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Lidwala Consulting Engineers

SLR PROJECT NUMBER: 721.23003.00001

REPORT NO. 01

October 2011

Hendrina Power Station Groundwater EIA Report

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Project Manager	J Cobbing
Project Manager e-mail	jcobbing@slrconsulting.com
Authors	J Cobbing, J Ellerton, K Lenkoe, T Rossouw, M Holland and K Witthueser
Reviewer	K Witthueser
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METAGO-SLR OFFICES	
Johannesburg, South Africa Physical Address: Metago House Fourways Manor Office Park Corner Roos and Macbeth Streets Fourways Johannesburg South Africa Postal Address: P O Box 1596 Cramerview 2060 Tel: +27 (011) 467-0945 Fax: +27 (011) 467-0978 Web: www.metago.co.za	Pretoria, South Africa Physical Address: Pentagon House 669 Plettenberg Rd Faerie Glen Pretoria South Africa Postal Address: P O Box 40161 Faerie Glen 0043 Tel: +27 (012) 991-8881 Fax: +27 (012) 991-1907 Web: www.metago.co.za

HENDRINA POWER STATION GROUNDWATER EIA REPORT

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ACRONYMS AND ABBREVIATIONS

Below a list of acronyms and abbreviations used in this report.

Acronym / Abbreviation	Definition
DEM	Digital Elevation Model
DWA	Department of Water Affairs
GMS	Groundwater Modelling System
GRA1 / 2	Groundwater Resource Assessment Phase 1 / 2
MAMSL	Metres above mean sea level
MRD	Mine Residue Deposit (e.g. a tailings dam)
MPRDA	Mineral and Petroleum Resources Development Act (Act 28 of 2002)
NEMA	Natural Environment Management Act (Act 107 of 1998)
NGA	National Groundwater Archive
NWA	National Water Act (Act 36 of 1998)
WA	Water Act of 1956 (now superseded)

EXECUTIVE SUMMARY

This report is the main output of a groundwater study of the Hendrina power station proposed new ash dam area. The study began in July 2010. The study was done in support of the Environmental Impact Assessment process necessary for the construction of a new ash disposal facility at the power station. The EIA process was managed by Lidwala Consulting Engineers. Hendrina power station uses a wet ashing system, which means that ash is mixed with water and transported as a slurry to a series of ash dams (similar to mine tailings or slimes dams). The existing ash dams close to the power station will reach their maximum capacity in about 2016, and a new facility is needed.

Following Pre-screening and Scoping phases of the work, a single potential ash dam site was selected (Figure 1-1). This report assesses the impacts of this site on the local groundwater for the construction, operational and closure stages of the proposed new ash dam. If the ash dam is built, a water pipeline beneath the site and electricity transmission lines running across the site will need to be moved. This EIA therefore also considers the alternative routes for these facilities (two possible routes for the pipeline, and two possible routes for the transmission lines).

The main impact of the new ash dam on groundwater is likely to be deterioration in groundwater quality beneath the ash dam and in the vicinity of the ash dam. This is because the leachate percolating downwards from the ash dam is of poorer quality than the local groundwater, with which it will mix. The downwards movement of leachate from the ash dam is likely to continue after the ash dam has been decommissioned due to natural rainwater falling on the ash dam, but the volumes will be considerably reduced. This downward migration of leachate is also likely to cause local mounding of the water table, and possibly alter local flow directions of groundwater. These effects are likely to be fairly minor and limited to the immediate area of the ash dam. Mitigation of the impacts of downward leachate migration include providing and maintaining an efficient drainage system, and re-vegetating and maintaining the ash dam once it has been decommissioned.

If any other pollutants are disposed of on the ash dam (i.e. in addition to ash), and these pollutants are highly toxic or persistent or both, then local groundwater pollution could be more serious. This impact is easily avoided by controlling what is disposed of onto the ash dam.

If a low permeability liner is installed beneath the proposed ash dam, this should greatly reduce the downward movement of leachate or other pollutants into the local groundwater. The liner will need to be managed together and maintained with the under drain system.

The effects on local groundwater of the pipeline and transmission line alterations are likely to be limited to possible pollution during the construction phase (e.g. spillages of diesel, disposal of waste into the trenches or pits excavated). These effects can be easily avoided by taking standard precautions and controlling operations during construction.

The conceptual groundwater model for the Hendrina Power Station site was converted into a numerical groundwater model to simulate the potential spreading of leachate emanating from the proposed ash dam and evaluate associated impacts on the groundwater environment. A 3-dimensional 3-layer, steady-state groundwater model using the internationally accepted MODFLOW code (GMS interface) was constructed. Using eight groundwater level data points and eleven data points derived from the NGA database within the model domain, a good calibration of the numerical model was achieved and the model subsequently used for contaminant transport simulations of a plume emanating from the proposed

ash dam. The conservative transport simulations over up to 150 years assumed a worst case scenario, i.e. continuous source strength for the ash dam and no degradation of any pollutants. The model simulations show a relatively slow migration of the contaminant plume towards a receiving water course to the north west of the proposed ash dam site. Better model simulations will be possible with more hydrogeological data, and the model could be updated in future as more data becomes available.

HENDRINA POWER STATION GROUNDWATER EIA REPORT

1 INTRODUCTION

1.1 BACKGROUND

This report is intended as the groundwater contribution to the Environmental Impact Assessment Phase for the proposed expansion of ash disposal facilities at Eskom's Hendrina power station. Hendrina Power Station is located on the east and south-east boundary of Pullens Hope, Mpumalanga, and about 40 km south of Middelburg. It lies approximately 5 km to the west of the N11 road, which runs north-west to south-east between the towns of Middleburg and Hendrina. The facilities at the site comprise the power station, associated ash disposal site together with return water facilities, coal stockyard and pit area. Optimum Colliery, the source of coal for the power station, is located immediately to the north-east of the site. The surface topography of the area is typical of the Mpumalanga Highveld; consisting of a gently undulating plateau. Surface elevations vary between approximately 1600 meters above mean sea level (mamsl) and 1680 mamsl. The surrounding area has been heavily exploited for coal and much of the land use is associated with mining activities.

Hendrina power station requires additional ash disposal facilities in order to keep generating electricity. The power station is expected to produce approximately 64.2 million m^3 of ash between now and the end of its estimated life span in 2035. There are currently five ash disposal dams at the site which form one contiguous ash disposal facility covering about 240 Ha and extending approximately 40 m above ground level. The northernmost two dams (ash dams 1 and 2) are no longer in use and have been restored. The proposed new ash dam would be located close to the current active dams as shown on Figure 1-1. The current ash disposal facilities (ash dams 3 and 5) will only last another five or so years. Hendrina power station uses a wet ashing facility (ash is pumped to the ash disposal facility as a slurry), incorporating ash water dams, pipelines, storm water trenches, seepage water collection systems, pump stations and seepage dams. Five potential sites for the new ash dam identified in the Pre-Screening Phase were evaluated in a Scoping Phase of the work (see previous report), and it was decided that only one of these sites (Site E) could be considered for the new ash dam. All of the other sites had fatal flaws.

A number of surface water courses flow through the catchment area, many of which have been dammed creating small to large surface water bodies. The main water course that flows through the site area is the Woes-Alleen Spruit which flows to the north. Prior to the development of the site, the Woes-Allen Spruit branched off forming the Woes-Allen Spruit (East) and the Woes-Allen Spruit (West). Based on available information, it is understood that the water course branched off at a location to the north-east corner of the ash disposal facility. Due to the construction of the site the Woes-Allen Spruit (East) was dammed and diverted across the site via an underground conduit. The Woes-Allen Spruit (East) and dam are located adjacent to the existing ash disposal facility. The channel in which it lies is deeply incised forming a topographic low to the east of the ash dams. The channel in which the Woes-Allen Spruit (West) lies is also deeply incised. The topographic features are presented in Figure 1-1.

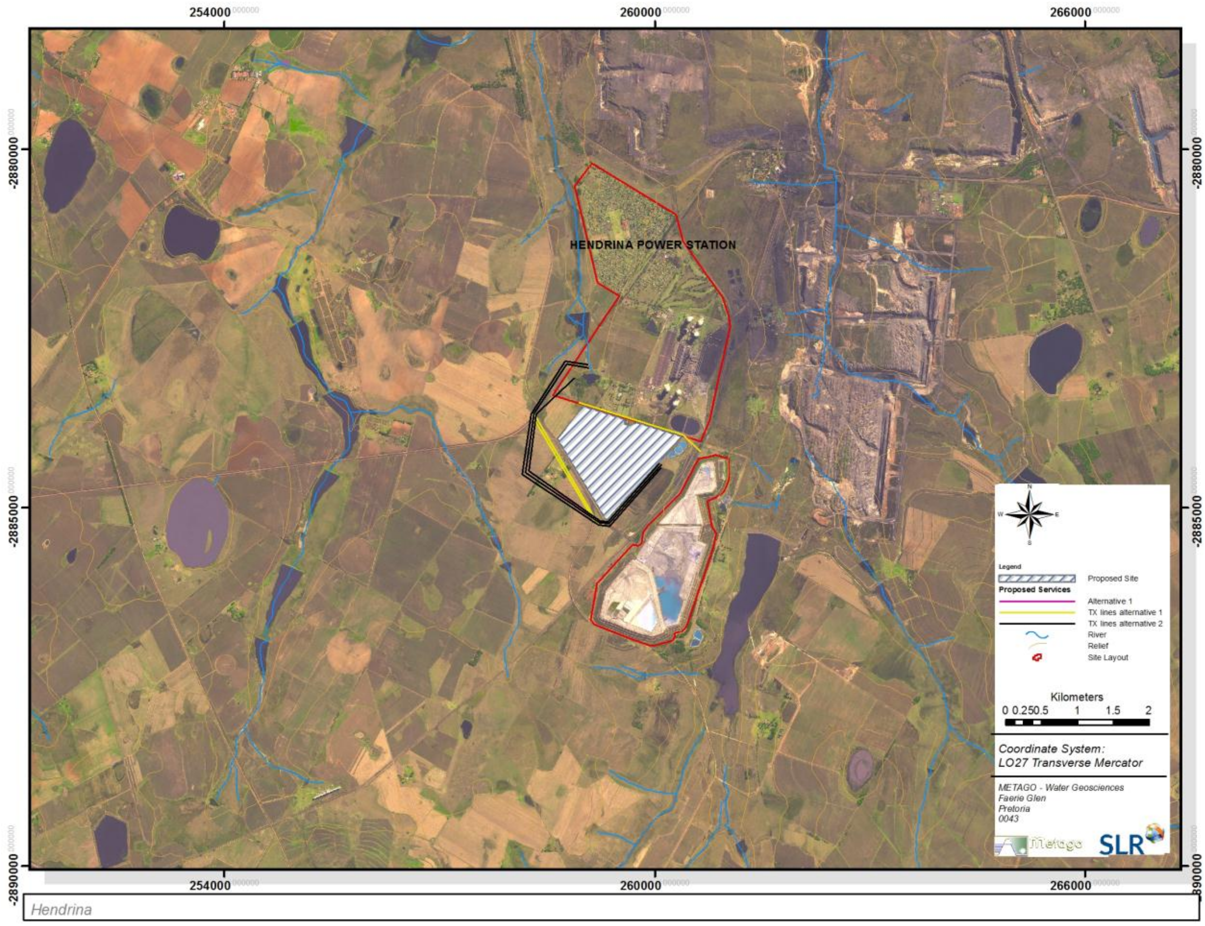

FIGURE 1-1 LOCALITY OF THE STUDY AREA SHOWING EXISTING AND PROPOSED ASH DAMS

1.2 OBJECTIVES OF THE REPORT

The objectives of this report are as follows:

- To describe the hydrogeological (groundwater) environment in the vicinity of Hendrina power station, but particularly close to and beneath the proposed new ash dam;
- To identify the impacts on local groundwater of the proposed new ash dam and the proposed changes to the pipeline and transmission line routes. These will apply to the construction, operational and decommissioning phases of each. The consequences of a "no-go" option will also be evaluated;
- To assess the impacts identified using a standard significance rating methodology;
- To suggest appropriate management and mitigation measures.

