REPORT

Kendal Power Station - Continuous Ash Disposal Facility - Exemption Extension

Groundwater Baseline Study and Qualitative Impact Assessment

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Executive Summary

Eskom Holdings SOC Ltd (Eskom) was granted an Integrated Environmental Authorisation (IEA) on the 28th of July 2015 for their Kendal Power Station, continuous Ash Disposal Facility (ADF) to accommodate the ash to be produced by the power station up to the year 2030. The Integrated Water Use Licence (IWUL) number: 04/B20E/ABEGI/3888 for the extension, including the river diversion, was received in December 2015. One of the conditions of the IEA is that the ADF should be lined with a Class C liner. However, as a way to cater for the extended construction of the ADF a transitional period exemption was applied for and granted in May 2016. This was for Eskom to ash without lining until May 2020, for a period of 4 years (DEA Ref No. 14/12/16/3/3/3/63AM1).

Eskom now intends to extend the exemption authorisation period to continue ashing on the exempted area until the exempted footprint is covered with ash and ensure a smooth transition to the lined area. Green Gold Group has been appointed as an independent Environmental Assessment Practitioner (EAP) to facilitate the Part 2 amendment process in terms of the National Environmental Management Act, Act No. 107 of 1998 (NEMA) as amended, read in conjunction with Chapter 5 of the Environmental Impact Assessment (EIA) Regulations 2014 as amended.

Golder Associates Africa (Pty) Ltd (GAA) was appointed by Green Gold Group to update the 2014 groundwater baseline water quality and qualitative impact assessment for their amendment application of an exemption authorisation for Kendal Power Station ADF.

The 2014 groundwater specialist study was in support of the Integrated Environmental Authorisation Application process at Kendal power station and for the Integrated Water Use License (IWUL) for the extension of the existing dry ashing facility at Kendal power station.

The updated groundwater report will inform the amendment application being undertaken by Green Gold Group.

Study Objective

The objective of the groundwater study is to update the groundwater baseline report and qualitative impact assessment of existing ADF on the groundwater system, with updated groundwater monitoring data as supplied by the client.

Groundwater Baseline (2014)

Desk study and Information Review

The desk study and information review include the existing hydrogeological reports, National Groundwater Database (NGWD), groundwater monitoring database and regional geology and hydrogeology maps.

Climate

The mean annual rainfall of the area of investigation is approximately 735 mm per annum and the temperature extremes range from 27.7°C in summer to -1.89°C in winter.

Geology

The Kendal power station is mainly underlain with Karoo Sequence sediments comprising of shale, carbonaceous shale, sandstone and coal of the Vryheid formation of the Ecca Group. A pre-Karoo diabase sill is present to the west of the site. Medium to coarse grained porphyritic and biotite granite of the Lebowa granite suite, part of the Bushveld Igneous Complex (BIC) together with sediments of the Transvaal Sequence (TS) Rooiberg Group (Selons River Formation) part of the continuous ash disposal site.

Hydrocensus

Two private boreholes were located in the vicinity of the ADF; boreholes were sampled to determine groundwater background water quality of surrounding groundwater users.

Aquifer Classification and Borehole Yield

The Kendal power station aquifer is classified as a minor aquifer system with intergranular and fractured aquifer zones. The published hydrogeological maps (DWAF 1996) indicate that the average borehole yield in the area is between 0.5l/s and 2.0l/s.

The average borehole yield recorded on the groundwater data base is 0.24 l/s, with maximum yield being 1.3 l/s and the minimum yield recorded as 0.0001l/s.

Groundwater Flow Direction

The groundwater flows mimic the topography and is toward the surface streams. The groundwater flow is toward the west at the ADF.

Groundwater Conceptual Model

The initial regional groundwater conceptual model identifies three aquifer zones namely weathered, fractured and deep fractured to fresh aquifer zones, but needs to be confirmed and updated with hydraulic parameters.

