Majuba Power Station Ash Disposal Facility Rehabilitation and Extension

Groundwater Specialist Report

May 2019

31 Allen Drive
Loevenstein
Cape Town 7530
South Africa

C00800-GW-SS-001

www.advisian.com

Advisian
WorleyParsons Group

Synopsis

Advisian, a WorleyParsons (Pty) Ltd Group Company, was appointed by Eskom, as an independent environmental consultant to compile the Groundwater Specialist Report for the for Majuba Power Station Ash Disposal Facility Rehabilitation and Extension. The investigation is for the construction of 2 new Rehabilitation Dams and extension of the 2 existing ash dams. The dams will be utilised for storm water management within the ash disposal facility. This specialist report will provide the environmental practitioners with necessary information to compile and EIA and ensure compliance to environmental legislation and protection to the environment.

Seepage and groundwater movement from these new and extension dams into the groundwater will be controlled by hydraulic conductivity (permeability), hydraulic gradient and the transmissivity of the aquifer, dam lining, material/lining underlying the dams and aquifers underlying the site. Two types of aquifers underlie the ADF area:

- A shallow, weathered rock aquifer'; and
- A deeper, hard rock fractured aquifer.

The upper aquifer often shows groundwater within a few metres below surface with infiltration and seepage from surface water and rainfall. Groundwater in the area is topographically controlled. Groundwater storage and flow in the deeper aquifer is along fractures, bedding planes, joints and other secondary discontinuities. Groundwater flow directions is predominantly to the north with local western and eastern flow towards streams around the ADF. Groundwater levels around the ADF range from seepage at 0 m to 15 m in the deep aquifer.

Potential impacts from the construction of the new dams and extension to the existing dams are as follows:

1. Water Migration from the dams into the underlying groundwater transporting contaminants to the underlying aquifer.

2. Soil and groundwater pollution from hydrocarbons during construction of the dams and during the post-operational phase.

3. Top soil removal from the ADF during construction of the dams leading to downward migration of potential groundwater contaminants. This zone adjacent to the ADF is already disturbed due to construction of the ADF.

4. Local mounding of groundwater due to increased recharge from the dams and change in local groundwater flow directions.

The potential groundwater contamination and seepage of water from the dams to be constructed/extended can be mitigated by compaction of material below the construction are, lining of the dams and following good practice as per the existing management plan, integrated water and waste water plan and best practice. The footprint of the new dams and extension to the dams is considerably smaller than the existing and ADF footprint and groundwater modelling shows that any leakage or migration of contaminants will be masked by potential leakage or seepage from the ADF. Continued monitoring of the existing network of surface and groundwater monitoring points will continue to provide and early warning system to potential pollution from both the ADF and the new dams.

Disclaimer

This report has been prepared on behalf of and for the exclusive use of Eskom, and is subject to and issued in accordance with the agreement between Eskom and Advisian.

Advisian accepts no liability or responsibility whatsoever for it in respect of any use of or reliance upon this report by any third party.

Copying this report without the permission of Eskom and Advisian is not permitted.

Project No: C00800-GW-SS-001 – Majuba Power Station Ash Disposal Facility Rehabilitation and Extension: Groundwater Specialist Report

Rev	Description	Author	Review	Advisian Approval	Date
Rev1	Draft	KM Burgers	L Hattingh	R Kuffner	May 2019
Rev2	Final Draft	KM Burgers	L Hattingh	R Kuffner	June 2019
Rev3	Final	KM Burgers	L Hattingh	R Kuffner	June 2019

Table of Contents

Figure List

Table List

Abbreviations

The following abbreviations are used in this report:

Abbreviations	Description
AD	Ash Dam
ADF	Ash Disposal Facility
DEA	National Department of Environmental Affairs
DEADP	Western Cape Department of Environmental Affairs and Development Planning
DSR	Draft Scoping Report
EA	Environmental Authorisation
EIA	Environmental Impact Assessment
EIR	Environmental Impact Report/Reporting
EHS	Environmental Health and Safety
EMPr	Environmental Management Programme
GSS	Groundwater Specialist Study
IAPs	Interested and Affected Parties
IEM	Integrated Environmental Management
NEMA	National Environmental Management Act, Act 107 of 1998, as amended
NWA	National Water Act, Act 36 of 1999
PS	Power Station
RD	Rehabilitation Dam
WUL	Water Use Licence

1 INTRODUCTION

The purpose of this Groundwater Specialist Study (GSS) is to provide sufficient information and data to assess the surrounding environment with regards to groundwater and assess the impact the facility will have on the aquifer and water environment surrounding and underlying the proposed facility. The report provides an overview of the proposed establishment of two Rehabilitation Dams and extension of two Existing Ash Dams for Majuba Power Station Ash Disposal Facility, hereafter referred to as the 'proposed development' or site / site area.

The GSS provides insight into the proposed development, and identifies potential groundwater impacts, risks and mitigation of these factors. The goal is to prioritise and focus the planning and assessment of the potential issues that may be identified as significant.

1.1 Project Description

Majuba Power Station is a six (6) unit coal fired power plant situated within Mpumalanga, with a capacity to generate 4110 MW of energy. Majuba lies to the south-east of Standerton within the Pixley Ka Seme Local Municipality which falls within the Gert Sibande District Municipality of the Mpumalanga Province (**Figure 1**). The first of Majuba's generating units was commissioned the 1990's and the last in 2001. Eskom's core business is the generation, transmission and distribution of electricity throughout South Africa. Electricity by its nature cannot be stored and must be used as it is generated. Therefore, electricity is generated according to supply-demand requirements. The reliable provision of electricity by Eskom is critical to industrial development and other poverty alleviation initiatives in the country.

The Majuba power station is a major stabilising link to South Africa's network and produces ±9% of South Africa's electricity supply. Majuba is Eskom's only power station that is not linked to a specific mine and it receives its coal from various sources. The power station is running out of space for ash disposal and in order for the station to be able to continue with the generation of electricity it requires an extension to the existing ash disposal facility (ADF) area for the continuous disposal of the ash for the remaining life of the station.

Majuba uses dry methods of ash disposal. The process involves ash being transported from the power station terrace to the ash disposal facility by means of a conveyor and stacker system. The ash handling currently occurs in two independent phases, handling ash on terrace to a centralised loading system at a transfer house. The ash overland conveyor transfers the material off terrace to the ash disposal facility. The ash is disposed by two stacker methods the parallel front-stacking method and the Radial front-stacking method.

An EIA process was previously undertaken for the continuous ash disposal facility (ADF) and an Environmental Authorisation (reference number 14/12/16/3/3/3/53) received from Department of Environmental Affairs. A change in the scope of work during the detailed engineering design for the ADF, **requires 2 new Rehabilitation Dams (RD) and extension of the 2 existing ash dams (AD)** as per the specifications shown in **Table 1**. The RD and AD dams will be utilised for storm water management within the ADF area and their location around the ash dam is show in **Figure 2**.

The above mentioned activity will require an integrated environmental authorisation to be issued by the National DEA and the DWS as the project will trigger certain listed activities in terms of the NEMA, NEM:WA and the NWA. The NWA legislation relevant to this project is discussed in detail in **Section 1.2** of this report.

The following facilities (listed in **Table 1**) within the ADF area will need to be extended to cater for the projected final volumes required by Eskom to adequately sustain the storage of the ash for the remaining life of the power station.

Table 1: Ash and rehabilitation dams' required specifications

Facility Description	Surface footprint change (m^2)		Final storage capacity required (m^3)
Ash Dam 1	Existing =	110 000 m^2	**150 000 m^3**
	Decrease =	69 500 m^2	
	Final area required	**40 500 m^2**	
Ash Dam 2	Existing =	95 000 m^2	**390 000 m^3**
	Increase =	65 000 m^2	
	Final area required	**160 000 m^2**	
New Rehabilitation Dam 1	Final area required	**80 000 m^2**	**240 000 m^3**
New Rehabilitation Dam 2	Final area required	**19 300 m^2**	**65 000 m^3**

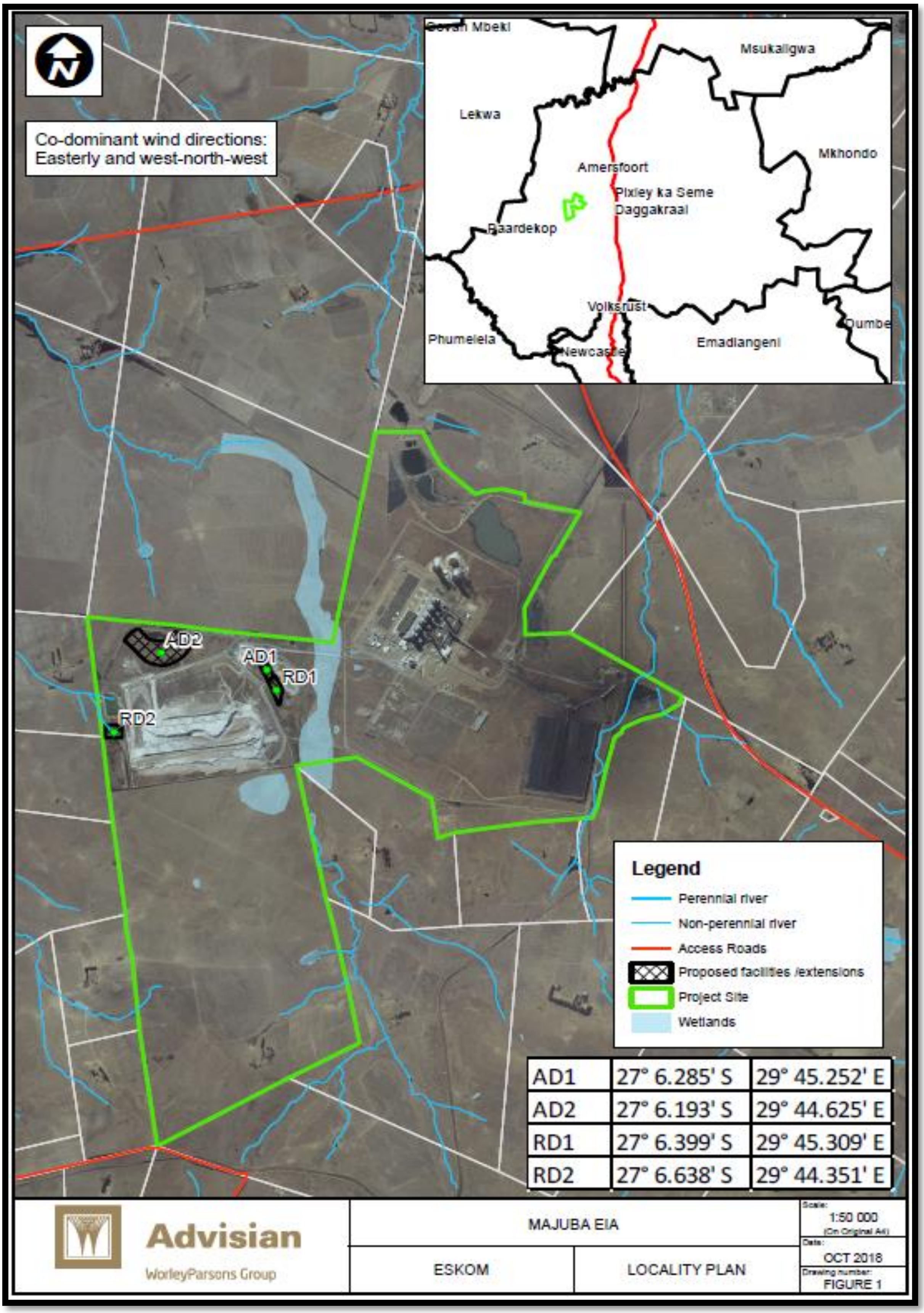

Figure 1: Project site locality

Figure 2: Ash Dam extension plans

1.2 Legal Requirements/Environmental Compliance

The extension of the two ashing dams and construction of 2 new rehabilitation dams requires assessment under the terms of the National Water Act (NWA), Act 36 of 1998. The legislative requirements under which the activities are regulated are listed below. In addition, several documents are needed in order to manage the listed activities under the existing water use license, the Integrated Waste Water Management Plan (IWWMP), method statements regarding operations, activities, pollution prevention and monitoring plans. All of these documents currently exist and were reviewed, and sections integrated in this specialist study. The IWWMP fulfils the requirement of the water use license (WUL) and provides a plan for implementation of the WUL conditions for the water uses related to the current operations at the site (*Eskom, 2016*). The IWWMP details the water and waste water management plan during construction, operation and closure, rehabilitation, monitoring and control of the ADF. Additionally, operations management manuals list activities such as the ash dump strategic plan, environmental controls such as storm water management, dust suppression, rehabilitation and overall water management (*Eskom, 2001*).