1.3 LEGISLATIVE FRAMEWORK

This section is summarised after Van Reenen (2009). Before the promulgation of the National Water Act (NWA) 1998, the status of groundwater was regulated by the common law and the Water Act (WA) of 1956 which entrenched the principle that most groundwater was a private resource belonging to the owner of the overlying property. The ownership right was partially based on the riparian principle which meant that the holder of the right to private property simultaneously held the rights to the water occurring or found on or below (i.e. groundwater) it. Once such groundwater was out of the ground it was considered to be private surface water and was governed by the WA (1956).

When the NWA came into effect it abolished the above-mentioned system, and groundwater received no particular attention. Groundwater was henceforth simply considered to form part of the hydrological cycle and was regulated as such. The NWA does not define the concepts of 'water', 'groundwater' or 'surface water'.

The use of groundwater is regulated by the same legal rules as the uses of water from all (other) water resources. All types of uses are provided for in terms of 'entitlements' or 'statutory rights' in the NWA. These entitlements (in their different forms) differ fundamentally from the fundamental human rights to water guaranteed in the Bill of Rights in the Constitution. Water supply for the latter type of rights is guaranteed by means of the water in the Reserve. What water remains after the determination of the Reserve is made available for access by (allocation to) water users in terms the NWA, either by way of Schedule 1 uses; use as a continued existing lawful use; use under a general authorisation; or a use in terms of a water licence.

The Natural Environment Management Act (NEMA, Act 107 of 1998) is a very important Act for all aspects of the environment and natural resources in South Africa. As a framework Act NEMA applies to all law regulating the protection or management of the environment. It contains a number of environmental management principles that apply to all actions that may significantly affect the environment. These principles apply alongside, amongst others, the socio-economic rights in the Bill of Rights. They serve as the framework within which environmental management and implementation plans must be formulated; serve as guidelines by reference to which organs of state must exercise their functions or take decisions in terms of NEMA or any other statutory provision concerning the protection of the environment; guide the interpretation, administration and implementation of the Act (i.e. NEMA) and any other law concerned with the protection or management of the environment. NEMA also lays out obligations in terms of Environmental Impact Assessments.

1.4 STUDY APPROACH AND METHODOLOGY

Information from the three site visits made in 2011 was combined with a review of available literature and available data sources to form a conceptual model of groundwater occurrence in the vicinity of Hendrina power station. The five potential new ash dam sites were evaluated against the conceptual model to arrive at an estimate of their relative impacts on local groundwater resources, before a final proposed site was selected. A numerical groundwater flow and transport model was constructed using the finite-difference groundwater modelling code MODFLOW. This model (described later in this report) was then used to assist in the evaluation of the impact of the proposed new ash dam.

The DWA Best Practice Guideline – Water Management for Mine Residue Deposits (DWA, 2008) suggests that the groundwater impacts of a mine residue deposit (similar to an ash disposal facility) should be identified before a final site is chosen. Suggested criteria (DWA, 2008) include:

- The impact on downstream water users
- Impacts on sensitive or protected areas

- Impacts on any open-cast or underground workings, shafts or occupied premises; the stability of the underground/excavated workings can be affected by possible seepage and the mass of the MRD,
- Effects of seepage on dam stability, and/or
- Groundwater quality impacts.

These factors and others have been considered in this study.

1.5 ASSUMPTIONS

It is assumed that the data and information related to groundwater at the site (both data in the public domain and data made available by the client) is reasonably correct. It is also assumed that the proposed ash dam will be designed to function in a similar manner to the existing ash dams, and that standard operating procedures relating to ash dams will be followed (e.g. under drain system maintenance, slope stability monitoring, etc).

1.6 LIMITATIONS OF THIS STUDY

This study is limited to a consideration of groundwater and hydrogeology in the vicinity of Hendrina power station. Three field visits (the second and third to measure water levels and field parameters in boreholes, and to take water samples) have been made to Hendrina by SLR staff members, but this study also relies on available published information about the geology and hydrogeology of the area. It is assumed that the available data is correct in its representation of the groundwater conditions in the area. This document does not evaluate the existing groundwater monitoring and management programme at Hendrina; it is assumed that this is in line with best practice (see DWA, 2008 for more information).

2 DESCRIPTION OF THE PROJECT

This report is the output of the third phase of the Hendrina study, the Environmental Impact Assessment (EIA) phase. The EIA phase was preceded by the Scoping phase of the study, and before that the Pre-Screening phase. These phases allowed an initial series of sites to be selected for the ash dam, and then for the sites to be ranked in terms of suitability.

2.1 THE PRE-SCREENING PHASE GROUNDWATER STUDY

A sensitivity analysis was completed for the first (pre-screening) stage of the EIA process, and an interim groundwater vulnerability map was produced allowing a basic distinction to be made between more and less favourable areas for the siting of the proposed ash dam at Hendrina power station. This map was based on the hydrogeological map classification of the area within 8 km of the power station, combined with a 250 m buffer zone placed around surface water features. This allowed three zones (lower, medium and higher sensitivity) to be defined within the 8 km buffer zone, as shown in Table 2-1 below:

TABLE 2-1 SENSITIVITY CLASSIFICATIONS USED IN THE PRE-SCREENING PHASE STUDY

Lower Sensitivity	Areas falling outside of the 250 m buffer around surface water features, and outside of the area classified as “D3” on the general hydrogeology map series (GRA1 data)
Medium Sensitivity	Areas falling within the area classified as “D3”, but still outside of all areas within the 250 m surface water buffer zone.
Higher Sensitivity	Those areas within the 250 m surface water buffer zone.

2.2 THE SCOPING PHASE GROUNDWATER STUDY

The second phase of the study (the Scoping phase) ranked five potential ash dam sites in terms of their estimated impact on local groundwater resources. These potential sites are shown in Figure 2-1 below, together with the 250 m buffer zones developed for surface water features in the pre-screening phase study:

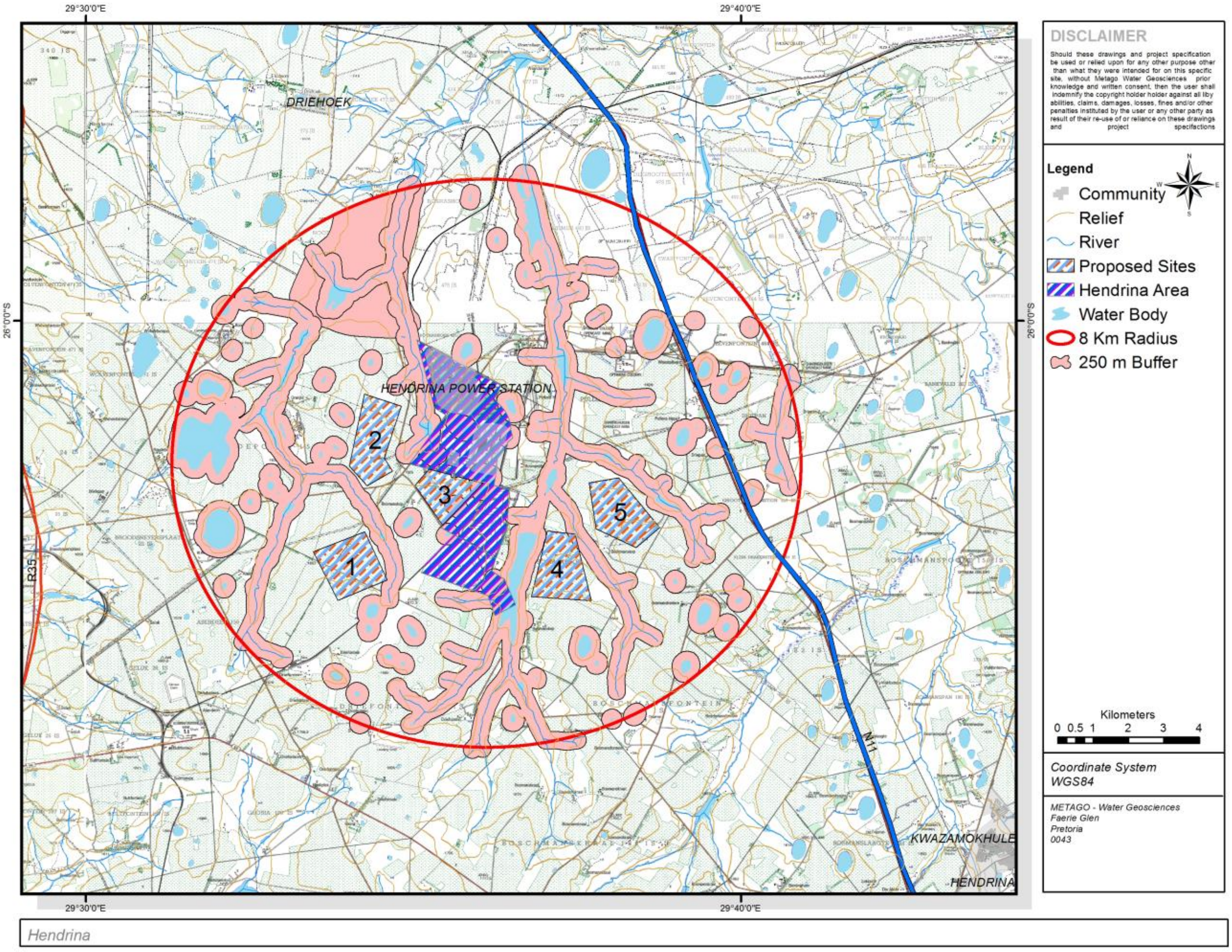

FIGURE 2-1 MAP SHOWING POTENTIAL SITES CONSIDERED FOR SCOPING PHASE

The Scoping phase relied on two field visits to Hendrina power station, a review of existing data, and the development of a groundwater conceptual model for the vicinity of the ash dam. All five sites had the same DWA hydrogeological classification (i.e. D2), and lay on the same geological formation (Vryheid Formation). Proximity to surface water resources and mine workings (potential receivers of leachate from the ash dam), proximity to the existing ash disposal dam, and topographic setting were therefore considered the most important factors in distinguishing one site from another. All five sites were at similar elevations (i.e. between 1620 and 1660 mamsl). No major groundwater abstractions are shown on the DWA 1:500 000 scale hydrogeology map of the area (Sheet 2526 Johannesburg) and the sites were not situated near existing groundwater abstractions as shown on the DWA WARMS database. According to the available data, site 1 was chosen as the most suitable site as it was near to the existing ash storage facility. This would minimise pumping costs and make groundwater monitoring easier. While the hydrogeological setting of site 2 was very similar, it was less preferred due to its potential impacts on two water courses in close proximity in comparison to site 1, which was likely to impact on only one. Sites 3 and 4 fell partially within the 250 m buffer zone around surface water features (wetlands and water bodies in the area) and were therefore not preferred. Site 4 was also in close proximity to an open cast mine. Site 5 was adjacent to an existing open cast mine and as a result was also not preferred. The scoping phase sites were ranked using a site preference rating system, and the final site rankings obtained are shown in Table 2-2 below:

TABLE 2-2 SITE PREFERENCE RATINGS FOR THE SCOPING PHASE PROPOSED SITES

Site	Score	Site Preference rating
1	4 (preferred)	First
2	3 (acceptable)	Second
3	2 (not preferred)	Third
4	2 (not preferred)	Third
5	2 (not preferred)	Third

In the end, all of the sites were eliminated apart from a site close to Site 3 (known as Site E), which was taken forward for assessment in the Environmental Impact Assessment (EIA) phase study.