Existing Groundwater Monitoring Network

The existing groundwater monitoring network as confirmed from groundwater data base and monitoring reports consists of 45 monitoring boreholes, which are adequate to monitor the groundwater quality at the ADF.

Groundwater Quality (2014)

The background groundwater quality of the Kendal power station is representative of calcium, magnesium bicarbonate type of water (Ca, Mg) $(HCO_3)_2$.

The following constituents however exceed the SANS 241 (2011) drinking water compliance standards manganese, iron, sulphate and fluoride, but it is unlikely that the ADF contribute to these elevated values.

The elevated manganese concentrations reported are present in monitoring boreholes covering the Kendal power station site. It is therefore highly unlikely that the ash disposal facilities have an impact on the manganese concentrations of these monitoring boreholes. Groundwater quality results from surrounding groundwater users could confirm if this is a regional and natural trend or site specific.

The elevated sulphate level detected at AB08 is probably related to fertilizer used for irrigation purposes by surrounding landowners, and potentially from coal mining activities.

The elevated concentrations reported fluoride is probably related to the surrounding geology in the area comprising out of granite and diabase.

The high iron concentration reported need to be monitored in future to determine if there is a trend noticeable.

The latest analytical results confirm that presently, the existing continuous and emergency ADF have limited impact on the surrounding groundwater quality although an increased pH value is noticed downstream of the conveyor belt between the ash dump and the power station.

Groundwater Recharge

From the published hydrogeological maps (DWAF 1996) the average recharge for the study area is shown as between 50mm to 75mm per annum.

Groundwater Vulnerability

Groundwater vulnerability at the Kendal continuous and emergency ash site is shown on the national groundwater vulnerability map as low to medium.

Groundwater Quality (2019)

The 33 analytical results of the Phase 87 monitoring programme were compared to the:

- SANS 241-1 (2015) water compliance standard, which specifies aesthetic, operational, chronic and acute health limits. Values exceeding specified limits are highlighted accordingly; and
- Kendal power station WUL (Licence No.04/B20E/BCEG/1048) limits. Values highlighted in red exceeds the maximum allowable WUL limit.

Most of the constituents of the groundwater samples are below SANS 241-1 (2015) water compliance standard limits. The following constituents however exceed the relevant standards:

- Manganese (Mn;
- Sodium (Na);
- Sulphate (SO_4);
- Ammonia as N;
- Iron (Fe); and
- Turbidity.

The 2019 analytical results confirm that presently the existing, continuous and emergency ash disposal facilities have very limited impact on the surrounding groundwater quality. These results correlate with the 2014 groundwater study findings.

Groundwater Impact Assessment

By using the standardised impact assessment methodology, the impact risk is on groundwater quality is classified according to the impact risk classes as class 2 with a **low impact**.

Recommended Mitigation

The following mitigation measures are proposed for the continuous ashing on the exemption area:

- Lining and sealing of proposed new continuous ash disposal facility as per engineering designs will reduce the risk of groundwater contamination;
- Additional mitigation measures that can be implemented are summarised below:
  - Scavenger borehole system at the two water quality outliers (AB08 and AB57) may contain/deplete the development of these local plumes although the source of potential contamination needs to be investigated;
  - Part of the mitigation and management could include a deeper (intersecting the groundwater level ~3.5m below surface) subsoil drainage collection trench between the ash dump and the stream to the west thereof. This is only necessary if contamination migration from the ADF to the stream is noticed. At this stage it is recommended that this subsurface drain should be designed but not installed. If contamination is noticed during monitoring it can be installed at specific contamination flow zones (determined by monitoring). The design must be as such that the inflow in the trench is limited to upstream and below and not from the downstream side. Thus, impermeable layers at the stream side of the trench;

- Although existing groundwater monitoring is sufficient as baseline, expansion/optimisation of the groundwater monitoring network is recommended on the continuous ADF area to form part of the mitigation and management of the ash dump, to cover the outline of the proposed CADF area. This will be included in the monitoring network and will be used as a warning system for contaminant migration.