The National Water Act (NWA) is the principal legal instrument relating to water resource management in South Africa and contains comprehensive provisions for the protection, use, development, conservation, management and control of the country's water resources. In addition, the management of water as a renewable resource must be carried out within the framework of environmental legislation, *i.e.* NEMA.

A key aspect of the National Water Policy is Integrated Water Resources Management (IWRM). This recognises that water resources can only be successfully managed if the natural, social, economic and political environments, in which water occurs and is used, are taken into consideration. IWRM aims to strike a balance between the use of water resources for livelihoods and conservation of the resource whilst promoting social equity, environmental sustainability and economic growth and efficiency.

The main legislation, applicable guidelines and quality standards of relevance to operating, monitoring and licensing of water use activities are as follows:

- *The National Water Act No. 36 of 1998: Chapter 4 Use of water Sections 21 to 35.*
- *The National Water Resource Strategy (NWRS, 1st Ed., September 2004).*
- *Water Services Act No. 108 of 1997.*
- *National Water Policy White Paper (1997).*
- *Integrated Catchment Management Policy of 2004.*
- *The National Environmental Management Act (NEMA) 107 of 1998.*
- *Department of Environmental Affairs and Development Planning's (DEA&DP) Guideline for Involving Hydrogeologists in EIA Processes (June 2005).*
- *Department of Water Affairs and Forestry's (DWAF, 2004) Integrated Water Resource Management: Guidelines for Groundwater Management in Water Management Areas in South Africa.*
- *A guideline for the Assessment, Planning and Management of Groundwater Resources in South Africa, DWAF, March 2008.*

The water use license for the Majuba Power Station, including the existing ash disposal facility, was granted in 2011 by DWS (License No. 08/C11J/BG/669). The IWWMP addresses all the license conditions contained in the WUL granted but is superseded by the license granted for the extension of the ADF which was granted in 2016 (License No. 08/C11J/BCGI4253) and the activities listed are storing of water in reservoirs, disposal facilities and construction of ash dump facilities over the wetlands and its associated infrastructure within a regulates area of 500 m of other wetlands.

1.3 Scope of Work

The scope of the services for the Groundwater Assessment provided by Advisian are as follows:

1. A desktop study to review, compile and report on existing and available groundwater information contained in reports, maps and databases for the site and surrounding area.

2. Assess data to determine climatological, catchment, surface water features, topographic, geological and hydrogeological information to assess the aquifers, groundwater depth and flow direction and construct a conceptual model or cross-section for the site.

3. Report on all data including producing site layout, aquifer, geology and groundwater flow maps.

4. Conduct a risk assessment that the new and extension to the ash dams poses to the groundwater regime.

5. Make recommendations on the monitoring, protection and management of the groundwater regime underlying the site and provide input to the EIA.

1.4 Deliverables

Specific deliverables from the engagement are as follows:

- Groundwater specialist study compilation of available information.
- Data Analysis.
- Conceptual model review and groundwater assessment.
- Risk Assessment.
- Final Groundwater specialist report with recommendations regarding monitoring and management.

1.5 Project Team

The geohydrological project team for the baseline assessment comprised:

Karen Burgers (Pr. Sci. Nat.), Specialist Hydrogeologist: Karen has 18 years of experience in geohydrology, geology and geochemistry work. She has conducted groundwater studies in many areas; project managed numerous groundwater studies, conducted Water Use License assessments and managed, conducted and set up environmental monitoring programmes. Karen has conducted numerous groundwater specialist studies, contamination assessments and water supply projects, in areas of nuclear power, solar power, municipal supply and management, industrial sites, private, rural and mining projects in Southern Africa. Karen was the project manager for this study and compiled this report.

Rian Kuffner, Senior GIS Associate: Rian is a GIS Professional with over 10 years' experience of applying GIS in the engineering and environmental fields and currently is the GIS Lead for WP RSA.

oversees and manages the development, maintenance and practices of GIS in the region. Rian is experienced in data capturing and modelling, spatial analysis and map production.

1.6 Information Sources

All information sources are listed in the reference list contained in **Section 6**. The data and information predominantly consist of previous studies for the EIA, WUL application and for construction activities for the siting and construction of the ash disposal facility.

2 GEOGRAPHIC AND PYSIOGRAPHIC SETTING

2.1 Geographic Location

The Majuba Power Station (PS) is located approximately 16 km southwest (SW) of Amersfoort and approximately 40 km north-northwest (NNW) of Volksrust in the Mpumalanga Province. The power station falls within the Pixley Ka Seme Local Municipality which falls within the Gert Sibande District Municipality. The ADF and new and extension dams is located just to the west of the power station. The power station and ADF are surrounded by agricultural land but the farms on which the PS and ADF are situated is zoned for industrial use.

2.2 Physical Environment

The area surrounding the PS is characterised by high levels of habitat transformation, isolation and habitat fragmentation, resulting from persistent increases in mining and agricultural activities, urban developments, linear infrastructure (roads, railway lines) and poor land management practices. The effects of commercial agriculture (maize production), infestation by alien invasive trees and recent increase in mining activities are evident from the mosaic appearance of land cover in the immediate region. Road and railway infrastructure in the region caused a moderate level of habitat fragmentation and isolation.

The area around Majuba Power Station and ash dams and is located on the eastern edge of the Highveld plateau, with generally undulating slopes of between 2 and 8%. The elevation is between 1 700 and 1 800 meters above sea level. No major rivers occur in the area, although several wetland areas, both seasonal and perennial, surrounding the ADF. A tributary of the Palmiet Spruit flows northward from the western part of the study area, while the Skulp Spruit flows from the eastern parts. The area previously comprised a mixture of natural grassland, previously cultivated areas and natural grazing utilized by livestock (*ARC, 2014*).

The study area falls entirely within the Amersfoort Highveld Clay Grassland vegetation unit. The vegetation is described as undulating grassland plains, with localised patches of dolerite outcrops in certain areas. The landscape is typically comprised of short closed grassland cover which is often severely grazed to form a short lawn. Approximately 25 % of the vegetation type is transformed of which 22 % is through cultivation, while alien vegetation invades drainage lines. Overgrazing has led to the invasion of bankrupt bush. According to the Mpumalanga Terrestrial Biodiversity Conservation Plan map, the study area intersects both “Least Concern” and “No Natural Habitat Remaining” areas (*Ecotone, 2014*).

2.3 Topography

The study area, within the 12 km radius, is characterised by strong undulating character typical of the Mpumalanga province with hills and koppies to the south and east. The natural topography of the area has been disturbed as a result of various mining, agricultural and power generation activities. The general topography of the site shows a slope from south to the north in the area surrounding the ADF and PS from 1740 to 1700 mamsl.

2.4 Climate

The Majuba Power Station lies within quaternary sub-catchment C11J of rainfall zone C1B. The Majuba Power Station area is characterised by moderate summer rainfall and according to the Köppen Classification, the climate of the area is defined as temperate to warm temperature with summer rainfall. The climate in the study area can be described as typical highveld conditions with summers that are moderate and wet, while winters are cold and dry. Severe frost and snow are sometimes experienced. The area also falls within the mist belt. The winds in the region are usually north-westerly and reach maximum speeds in the afternoon. During thunderstorms, strong and gusty south-westerly winds are common but short in duration for these wind periods. During prolonged droughts, dust storms may be frequent. Local thunderstorms and showers are responsible for most of the precipitation during the summer. Hail and lightning is sometimes associated with the thunderstorms and mainly occur from October to December and in March. Fog occurs frequently throughout the year. The winds in the region are usually north-westerly and reach their maximum speed in the afternoon.

2.4.1.1 Rainfall

The average precipitation for this region (from the closest weather station Zaaihoek is 837 mm per annum. The data from the Majuba monitoring station shows a mean annual precipitation is approximately 760 mm/year. The study area falls within a summer rainfall region, with over 85% of the annual rainfall occurring during the October to March period with average monthly rainfall during these months ranges from 30 to 122 mm per month. The area shows a mean annual evaporation of 1677 mm and a mean annual runoff of 50-100 mm. The climate is therefore one where potential evaporation exceeds precipitation. Mean temperatures reach a maximum during December/January (average minimum of 12.9°C and average maximum of 37.6°C) and a minimum in June/July (average minimum of -1.6°C to average maximum of 25°C). **Figure 3** shows the average monthly rainfall for the Majuba Power Station and the average monthly minimum and maximum temperatures.

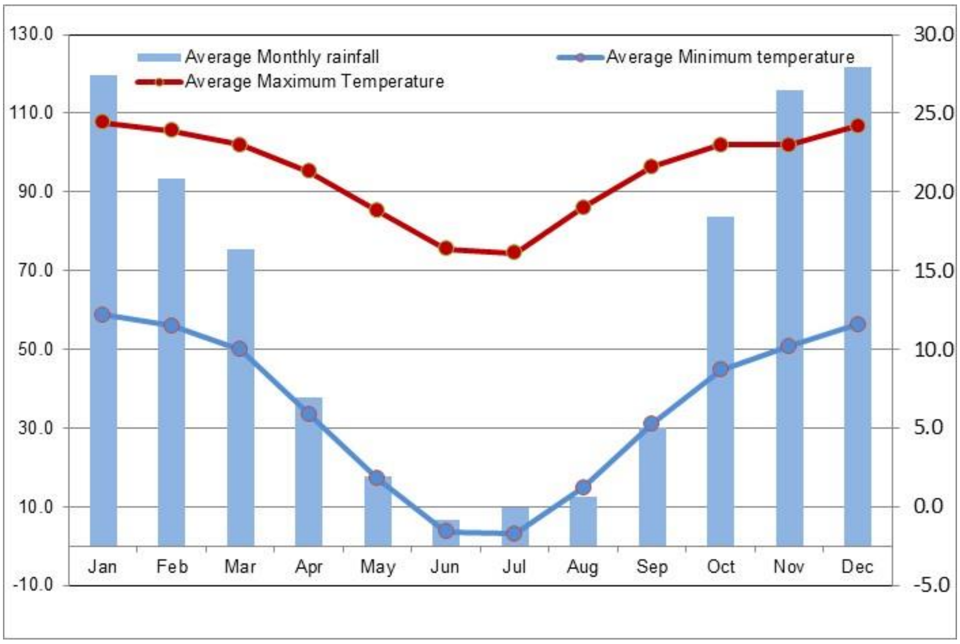

Figure 3: Average monthly rainfall and minimum and maximum temperatures for the Majuba Power Station (mm/annum)

2.4.1.2 Wind

The prevailing wind direction is recorded as being co-dominant, with both easterly and west north-westerly winds prevailing. **Figure 4** shows the period, day-time and night-time wind roses for the Majuba Power Station from 2009 to 2012. The easterly winds occur predominantly at night and the westerly winds during the day.