3 DESCRIPTION OF THE AFFECTED ENVIRONMENT

3.1 GEOLOGY OF THE HENDRINA AREA

Hendrina power station and surrounds is located on coal-bearing rocks of the Vryheid Formation, part of the Ecca Group of the lower Karoo Supergroup. These rocks are principally deltaic and fluvial siltstones and mudstones, with subordinate sandstones (Johnson et al, 2006). The coal seams originated as peat swamps, or similar environments. Where the Dwyka Group is absent (suspected in the study area) the Vryheid Formation has been deposited directly onto rugged pre-Karoo topography and the thickness of the Formation can be quite variable as a result. The Vryheid Formation rocks are well lithified (hard) and have little primary porosity. The geological map (Figure 3-1) also identifies outcrops of volcanic rocks (Rooiberg Group) within the catchment area. Immediately to the south-west of the current ash dams there is a large outcrop of the Rooiberg Formation which consists predominantly of flow-banded rhyolite. Another outcrop lies to the north-west of the existing ash disposal facility. Volcanic rocks of the Kwaggasnek Formation outcrop along the lower reaches (within the catchment area) of the Woes-Allen Spruit (West) and typically consist of flow-banded rhyolite with quartzite xenoliths. The geological map also identifies a small area of quaternary deposits along the course of the Woes-Allen Spruit (West). The geology of the Hendrina area is shown in Figure 3-1 below.

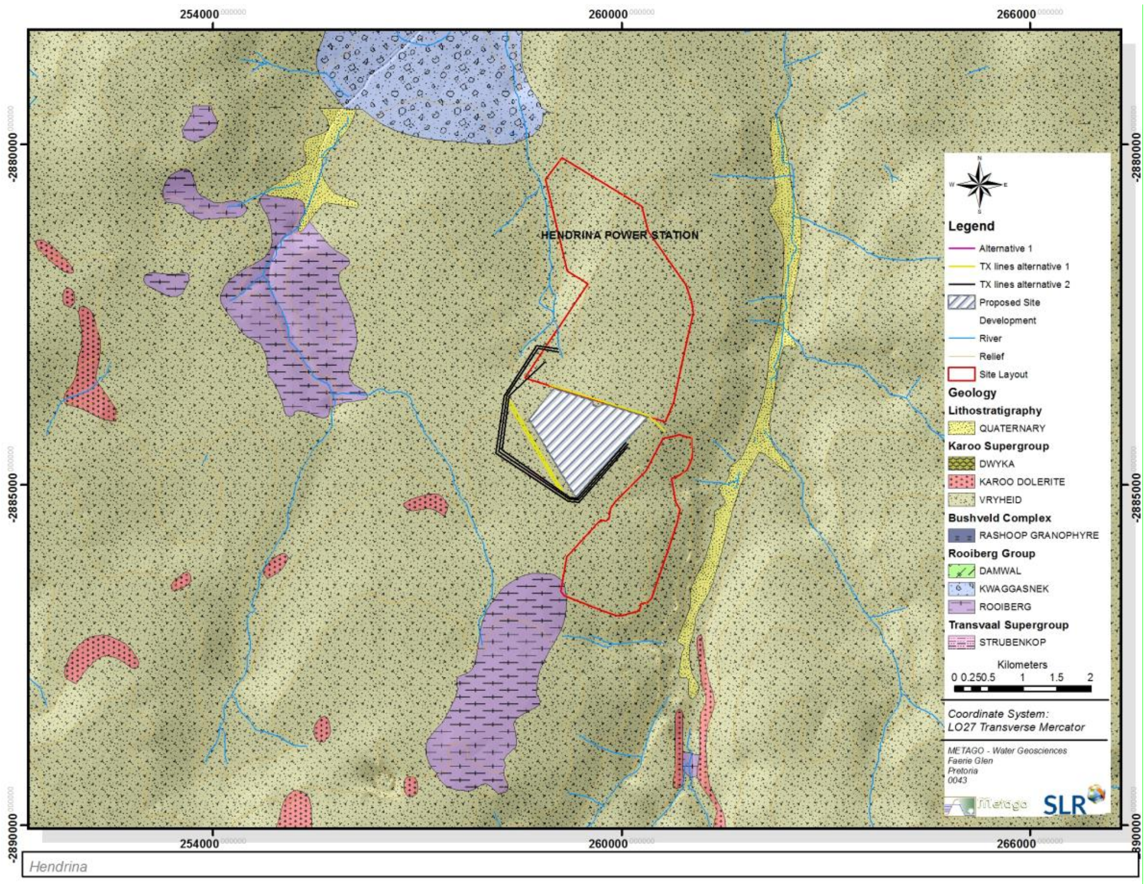

FIGURE 3-1 GEOLOGY OF THE HENDRINA AREA

3.2 HYDROGEOLOGY OF THE HENDRINA AREA

Based on the geology, it is considered that there are two main aquifer systems that exist in the area of interest:

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

Groundwater storage and transport in the unweathered Vryheid Formation is likely to be mainly via fractures, bedding planes, joints and other secondary discontinuities. The success of a water supply borehole in these rocks would depend on whether one or more of these structures are intersected by the borehole. In general the Vryheid Formation is considered to be a **minor aquifer**, with some abstractions of local importance. Although, groundwater may exist within fractures in the volcanic rocks, they have not been classed as a 'third aquifer' due to their limited areal extent in the study area.

The Department of Water Affairs (DWA) has produced a series of 1:500 000 scale hydrogeology maps (the General Hydrogeology Map Series), together covering the whole of South Africa. Analysis of median borehole yields and aquifer types has allowed DWA to classify the hydrogeology of the country according to an alphanumeric code incorporating aquifer type and borehole yield, as follows:

TABLE 3-1 GENERAL HYDROGEOLOGY MAP CLASSIFICATION OF SOUTH AFRICA

Aquifer Type	**Borehole Yield Class (L/s)**				
	Class "1" 0 - 0.1	Class "2" 0.1 - 0.5	Class "3" 0.5 - 2.0	Class "4" 2.0 - 5.0	Class "5" >5.0
Type "a": Intergranular	A1	A2	A3	A4	A5
Type "b": Fractured	B1	B2	B3	B4	B5
Type "c": Karst	C1	C2	C3	C4	C5
Type "d": Intergranular and fractured	D1	D2	D3	D4	D5

The area within an 8 km radius of the Hendrina site is almost all classified as "D2" (i.e. intergranular and fractured aquifers with median borehole yields of between 0.1 and 0.5 litres per second). The outcrop of Kwaggasnek Formation in the NW of the study area appears to be the reason for the area classified as "D3" on the general hydrogeology map series (Figure 3-2).

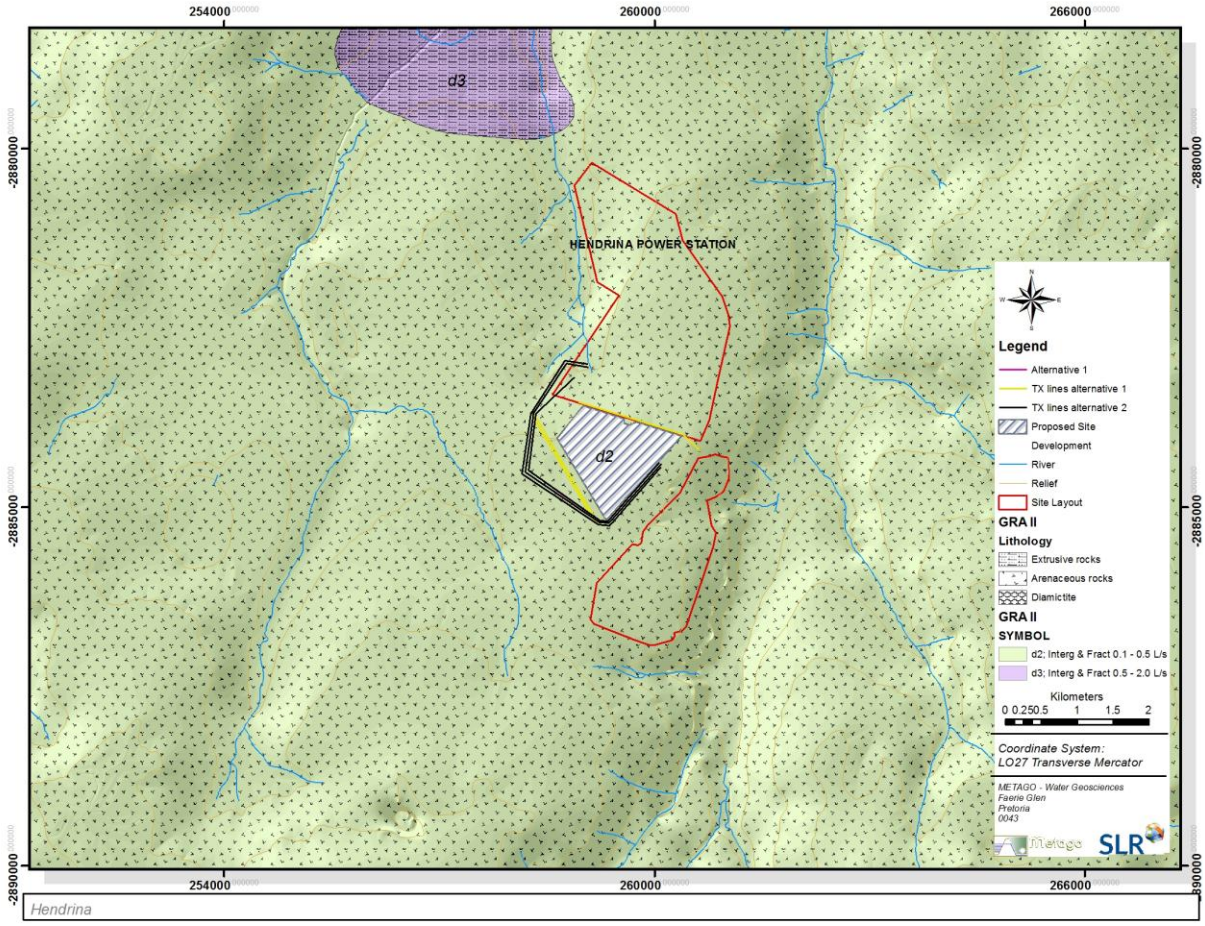

FIGURE 3-2 HYDROGEOLOGY OF THE HENDRINA AREA: DWA GRA2 CLASSIFICATION

The study area is located in quaternary catchment B12B, within the Olifants Water Management Area. The Groundwater Harvest Potential Map of South Africa (Baron et al, 1998) classifies the study area as having an estimated groundwater harvest potential of 10 000 to 15 000 m^3/km^2/year (i.e. relatively low). The average borehole yield is > 0.4 litres per second (L/s), and the total dissolved solids concentration of the (unpolluted) groundwater is between 200 and 300 mg/l (i.e. relatively fresh). No major groundwater abstractions are shown on the DWA 1:500 000 scale hydrogeology map of the area (Sheet 2526 Johannesburg) in the area. The GRA2 data for the quaternary catchment B12B is summarized in Table 3-2 below:

