ash dump as having the most significant hazard on the water resources. Any proposed new ash dump will therefore have to be designed and managed to reduce this risk / threat.

6.8.6. Overall risk assessment

The risk estimate and risk evaluation for each of the ten (10) hazards is combined to obtain an overall risk assessment.

Please note: The risk estimate (R) is the product of the probability (P) and magnitude (M) of the given consequence, i.e $R = P \times M$.

Table 6.8 – Risk assessment summary

Hazard	Consequences	Probability	Risk Estimate (R)	Overall risk	Management options
Hazard 1 Poor quality water entering the groundwater	An alteration in the ambient groundwater quality Contamination can move off site and impact on other users	**Medium:** Poor quality recharge will occur through permeable soil and weathered material	**9**	Risk is reduced due to limited groundwater use and potential, localised impacts and variable hydrochemistry The overall risk is **TOLERABLE**	• Geological assessment for dam site selection • Backfill existing boreholes Ensure sufficient capacity • Construct lined dams • Monitor groundwater quality and water levels • Monitor neighbouring boreholes
Hazard 2 Artificial recharge to groundwater	Groundwater mounds created adjacent to raw water dams, alteration in groundwater flow patterns Possible mobilisation of salts with infiltration	**Medium:** Artificial recharge will occur if the dam is unlined	**0**	Limited volumes of recharge with a localised impact, quality may improve Overall risk is **TOLERABLE**	• Ensure sufficient capacity and prevent overflow / spillage • Clay base to minimise seepage • Install a down gradient monitoring borehole to monitor quality and water levels
Hazard 3 Poor quality run off from solid waste site	Contaminated run off water can recharge groundwater	**Low:** Limited rainfall run off over small area. Area managed to prevent ponding of poor quality water	**0**	Limited volumes of poor quality water are envisaged due to small area and low rainfall Overall risk is **TOLERABLE** providing water controls are installed	• Install clean and dirty run-off separation controls • Ensure gradients to prevent ponding • Poor quality water to be diverted to lined recovery dams

Table 6.8 – Risk assessment summary (Page 2)

Hazard	Consequences	Probability	Risk Estimate	Overall risk	Management options
Hazard 4 Seepage below ash dump	Contaminated water can alter the groundwater quality The contaminated groundwater can impact on other users and future groundwater development	**High:** Existing ash dump is unlined and is recognised to impact on groundwater Initial ash disposal will have high seepage rates, ash contains 10 –12 % moisture	**15**	The risk of a constant contamination source associated with an unlined ash dump is **HIGH** The overall risk is **TOLERABLE** if the ash dump is correctly designed	• Assess backfilling at Grootegeluk • Design a drainage system • Drainage system below ash • Design optimum toe dam • Back fill existing holes and install monitoring holes • Surface water controls to be installed and maintained
Hazard 5 Poor quality surface water on site	Rainfall will form "dirty" runoff within the site and can leave site Ponding of poor quality can recharge groundwater	**Low:** Surface water controls, separating clean and dirty water, to be implemented Low rainfall area	**1**	The volumes of poor quality water will be limited but topography if flat Overall risk is **TOLERABLE** providing storm water and separation controls are installed	• Separate clean and dirty runoff, • Minimise disturbed areas • Install and maintain controls, including berms and furrows • Slope topography to prevent ponding • Monitor the water quality used for irrigation
Hazard 6 Sewage facility	Seepage, spills or overflow can enter the groundwater and alter the hydrochemistry.	**Low:** Correctly designed and managed facility	**1**	Poor quality water seepage or overflow may occur but the impact will be Very localised due to poor aquifers The overall risk assessment for this threat is **TOLERABLE**.	• Correctly sized, designed and constructed facility • Groundwater monitoring

Table 6.8 – Risk assessment summary (Page 3)