Conclusions

The following groundwater conclusions are made for Kendal Power Station ashing on the exemption area footprint:

- The site is mainly underlain by sub–horizontal sediments of the Karoo Sequence comprising of shale, carbonaceous shale, sandstone and coal layers of the Vryheid formation of the Ecca group;
- The initial regional groundwater conceptual model identifies three aquifer zones namely weathered, fractured and deep fractured to fresh aquifer zones, but needs to be confirmed and updated, from future test pumping and borehole logs;
- The average groundwater levels of the deep monitoring boreholes for 2014 are 6.1 mbgl and for the shallow monitoring boreholes 2.21mbgl;
- The minimum and maximum water levels reported by Kimopax during the phase 87 2019 monitoring round range between 0.74 mbgl to 14.03 mbgl.
- The groundwater flow mimics the topography and the direction are towards the surface streams;
- The background groundwater quality of the Kendal Power Station are representative of calcium, magnesium bicarbonate type of water (Ca, Mg)$(HCO_3)_2$.;
- The following inorganic constituents exceed the SANS 241 (2015) drinking water compliance standards manganese, iron, sulphate, sodium, ammonia as N and turbidity;
- The 2014 and 2019 analytical results confirm the existing, continuous and emergency ash disposal facilities have limited impact on the surrounding groundwater quality;
- Groundwater vulnerability at the Kendal continuous and emergency ash site is shown on the national groundwater vulnerability map as **low** to medium; and
- According to qualitative groundwater impact assessment for the exemption area footprint, the impact risk on the groundwater quality is classified as class 2 with a **low impact**, therefore it can be concluded that the exemption area has a low impact on the groundwater quality.

Recommendations

The following recommendations are made for Kendal Power Station ashing on the exemption area footprint:

- Based on the outcome of the groundwater impact assessment for the exemption area footprint, the impact risk on the groundwater quality is classified as class 2 with a low impact and the impacts on the groundwater are not exceed the current conditions. The application for the exception extension therefore could be granted;
- Groundwater monitoring in and around Kendal Power Station must continue, to enable early warnings where changing trends are noted and ensure mitigation is implemented timeously;
- The following monitoring tasks should be conducted to be consistent with the existing WUL (Licence No.: 04/B20E/ABCEGI/3888):
  - Quarterly monitoring of groundwater levels and quality;
  - Purged groundwater sampling;
  - The analytical suite for groundwater samples should include determinants as listed in table below; and

Analytical Suite as per existing WUL

Variable	Units
pH	pH Units
Electrical Conductivity	mS/m
Total Dissolved Solids (TDS)	mg/l
Total Alkalinity	mg/l
Major cations (Na, K, Mg, Ca)	mg/l
Major anions (Cl, F, SO_4)	mg/l
Nitrate (NO_3 as N)	mg/l
Nitrite (NO_2 as N)	mg/l
Chemical Oxygen demand (COD)	mg/l
Orthophosphate	mg/l
Turbidity (as N.T.U)	mg/l
Trace elements by ICP-OES scan including Fe, Mn, Al, Cu, B, Pb, Zn, Hg, Cd and As	mg/l
Total Chromium (as Cr)	mg/l
Cyanides (as CN)	mg/l
Silica (as SIO_2)	mg/l
Free and saline Ammonia NH3 (as N)	mg/l
E. coli	In cfu/100ml

- A proposed mitigation trench between the ash dump and the stream to the west thereof, should only be implemented if contamination migration from the dumps to the stream is noticed.

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1.0 INTRODUCTION

Eskom Holdings SOC Ltd (Eskom) was granted an Integrated Environmental Authorisation (IEA) on the 28th of July 2015 for their Kendal Power Station, continuous Ash Disposal Facility (ADF) to accommodate the ash to be produced by the power station up to the year 2030. The Integrated Water Use Licence (IWUL) number: 04/B20E/ABEGI/3888 for the extension, including the river diversion, was received in December 2015. One of the conditions of the IEA is that the ADF should be lined with a Class C liner. However, as a way to cater for the extended construction of the ADF a transitional period exemption was applied for and granted in May 2016. This was for Eskom to ash without lining until May 2020, for a period of 4 years (DEA Ref No. 14/12/16/3/3/3/63AM1).