TABLE 3-2 GRA2 DATA SUMMARY FOR QUATERNARY CATCHMENT B12B

Area (km^2)	658.5
Average water level (metres below ground level)	8.7
Volume of water in aquifer storage (Mm^3/km^2)	467.7
Specific Yield	0.003
Harvest Potential (Mm^3/a)	14.6
Contribution to river base flow (Mm^3/a)	7.8
Utilizable groundwater exploitation potential in a wet season (Mm^3/a)	9.5
Utilizable groundwater exploitation potential in a dry season (Mm^3/a)	6.3

A hydrocensus was undertaken by SLR staff members in April 2011 where groundwater level monitoring data was collected from eight monitoring boreholes in the vicinity of the ash dam. Water levels for an additional eleven boreholes were also obtained from the National Groundwater Association (NGA) database. Details of these groundwater monitoring boreholes are presented in Table 3-3 below. A second field visit was undertaken by SLR staff in September 2011 in order to take water samples for hydrochemical analysis. The water levels at three of the boreholes visited in April 2011 were measured again during the September visit (see Table 3-4).

Review of groundwater level data show that groundwater in the study area is shallow (generally <10 mbgl) and is likely to be unconfined. Groundwater in the 'deeper aquifer' is likely to be confined / semi-confined.

Pumping test / hydraulic test data was not available as part of this review.

TABLE 3-3 SUMMARY OF GROUNDWATER MONITORING BOREHOLES

Borehole	UTM_X	UTM_Y	Elevation (Z) (mamsl)	Static Water Level (mbgl)	Static Water Level (mamsl)	Geological Unit Monitored
AB00001	259095.948	-2886595.931	1658.22	3.28	1654.94	Contact between Vryheid Sediments and Rooiberg
AB00003	260671.536	-2886900.137	1626.19	0.52	1625.67	Vryheid Sediments
AB00005	259748.299	-2885627.478	1640.00	0.36	1639.64	Vryheid Sediments
AB00007	260381.200	-2884282.722	1641.84	1.61	1640.23	Vryheid Sediments
AB00043	260716.727	-2886343.229	1619.55	9.53	1610.02	Vryheid Sediments
AB00044	259601.847	-2886895.431	1640.36	2.25	1638.11	Vryheid Sediments
AB00053	260264.672	-2884599.779	1640.08	1.04	1639.04	Vryheid Sediments
Unknown	260431.216	-2884537.673	1639.75	2.25	1637.50	Vryheid Sediments
BA00046	262563.262	-2894502.684	?	9.75	1688.11	Unknown
BA00041	257838.408	-2889998.641	?	4.57	1677.07	Unknown
BA00091	253910.971	-2887742.326	?	7.32	1652.00	Unknown
BA00053	262422.350	-2886241.764	?	5.33	1618.12	Unknown
BA00070	255252.560	-2884438.222	?	4.57	1635.00	Unknown
BA00021	259490.266	-2881256.813	?	8.84	1593.38	Unknown
BA00013	272292.558	-2881395.267	?	12	1607.90	Unknown
DC00045	266200.100	-2878559.169	?	12.49	1606.76	Unknown
DC00043	268456.484	-2878603.052	?	14.63	1595.73	Unknown
DC00066	264327.103	-2874668.331	?	3.65	1596.43	Unknown
DC00049	262783.141	-2871062.850	?	6.7	1553.30	Unknown

Note: **mbgl** – metres below ground level and **mamsl** – metres above mean sea level.

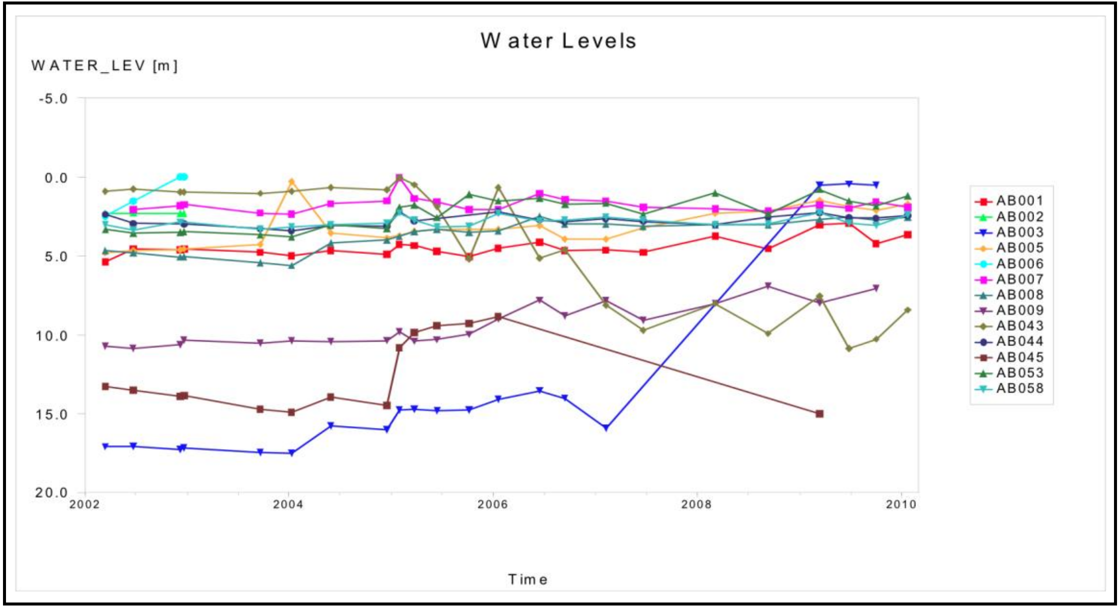

FIGURE 3-3 GROUNDWATER LEVELS (MBGL) CLOSE TO THE HENDRINA ASH DAM (AFTER GHT, 2010)

Several of the boreholes in the ashing area that are routinely sampled (GHT, 2010) have poor water quality, due to increased concentrations of elements such as K, Cl, Mn, SO_4, or due to low pH values. Low pH can lead to increased mobility of a range of groundwater contaminants, such as trace metals. A range of conductivity values were observed in the boreholes visited, and groundwater levels (with one exception) were found to be within 5 m of the ground surface. With one or two exceptions, groundwater levels appear to be stable in the vicinity of the ash dam (see Figure 3-3 above). Borehole AB03, which has shown a large rise in groundwater level in the last eight years, is located close to a pumping station used for the control of water from the ash dam, and may have been influenced by leakage or discharge from this facility.

3.3 CONCEPTUAL MODEL OF GROUNDWATER OCCURRENCE AT HENDRINA

Recharge moving through the soil zone combines with leachate from the ash storage facility and migrates downwards through the unsaturated zone to the water table. Groundwater below the water table moves with the local groundwater gradient towards discharge zones (surface water resources such as wetlands and dams). Due to the shallow depth to groundwater in the immediate vicinity of the ash dams and associated infrastructure it is assumed that leakage from the base of the ash dam occurs (i.e. a groundwater mound has formed under the ash dam). This is supported by the poor groundwater quality in some boreholes close to the ash dam, reported by GHT (2010). Following observations made during the field visit it is likely that any leachate from the current ash disposal area that is not intercepted by the under drain systems (or other leachate control facilities) will flow through the aquifer towards the lake or dam that is located about 1 km due east of the ash dam. Groundwater will flow via fractures, faults, fissures and other secondary discontinuities in the rock. Locally the groundwater gradients are expected to be modified by mounding associated with the ash dams and other water sources.

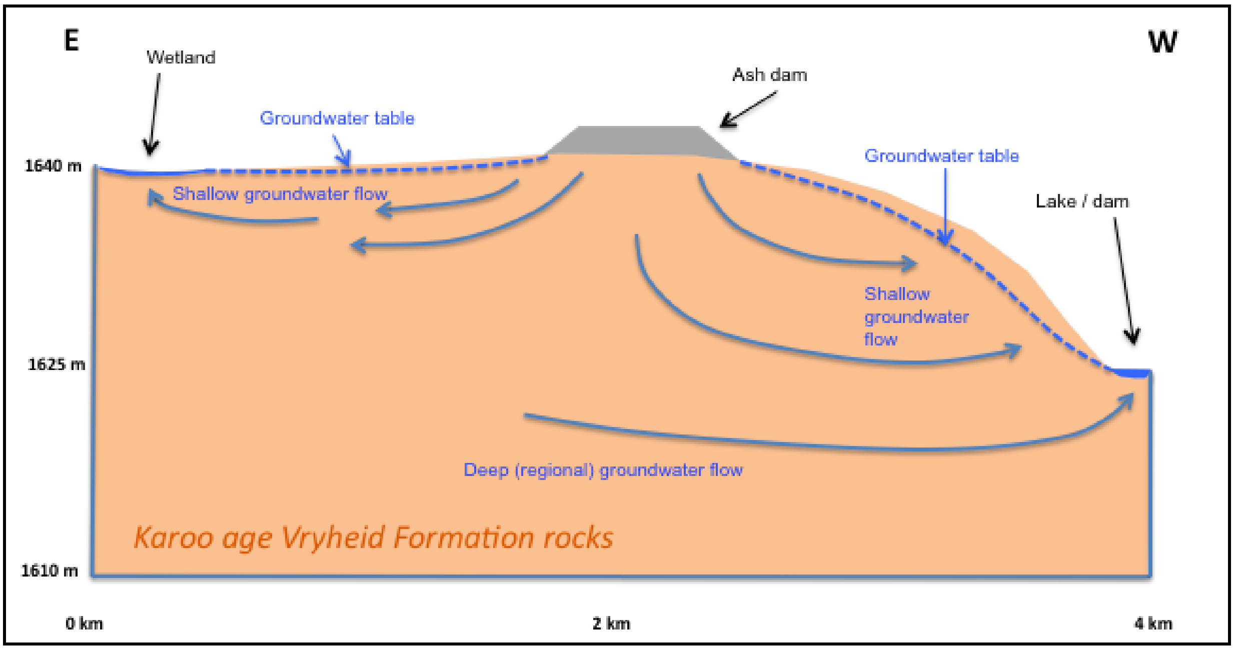

FIGURE 3-4 SKETCH CROSS-SECTION OF GROUNDWATER OCCURRENCE AT THE EXISTING HENDRINA ASH DAM (NOTE VERTICAL EXAGGERATION)

3.4 Hydrologic Boundaries

Based on the conceptual model for the Hendrina aquifers described above, groundwater flow within the shallow aquifer is likely to mimic topography on a local and regional scale. Surface water courses in the catchment area, specifically the Woes-Allen Spruit (East) adjacent to the existing ash disposal facility, appear to be deeply incised and create prominent topographic highs / lows. Locally, groundwater flow is likely to be towards, and discharge into the surface water courses; however on a catchment scale, groundwater is likely to follow the flow direction of the majority of the surface water course and flow towards the north.