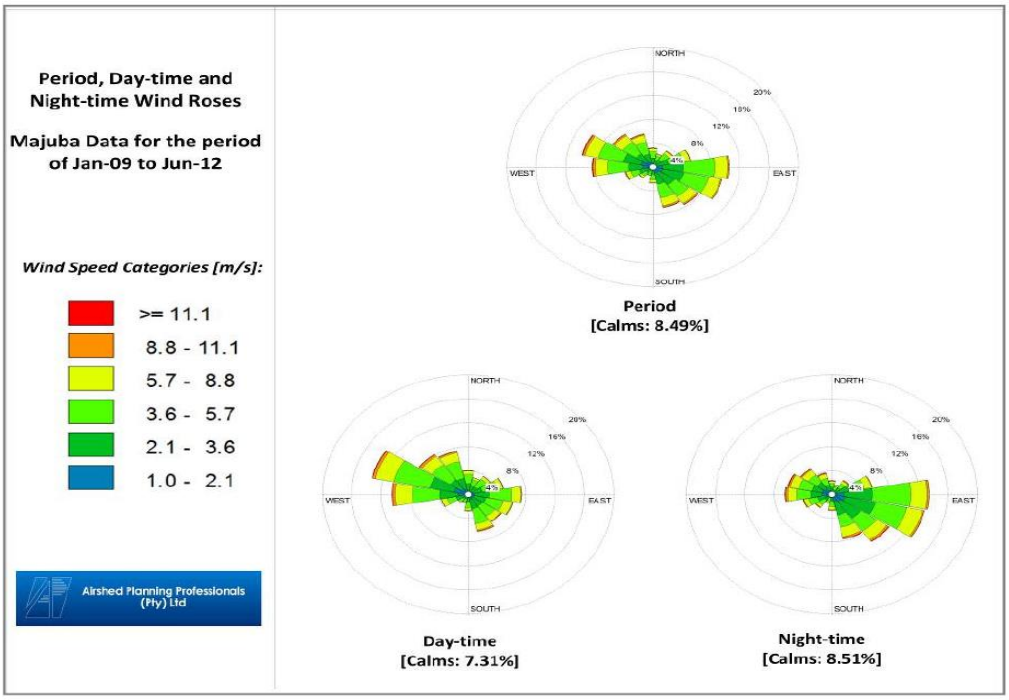

Figure 4: Wind roses for the Majuba Power Station

2.5 Hydrology and Drainage

The area of interest falls entirely within quaternary catchment C11J in the Upper Vaal Water Management Area (WMA). All watercourses draining the project area and its immediate vicinity ultimately flow into the Geelklip Spruit River which flows in a north-westerly direction and joins the Vaal River (**Figure 5**). The facility falls within the Upper Vaal River Primary Drainage Region and lies within the upper reaches of the Geelklip Spruit. The Geelklip Spruit flows past the eastern side of the Majuba PS, with the proposed new dams and extensions are located to the west of the Geelklip Spruit. Several perennial and ephemeral surface water courses occur within the radius of Majuba PS (*GHT, 2017b*).

The Majuba Power Station and ashing area can be sub-divided into secondary drainage regions comprising smaller catchment areas and streams. The surface topography of the area is typical of the Mpumalanga Highveld, consisting of gently undulating plateaus. The flood plains of the local streams are between 1 700 and 1 720 meters above mean sea level (mamsl). The surface drainage direction of the Ashing Area occurs to both the north, east and west of this facility. The water drainage which originates from the Ashing Area will flow either into the Mezig or the Palmiet Spruits. The surface drainage of the Power Station Area and the Coal Stockyard area will be to the north and east of these facilities draining into the Geelklip and Witbank Spruits, respectively (*GHT, 2017b*).

The 2 new Rehabilitation Dams (RD) and extension of the 2 existing ash dams (AD) could potentially affect a non-perennial stream close to the western ash dam, a non-perennial stream to the north of the dams which drains in a northerly direction and numerous wetland seeps to the east of the ash dam (**Figure 6**).

The majority of wetlands throughout the study area have been categorised as being in a near natural state, Present Ecological State (PES) of A/B. The non-perennial watercourse draining to the west of the ADF is classified as a seep wetland, also with a PES of A/B (*Ecotone, 2014*).

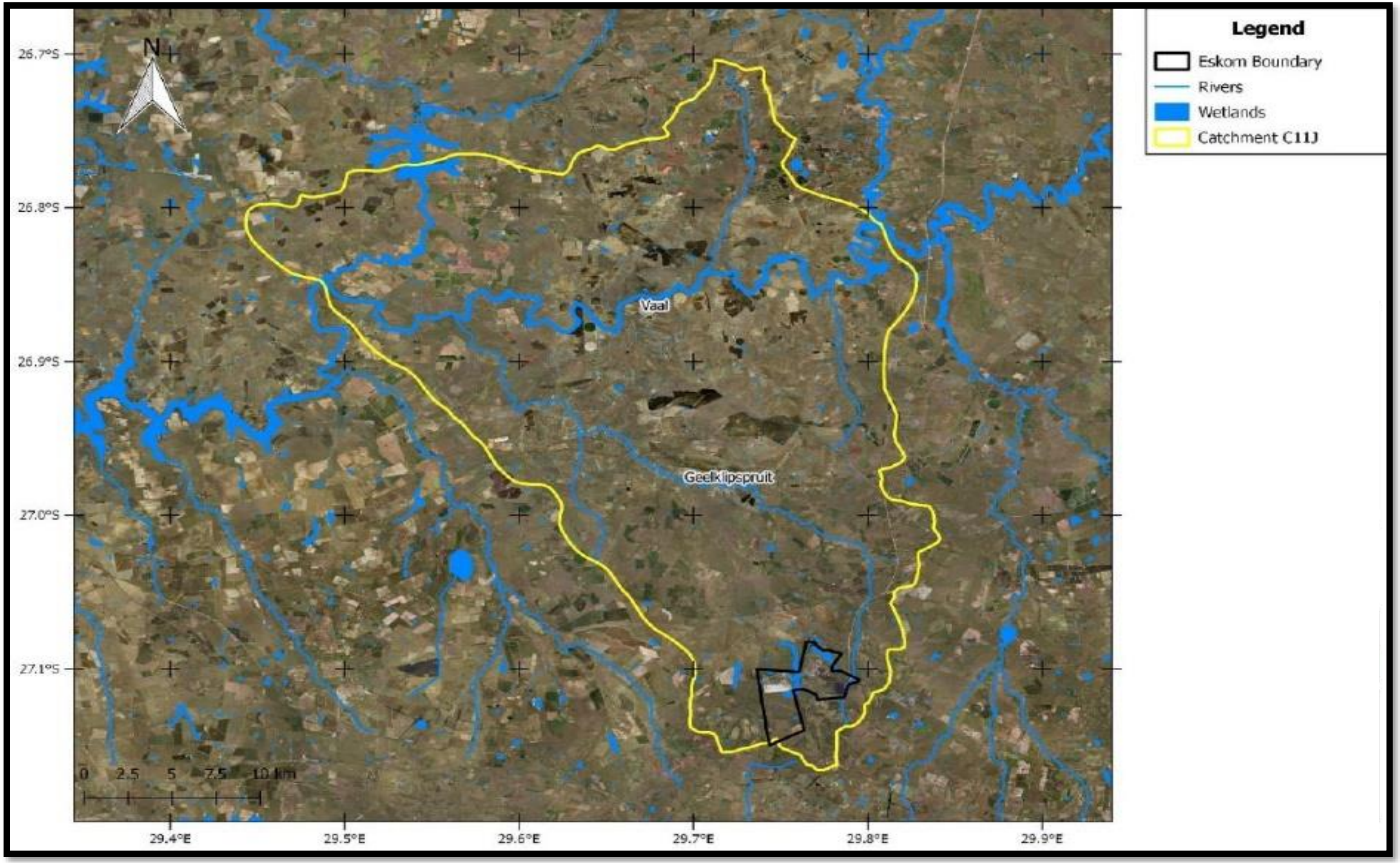

Figure 5: Location of Majuba power station property boundary within quaternary catchment

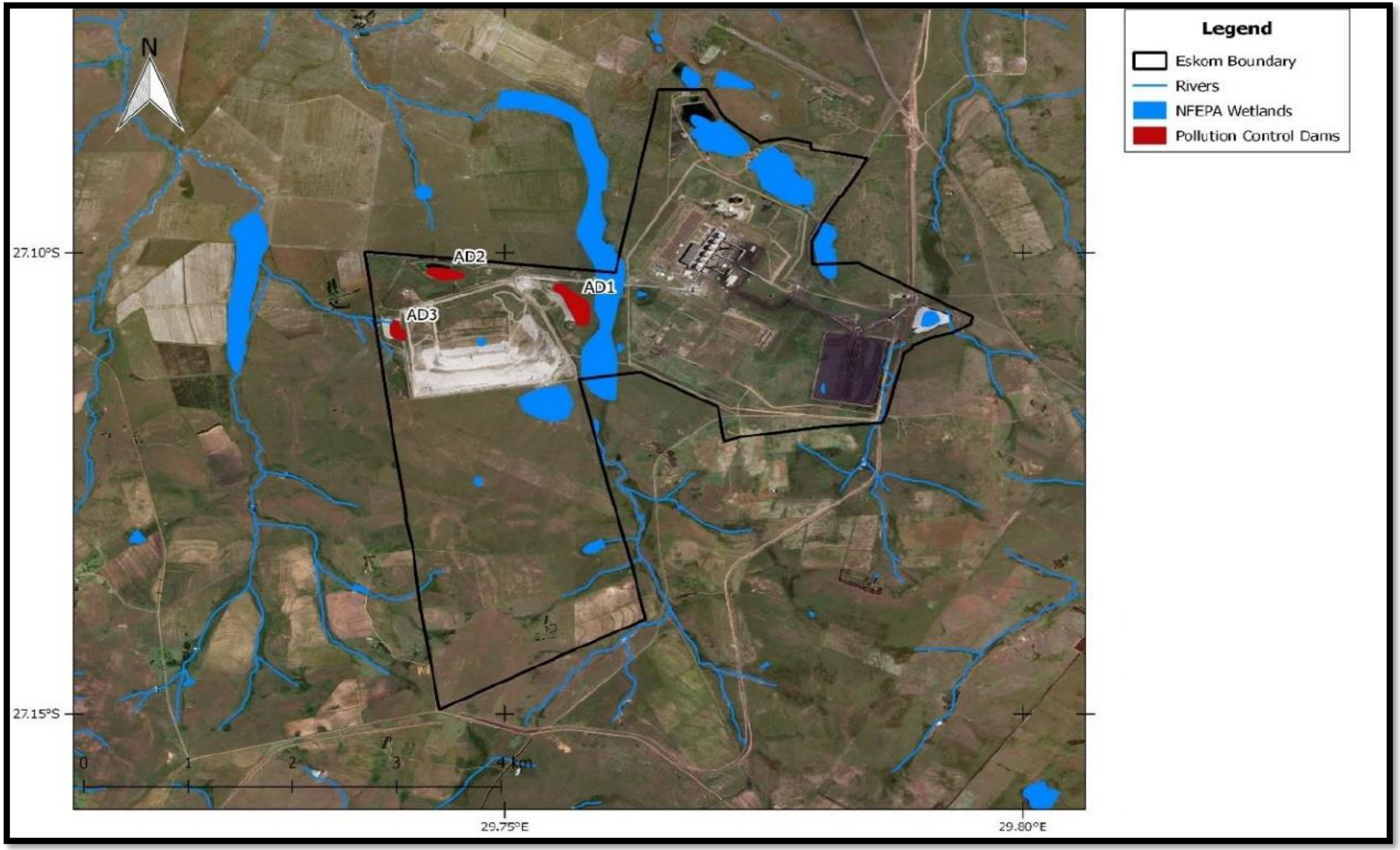

Figure 6: Freshwater resources potentially affected by new dams

3 GROUNDWATER ENVIRONMENT

3.1 Geology

Majuba Power Station lies on the north-eastern rim of the Great Karoo Basin which predominantly comprises sediments of the Karoo Supergroup. The Carboniferous to early Jurassic aged Karoo Supergroup have been intruded by Karoo dolerite along planes of weakness and form a large part of the Karoo rocks in the area. The Permian Ecca group which underlies the study area comprises sedimentary rocks of the Vryheid and Volksrust Formations.