Hazard	Consequences	Probability	Risk Estimate	Overall risk	Management options
Hazard 7 Fuel (bunker) oil in water migrating off site	Oil in the recovery / surface water run-off dams, can overflow and add hydrocarbons to soil and groundwater	**Medium:** Oil is collected from existing recovery dams	**3**	Costly and difficult to clean up, however, only small amounts envisaged The overall risk is **TOLERABLE** if oil management measures are in place	• Contain oil in bunded area • Ensure clean up protocols in place and followed • Install oil traps and separators • Keep accurate oil records (purchased, disposal, and recycled)
Hazard 8 Insufficient water supply	Insufficient water supply will impact on development projects in the Lephalale area, Eskom's power production which will impact on the quality of life and the economy	**Low:** Current DWAF allocation is assured Plans to augment surface water supplies	**5**	The overall risk is **HIGH**, however, once surface water augmentation occurs then the risk will be **TOLERABLE**.	• Implement water use or water wastage minimisation • Reduce water demand • Investigate recycling, new technology, conjunctive use with Kumba
Hazard 9 Coal stockyard	Seepage from the wet coal can recharge the groundwater AMD can occur associated with the coal	**Medium:** Wet coal is stockpiled on bare ground, no lining Temporary piles reduces constant contaminant source	**9**	The overall risk associated with the coal stockyard is **TOLERABLE** but will require management to ensure limited impacts on the groundwater.	• Construct clay base • Separate clean and dirty runoff • Minimise coal stock piles and size of yard • Install and maintain surface water controls • Slope topography to prevent ponding • Monitor groundwater levels and quality
Hazard 10 Downstream users	Reduction in Mokolo River flow	**Medium:** Reduction in flow occurs with dam size	**9**	The overall risk is **HIGH**, water augmentation schemes initiated by DWAF will make risk **TOLERABLE**.	• Implement water use or water wastage minimisation

6.9. Emission Control Technologies

Should air quality predictions (modelling) indicate an incremental impact on the air quality then Eskom will consider the feasibility of including sulphate dioxide reduction in their power station design.

The objective of this section is to assess suitable flue gas emissions reduction technologies and to determine the possible impacts and management of utilising these technologies with respect to the water resources.

6.9.1. Flue Gas Desulphurisation (FGD) Technologies

Sulphate dioxide (SO_2) is a result of coal combustion required for power generation. Mr. Naushaad Haripersad of Eskom has conducted an extensive review of (SO_2) emission removal technology. The emission removal techniques include the introduction of a sorbent to effectively remove SO_2.

Eskom assessed the various technologies based on the following criteria: -

- Resource availability
- Proven technology (the technology must have a proven technical and commercial track record)
- Must be able to mitigate stipulated SO_2 removal limits (used World Bank as a guideline, however such high removals would not be required to meet SO_2 ambient air quality standards.)
- Associated risks of using the technology must be low and manageable

The most suitable flue gas desulphurization (FGD) technologies for the proposed Matimba B power stations includes the use of wet or dry (semi-wet) scrubbers. These technologies allow for the introduction of calcium (Ca), which removes the SO_2 through the formation of calcium sulphite ($CaSO_3$) or calcium sulphate ($CaSO_4$).

The sources of the Ca include: -

- Lime (CaO) – unslaked lime
- Limestone ($CaCO_3$ and $MgCO_3$)
- Calcrete (precipitated calcite)
- Dolomite (limestone with magnesium carbonate ($MgCO_3$) greater than 8%)

- *Wet process*
  In the wet FGD process, flue gases are brought into contact with an absorber (scrubber). The SO_2 reacts with the Ca to form a $CaSO_3$ or $CaSO_4$ slurry.

  Wet scrubbers are most widely used throughout the world and are proven to achieve up to 99% SO_2 removal efficiency.

The Ca slurry sorbent allows for the removal of SO_2 through the reaction: -

$$CaCO_3 + SO_2 = CaSO_3 + CO_2$$

The calcium sulphite ($CaSO_3$) waste product can be oxidised to form gypsum (hydrated calcium sulphate ($CaSO_4 - 2(H_2O)$), which may have commercial value.

Alternatively the generated waste can be dewatered (for some water reclamation) and mixed with flyash for deposition on a waste site.

This process is water intensive.

- *Semi-dry process*
  In a semi-dry absorption system, only 60% of the water used in the wet process is required to dissolve or suspend the reacting chemical. This process does, however, have a higher chemical consumption and has lower efficiencies.

  This technology is proven but not as popular as wet process FGD. The semi-dry process is capable of 90% SO_2 removal.

  Typical semi-dry scrubber processes include dry-circulating fluid bed (CFB) or spray dry FGD. The CFB process is more beneficial as it has less moving parts and can remove 90% SO_2.

- *Comparison of processes*
  Water consumption values for a typical 3 pack power station for effectively reducing SO_2 emissions indicate that the dry FGD process uses 35 % less water than the wet process, with a wet FGD system consuming approximately 0.147 l/kWh and a dry FGD system consuming approximately 0.055 l/kWh, hence a water consumption differential of approximately 0.092 l/kWh between a wet and a dry FGD system.

  The wet process is, however, cheaper due to the lower operational costs associated with the limestone sorbent and transportation..

6.9.2. Waste

Both processes produce waste, either calcium sulphite ($CaSO_3$) or calcium sulphate ($CaSO_4$), which can be processed to form gypsum. Gypsum has a commercial value if produced in a marketable environment.