Eskom now intends to extend the exemption authorisation period to continue ashing on the exempted area (Figure 1) until the exempted footprint is covered with ash and ensure a smooth transition to the lined area. Green Gold Group has been appointed as an independent Environmental Assessment Practitioner (EAP) to facilitate the Part 2 amendment process in terms of the National Environmental Management Act, Act No. 107 of 1998 (NEMA) as amended, read in conjunction with Chapter 5 of the Environmental Impact Assessment (EIA) Regulations 2014 as amended.

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The 2014 groundwater specialist study was in support of the Integrated Environmental Authorisation Application process at Kendal power station and for the Integrated Water Use License (IWUL) for the extension of the existing dry ashing facility at Kendal power station.

The updated groundwater report will inform the amendment application being undertaken by Green Gold Group.

2.0 LOCALITY

Kendal power station is situated in Mpumalanga Province 40km south west of Witbank and 6km west of Ogies as indicated on Figure 1. The Kendal power station fall into three quaternary catchments namely B20F, B20E and B11F to the east of the site. The existing and continuous falls into the B20E quaternary catchment.

3.0 STUDY OBJECTIVE

The objective of the groundwater study is to update the groundwater baseline report and qualitative impact assessment of existing ADF on the groundwater system, with updated groundwater monitoring data as supplied by the client.

4.0 GROUNDWATER BASELINE - 2014

4.1 Desk Study and Information Reviewed

The following information and data were utilised during the desk study and information review task:

- National Groundwater Database (NGDB);
- 1:250 000 geological map series;
- 1:2 500 000 Groundwater Resources map of RSA –Sheet 1 (WRC.DWAF 1995);
- 1:4 000 000 Groundwater Resources map of RSA – Sheet 2 (WRC.DWAF 1995);
- 1: 500 000 Hydrogeological Map Series of RSA (1996); and
- Review of existing monitoring report from GHT (February 2012); and

Groundwater monitoring data base received from GHT in Aquabase format.