The Karoo sediments that directly underlie the site belong to the Volksrust Formation (Ecca Group). The sediments consist of light to dark bluish grey micaceous mudrocks and shales with subordinate and intercalated siltstone/sandstone (*Johnson et. al., 2006*). Over much of the Karoo basin, the sedimentary rocks are horizontally bedded or have very gentle dips. Sandstones comprise a large portion of the Karoo sediments and are generally closely intercalated with mudstone, shale, siltstone, phosphate beds and nodules. The rocks underlying the Volksrust Formation are coal-bearing siltstones and mudstones of the Vryheid Formation. These rocks formed in deltaic and fluvial environments with coal forming in peaty swamps (*Johnson et. al., 2006*). The Volksrust Formation underlies the site and the Vryheid Formation outcrops 8 km north of the power station. These two formations appear to grade into one another and were deposited directly on the bedrock of Ventersdorp basement which formed the pre-Karoo topography. Both the Volksrust Formation and the Vryheid Formation rocks are well lithified (hard) and have little primary porosity. The geology of the study area is shown in **Figure 7**.

The Karoo sedimentary rocks are also extensively intruded by igneous Jurassic dolerite rocks of the Karoo Igneous Province, regarded as the uppermost unit of the Karoo Supergroup (*Johnson et al, 2006*). The intruding dolerites dykes comprise dark-coloured, crystalline, igneous basaltic rocks weathering as prominent ridges or hills. These rocks form a network of dykes, sills and sheets. Surface outcrops of Karoo dolerite are mapped both to the north and south of Majuba power station, but these rocks are also likely to underlie the power station area in places within the surface outcrops of sedimentary Karoo rocks.

No quaternary or unconsolidated deposits such as sand, alluvium or colluvium are mapped in the vicinity of Majuba power station, but there are likely to be relatively small deposits of such material associated with the larger river or stream courses in the wider study area.

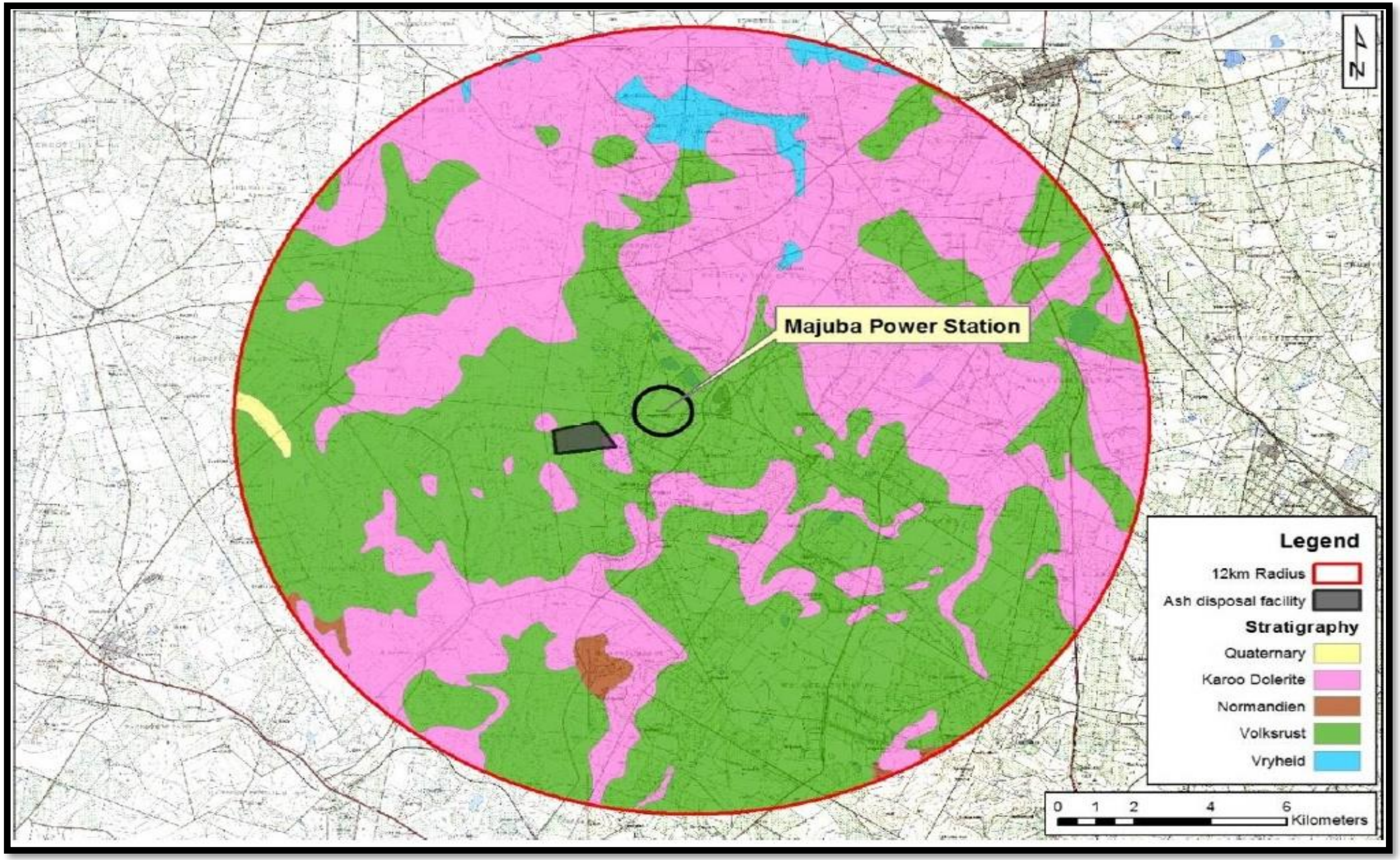

Figure 7: Geology of the study area

3.2 Soils

Work conducted to assess the soils in the area underlying the ash dams reflected the varied nature of the soils occurring in the area (*ARC, 2014*). The area has a mixture of different soil forms, ranging from yellow-brown, structureless sandy clay loams (*Avalon* unit) to areas of shallow, rocky soils (*Mispha* unit), as well as black clayey, structured soils (*Arcadia* unit). Soils sampled surrounding the ash dam were wetland soil are composed of high clay subsoil as well as swelling clay soils and are derived from igneous rocks with high to very high clay contents, high pH values and high base status. The remaining soils observed are derived from the Ecca shale and sandstone, with light to moderate texture and a higher degree of leaching, reflected in the lower (more acidic) pH values. The area shows a lack of cultivation and low phosphate show low fertilization in the area and low phosphates in the soil overall.

The geotechnical work conducted prior to the construction of the existing ash dam found the following conditions underlying the area of the rehabilitation and ash dams (*Jones & Wagener, 2016*):

1. Soil properties and potential problem soils:
   - The topsoil and hillwash material were pinhole voided but this layer is thin and has a slight collapse potential;
   - The presence of Nodular Ferricrete, found in approximately 30% of the test pits excavated above the clay rich reworked residual soils creates a potential flow path for seepage and a possible path for contaminants;
   - Material in the lower lying, wetter areas, specifically within the reworked residual, gullywash and alluvial clays, had a slickensided structure which could cause soil stability problems.;
   - The above materials also had a shattered fabric at the surface in the slightly drier areas, characteristic of the potential to heave or shrink in response to moisture changes, but heave is expected to be minimal.
2. Groundwater/ seepage:
   - Ground water seepage was recorded in 4 test pits within lower lying areas and the material within the alluvial profile tend to be moist as is expected within a wetlands area.
   - Potential seepage along the nodular ferricrete layer needs to be noted as evidence of leaching along this layer was found.
3. Excavatability:
   - The hillwash, gullywash, reworked residual and residual soils classify as soft excavation material underlying the ash dam. An exception are stiff dried out clays (gullywash) and classify as intermediate excavation material.
   - Blocky dolerite occurs within the side banks of the Palmiet Spruit tributary.

3.3 Aquifers

The geology underlying the site determines groundwater flow, aquifer characteristics and potential migration of contaminants. Seepage and groundwater movement is controlled by the hydraulic conductivity (permeability), hydraulic gradient and the transmissivity of the aquifer and rocks underlying the site. Based on the geology, there are two aquifer systems underlying and surrounding the site are:

- A shallow, weathered rock aquifer, referred to as the 'shallow aquifer'; and
- A deeper, hard rock fractured aquifer, referred as the 'deeper aquifer'.

The upper shallow weathered zone aquifer is a combination of primary (groundwater in alluvium and weathered soils) and weathered fractured rock aquifer. Within this aquifer water is often found within a few metres below surface. Surface water and rainfall infiltrates this weathered material and flows along deeper barriers or layers (shale/dolerite). Flow is then lateral in the direction of the surface slope as groundwater follows surface topography and groundwater in the area is topographically controlled. This horizontal flow can appear on surface as baseflow in streams or as springs downgradient of infiltration (*SLR, 2014*).

Groundwater storage and flow in the deeper aquifer is predominantly in and along fractures, bedding planes, joints and other secondary discontinuities (*DWAF, 2000*). The success of a water supply boreholes in these aquifers is dependent on the density, number and intersection of these structures intersected by a drilled borehole. Dolerite and sandstone show better development of these structures therefore these formations show higher water-yielding potential. Yields from boreholes in the deep aquifer vary from 0.01 l/sec to 16 l/sec and on average between 0.1-0.5 l/s (*DWAF, 2002*) underlying the ADF and power station area.

In general, the Volksrust Formation underlying the ADF and PS is considered a minor aquifer, with some abstractions of regional importance in fracture zones adjacent to dolerite intrusions (*Parsons, 1998*). A minor aquifer is a moderately yielding aquifer system of variable water quality (*Parsons, 1995*). Although these aquifers seldom produce large quantities of water, they are important in supplying base flow to rivers.

Groundwater seepage to the underlying aquifers is derived predominantly from infiltration from rainfall. In the ADF are additional sources can be from moisture in the ash seeping into the shallow aquifer, runoff around the dams and from infiltration of water used for dust suppression (*SLR, 2014*).

3.4 Groundwater Levels

Boreholes targeting groundwater in the Volksrust or Vryheid formations are, in general, drilled between 35-40 m deep and those targeting dolerite intrusion are drilled, in general, between 50-60 m. Natural groundwater quality is in general of a potable nature with local high occurrences of salinity causing brak water (*SLR, 2014*).

On average the water levels below the Majuba Power Station area occur at a depth of 3.06 mbgl with a minimum depth of 0.31 mbgl between ash disposal facility and Witbank Spruit and maximum depth of 15 mbgl between the ash disposal facility and Palmiet Spruit. Artesian water and seepage does occur surrounding some of the ash dams (*GHT, 2017a*).

Routine surface water and groundwater monitoring reports are available and contain groundwater levels and quality in the vicinity of Majuba Power Station (*GHT, 2017a*). The surface water and groundwater monitoring network at Majuba is divided into specific areas according to their location relative to the infrastructure. Several different monitoring areas are identified at the power station:

- Palmiet Spruit Drainage System: drainage to the west of the power station, drainage to the east and north of the ash dump and clean and dirty water to the south of the ash dump.

- Metzig Spruit Drainage System: drainage to the west of the ash dump.
- Geelklip Spruit Drainage System: drainage to the north of the coal stockyard, the sewage plant and power station and drainage to the west of the game camp.
- Witbank Spruit Drainage System: coal stockyard.

The monitoring sites are composed of 8 different types of monitoring (*GHT, 2017a*):

- Groundwater
- Rivers or natural streams
- Canal or trenches
- Sewage effluent or discharge sites
- Pan or dams
- Seepage sites
- Other sites.

The monitoring points in various conditions are routinely monitored at the power station and ashing area (*GHT, 2017a*). The Palmiet Spruit drainage area contains 61 monitoring points, the Mezig Spruit drainage area contains 13 monitoring points, The Geelklip Spruit Drainage System contains 28 monitoring points and the Witbank Spruit Drainage System contains 18 monitoring points. Therefore, a total of 110 monitoring points in various conditions and types are monitored on a quarterly basis, depending on access and condition. Some of the sampling points often do not contain water or the equipment is out of order and sampling cannot take place.