The waste can be dewatered and the poor quality water reused until no longer suitable. This water will then have to be disposed on a waste site or evaporation dam.

The slurry can be mixed with flyash and fixation lime (approximately 5%) and deposited on a landfill site.

The proposed method of disposal is to: -

- Dewater the slurry waste
- Blend it with flyash or fixation lime
- Deposit on the proposed new ash dump
- Or used as backfill in the old existing Grootegeluk Colliery workings (still to be investigated)

Eskom have investigated the potential for treating the $CaSO_3$ and $CaSO_4$ slurry to generate gypsum. The production of gypsum is not considered due to: -

- No local demand for gypsum
- The high cost of transportation of gypsum to a saleable market elswhere
- Consistent high quality gypsum requires additional resources and processes which would only be considered if there was a market for the product.

In addition, the gypsum is classified as a treated waste and would require a hazardous waste rating / classification. Based on the results it is assumed that solid waste from the FGD process (and the power station ash) would have to be deposited on suitable licensed landfill sites, according to the Department of Water Affairs and Forestry's minimum requirements for waste disposal by landfill (DWAF, 1994).

The production of gypsum would therefore require an additional licensed landfill site, for temporary storage before being sold, if possible.

Ash and FGD waste could be co-disposed on a single suitable waste disposal facility, which would be more environmentally acceptable.

6.9.3. Surface Water

Surface water resources are poorly developed due to flat topography, permeable soil, and low mean annual rainfall. There are no well defined drainage courses within the study area, thus the proposed power station and infrastructure will not have a direct impact on the surface water.

The use of any SO_2 emission removal technology will, however, increase the water consumption of the proposed power station.

Water consumption at a typical 4000 MW dry cooled power station is in the order of 0.1 to 0.2 l/kWh (litres per unit of electricity produced). The average water use is 0.12 l/kWh sent out from the power station.

The current water use at Matimba Power Station is 3.3 million m^3/annum (source Heine Hoffman Eskom, 2005). This water use volumes is based on the power station being capable of generating 3 990 MWh with an Energy Availability Factor (EAF) of 94.

To reduce SO_2 emissions (Table 1), the water consumption at a dry cooled power station **doubles** to 0.26 l/kWh for dry process and 0.33 l/kWh for the wet FGD process.

At present the only source of water to the existing power station is the Mokolo Dam. Should an additional power station be built and SO_2 emission removal is required then the water demand will be increased and the Department of Water Affairs and Forestry (DWAF) will be required to provide an assured water supply. However, in its water license application, Eskom has applied for a water allocation based on worse-case scenario, i.e 4800 MW power plant, with wet FGD.

6.9.4. Groundwater

The use of FGD technology on site will increase the impact on the groundwater environment due to the additional wet waste that will be generated. The waste will require a hazard rating, once the waste has been hazard classified the waste disposal site will be required to conform to the DWAF minimum requirements for waste disposal by landfill.

The correctly designed waste disposal facility will reduce the impact of the slurry waste and water on the groundwater resources.

6.9.5. Risk Assessment (Fgd Impacts)

A risk assessment regarding the use of FGD technology on the groundwater and surface water resources was conducted based on Skivington's report (WRC report No. TT90/97) entitled "Risk Assessment for Water Quality Management" (1997).

The methodology followed is as follows: -

- A description of intention
- Hazard identification
- An estimation of the probability and magnitude of the consequences of the hazard
- A risk estimate
- A risk evaluation
- An overall risk assessment
- Risk management recommendations

The risk assessment is based on the use of FGD technology at the proposed power station. The risks identified during this assessment and the proposed mitigation measures can be considered when finalising the proposed power station design.

- *Description of intention*
  Eskom want to assess the risks associated with using FGD technology with regards to groundwater and surface water resources. The risk assessment will assist in making decisions and management plans.

- *Hazard identification*
  The hazards identified with the use of FGD technology at a power station are related to the use of water in the emissions reduction process, the creation and storage of poor quality water and waste, and its impact on the groundwater and surface water environments.

  These hazards include:

  - Increased water demand
  - Poor quality water stored on site recharging the groundwater
  - Wet waste disposal
  - Removal of surface water from catchment
  - Gypsum temporary stockpile

  Please note that this preliminary risk assessment only assess possible impacts / threats to the water resources. No consideration for the hazards of sorbent mining at source, transport, material and waste handling, or economic impacts (increased power costs) have been included.

- *An estimation of the probability and magnitude of the consequences of the identified hazards*
  The probability and magnitude of the consequences of any or all of the identified hazards occurring has been estimated.