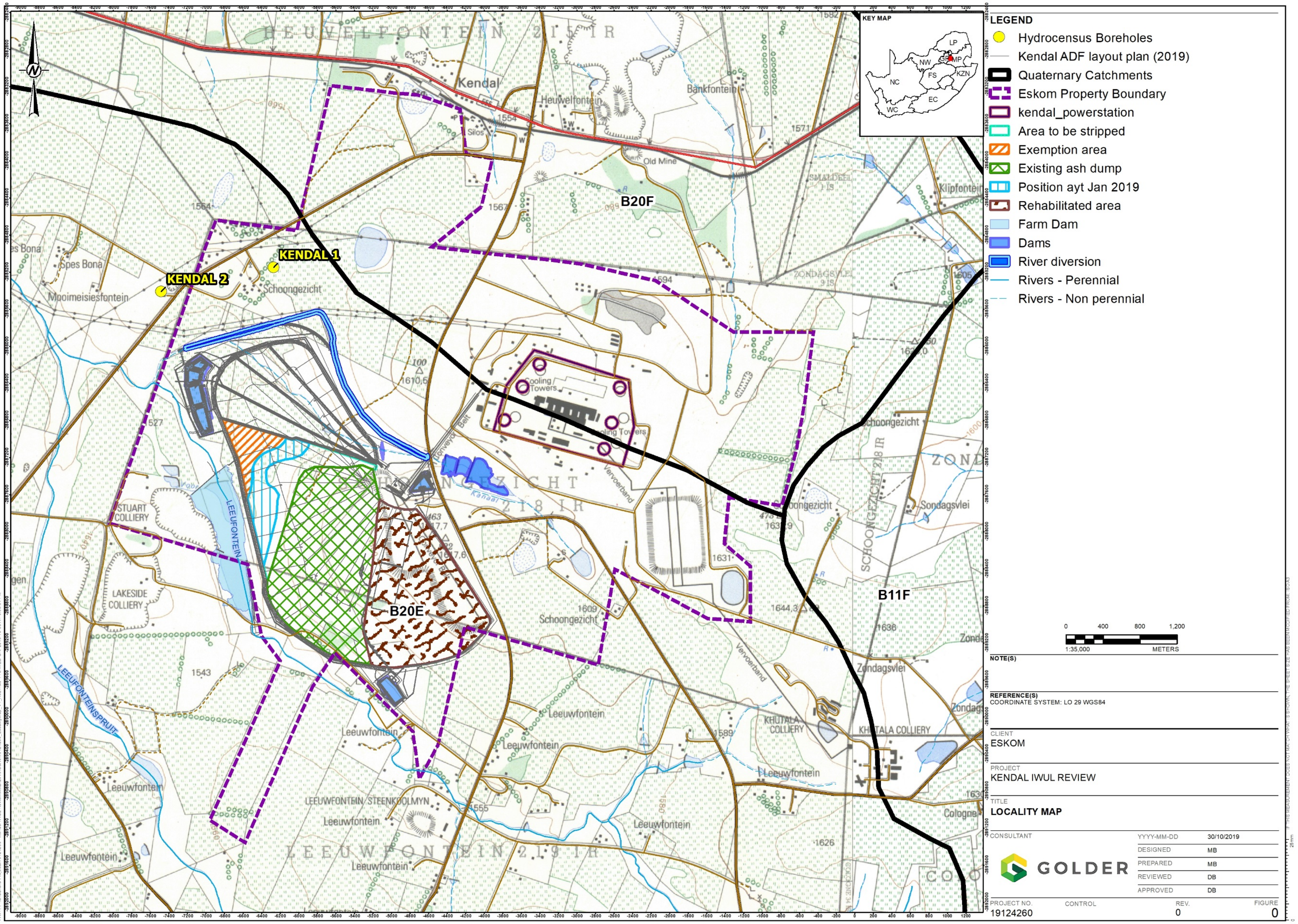

Figure 1: Locality Map

4.2 Climate

4.2.1 Rainfall

The Middelburg EDE farms (0516/232LO) are the closest rainfall station to Kendal power station. Rainfall data are available for an 11.9-year period and was used to calculate the mean annual precipitation as approximately 735 mm per annum. Average rainfall is summarised in Table 1.

Table 1: Average Precipitation for Period 2001 to 2013

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1/06/2001 to10/05/2013	159.69	87.74	79.35	44.35	12.52	9.68	2.69	9.3	16.23	83.2	108.5	139.3	753

4.2.2 Temperature

Temperature extremes range from 27.7°C in summer to -1.89°C in winter. Mean monthly temperatures as recorded at Middelburg EDE farms are listed in Table 2.

Table 2: Mean Monthly Temperatures for 2001 to 2013 (Minimum and Maximum)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min (°C)	14.07	13.1	11.39	7.34	2.6	-0.72	-1.89	1.64	6	10.3	12.33	13.67
Max (°C)	27.77	28.37	27.23	24.54	22.55	20.03	19.58	22.61	26.04	27.02	26.58	27.13

4.3 Geology

Based on the published 1:250 000 geology map series (2628East Rand), the area of investigation are mainly underlain by Karoo Sequence sediments (Figure 2). The Karoo Sequence consists of the older Dwyka formation at the base, followed by the Ecca, Beaufort and Lebombo groups. The sediments in the areas of investigation comprise of shale, carbonaceous shale, sandstone and coal of the Vryheid formation of the Ecca Group.

A pre-Karoo diabase sill is present to the west of the site underling part of the continuous ash disposal site. Medium to coarse grained porphyritic and biotite granite of the Lebowa granite suite, part of the Bushveld Igneous Complex (BIC) together with sediments of the Transvaal Sequence (TS) Rooiberg Group (Selons River Formation) underlie part of the continuous ash disposal site.