The variability in water level elevations across the Majuba Site is estimated to be a function of the topography, with shallow groundwater observed in lower lying areas and deeper groundwater levels on the ridges (*GHT, 2017a*). Groundwater levels close to the existing ash disposal facility are very close to the surface (and in some cases artesian). This is thought to be as a result of topography, but also due to seepage from the ash disposal facility and associated surface water infrastructure such as the toe drains, clean and dirty water dams. In general, groundwater in the study area flows from areas of higher topography to lower-lying areas. Groundwater discharge (e.g. springs, seeps, marshy areas) occurs in lower lying areas, pans and river courses. Water levels in the Ash Dump site and the majority of the boreholes vary between 1-7 mbgl. Water levels in the deeper aquifer have been observed to 15 mbgl (*GHT, 2017a*). The Mezik drainage area water levels vary between 0-11 mbgl. The Geelklip Spruit drainage area shows water levels between 1-6 mbgl and the Witbank Spruit drainage area water levels between 0.3-4.3 mbgl.

3.5 Ground Water Quality

Two types of groundwater have been observed to occur in the Majuba Power Station area. These two types are (*SLR, 2014; GHT, 2017a &b*):

- Calcium-bicarbonate (Ca-HCO_3) water which originates as runoff (ash moisture, dust suppression, etc.) and enters the groundwater system through Ash Dump area. This is typical of shallow, fresh groundwater, implying that it is freshly recharged water (rainwater or seepage).
- Sodium-bicarbonate (Na-HCO_3) water – this type of groundwater occurs in the deeper aquifer within the fracture rock aquifer in the groundwater found in sandstone and dolerite.
- Variable concentrations of SO_4, Mg and Cl in the above water types.

Figure 8 shows the variations in groundwater type on a piper diagram, as analysed for from site boreholes. Groundwater monitoring has been occurring on the site since 2010 (*SLR, 2014)*.

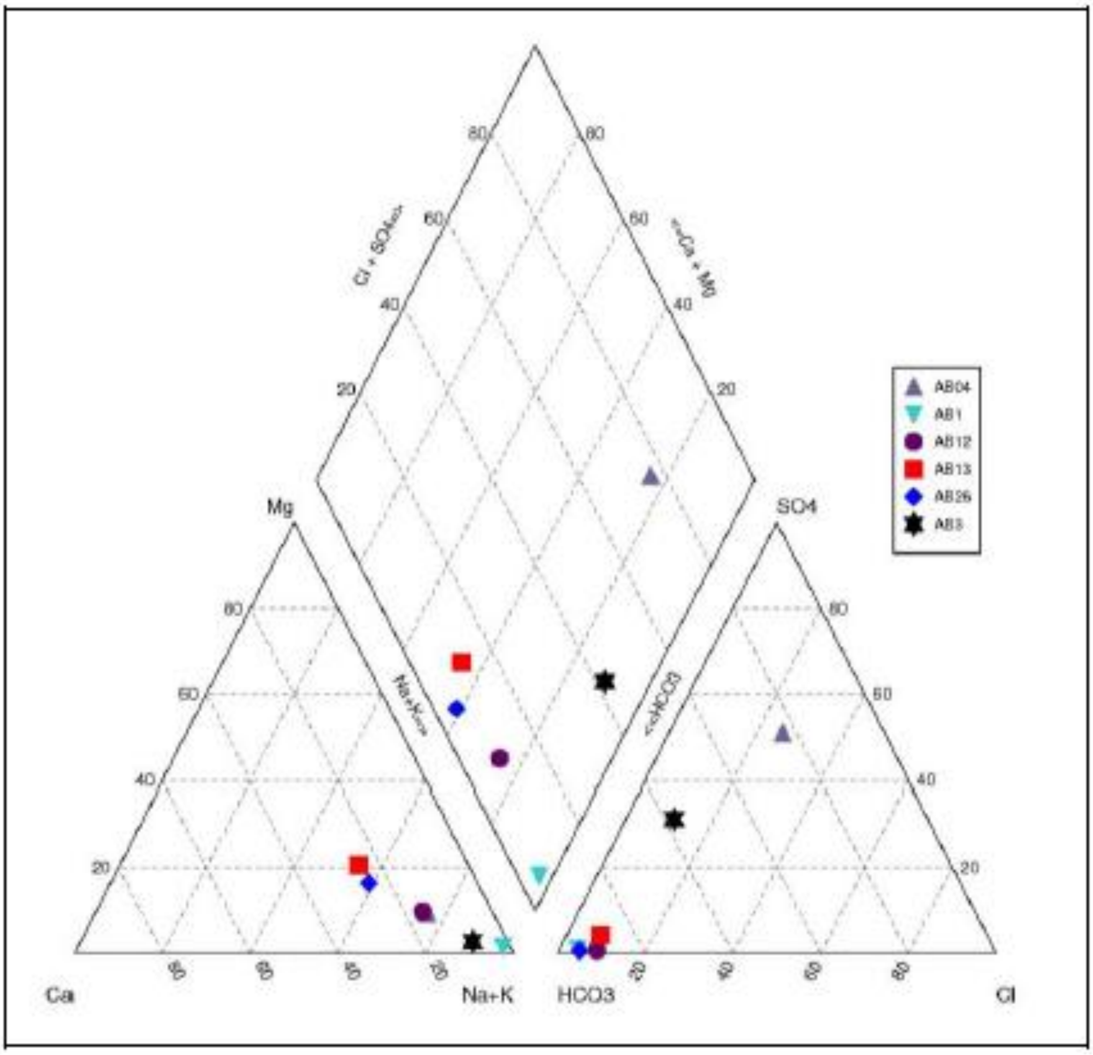

Figure 8: Groundwater chemistry underlying the Majuba site

3.6 Groundwater Flow

Recharge moving through the soil or upper weathered aquifer can combine with leachate from the ash storage facility and then migrates downwards through the unsaturated zone to the water table. The volume of leachate produced by each ash storage facility depends partly on the hydraulic properties of the compacted ash and the lining below the ash dams.

Groundwater below the water table moves with the local groundwater gradient towards discharge zones (i.e. water resources such as nearby streams, springs, wetlands and dams). Groundwater gradients are determined by surface topography and the water table follows the topography (i.e. groundwater flows from higher areas to lower areas). Due to the shallow depth to groundwater below and around the ADF and associated infrastructure it is assumed that some leakage from the base of the ash disposal facility the shallow groundwater (groundwater mounding has formed under the ash disposal facility) (*SLR, 2014)*. This is supported by the poor groundwater quality in some boreholes close to the existing ash disposal facility (*GHT, 2017a*). Due to proximity it is difficult to separate the effects of leakage from the ash disposal facility from the effects of leakage from return water dams, toe drains and other surface water impoundments. Any seepage or leakage from the new RD's and extension to the existing AD's will also be unable to be separated from any leakage from the ADF. The larger ADF overshadows all potential contamination and leakage from the site as a whole. Therefore, the impact of leakage from these proposed dams is combined with the existing ADF. Any leachate from the current ash disposal area that is not intercepted by leachate control facilities, will flow through the aquifer and discharge at nearby surface water courses. Due to confining layers of shale or dolerite at depth this seepage to the deep aquifer is unlikely. Groundwater will flow via fractures, faults, fissures and other secondary discontinuities in the rock. Locally the groundwater gradients are expected to be modified because shallower groundwater depths are associated with the ash disposal facilities and other water sources(mounding) (*GHT, 2017b*). **Figure 9** shows groundwater flow direction and elevation based on topography of the site (*GHT, 2017b*). These water levels and flow directions are based on pre-operational data and therefore reflect information prior to construction of the ashing facility. The predominant groundwater flow is to the north with some flow towards surface water features to the east and west.

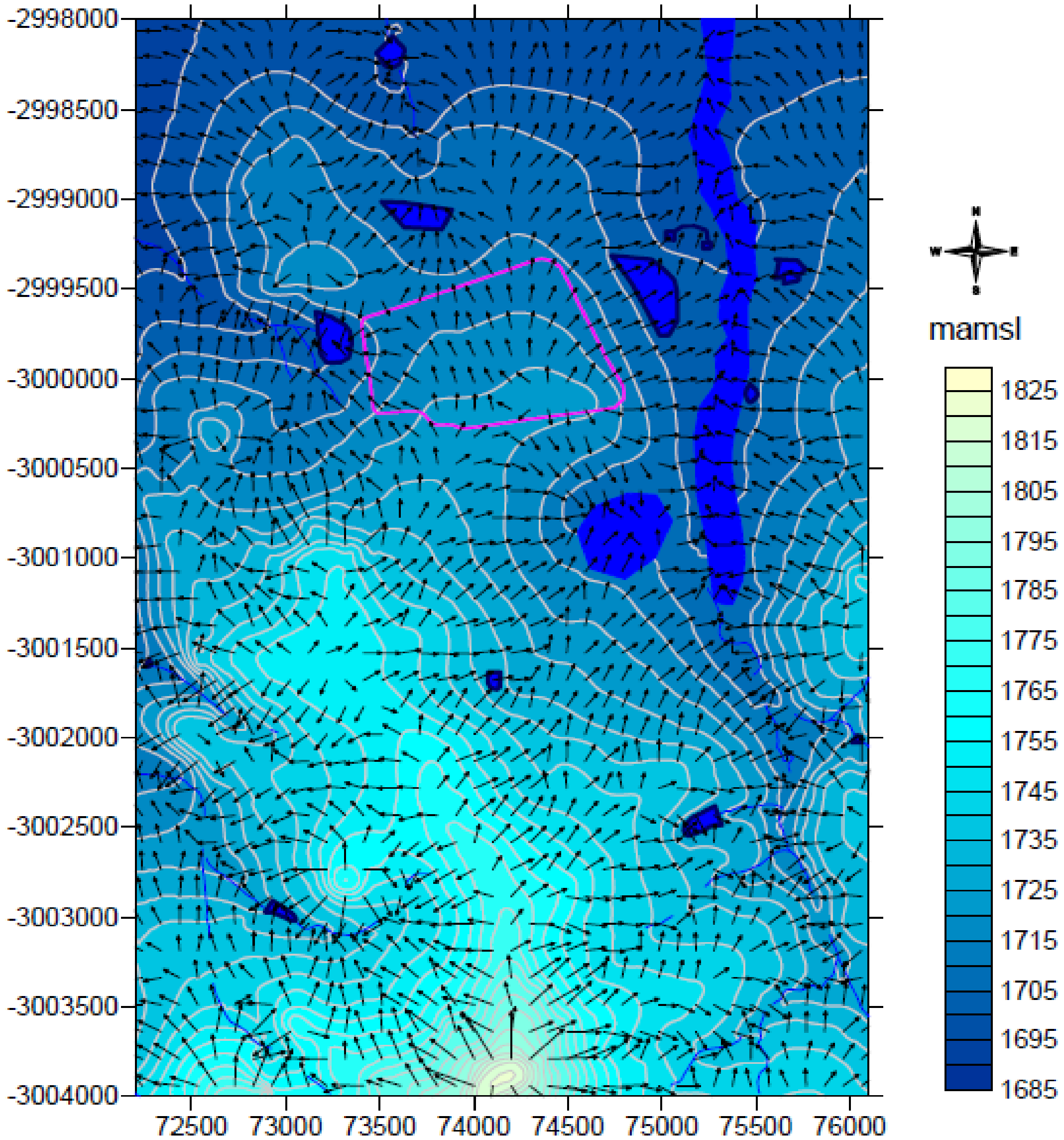

Figure 9: Groundwater flow directions underlying the Majuba site and ADF

3.7 Aquifer Properties

Slug test were previously performed on all the boreholes to determine the hydraulic properties of the aquifer in the immediate vicinity around the boreholes. Conductivities are relative low due to the fractured rock nature of the aquifers with values between 0.008 and 0.78 m/d (*GHT, 2017b*).

3.8 Conceptual Model

The conceptual model of the ADF and surrounding area was developed by GHT (*2017b*) and SLR (*2014*) during pervious EIA applications and for pollution plume modelling. The conceptual model details three model layers for the conceptual mode. The layers are differentiated by hydrological characteristics and therefore respond differently during the numerical modelling to water infiltration and are modelled differently with regards the pollution plume modelling. The three layers are as follows (*GHT, 2017b*):

- An upper layer of all manmade structures like the ash stack, waste sites cut of drains, rivers, streams and dams.
- A thin weathered zone comprising weathered dolerite and dolerite dykes, clays and soil – the unsaturated zone forms part of the top weathered formations.
- The underlying rock of possible fractured dolerite and less permeable sediments which may contain intrusions or fractures. These fractures or dykes may act as preferential pathways for pollution migration. Semi-confined aquifers within the Ecca Formation occurred in this layer as well.