  This exercise allows for the development of the correct management plan to be developed to ensure that the operation or process failure that can lead to the hazard occurring is addressed.

  Table 6.9 provides a summary of the identified hazards, the consequences of the hazard becoming a reality, the probability of the hazard occurring, and the magnitude of these consequences.

  Please note: The following values represent the various probabilities and magnitudes: -

PROBABILITY	SCORE	MAGNITUDE
High	5	Severe
Medium	3	Moderate
Low	1	Mild
Negligible	0	Negligible

Table 6.9: Hazards, consequences, probability and magnitude relating to FGD impacts on water resources

Hazard	Consequences	Probability (P)	Magnitude (M)
Hazard 1 Increased water demand	Reduction of surface water for development in the Limpopo Water Management Area Impact on downstream users within the Mokolo River	**High (5):** Eskom is of a strategic importance to RSA, hence the assumption that water will be made available for power generation associated emissions control technologies	**Moderate (3):** The water augmentation schemes will ensure that the impact of increased water use by Eskom is minimised
Hazard 2 Poor quality water stored on site recharging the groundwater	Waste will be dewatered and the poor quality water stored on site for reuse in the FGD process	**Medium (3):** Artificial recharge will occur through permeable soil and weathered material	**Negligible (0):** Very limited zone of impact, very localised changes to poor groundwater resources
Hazard 3 Wet waste disposal	Contaminated water associated with the waste can recharge groundwater and run off site and impact on surface water	**High (5):** The wet waste will have the potential for leachate generation which could migrate into the underlying aquifers or form run-off and migrate off site	**Mild (1):** The poor quality leachate can contain heavy metals[9] and high dissolved solids content, which will impact on the ambient water qualities The waste must be deposited on a correctly designed waste disposal facility

[9] Eskom's research indicates heavy metals can be concentrated within the slurry

Hazard	Consequences	Probability	Magnitude
Hazard 4 Removal of surface water from catchment	The water used in the FGD process will become of such poor quality that it has to be deposited on a waste site, thus the water cannot be treated and returned for use in the catchment	**High (5):** The water used in the FGD processes cannot be treated for discharged back into the river	**Moderate (3):** The study area is located within a water scarce area and any loss of water impacts on other possible developments within the catchment. The augmentation of the surface water resource will reduce the impact
Hazard 5 Gypsum temporary stockpile	Gypsum manufacturing will require stockpiling according to minimum requirements as it has the potential to impact negatively on the groundwater and surface water resources	**Low (1):** Gypsum manufacture is not commercially viable for Eskom	**Mild (1):** Any temporary stockpiling of gypsum must take place on a correctly designed waste disposal facility

Table 6.10 contains a summary of the risk assessment, including hazards, consequences, probabilities, overall risks, and management actions required.

Please note: The risk estimate (R) is the product of the probability (P) and magnitude (M) of the given consequence, i.e $R = P \times M$.

Table 6.10: Risk assessment summary

Hazard	Consequences	Probability	Risk Estimate (R)	Overall risk	Management options
Hazard 1 Increased water demand	Reduction of surface water for development in the Limpopo Water Management Area Impact on downstream users within the Mokolo River	**High:** Eskom is of a strategic importance to RSA so water will be made available for power generation associated emissions control technologies	**15**	It is recognised that the overall risk is **TOLERABLE**; however, the optimum FGD process must be selected. Management procedures and augmentation of water resources are required to ensure the negative impacts are reduced.	• Select least water intensive FGD • Maximise water recycling • Minimise water wastage • Monitor water use
Hazard 2 Poor quality water stored on site recharging the groundwater	Waste will be dewatered and the poor quality water stored on site for reuse in the FGD process	**Medium:** Artificial recharge will occur through permeable soil and weathered material	**0**	The overall risk assessment for this hazard on the groundwater is **TOLERABLE**.	• Geological assessment for dam site selection • Backfill existing boreholes • Ensure sufficient capacity • Construct lined dams • Monitor groundwater quality and water levels • Monitor neighbouring boreholes
Hazard 3 Wet waste disposal	Contaminated water associated with the waste can recharge groundwater and run off site and impact on surface water	**High:** The wet waste will have the potential for leachate generation which could migrate into the underlying aquifers or form run-off and migrate off site	**5**	The overall risk assessment for this hazard on the water resources is **TOLERABLE**.	• Select optimum waste dewatering scheme • Evaluate water disposal technique to reduce water in waste disposal • Monitor water resources