3.4.1 Ponded Water / Wetland at Proposed Ash Dam Site

During the field visit in September, SLR staff observed shallow ponded surface water in the area of the proposed new ash dam (Figure 3-5), at approximately 26.04252ºE, 29.58960ºS. A sample of the water was taken (sample SLR04, see Table 3-4 and Appendix A), but it is not possible to say with certainty whether this water is groundwater or surface water. It is thought most likely that this is surface water resulting from rainfall supplemented by shallow perched groundwater associated with the porous laterite observed in the immediate area. It is thought unlikely that this is deep, “upwelling” groundwater, since the area is a local topographic high point. It is unfortunately not possible to say on the basis of the water analysis whether this is a wetland or not.

FIGURE 3-5 SHALLOW PONDED WATER AT NEW ASH DAM SITE

3.5 HYDRAULIC PROPERTIES

No hydraulic testing at the site has been undertaken by SLR Consulting. Aquifer tests, in the form of slug tests were undertaken in 28 boreholes by GHT Consulting in 1997 (GHT 2010b). Methodologies for the tests and the analysis of data along with borehole installation details are unavailable. Although the depth of the borehole and associated geological unit in which the test were focused on is unknown, it is assumed that the borehole installations are shallow. A geometric mean of 0.018 m/d was calculated from the data set and is comparable with values associated with shallow sandy clay aquifers (0.1 m/d to 0.5 m/d).

No tests (e.g. core testing, de-watering analyses) have been carried out and values of storativity and porosity can only be estimated based on published values.

3.6 GROUNDWATER QUALITY IN THE HENDRINA AREA

Six water samples were collected in the Hendrina Eskom site during a site visit in September 2011 (SLR01 – SLR06). Four of the samples were from boreholes, one was from the outflow of an ash dam toe drain (SLR03), and one was from a pond at the proposed new ash dam site (SLR04). Borehole sample SLR01 was taken at the farm of Mr Danie van Wyk, from a tap adjacent to the overhead water storage tank (it was impossible to take a sample directly from the borehole). The other borehole samples were taken using a bailer directly from boreholes surrounding the existing ash dams. Field parameters (T, EC, pH) were recorded at all sites, and depth to water level recorded in boreholes where access allowed. Laboratory analysis for major and minor constituents was performed by Waterlab in Pretoria, an accredited South African laboratory (results shown in Appendix A). Samples were kept cool between sampling and submission to the laboratory using a cooler box and ice bricks.

The accuracy of the chemical analyses was evaluated according to missing main components, plausibility of the single values as well as acceptable ion (charge) balance errors as determined by the electro-neutrality (E.N):

$$EN[\%] = \frac{\sum cations[meq/L] - \left|\sum anions[meq/L]\right|}{\sum cations[meq/L] + \left|\sum anions[meq/L]\right|} \cdot 100\%$$

While aqueous solutions should be electrically neutral, an error of 5 % for a sample analysis is generally considered reasonable. The criterion is relaxed to 10 % for low-mineralised samples. Interpretations based on samples with larger errors in the ion balance should be generally treated with caution. All of the samples had EN errors of 5 % or less, apart from sample SLR 04 which had an EN of 5.2 %.

3.6.1 RESULTS

The results of the field parameters and observations are shown in Table 3-4 below. The full laboratory results are shown in Appendix A.

TABLE 3-4 SUMMARY OF THE WATER SAMPLES TAKEN IN SEPTEMBER 2011

Sample ID	Source	Lat.	Long.	Field pH	Field EC (µS/cm)	Field TDS (mg/L)	Field T ºC	SWL (mbgl)
SLR01	Borehole	26.04653	29.58361	7.64	n/a	n/a	21.5	not measured
SLR02	Borehole	26.05546	29.59541	8.62	393	247	18.5	0.78
SLR03	Ash dam toe drain	26.05542	29.59546	11.53	1284	884	21.7	n/a
SLR04	Pond	26.04252	29.58960	7.41	554	389	26	n/a
SLR05	Borehole	26.06699	29.59417	7.44	183.8	120.9	20	2.28
SLR06	Borehole	26.06419	29.58918	6.83	420	292	18.1	3.6

Borehole samples present groundwater with a Mg-Ca-HCO_3 facies with exception of SLR01 which has a Ca.Mg-Cl water type. The SLR01 sample (Mr van Wyk's farm) also has elevated concentrations of Cl (247 mg/L) and NO_3 (55 mg/L as N). These concentrations are higher than those found in any of the other samples, and this may indicate local pollution of the borehole rather than pollution by the ash dam. Further work would be needed however to establish the source of high ion values at SLR01. The major ion chemistry has been plotted as a tri-linear (Piper) diagram (Figure 3-6), and the sample water water types are summarised in Table 3-5.

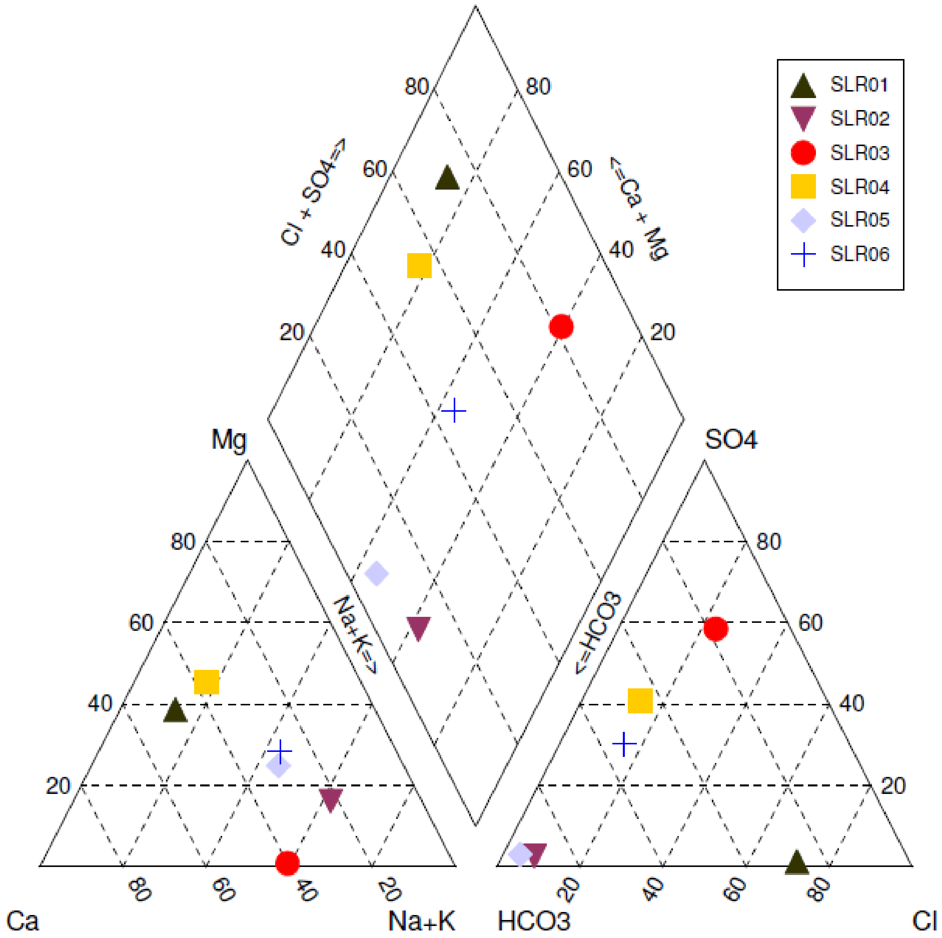

FIGURE 3-6 PIPER DIAGRAM SHOWING WATER SAMPLES TAKEN IN SEPTEMBER 2011

TABLE 3-5 WATER SAMPLE WATER TYPES

Sample ID	TDS (mg/)	SO_4 (mg/l)	Water Type	E.N.
SLR01	1 006	6	Ca-Mg-Cl-NO3	1.6
SLR02	224	5	Na-Ca-HCO3	0.5
SLR03	704	286	Na-Ca-SO4-Cl	-0.5
SLR04	324	98	Mg-Ca-HCO3-SO4	5.2
SLR05	132	<5	Na-Ca-Mg-HCO3	-1.4
SLR06	210	45	Na-Mg-Ca-HCO3-SO4	2.1

4 HENDRINA NUMERICAL GROUNDWATER MODEL

4.1 MODELLING OBJECTIVES

The project scope of work includes the development of a numerical groundwater flow and solute transport model to evaluate the growth in the potential leachate plume from the proposed ash dam. The detailed modelling objectives were:

- To determine the flow path of the potential contaminant plume from the ash dam;
- To determine the contaminant transport rates of the potential contaminant plume.

4.2 MODEL FUNCTION

Despite limited site-specific groundwater level data for the Hendrina site, the numerical model is considered an important evaluation tool for potential contamination from the proposed ash dam. Using realistic assumptions of aquifer properties and net infiltration rates for the proposed ash dam, the model was set-up and run to evaluate the spreading of potential pollutants (plume migration) and the estimated migration time to local receptors. A review of the resulting plume allows appropriate mitigation and management procedures to be put in place to limit plume migration and potential contamination of the water environment.

4.3 DATA SOURCES AND DEFICIENCIES

The conceptual and numerical groundwater model for the Hendrina site was based on the following available information:

- Regional topographical and geological maps
- 1:500 000 scale hydrogeological maps of the Department of Water Affairs
- Digital elevation model based on spot heights
- Groundwater elevation data from field visits by SLR Consulting staff in April and September 2011, from the National Groundwater Archive (NGA), and from previous groundwater monitoring by GHT Consultants (GHT 2010b).
- Previous investigative reports and assessments completed for the site.

Recent groundwater level monitoring data for the site (hydrocensus) is limited to eight boreholes therefore the model confidence is limited by data scarcity. Critical data deficiencies include:

- Regional topographical and geological maps;
- The depth of boreholes and associated screening depth and the monitored geological unit is unknown;
- Site-specific estimates of recharge and seepage (ash dam) rates
- No pumping tests have been undertaken and therefore values of storativity must be estimated;

The developed model should therefore be seen as an initial site model which should be refined and recalibrated once more groundwater monitoring and other data become available.