3.9 Ash Properties and Source-Path-Receptor Information and Groundwater Modelling

A conceptual model was developed by Eskom in order to determine source path receptors for the existing and proposed extensions (*Eskom 2018*). The conceptual model of the layers, potential flow paths of pollutants and layers of the conceptual model is show in **Figure 10**.

A numerical groundwater flow and transport model was developed to simulate the potential movement of leachate from the ash disposal facilities to groundwater (*GHT, 2017b*). Leachate plumes are likely to move with the groundwater flow in a direction determined largely by the surface topography and gradient. However, the predictions depend on aquifer properties and on leachate seepage rates.

A detailed Source-Pathway-Receptor (SPR) study was conducted by for the ash disposal facility (ADF) on the Majuba site as well as characterisation of the ash as a potential pollutant (*Eskom 2018*). This study identifies and assesses potential liabilities associated with the operation of a lined and unlined ADF. The study was conducted with hydrogeological data collected prior to construction of the ADF, during monitoring and using a calibrated numerical model (*Eskom 2018*).

3.9.1 Source Characterisation

The Majuba Power Station employs a dry ash disposal method, *i.e.* the ash has a 20% moisture content. The ash from the Majuba Power Station was provisionally classified as hazardous. This is because the Minimum Requirements classifies the energy sector, specifically the production of electricity from coal, as an industrial sector which may generate hazardous waste. Based on the results obtained from the distilled water leach performed on the leach solution and total concentration analyses performed on the ash, the ash sample is classified as a Type 3 waste requiring disposal on a waste disposal facility with a Class C barrier system provided there are no site-specific risks that require a more conservative barrier system (*Eskom 2018*).

The Type 3 waste classification was the result of the concentrations of chromium VI (Cr^{+6}), arsenic (As), barium (Ba), molybdenum (Mo) and fluoride (F). The ash is also not classified as a carcinogen. No evidence could be found that the ash is teratogenic or mutagenic either. The ash is also excluded from regulatory control with respect to radioactivity (*Jones & Wagner, 2013*).

For the ash disposal facility (ADF), extension to the ash dams and the new rehabilitation dams, the ash from the dams and water seeping in and flowing off the ash dams will be the source of contaminants with the potential to reach and pollute the groundwater. Water into these dams will come from natural rainwater, infiltration from dust suppression and irrigation. From geochemical perspective, the old fly ash material is classified as Type 4 based upon the leachable concentrations (B, Mo, As, Ba, F and Cr^{+6})) and the fresh ash material as Type 3 as no concentrations exceeded the leachable or total thresholds. The older fly ash may contain elevated metals due to poorer quality coal use in the past or weathering which has exposed metals in the ash (*Jones & Wagner, 2013*).

3.9.2 Pathway

Any contaminated leachate leaving the ADF and new proposed dams, would seep through the underlying unsaturated zone before entering the shallow aquifer. The leachate would then be transported along with groundwater to nearby receptors. The upper aquifer (shallow) is associated with the weathered zone is often found within a few meters below the surface. The saturated zone movement occurs above the shale layers or dolerite and follows the surface slope. On the surface this water appears as either baseflow in nearby streams or as seeps. Groundwater flow and migration of potential contaminant from the ADF will be controlled by fractures with very low permeability (*Eskom 2018*). The potential flow paths of contaminants are shown in **Figure 10**.

3.9.3 Receptors

Abstraction boreholes, springs surface water streams and wetland, with their respective ecosystems, represent the main receptors of potential impacts from the ADF and new dams. The receptors fall within two catchments, a high risk and a low risk catchment. All downstream boreholes between the ADF, Witbank Spruit and Geelklip Spruit fall within the high-risk area and the Palmiet Spruit falls within low risk receptor catchment (*Eskom 2018*).

3.9.4 Model Results

Two scenarios were modelled using the numerical model: a high-risk scenario with no liner underlying the ADF and with a class C liner underlying the ADF. As the new RD and AD will be constructed using Class C liners the assessment, risk and mitigation with regards to the source, receptors and pathways is discussed here, only. Any contaminants reaching the groundwater from these new dams will be completely masked by potential contaminants from the larger and adjacent ADF. The ADF potential pollution plumes dominate the surrounding aquifer material and no distinction will be able to be made from where the pollution originates.

Class C Liner in place: The RD and AD with mitigation measures (Class C liner), including cut-off trench and the underlying clay well compacted to ensure that the hydraulic conductivity is $1x10^{-9}$

m/d or above. The leakage rates are predicted to range between 0.047 m^3/d and 0.4747 m^3/d for the full operational duration (*Eskom 2018*).

The maximum Chromium (VI) and Boron (B) concentration that reaches groundwater system is predicted at 0.003 mg/ℓ and 0.045mg/ℓ, respectively. The maximum sulphate (SO_4) and TDS concentration that reaches groundwater system are predicted at 16 mg/ℓ and 365 mg/ ℓ, respectively. Therefore, Class C liner scenario where mitigation is in place, the following is anticipated. The plume is predicted to spread a maximum of 40 m around the perimeter of the ash disposal facility (ADF) and migrate not further than 25 m north-east and north-west of the in the underlying aquifer. Due to a well compacted clay liner, it is predicted to have different characteristics to the plume associated with class C liner and as such the impact is rated low to medium using significance of Impact in accordance with EIA ratings. The risk receptors in the area are:

- Witbank Spruit
- Geelklip Spruit
- Palmiet Spruit (lower risk)
- Wetlands /Pans along the Witbank Spruit /Geelklip Spruit and low risk along Palmiet Spruit
- Monitoring boreholes along and within Witbank Spruit

The assessment indicated and proves that all liners without mitigation (worst case scenario) and with mitigation (Class C liner) do leak but differ at the leakage rates. It is recommended that a well compacted clay liner, bentonite with leachate collection and subsoil drain or a Class C liner be installed under the RD and AD dams.

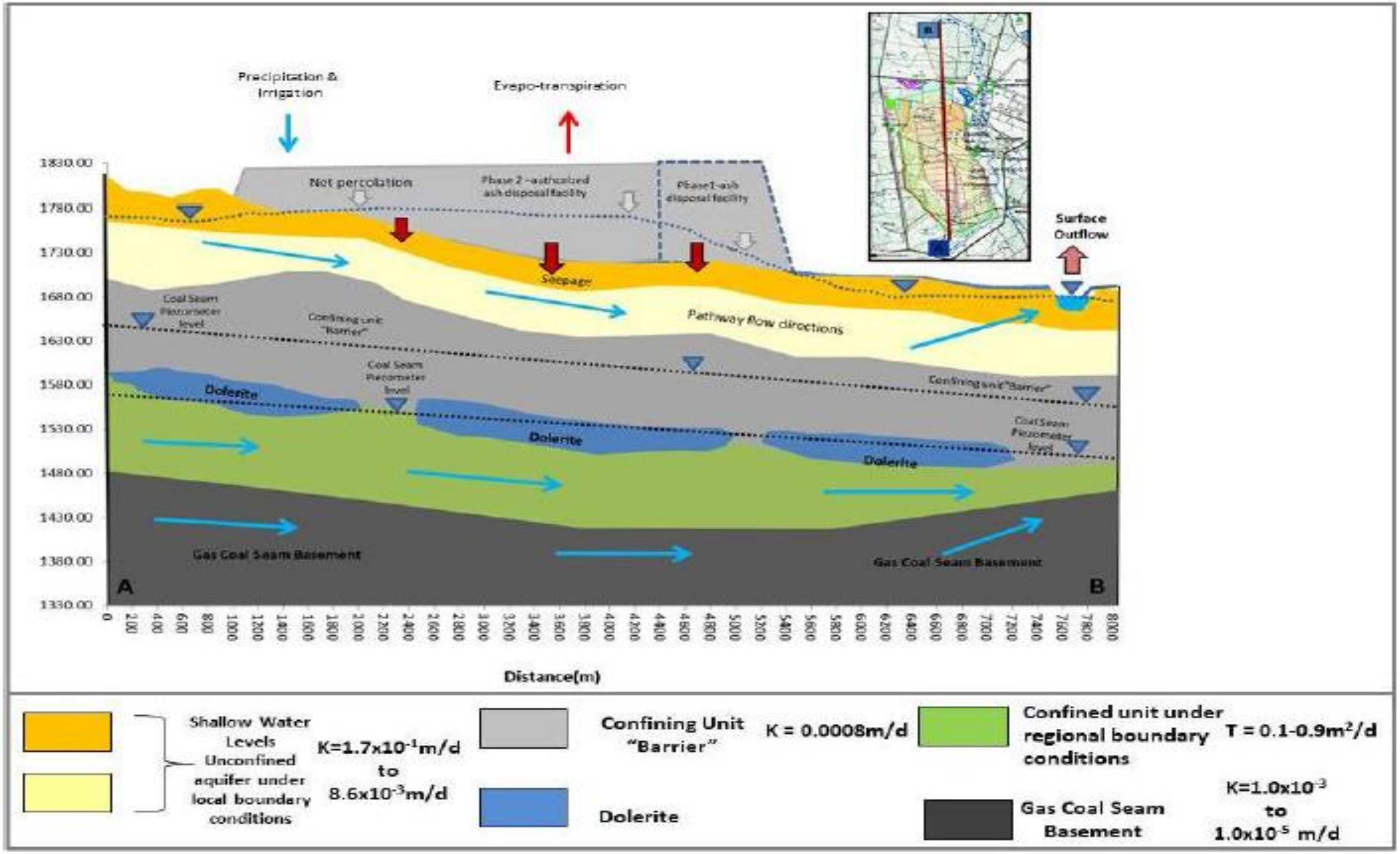

Figure 10: Conceptual model for the Majuba site and ADF

4 GEOHYDROLOGICAL IMPACTS

4.1 Impact Assessment Methodology

In accordance with the 2014 EIA Regulations, promulgated in terms of Section 24(J) of the National Environmental Management Act, 1998 (Act 107 of 1998), specialists will be required to assess the significance of potential impacts in terms of the following criteria:

- Cumulative impacts;
- The nature, significance and consequences of the impact and risk;
- The extent and duration of the impact and risk;
- The probability of the impact and risk occurring;
- The degree to which the impact and risk can be reversed;
- The degree to which the impact and risk may cause irreplaceable loss of resources; and
- The degree to which the impact and risk can be mitigated.

The potential environmental impacts will be evaluated according to their extent, duration, severity, frequency, probability and confidence of the impact. Furthermore, cumulative impacts will also be taken into consideration.

4.1.1.1 Identification of Environmental Impacts and Aspects

Once a potential issue and/or possible impact has been identified during the Scoping process, it is necessary to identify which activity and specifically what aspect of the operations/activities result in the issue being raised or the possible impact being identified.

By considering the root cause of the issue in this way the probability that the activity undertaken does or may result in an impact can be determined. The associated impact can then be assessed in order to determine its significance and to define mitigation measures or management measures to address the impact.

The following definitions therefore apply:

- An activity is a distinct process or task undertaken by an organisation for which a responsibility can be assigned. Activities also include facilities or pieces of infrastructure that are possessed by an organisation;
- An environmental aspect is an 'element of an organisations activities, products and services which can interact with the environment.[1] The interaction of an aspect with the environment may result in an impact;
- Environmental impacts are the consequences of these aspects on environmental resources or receptors of particular value or sensitivity, for example, disturbance due to noise and health effects due to poorer air quality;
- Receptors can comprise, but are not limited to, people or human-made systems, such as local residents, communities and social infrastructure, as well as components of the biophysical environment such as aquifers, flora and palaeontology. Impacts on the environment can lead to changes in existing conditions; the impacts can be direct, indirect or cumulative;

[1] The *definition* has been aligned with that used in the ISO 14001 Standard.