Hazard	Consequences	Probability	Risk Estimate (R)	Overall risk	Management options
Hazard 4 Removal of surface water from catchment	The water used in the FGD process will become of such poor quality that it has to be deposited on a waste site, thus the water cannot be treated and returned for use in the catchment	**High:** The water used in the FGD processes cannot be treated for discharged back into the river	**15**	The overall risk assessment for the surface water loss is **TOLERABLE**; however, management of the water is required to ensure the recycling of water.	• Ensure minimum water use in FGD • Ensure maximum recycling throughout power plant • Reuse of water, minimise clean water use • Implement less water reliant processes
Hazard 5 Gypsum temporary stockpile	Gypsum manufacturing will require stockpiling according to minimum requirements as it has the potential to impact negatively on the groundwater and surface water resources	**Low:** Gypsum manufacture is not commercially viable for Eskom	**1**	The overall assessment of this hazard is **TOLERABLE** as the gypsum would be piled on a correctly designed waste disposal facility.	• Stockpile on correctly designed disposal facility • Must be managed

6.10. Conclusions

- Through the National Water Resource Strategy, 45 million m^3/annum water has been reserved for the possible development of a new power station in the Limpopo Water Management Area.
- The study area is underlain by complex faulted Karoo sediments and unaltered older Waterberg Group sandstone.
- Large faults, aerial magnetic lineations, and minor faulting occur across the study area, these geological structures can enhance the groundwater potential in the area and act as preferential pathways for groundwater and contaminant migration.
- The regional hydrogeology comprises a non-aquifer system, with very low yielding boreholes and incidents of very high salinity hydrochemistry.
- Little or no groundwater use occurs within the area, however, persistent contamination can have an impact on the groundwater users with time.
- Surface water resources are limited due to low rainfall, flat gradients, and permeable soil cover.
- Groundwater has been impacted on by the existing power station and infrastructure; the impact on hydrochemistry is not quantified due to natural pollution.
- A preliminary site suitability assessment indicates that the groundwater resources within the Waterberg Group sediments are the least vulnerable and that the farms within this area are more suitable for the development of a new power station.
- An initial risk assessment identifies that unlined ash dump or dams could be sources of artificial recharge that require risk reduction measures.
- The correct site selection, construction and management of the new power station and infrastructure will ensure that the overall risk to the groundwater and surface water resources is acceptable.

Flue gas desulphurisation (FGD) is recognised as the most suitable (proven) technology to reduce SO_2 emissions; however it is water and sorbent (Ca) intensive.

The dry (semi-wet) FGD process uses ± 35% less water than the wet FGD process, however, water use at the proposed power station would increase by a third if FGD is utilised.

The use of FGD technology has a negative impact on the environment due to increased mining (Ca source), increased water use for industrial purposes, and increased waste generation ($CaSO_3$ and $CaSO_4$ slurry).

The slurry waste can be converted to gypsum, which can have commercial value. There is currently not a market for Gypsum in South Africa.

Water augmentation is required to ensure that the additional water required for the power station and for other developments in the Lephalale area can be assured. The use of FGD will increase Eskom's water demand and will require larger volumes of water being set aside to ensure Eskom a reliable assured supply (99.5%).

The limited groundwater resources in the Lephalale area can be impacted on by the FGD process, due to the need to store poor quality (recycled) water and due to the large volumes of wet waste that will be generated.

The preliminary risk assessment indicates that any proposed FGD technology to be incorporated in the power station must aim at reducing the amount of water required and that recycling and treatment be utilised to ensure the impacts of additional clean water use minimal.

6.11. Recommendations

- All risk reduction recommendations must be considered during the planning of the new power station.
- Eskom needs to make a integrated water use licence application to DWAF for the water uses the proposed new power station would undertake.
- Eskom include the Main Report of the Crocodile West River Return flow Analysis study.
- Details of the current DWAF studies and its associated public participation processes should be included in the EIA for the proposed power station.

Further to the EIA studies, through the Environmental Management Plan (EMP), the following would be required:

- Monitoring boreholes are to be drilled and constructed on site. The groundwater monitoring points are to include a shallow (± 10 m) and a deep (± 30 m) pair of monitoring boreholes. The pair of monitoring boreholes is to be designed and constructed to allow sampling of the shallow weathered aquifer and the deeper fractured rock aquifers. The monitoring boreholes are to be located adjacent to the potential contaminant sources and approximately 30 to 50 m down gradient of the identified sources.
- Groundwater water levels and hydrochemistry are to be monitored on a quarterly basis. The list of determinants for analysis is the same as presented in Table 6.5.
- Groundwater modelling and potential plume migration is recommended to assess risk reduction measures and potential impacts.