4.4 MODEL CODE DESCRIPTION

The conceptual groundwater model developed for the Hendrina study area was converted into a numerical groundwater model. The software code chosen for the numerical modelling work was the modular 3D finite-difference ground-water flow model MODFLOW, developed by the United States Geological Survey (USGS) (MacDonald and Harbaugh, 1988). The code was first published in 1984, and since then has undergone a number of revisions. MODFLOW is widely accepted by environmental scientists and associated professionals. MODFLOW uses the finite-difference approximation to solve the groundwater flow equation. This means that the model area or domain is divided into a number of equal-sized cells – usually by specifying the number of rows and columns across the model domain. Hydraulic properties are assumed to be uniform within each cell, and an equation is developed for each cell, based on the surrounding cells. A series of iterations are then run to solve the resulting matrix problem, and the model is said to have “converged” when errors reduce to within an acceptable range. MODFLOW is able to simulate steady and non-steady flow, in aquifers of irregular dimensions, as well as confined and unconfined flow, or a combination of the two. Different model layers with varying thicknesses are possible. The edges of the model domain, or boundaries, typically need to be carefully defined, and fall into several standard categories. Various pre- and post-processors are available for MODFLOW, aimed at making data input and 2-D and 3-D visualisation faster and simpler. In the case of the Hendrina groundwater model, the internationally accepted package GMS 8.0 (Groundwater Modelling System) was used as the software interface for the MODFLOW code.

4.5 WATER SOURCES AND SINKS

Water enters the model domain as direct recharge from rainfall and as seepage from the ash dams. In the absence of detailed information from the design engineers, recharge (leachate infiltration) from the proposed ash dam was estimated to be double the regional average recharge rate of 36.5 mm/a. Water leaves the model domain by evapotranspiration, groundwater outflow, and discharge to surface water courses.

4.6 MODEL DOMAIN AND BOUNDARIES

The model domain was vertically discretised into three model layers, representing the weathered unconsolidated zone (to include the proposed ash dam) (20 m thick, Layer I) and the highly weathered zone (150 m thick, Layers II and III). The highly weathered zone was split into two layers (Layers II and II) for the purpose of numerical model stability only. The upper boundary of the model (Layer I) was specified as the surface topography, represented by digital elevation model (DEM) data supplied by the client.

The base of the Layer I was regionally set to 20 m below the DEM, the base of Layer II and Layer III were regionally set to 75 m and 150 m below the DEM respectively. A regular horizontal grid size of 100 m x 100 m was used.

Based on the conceptual site model presented in Chapter 3, it was considered appropriate to use no flow boundaries along the northern, southern and western boundaries of the site to represent the surface water catchment area (surface water divide along the prominent topographic high). The north eastern model boundary was aligned along a watercourse, and modelled as a drain (Figure 4-1).

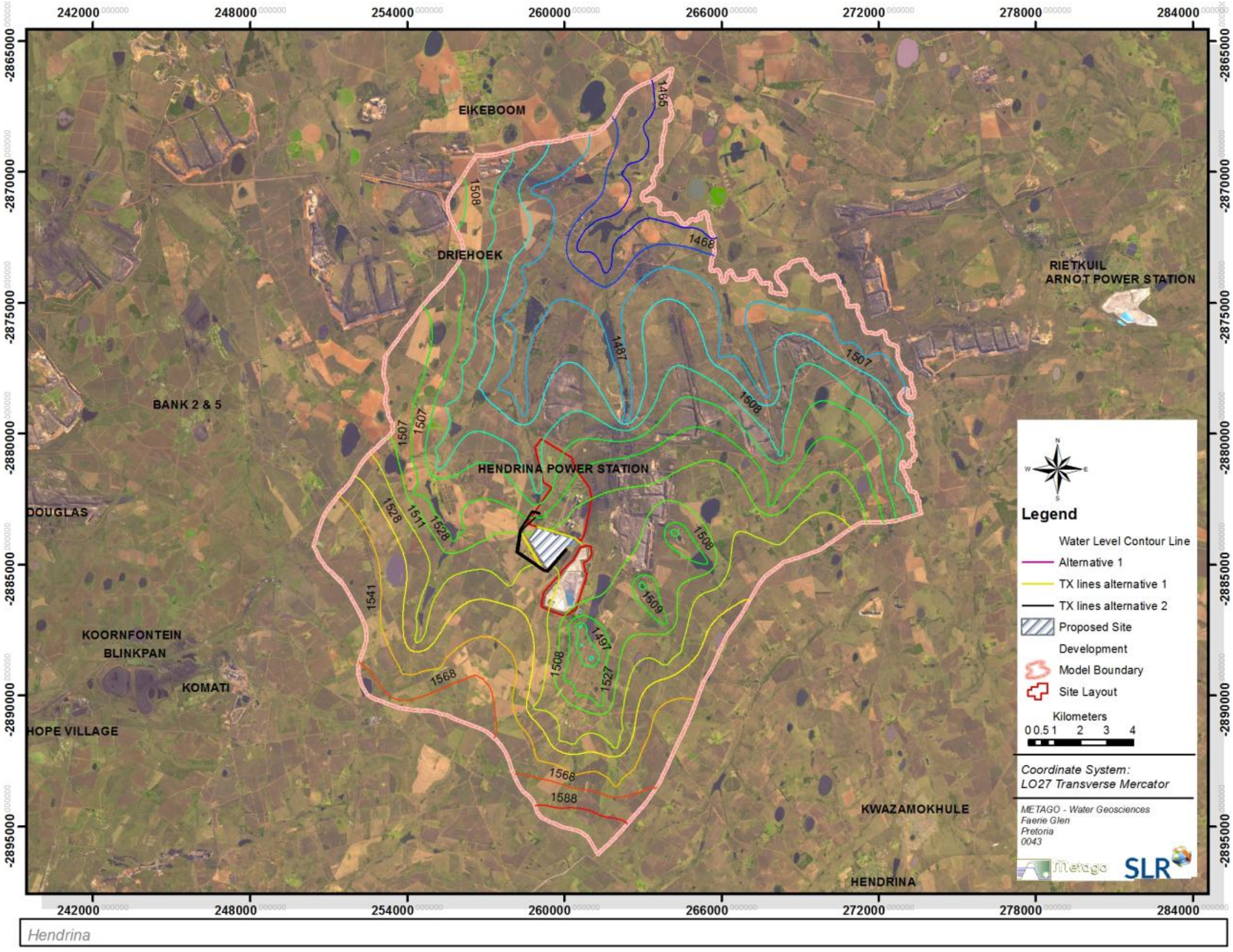

FIGURE 4-1 HENDRINA MODEL BOUNDARIES WITH MODELLED WATER LEVELS

4.7 HYDRAULIC PARAMETERS

Based on literature values, a hydraulic conductivity (K) value of 0.5 m/d was assigned to the upper weathered zone across the whole model domain, with a K value of 0.05 m/d assigned to the lower fractured aquifer across the whole model domain. Recharge of 36.5 mm/a (about 5.6 % of average rainfall) was assigned across the model area, with double that value beneath the proposed new ash dam to account for the impact of the leachate. A constant porosity of 0.3 was assumed across the model domain.

4.8 MODEL CALIBRATION

The model was run with the initial parameters and boundaries as described above, and calibration yielded only marginal improvements of the model fit. The initial hydraulic parameters were therefore not changed. Using these parameters, a reasonable agreement between observed and modelled heads was achieved (R^2 of 0.9663, Figure 4-2). The model proved sensitive to recharge rates and to K values, as expected.

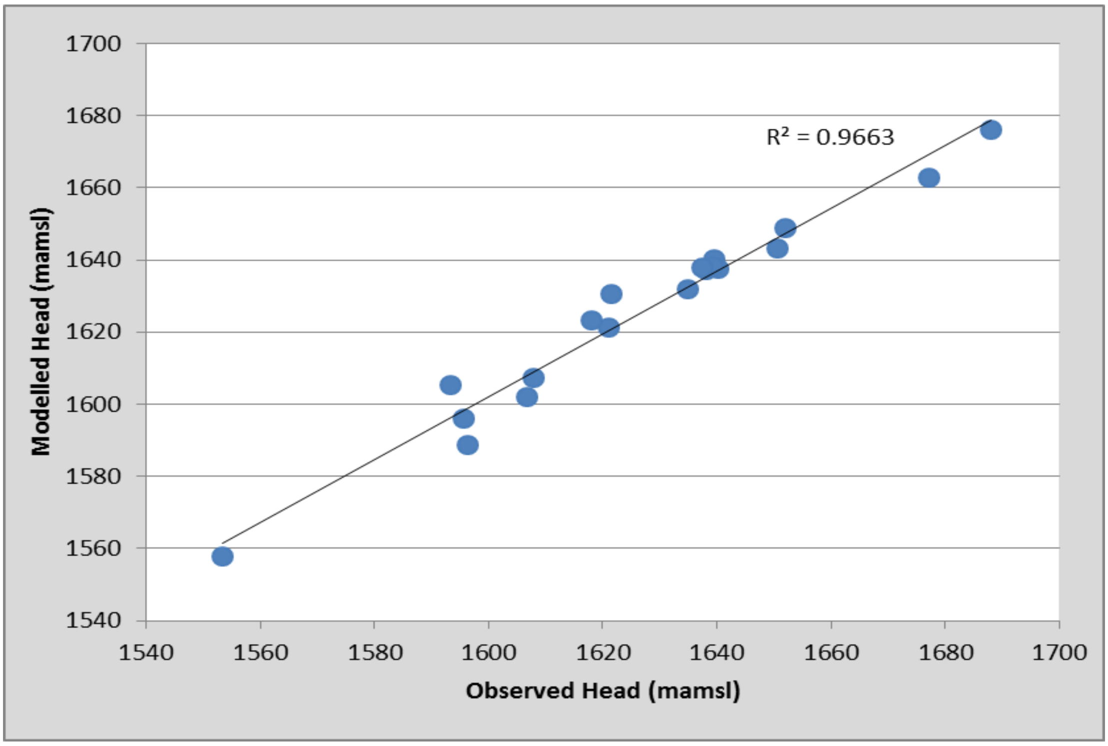

FIGURE 4-2 HENDRINA MODEL CALIBRATION

4.9 MODEL PREDICTIVE SIMULATIONS

The calibrated steady-state groundwater flow model was used as a basis for transient contaminant transport simulations. Following the precautionary principle, only advective-dispersive (longitudinal dispersivity 75 m, porosity 0.3) transport of potential pollutants without any retardation or transformation was assumed. The impacts of potential pollution sources on the groundwater quality are therefore conservative.

The source concentration was specified as 1 (one) and the modelled plumes represent therefore fractions of the actual source concentrations. Since no element specific retardation or transformation is modelled, concentrations for individual elements of concern can be easily derived by multiplying given fractions with the respective source concentration for an element once a detailed geochemical source characterization is performed.

Model simulations for up to 150 years into the future were run. The results show a gradual movement of a contaminant plume towards the north-west, with the upper part of the watercourse to the west of the power station being the ultimate receiver of the plume. See Figure 4-3 below. The rate of movement of the plume is obviously sensitive to the selected recharge value beneath the proposed ash dam.

The maximum plume extent after 50 and 150 years is expected to be approximately 200 m and 500 m respectively. Estimation of breakthrough at the receiving surface water course is complicated because the location of the surface water course appears to change seasonally – however, this is expected to be around 20 years from the start of ash deposition. The maximum (unit) concentration at the surface water receiver was not reached in the 150 year model simulation period. Both of these estimates (breakthrough and maximum concentration are however highly dependent on local aquifer properties, which are not known with any degree of confidence.