- Direct impacts refer to changes in environmental components that result from direct cause-effect consequences of interactions between the environment and project activities. Indirect impacts result from cause-effect consequences of interactions between the environment and direct impacts; and
- Cumulative impacts refer to the accumulation of changes to the environment caused by human activities.

4.1.1.2 Description of Aspects and Impacts

The accumulated knowledge and the findings of the environmental investigations form the basis for the prediction of impacts. Once a potential impact has been determined it is necessary to identify which project activity will cause the impact, the probability of occurrence of the impact, and its magnitude and extent (spatial and temporal).

This information is important for evaluating the significance of the impact, and for defining mitigation and monitoring strategies. The aspects and impacts identified are therefore described according to the following:

Spatial Scope / Extent

The spatial scope for each aspect, receptor and impact is defined. The geographical coverage (spatial scope) description takes account of the following factors:

- The physical extent/distribution of the aspect, receptor and proposed impact; and
- The nature of the baseline environment within the area of impact.

For example, the impacts of noise are likely to be confined to a smaller geographical area than the impacts of atmospheric emissions, which may be experienced at some distance. The significance of impacts also varies spatially. Many are significant only within the immediate vicinity of the site or within the surrounding community, whilst others may be significant at a local or regional level. The spatial scales of the impacts are listed in ***Table 2***.

Table 2: Spatial Scale of the impact will be rated according to the following scale:

Spatial Scale	Rating
Activity specific	1
Area specific	2
Whole site/plant/mine	3
Regional/neighbouring areas	4
National	5

Duration

Duration refers to the length of time that the aspect may cause a change either positively or negatively on the environment. The environmental assessment will distinguish between different time periods by assigning a rating to duration based on the scale listed in **Table 3**.

Table 3: Duration of the impact will be rated according to the following scale:

Duration	Rating
One day to one month	1
One month to one year	2
One year to ten years	3
Life of operation	4
Post closure	5

Severity

The severity of an environmental aspect is determined by the degree of change to the baseline environment, and includes consideration of the following factors:

- The reversibility of the impact;
- The sensitivity of the receptor to the stressor;
- The impact duration, its permanency and whether it increases or decreases with time;
- Whether the aspect is controversial or would set a precedent; and
- The threat to environmental and health standards and objectives.

The severity of each of the impacts will be rated on the scale listed in **Table 4**.

Table 4: Severity of each of the impacts will be rated according to the following scale:

Severity	Rating
Insignificant/non-harmful	1
Small/potentially harmful	2
Significant/slightly harmful	3
Great/harmful	4
Disastrous/extremely harmful	5

Frequency of the Activity

The frequency of the activity refers to how regularly the activity takes place. The more frequent an activity, the more potential there is for a related impact to occur. The frequency categories have been defined and are listed in **Table 5**.

Table 5: Frequency of impacts will be rated according to the following scale:

Frequency	Rating
Annually or less	1
6 monthly	2
Monthly	3
Weekly	4
Daily	5

Probability of the Impact

The probability of the impact refers to how often the aspect impacts or may impact either positively or negatively on the environment. After describing the frequency, the findings will be indicated on the probability scale as listed in **Table 6**.

Table 6: Probability of impacts will be rated according to the following scale:

Probability	Rating
Almost never/almost impossible	1
Very seldom/highly unlikely	2
Infrequent/unlikely/seldom	3
Often/regularly/likely/possible	4
Daily/highly likely/definitely	5

4.1.1.3 Determination of Impact Significance

The information presented above in terms of identifying and describing the aspects and impacts is summarised in tabular form and significance is assigned with supporting rational. A definition of a 'significant impact' for the purposes of the study is:

> *"An impact which, either in isolation or in combination with others, could, in the opinion of the specialist, have a material influence on the decision-making process, including the specification of mitigating measures."*

Significance will be classified according to the following:

- Very Low to Low - it will not have an influence on the decision;
- Medium to Medium-High - it should have an influence on the decision unless it is mitigated; and
- High to Very High- it would influence the decision regardless of any possible mitigation.

The environmental significance rating is an attempt to evaluate the importance of a particular impact, the consequence and likelihood of which has already been assessed by the relevant specialist. The description and assessment of the aspects and impacts is presented in a consolidated table with the significance of the impact assigned using the process and matrix detailed in **Table 7**.

Table 7: Consolidated Table of Aspects and Impacts Scoring

Spatial Scope	Rating	Duration	Rating	Severity	Rating
Activity specific	1	One day to one month	1	Insignificant/non-harmful	1
Area specific	2	One month to one year	2	Small/potentially harmful	2
Whole site/plant/mine	3	One year to ten years	3	Significant/slightly harmful	3
Regional/neighbouring areas	4	Life of operation	4	Great/harmful	4
National	5	Post closure	5	Disastrous/extremely harmful	5

Frequency of Activity	Rating	Probability of Impact	Rating
Annually or less	1	Almost never/almost impossible	1
6 monthly	2	Very seldom/highly unlikely	2
Monthly	3	Infrequent/unlikely/seldom	3
Weekly	4	Often/regularly/likely/possible	4
Daily	5	Daily/highly likely/definitely	5
Significance Rating of Impacts		**Timing**	

Spatial Scope	Rating	Duration	Rating	Severity	Rating
Very Low (1-25) Low (26-50) Low – Medium (51-75) Medium – High (76-100) High (101-125) Very High (126-150)			Pre-construction Construction Operation Decommissioning		
Adjusted Significance Rating					

The sum of the first three criteria (spatial scope, duration and severity) provides a collective score for the consequence of each impact. The sum of the last two criteria (frequency of activity and frequency of impact) determines the likelihood of the impact occurring. The product of consequence and likelihood leads to the assessment of the significance of the impact, shown in the significance matrix in Table 8: Significance Assessment Matrix in **Table 8**.

Table 8: Significance Assessment Matrix

	Consequence (Severity + Spatial Scope + Duration)														
Likelihood (Frequency of Activity + Frequency of Impact)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	2	4	6	8	10	12	14	16	08	20	22	24	26	28	30
	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45
	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90
	7	14	21	28	35	42	49	56	63	70	77	84	91	98	105
	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
	9	18	27	36	45	54	63	72	81	90	99	108	117	126	135
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150

Table 9: Positive and Negative Impact Mitigation Ratings

Colour Code	Significance Rating	Value	Negative Impact Management Recommendation	Positive Impact Management Recommendation
	Very High	126-150	Improve Current Management	Maintain Current Management
	High	101-125	Improve Current Management	Maintain Current Management
	Medium-High	76-100	Improve Current Management	Maintain Current Management
	Low-Medium	51-75	Maintain Current Management	Improve Current Management

	Low	26-50	Maintain Current Management	Improve Current Management
	Very Low	1-25	Maintain Current Management	Improve Current Management

4.2 Impact Assessment

4.2.1 Construction Phase

The Construction Phase will include the following:

- Activities to extend the 2 existing ash dams at the ADF.
- Activities to establish 2 new rehabilitation dams at the ADF.

4.2.1.1 Impacts on Groundwater Quantity and Quality

1. Water Migration: The dry ash stacking system that is being used at Majuba implies that no slurry is used in the ADF. The new and extension dams will however store stormwater and runoff for pollution prevention and the possibility of increased downward migration of potentially contaminated water will occur.

2. Hydrocarbons: The use of earth-moving plant also brings a risk of hydrocarbon spillages during the construction phase. This can be mitigated by careful storage and handling of hydrocarbons (e.g. diesel, lubricants, hydraulic fluids, etc), in bunded areas and prevent leakage from equipment.

3. Top soil removal: The soil zone is an important barrier to the downward migration of potential groundwater contaminants and can act as a physical, chemical and microbiological barrier. Removal of topsoil during the construction phase can increase contamination events from any spillages that may occur during this phase. This zone adjacent to the ADF is already disturbed due to construction of the ADF.

4. Local mounding of groundwater due to increased recharge from the dams or the existing ADF could occur during the construction phase, with possible changes of local groundwater flow directions.

4.2.1.2 Groundwater Management and Mitigation Measures

During the construction phase of the RD and AD dams disposal facility the impacts of ash leachate (including surface water runoff and leakage from surface water impoundments) are expected to be limited due to the short duration of the construction phase. It is expected to consist of clearing part of the site (most likely already disturbed due to the ADF construction), the installation of a liner, under-drain systems and related pipework, and construction of dam walls or bunds. The construction phase may also include the installation of piezometers for groundwater monitoring. There is likely to be a plant and equipment on the site at this time, with the possibility of spills and leaks of hydrocarbons and other polluting fluids. Solid wastes left at the site can also give rise to polluting leachates following rain.

Mitigation measures include:

- Preventing the disposal of any waste at the site (other than ash/dirty water/stormwater), particularly into any trenches / holes. Disturbing the surface layer / soil layer makes the aquifer more vulnerable to surface pollution.
- Taking steps to prevent any leaks or spills of fuels, solvents or other polluting liquids. This could include the provision of separate, bunded (concrete floors) refuelling and fuel storage areas. Regular maintenance of vehicles will also prevent oil leaks.
- Ensuring that any systems for the draining of leachates and / or supernatant water from the dams are in good working order and are installed correctly.
- Sufficient ash or other material must be in place to protect the underdrain system (if installed) before any vehicle may drive over it. If possible, the underdrain systems should be checked for integrity once this has been completed.
- Systems for removing or preventing blockages in drains or pipework must be installed correctly. Blocked pipework can cause leaks, and lead to additional groundwater pollution.
- Overall the contaminants from the two new RD and AD dams will be insignificant compared to the plumes or contaminants derived from the larger adjacent ADF due to proximity and size.

4.2.2 Operational and Maintenance Phase

During the Operational Phase of the ADF and additional dams, activities will be carried out by ESKOM according to the Operational and Maintenance Plan of the ADF (*Eskom, 2001*).

4.2.2.1 Impacts on Groundwater Quantity and Quality

Use of a dry ash stacking system would be unlikely to cause significant rise in the water table beneath the Ash dam extension. However, the rehabilitation dams will contain stormwater, runoff and dirty water which could reach the underlying groundwater. The low permeability ash would also prevent leaching of contaminants and any water from the ash. The use of liners, compaction and drainage channels will prevent seepage, but stormwater dams and other surface water storage is likely to lead to local water table rise with seepage. Therefore during operations, the following impacts are likely:

1. Mounding of groundwater in the vicinity of the AD and RD which could also change the groundwater flow direction.

2. A portion of the water from various sources listed previously may percolate downwards and reach the groundwater. Therefore, the quality of groundwater beneath the RD and AF dams is likely to deteriorate, since natural groundwater will be mixing with the poorer quality ash leachate and dirty/runoff water. Even if an under-drain system is used to convey any excess water away from the dams. It is important that infrastructure be designed to minimize and contain contaminated runoff and the dams are maintained in good condition. Clay compaction and linings would prevent such seepage and movement of leachate.

3. Diesel spills from equipment or plant carry a risk of hydrocarbon contamination of the soil and percolation to groundwater. Standard precautions, regular maintenance of equipment and prompt clean-up of any spills should be taken to minimize this risk.

4. There is also a possible risk to local groundwater of contaminated water discharging from holding dams or drains to surface water courses in the vicinity of the ash disposal facility (rivers

and streams), and later infiltrating into the subsurface some distance away from the ash disposal facility. Maintenance and regular inspections to prevent blockage or damage of these will prevent such spills.

4.2.2.2 Groundwater Management and Mitigation

The operational phase is likely to change both the quantity (water table level will gradually rise) and quality of local groundwater (deterioration underlying or surrounding the RD and AD dams). The local groundwater flow direction may also be modified due to the local rise in the water table. Minimizing the volume of leachate percolating through the ash dams and migrating downwards into the aquifer is the key to reducing all of these impacts. Mitigation measures therefore include:

- Ensuring that any and drains and return water dam systems are in good working order.
- Preventing the disposal of any "foreign" waste material (e.g. hydrocarbons or solvents) to the ash disposal facility.
- Ensuring sufficient freeboard and other measures in holding ponds, toe drains and storm water dams, to prevent any spills of contaminated water onto adjacent land.
- Lining of surface dams and clay compaction of dirty water / return water dams and drains be installed.
- Continued operation of a groundwater monitoring network in the vicinity of the ADF and new dams as a whole to act as an early warning system for detection of contaminants.

4.2.3 Decommissioning and Post-Operational Phase

The ADF will be decommissioned according to the guidelines detailed in the Majuba Power Station Decommissioning Plan. Rehabilitation of the ADF, once decommissioned, will be completed by following the guidelines stipulated in the Environmental Management Programme.

4.2.3.1 Impacts on Groundwater Quantity and Quality

Decommissioning of the ash disposal facility will involve halting ash disposal and removing ash disposal equipment. Changes to drain systems may also be made. This may be done in part or as a whole. The ADF and storage dams may also undergo some degree of shaping and re-vegetation, usually with the addition of a layer of topsoil and planting of indigenous vegetation. The immediate effect will be to reduce the volume of leachate available for percolation into the ground, but this is unlikely to cease altogether – natural precipitation falling onto the decommissioned ash disposal facility and collecting in drains or holding ponds will most likely mean that some leachate will continue to percolate downwards, leading to a persistent water quality impact with time. This may be mild in impact with cementation of the ash but it is important that infrastructure be designed to contain contaminated runoff from the ash disposal facility and this is maintained. Decommissioning of the ash disposal facility may also involve added diesel-powered plant on site, with attendant risks of hydrocarbon spills and prevention or mitigation of any spills be contained and cleaned up promptly.

4.2.3.2 Cumulative Impacts

The likely cumulative impacts of all three phases (RD and AD dams construction, operation and decommissioning along with the ADF) are likely to be:

1. A long-term rise in water table in the vicinity of the ADF, accompanied by a deterioration in groundwater quality. These impacts will most likely gradually reverse once the ash disposal facility is fully decommissioned and the ash begins cementation. But the impacts are unlikely to completely disappear for many years. In the event that highly toxic or persistent pollutants are inadvertently disposed onto the ash disposal facility, then the long-term cumulative impacts on local groundwater could be more serious.

2. However, the dry ash stacking system combined with the relatively low permeability of the underlying geology mean that impacts on groundwater are likely to be relatively limited. It is likely that other activities at Majuba power station (for example the coal storage yard) have more potential to pollute groundwater compared to the ash disposal facility. Care should be taken to prevent the discharge of polluted water into local surface water courses, from where it could potentially pollute groundwater in the local area. Integrity of dam walls is therefore of paramount importance.

4.2.3.3 Groundwater Management and Mitigation

Decommissioning of the ash disposal facility will mean that ash will no longer be disposed to the facility and the dams and less water is channelled to the dams and that a degree of rehabilitation and re-vegetation be conducted. Percolation of some leachate into local groundwater in the long term may not be totally obtainable, mitigation measures can reduce this and the following are recommended:

- Maintenance of the drain and return water systems.
- Continuous groundwater monitoring in order to quantify ongoing impacts and provide early warning for any contamination.
- Re-vegetation of the ash disposal facility to reduce the volume of rainwater percolating down into the facility through natural evapotranspiration and to improve the quality of runoff from the ash disposal facility.
- Laying top soil over the entire facility once deposition ceases.
- Maintain the structural integrity of the ADF as a whole, to prevent erosion and development of gulleys.
- Ensure that no other waste is disposed of at the ash disposal facility.

It is likely that minor changes to water table elevation and groundwater flow direction in the immediate vicinity of the site will persist after decommissioning, since the overlying ash disposal facility (even if vegetated and managed) will alter the flow / recharge characteristics of the local area. These issues are expected to be relatively minor.

The main impact on groundwater of the proposed ash disposal facility (or combination of facilities) is likely to be a reduction in water quality beneath the chosen site, and in the vicinity of the site. A summary and assessment of the identified risks is listed below in **Table 10** and **Table 11** .

Table 10: Risk assessment for Groundwater Contamination

1. Groundwater Quality/contamination		
Criteria	**Rating before mitigation**	**Rating after mitigation**
Status	Negative	Negative
Spatial Scope / Extent	Area Specific (2)	Area specific (2)
Duration	Post Closure (5)	Post Closure (5)
Severity	Significant/slightly Harmful (3)	Small/potentially harmful (2)
Frequency of Activity	Daily (5)	Monthly (3)
Probability of Impact	Likely (4)	Possible (4)
Significance	Medium	Low
Cumulative impacts	The deterioration of groundwater quality with mitigation can be monitored and with proper management prevented and significantly reduced.	

Table 11: Risk assessment for Groundwater seepage and doming

2. Groundwater seepage and doming		
Criteria	**Rating before mitigation**	**Rating after mitigation**
Status	Negative	Negative
Spatial Scope / Extent	Area Specific (2)	Area specific (2)
Duration	Post Closure (5)	Post Closure (5)
Severity	Significant/slightly Harmful (3)	Small/potentially harmful (2)
Frequency of Activity	Daily (5)	Monthly (3)
Probability of Impact	Likely (4)	Possible (4)
Significance	Medium	Low
Cumulative impacts	Seepage or infiltration of rainfall/water/seepage from dams would lead to mounding of groundwater underlying the dams and a change in groundwater flow direction. With mitigation seepage or infiltration can be minimised.	

The significant risks, impacts with and without mitigation and key mitigation are listed in **Table 12**.

Table 12: Potential Impacts and mitigation proposed for the proposed development

<table>
<tr><th rowspan="2">ID No.</th><th rowspan="2">Potential Impact</th><th colspan="2">Significance Rating</th><th rowspan="2">Preferred Option</th><th rowspan="2">Key mitigation / optimisation measures</th></tr>
<tr><th>Prior mitigation</th><th>Post mitigation</th></tr>
<tr><td colspan="6">Groundwater</td></tr>
<tr><td>G1</td><td>Groundwater contamination from the ash dams and rehabilitation dams</td><td>Medium</td><td>Low</td><td rowspan="2">N/A</td><td>▪ Only ash disposal
▪ Hydrocarbon contamination prevention
▪ Clay compaction and lining
▪ Prevention of hydrocarbon spills during construction and decommissioning
▪ Maintenance of walls and structural integrity of the dams
▪ Monitoring network maintained and continued monitoring</td></tr>
<tr><td>G2</td><td>Seepage and mounding of groundwater underlying the RD and AD dams</td><td>Medium</td><td>Low</td><td>▪ Maintenance of drain system
▪ Lining of the drainage system and dams
▪ Compaction of clays underlying the dams during construction to prevent seepage
▪ Prevention of spills and seepage during construction</td></tr>
</table>

5 CONCLUSIONS AND RECOMMENDATIONS

The 2 new Rehabilitation Dams and extension of the 2 existing ash dams will be utilised for storm water management within the ash disposal facility and ash disposal. The groundwater regime underlying the proposed new rehabilitation dams and extension to the ash dams comprises shallow groundwater in a weathered zone and deeper groundwater a fractured aquifer. Seepage and groundwater movement from these new and extension dams into the groundwater will be controlled by hydraulic conductivity (permeability), hydraulic gradient and the transmissivity of the aquifer, dam lining, material/lining underlying the dams and aquifers underlying the site.

The upper aquifer often shows groundwater within a few metres below surface with infiltration and seepage from surface water and rainfall. Groundwater in the area is topographically controlled. Groundwater storage and flow in the deeper aquifer is along fractures, bedding planes, joints and other secondary discontinuities. Groundwater flow directions is predominantly to the north with local western and eastern flow towards streams around the ADF. Groundwater levels around the ADF range from seepage at 0 m to 15 m in the deep aquifer. Potential impacts from the construction of the new dams and extension to the existing dams are as follows:

1. Water Migration from the dams into the underlying groundwater transporting contaminants to the underlying aquifer.

2. Soil and groundwater pollution from hydrocarbons during construction of the dams and during the post-operational phase.

3. Top soil removal from the ADF during construction of the dams leading to downward migration of potential groundwater contaminants. This zone adjacent to the ADF is already disturbed due to construction of the ADF.

4. Local mounding of groundwater due to increased recharge from the dams and change in local groundwater flow directions.

Mitigation of the above impacts can be done through the following measures:

1. Compaction of material (clays) below the construction area

2. Lining of the dams

3. Following good practice management and operation as per the existing management plan, integrated water and waste water plan

4. Continued monitoring of the existing network of surface and groundwater monitoring points.

Overall the impact on the groundwater from the 2 new rehabilitation dams and extension of the 2 existing ash dams will be minor compared to the larger and adjacent ADF Facility. Previous groundwater modelling indicates the location of the dams is overshadowed by modelled potential seepage and pollution from the ADF. Any potential contamination from the dams will be unable to be distinguished from seepage or contamination from the ADF. This being said, however, measures must be put in place to prevent, limit and restrict any seepage from the dams and contaminants from reaching the groundwater.

6 REFERENCES

Agricultural Research Council (ARC) Institute for Soil, Climate and Water (2014). *Soil Survey for proposed Ash Disposal Facility, Majuba Power Station, Mpumalanga Province*. Prepared by Paterson, D.G., Mushia, N.M. and Mkula, S.D. ISCW Report No. GW/A/2014/12.

DWA (2000). *Groundwater Resources Map of the Republic of South Africa*. Department of Water Affairs, Pretoria, 1:3 000 000 scale.

DWA (2002). *Hydrogeological Series Map 2726 Kroonstad*. Department of Water Affairs, Pretoria, 1:500 000 scale.

Ecotone (2014). *Proposed Continuous Disposal of Ash at Majuba Power Station: Aquatic Specialist Study*. Compiles by Jonker M., Walsh G., Alexandre M. and Ferreira L.

Eskom (2001). *Majuba Power Station, Ash disposal Facility Management Plan*. Compiled by Rajaruthnam, S. Document No. ENG/31745.

Eskom (2016). *Majuba Ash Dump Continuation Integrated Water Use License application / Water and Waste Management Plan.* Prepared by Dyambyini Construction & Project Solution.

Eskom (2018). *Eskom Majuba Power Station source pathway receptor Assessment model investigation application / Water and Waste Management Plan.* Prepared by Dyambyini Construction & Project Solution.

GHT Consulting Scientists (2017a). *Majuba Power Station Routine Monitoring Reports Phases 53-57*. Prepared by van Niekerk L.J., Staats S. and Makhanja C., Project No. 009-22-mon.665.

GHT Consulting Scientists (2017b). *Majuba Power Station Pollution Plume Model Final Report*. Prepared by Staats S. and Makhanja C., Report No. RVN 665.22/1793.

Johnson, M.R.; Anhaeusser, C.R. & Thomas, R.J. (eds.) (2006). *The Geology of South Africa*. Published jointly by the Geological Society of South Africa (Johannesburg) and the Council for Geoscience (Pretoria), 691 pp. Council for Geoscience.

Jones & Wagener (2013). *Majuba Power Station Expansion of Ash Disposal Facility: Ash Classification Report*. Prepared by Prinsloo, I., Report No. JW126/13/D880- Rev 0.

Jones & Wagener (2016). *Majuba Power Station Ash Dump Extension*. Prepared by Prinsloo, I., Report No. JW058/16/F224/- Rev 0.

Lidwala Consulting Engineers (SA) (Pty) Ltd, 2014. *Final Environmental Impact Assessment for the proposed continuous disposal of ash at the Majuba Power Station, Mpumalanga Province*.

Parsons, R.P. (1995). *A South African Aquifer System Management Classification*. Prepared for the Water Research Commission and Department of Water Affairs and Forestry, Report No. KV 77/95, December 1995. Groundwater Programme, Watertek, CSIR, Stellenbosch.

Parsons, R.P. and Conrad, J. (1998). *Explanatory Notes for the Aquifer Classification Map of South Africa*. Water Research Commission Report No KV 116/98, CSIR, Stellenbosch.

SLR (2014). *Proposed continuous disposal of ash at the Majuba Power Station – Groundwater Specialist Study EIA Phase*. Prepared by Cobbing J., Ellerton E., Rossouw T. and Lenkoe K., SLR Project No. 721.23003.00010.