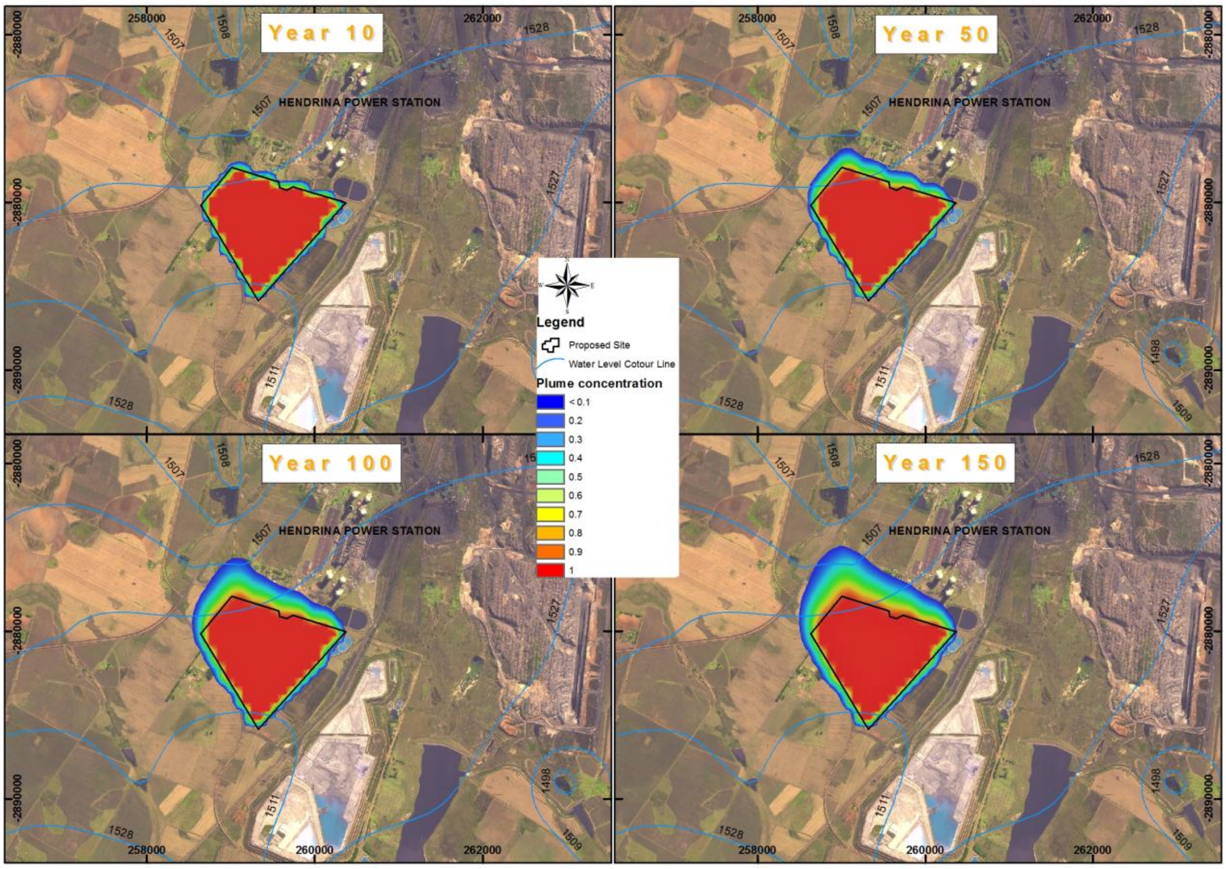

FIGURE 4-3 MIGRATION OF MODELLED PLUME AT HENDRINA IN THE SHALLOW AQUIFER (LAYER I)

4.10 MODEL SUMMARY AND CONCLUSIONS

The numerical groundwater model was able to reasonably approximate hydrogeological conditions at the site based on the agreement between observed and modelled water levels. Non-reactive contaminant transport modelling using a unit source term suggests a slow plume migration from the proposed ash dam site towards the north-west. The rate of migration is partly dependent on the volume of leachate percolating downwards in the model domain (modelled at twice the rate of regional groundwater recharge). The actual leachate volume will be sensitive to the efficiency of the under drain system at the proposed ash dam, as well as any liner that is installed. Despite all efforts to account for data uncertainties, the values presented are intrinsically of low to medium confidence and should be verified once more water level measurements, hydraulic conductivities of different geological units and groundwater monitoring data become available. Predicted plume migration rates for later years of mine development can significantly be improved by observation data from earlier years and subsequent updates of the groundwater model.

5 FINDINGS

5.1 Ash Dam

5.1.1 Alternative 1 - Site E:

5.1.1.1 Construction phase

The construction of the new ash dam is likely to require ash (particularly coarse ash) to be deposited at an early stage (e.g. to protect the under-drain system). This ash is likely to be deposited as a slurry. Some of the excess water from the slurry will find its way past the drains and percolate downwards into the rocks below. This will have an impact on both the quantity and quality of the local groundwater. The water table is likely to rise, and the quality of the groundwater beneath the ash dam will deteriorate. The change in water table elevation may also affect the local groundwater flow directions. The magnitude of these impacts during the construction phase will be proportional to the duration of construction, and the volume of slurry disposed of, but is not expected to be large.

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), preferably in bunded areas.

At present it is not known with certainty whether an impermeable liner will be installed at the base of the proposed ash dam. Such a liner, whilst presumably adding considerably to the cost of the ash dam, should greatly limit downward movement of leachate (in conjunction with an under drain system) when the ash dam is operational. There is of course still a chance of contamination (e.g. by hydrocarbons) while the ash dam is being constructed and before the liner system has been installed.

5.1.1.2 Operational phase

Ash dam operation (wet ash disposal by slurry) will lead to increased recharge to the groundwater in the vicinity of the site, and a rise in the water table. This also implies a possible change in groundwater flow direction. The quality of groundwater beneath the site is likely to deteriorate, since natural groundwater will be mixing with the poorer quality ash leachate. The under-drain and penstock system is designed to convey supernatant water away from the ash dam to the return water dam, but a portion of the water will percolate downwards into the aquifer. A liner (if fitted) should be able to greatly reduce the downward movement of leachate into the aquifer.

5.1.1.3 De-commissioning phase

Decommissioning of the ash dam will involve stopping the disposal of ash slurry and making changes to the drainage system (e.g. sealing or removing the penstocks). The ash dam may also undergo some degree of shaping and re-vegetation, ideally with the addition of a layer of topsoil. The immediate effect will be to greatly 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 dam will most likely mean that some leachate will continue to percolate downwards, leading to a persistent water quality impact (albeit possibly a relatively mild impact).

5.1.1.4 Cumulative impacts

The likely cumulative impacts of all three phases (ash dam construction, operation and decommissioning) are likely to be a long-term rise in water table in the vicinity of the site, accompanied by a deterioration in groundwater quality. These impacts will most likely gradually reverse once the ash dam is decommissioned, but are unlikely to completely disappear for many years. In the event that highly toxic or persistent pollutants are inadvertently disposed onto the ash dam, then the long-term cumulative impacts on local groundwater could be more serious.

5.1.2 ALTERNATIVE 2 – NO-GO:

If the ash dam is not constructed ("no-go" option) then there will be no additional impacts on groundwater at the site, provided no other activities are carried out at the site which could affect the groundwater.

5.2 TRANSMISSION LINES

It will be necessary to re-route the existing electricity transmission lines, since these presently cross the proposed ash dam site. The transmission lines will be routed round the ash dam to the south, close to the ash dam so as to minimize costs. Apart from possible local pollution during construction or decommissioning of the transmission lines (e.g. by a diesel fuel spill) there is likely to be very little impact on groundwater by the transmission lines during any of the phases. This applies to both possible transmission line corridors – both are located on the same geology (Vryheid Formation shales of the Karoo Supergroup) and on the same hydrogeological map classification (classified "D2"). Differences in elevation (and therefore presumably depth to water table) between the two proposed corridors are small. There is likely to be no impact of the "no-go" option (i.e. leaving the transmission lines as they are currently) on the local groundwater.

5.3 PIPELINES

It will be necessary to re-route the existing water pipeline carrying water south from the main pipeline at Hendrina since the pipeline presently crosses the proposed ash dam site. Eskom propose to route the pipeline round the ash dam to the south, close to the ash dam so as to minimize costs. Apart from possible local pollution during construction or decommissioning of the pipeline (e.g. by a diesel fuel spill) there is the possibility of a relatively small impact on groundwater during the construction and decommissioning phases (possible local dewatering of shallow perched groundwater during trench construction, and a slightly higher risk of groundwater pollution if contaminants enter the open pipeline trench. There is likely to be no impact of the "no-go" option (i.e. leaving the pipeline as it is currently) on the local groundwater.

6 ASSESSMENT OF IMPACTS

The impacts of the proposed ash dam, pipeline and transmission lines (including the no-go alternatives) on the local groundwater have been assessed using a series of spreadsheets. Each potential impact is briefly described, and the nature of the impact is assessed using a standard significance rating scale that takes into account the extent, duration, magnitude and probability of the impact. This leads to the calculation of a "significance" for each impact (low, medium or high) with an associated numerical value. Each assessment is also given a confidence rating (low, medium or high). **Please refer to the spreadsheets for full details of the impact assessment.** See below for an example of a significance impact rating, in this case the possible deterioration of local groundwater quality due to leachate migrating downwards from the ash dam, over all phases of ash dam operation (construction, operation and decommissioning).

Hendrina Ash Dam - EIA and Waste License Application									
Groundwater specialist study									
Significance Rating Table									
Cumulative Impacts									
Ash Dam - Site E									
Potential Impact	Mitigation	Extent (E)	Duration (D)	Magnitude (M)	Probability (P)	Significance (S=(E+D+M)*P)		Status (+ve or -ve)	Confidence
Deterioration of groundwater quality due to ash leachate	Nature of impact:	The ash dam is likely to lead to deterioration of local groundwater quality, which will be most severe during ash dam operation but which will likely persist in some form long after the ash dam has been decommissioned. This is because leachate will continue to be generated from the ash by natural rainfall percolation, even after ash slurry deposition has ended.							
	with	2	4	2	4	32	Medium	-	medium
	without	2	4	4	4	40	Medium	-	medium
	degree to which impact can be reversed:	The impact can be lessened but not reversed completely by maintaining good practices during ash dam construction and operation, and by revegetating and maintaining the ash dam after closure.							medium
	degree of impact on irreplaceable resources:	The degree of impact on irreplaceable resources is thought to be low, since local groundwater resources are limited and are theoretically replaceable with alternatives.							medium

FIGURE 6-1 EXAMPLE OF IMPACT SIGNIFICANCE RATING

7 MITIGATION AND MANAGEMENT MEASURES

The following section refers to the ash dam only and not to the pipeline or transmission line diversions. The diversions are considered to have only a small potential impact on local groundwater, and normal "good housekeeping" measures such as preventing diesel spills from plant and forbidding the disposal of any waste material into holes dug for the pipeline or power lines is recommended.

7.1 CONSTRUCTION PHASE

During the construction phase of the ash dam the impacts of ash leachate are expected to be limited, mainly because the construction phase is not expected to last very long (weeks or months). It is expected to consist of clearing the site, the removal of any infrastructure at the site, the installation of under-drain systems and related pipework, the penstock installation, and the initial construction of ash dam walls. The construction phase may also include the installation of piezometers for groundwater monitoring. There is likely to be a lot of 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, particularly into the trenches / holes that will be dug. 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) refueling and fuel storage areas.
- Ensuring that the under-drain, penstock and other systems for the draining of leachates and supernatant water from the ash dam are in good working order and are installed correctly. A leaking under-drain means larger fluxes of pollutants to groundwater in most circumstances.
- Sufficient ash or other material must be in place to protect the under drain system before any vehicle may drive over it. If possible the under-drain systems should be checked for integrity once they have been completed.
- Systems for removing or preventing blockages (e.g. rodding eyes, water traps) must be installed correctly. All work should be supervised by an experienced and qualified engineer. Blocked under-drains can cause leaks, and lead to additional groundwater pollution.

7.2 OPERATIONAL PHASE

The operational phase is likely to change both the quantity (water table level will rise) and quality of local groundwater (quality likely to deteriorate). The local groundwater flow direction may also be modified due to the local rise in the water table and the fact that the site is close to a water divide. Minimizing the volume of leachate percolating through the ash dam and migrating downwards into the aquifer is the key to reducing all of these impacts. Mitigation measures therefore include:

- Ensuring that the under-drain, penstock 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 dam;
- Ensuring sufficient freeboard and other measures, to prevent any spills of contaminated water onto adjacent land;
- Operating an adequate groundwater monitoring network in the vicinity of the ash dam in order to detect any problems early.

There is a particular requirement that persistent or highly toxic pollutants should not be disposed of together with the ash, since this could potentially lead to more serious long-term groundwater pollution which would be expensive and difficult to remediate. Official policy is to only dispose ash slurry to the ash dams, and this must be monitored / enforced.

7.3 DECOMMISSIONING PHASE

Decommissioning of the ash dam will mean that ash slurry will no longer be disposed to the facility, and also that a degree of re-vegetation may be achieved. Whilst it will be practically impossible to prevent the percolation of some leachate into local groundwater in the long term, mitigation measures can reduce this and the following are suggested:

- Maintenance of the under-drain and return water systems (and liner if fitted), in whatever final state is considered best;
- Continuous groundwater monitoring in order to quantify ongoing impacts and provide early warning of any problems;
- Encourage re-vegetation of the ash dam, since this is likely to reduce the volume of rainwater percolating down into the facility through natural evapotranspiration. If possible a layer of top soils should be added to the ash dam once deposition ceases;
- Maintain the structural integrity of the ash dam, to prevent slipping and gulley erosion;
- Ensure that no other waste is disposed of at the ash dam.

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 has finished, since the overlying ash dam (even if vegetated and managed) will alter the flow / recharge characteristics of the local area. These issues are expected to be relatively minor.

8 CONCLUSIONS

The main impact on groundwater of the proposed ash dam is likely to be a reduction in water quality beneath the site, and in the vicinity of the site. If toxic or persistent pollutants are disposed of onto the ash dam then local groundwater pollution will be more serious. The numerical model results suggest that the movement of leachate away from the ash dam should take place relatively slowly, with the surface water receiver being the drainage to the north west of the proposed ash dam site. Less serious is the anticipated water table mounding beneath the site and the potential alteration of local groundwater flow directions. The main way to mitigate all of these impacts is to maintain the ash dam in good condition (especially the drainage system) and to ensure that only ash slurry is disposed of. Once the ash dam is decommissioned, it should be re-vegetated and the drainage system maintained to reduce downward movement of leachate. The construction of a low permeability liner system should greatly reduce the downward movement of leachate into the subsurface, if managed together with the under drain system. The impact of the construction of the water pipeline diversion or the electricity transmission lines on groundwater is expected to be minimal, unless spills occur during construction or waste is disposed into the trenches or pits during the construction phase.

It is recommended that the ash dam and leachate control system continue to be maintained after ash disposal has ceased. If possible a layer of top soil should be added to the ash dam on closure to encourage re-vegetation. Monitoring of groundwater levels and quality in the vicinity of the ash dam should be continued after ash dam closure, and if required the numerical model updated with the new data.

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Jude Cobbing
(Project Manager)

Kai Witthueser
(Project Reviewer)

Jenny Ellerton, Karabo Lenkoe, Theo Rossouw, Martin Holland
(Project Assistants)

APPENDIX A: LABORATORY RESULTS

Analyses in mg/ℓ (Unless specified otherwise)	Method Identification	Sample Identification: SLR					
		01	02	03	04	05	06
Sample Number		15124	15125	15126	15127	15128	15129
pH – Value at 25°C	WLAB001	7.3	8.2	11.0	6.9	7.0	6.8
Electrical Conductivity in mS/m at 25°C	WLAB002	152	37.3	114	49.9	15.4	34.4
Total Dissolved Solids at 180°C *	WLAB003	1 006	224	704	324	132	210
Total Alkalinity as $CaCO_3$	WLAB007	132	180	92	112	80	84
Chloride as Cl *	WLAB046	247	11	85	25	<5	17
Sulphate as SO_4	WLAB046	6	5	286	98	<5	45
Fluoride as F	WLAB014	1.1	1.1	0.3	0.2	0.3	<0.2
Nitrate as N *	WLAB046	55	0.3	0.3	1.9	0.3	0.3
ICP-OES Scan *	WLAB015	See Attached Report: 32606-A					
% Balancing	---	98.9	100.0	95.7	99.4	96.5	98.8

*** = Not SANAS Accredited**

Tests marked "Not SANAS Accredited" in this report are not included in the SANAS Schedule of Accreditation for this Laboratory.

All in [mg/L]	Alkalinity as CaCO3	EC (mS/m)	pH	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Cl
WHO Drinking Water (2008)	N/A		N/A	N/A	0.2	0.01	0.5	0.7	N/A	N/A	300	0.003	250
IFC Mining Effluents (2007)	N/A		N/A	N/A	N/A	0.1	N/A	N/A	N/A	N/A	N/A	0.05	N/A
SANS 241 Class I (2006)		<150	5.0-9.5		<0.3	<0.01					<150	<0.005	<200
SANS 241 Class II (2006)		150 - 370	4.0-10		0.3 - 0.5	0.01 - 0.05					150-300	0.005 - 0.01	200-600
SANS Class II (Period of Consumption)		7 years			1 year	1 year					7 years	6 mnths	7 years
SLR01	132	152	7.3	<0.025	<0.100	<0.010	<0.025	0.533	<0.025	<0.025	135	<0.005	247
SLR02	180	37.3	8.2	<0.025	<0.100	<0.010	0.080	0.463	<0.025	<0.025	18	<0.005	11
SLR03	92	114	11	<0.025	0.547	<0.010	1.65	0.061	<0.025	<0.025	78	<0.005	85
SLR04	112	49.9	6.9	<0.025	<0.100	<0.010	0.046	0.199	<0.025	<0.025	42	<0.005	25
SLR05	80	15.4	7	<0.025	<0.100	<0.010	0.043	0.281	<0.025	<0.025	10	<0.005	<5
SLR06	84	34.4	6.8	<0.025	<0.100	<0.010	0.069	0.139	<0.025	<0.025	18	<0.005	17

Red- Exceedance of all specified guideline limits

All in [mg/L]	Co	Cr	Cu	F	Fe	K	Li	Mg	Mn	Na	Ni	Cr^{+6}
WHO Drinking Water (2008)	N/A	0.05	2	1.5	N/A	N/A	N/A	N/A	0.400	200	0.07	0.05
IFC Mining Effluents (2007)	N/A	N/A	0.3	N/A	2	N/A	N/A	N/A	N/A	N/A	0.5	0.1
SANS 241 Class I (2006)	<0.5	<0.1	<1	<1.0	<0.2	<50		<70	<0.1	<200	<0.15	
SANS 241 Class II (2006)	0.5-1	0.1 - 0.5	1-2	1.0-1.5	0.2-2	50 - 100		70-100	0.1-1	200 - 400	0.15- 0.35	
SANS Class II (Period of Consumption)	1 year	3 mnths	1 year	1 year	7 years	7 years		7 years	7 years	7 years	1 year	
SLR01	<0.025	<0.025	<0.025	1.1	0.028	22	<0.025	66	<0.025	30	<0.025	<0.025
SLR02	<0.025	<0.025	<0.025	1.1	20	5.7	<0.025	8	0.14	55	<0.025	<0.025
SLR03	<0.025	<0.025	<0.025	0.3	<0.025	44	2.43	<2	0.037	107	<0.025	<0.025
SLR04	<0.025	<0.025	<0.025	0.2	6.18	7.8	<0.025	31	0.781	18	<0.025	<0.025
SLR05	<0.025	0.048	<0.025	0.3	19	3.7	<0.025	5	0.491	15	<0.025	0.048
SLR06	<0.025	<0.025	<0.025	<0.2	50	7.0	<0.025	11	0.639	28	<0.025	<0.025

Red- Exceedance of all specified guideline limits

All in [mg/L]	NO3_N	P	Pb	SO_4	Se	Si	Sn	Sr	Ti	V	Zn
WHO Drinking Water (2008)	11.3	N/A	0.01		0.01	N/A	N/A	N/A	N/A	N/A	N/A
IFC Mining Effluents (2007)	N/A	N/A	0.2		N/A	N/A	N/A	N/A	N/A	N/A	0.5
SANS 241 Class I (2006)	<10		<0.02	<400	<0.02					<0.2	<5
SANS 241 Class II (2006)	10 - 20		0.02 - 0.05	400-600	0.02- 0.05					0.2- 0.5	5 - 10
SANS Class II (Period of Consumption)	7 years		3 mnths	7 years	1 year					1 year	1 year
SLR01	55	0.044	<0.020	6	0.032	14.6	<0.025	1.28	<0.025	<0.025	<0.025
SLR02	0.3	0.037	<0.020	5	0.031	8.3	<0.025	0.316	<0.025	<0.025	<0.025
SLR03	0.3	0.043	<0.020	286	0.04	7.0	<0.025	3.02	<0.025	0.359	<0.025
SLR04	1.9	0.043	<0.020	98	0.032	5.9	<0.025	0.269	<0.025	<0.025	<0.025
SLR05	0.3	0.274	<0.020	<5	0.028	11.5	<0.025	0.119	<0.025	<0.025	<0.025
SLR06	0.3	0.037	<0.020	45	0.031	12.7	<0.025	0.252	<0.025	<0.025	<0.025

Red- Exceedance of all specified guideline limits

metago (part of the SLR Group) SLR

Johannesburg office: Unit 7, Fourways Manor Office Park, Cnr Roos and Macbeth Str, Fourways - PO Box 1596, Cramerview, 2060 - T: +27 11 467 0945, F: +27 11 467 0978
Pretoria Office: Pentagon House, 669 Plettenburg Rd, Faerie Glen - PO Box 40161, Faerie Glen, 0043 - T: +27 12 991 8881, F: +27 12 991 1907

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