An east-west striking lineament (possible dolerite dyke) is present to the north of the site boundary. There are no identified geological structures (fault zones and dykes) in the vicinity of the ash disposal facility. These geological structures if present act as preferred groundwater flow paths.

A typical stratigraphic section at Kendal power station is illustrated in Figure 3.

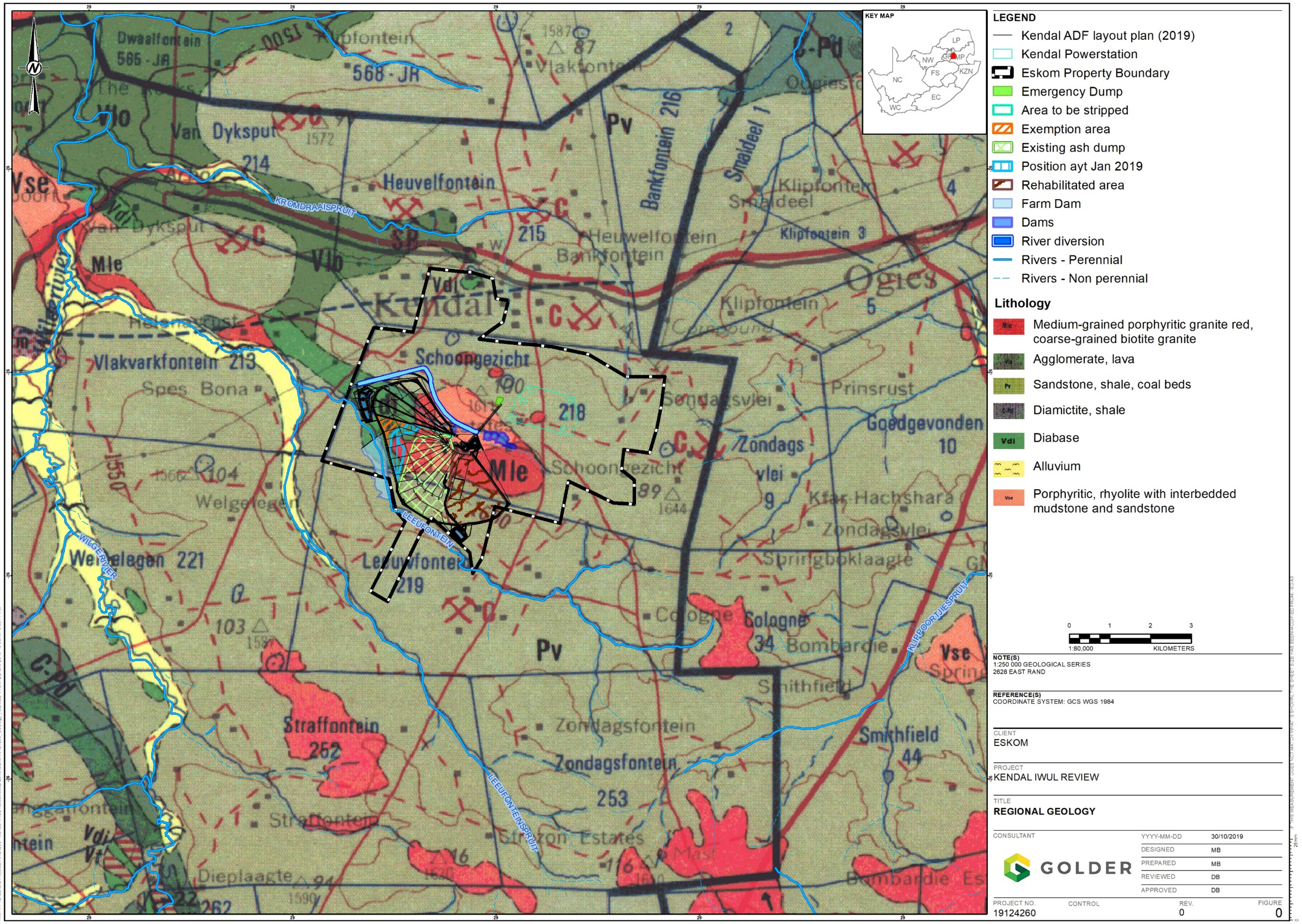

Figure 2: Geology Map

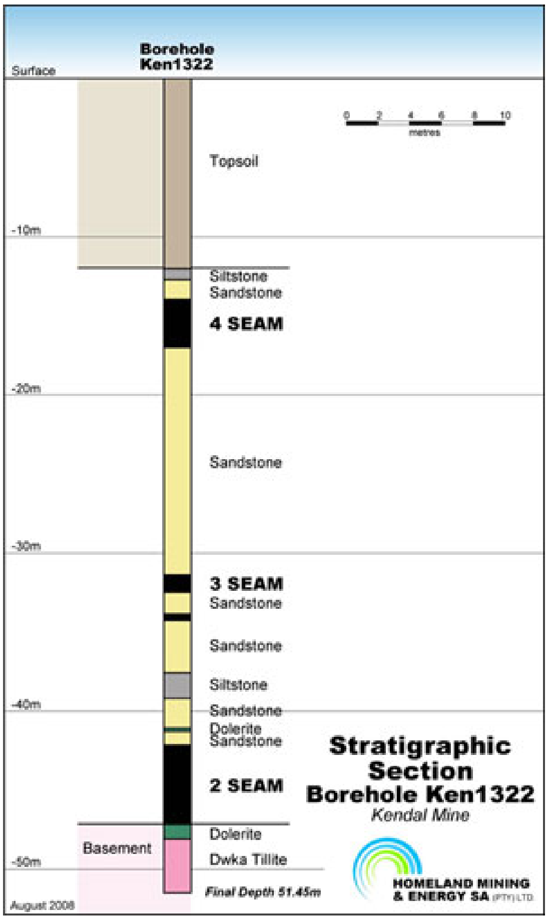

Figure 3: Typical Stratigraphic Section at Kendal Power Station (Homeland Mining & Energy SA, 2008)

4.4 Hydrocensus

Borehole records of existing private boreholes in the close vicinity of the existing and continuous ADF could not be located on the NGDB. The NGDB is initiated and driven by Department of Water Affairs (DWAF). Groundwater information is captured from numerous government and private projects. This borehole information is available through data request to DWAF and some of the borehole information is online obtainable.

Assisted by an Eskom representative, Golder conducted a hydrocensus during February 2013 to locate private owned boreholes in the close vicinity of the existing and continuous ADF. The position of the two private boreholes found is indicated on Figure 1.

The main objectives of the hydrocensus were to:

- Record GPS coordinates of existing private owned boreholes;
- Determine the status of existing private boreholes;
- Record static water levels and borehole depths; and
- Conduct groundwater sampling.

All coordinates were measured with a handheld GPS using the WGS 84 reference datum. The hydrocensus borehole information is summarised in Table 3 with a photo record shown in Table 4.

Table 3: Hydrocensus Borehole Information

Hydrocensus Number	Latitude	Longitude	SWL (mbgl)	Status	Use	Equipment	Sampled
Kendal 01	26.07506	28.93734	3.6	In use	Domestic	Submersible	13/02/2013
Kendal 02	26.07738	28.92523	14.21	In use	Domestic	Submersible	13/02/2013

Table 4: Hydrocensus Borehole Photo Record

	**Kendal_1**
	**Kendal_2**

4.5 Aquifer Classification and Borehole Yield

The published hydrogeological maps series by DWAF (1996) was used to define the regional aquifer classification (Figure 4). The aquifer is classified as a minor aquifer system with intergranular and fractured aquifer zones.

The published hydrogeological maps (DWAF 1996) indicate that the average borehole yield in the area is between 0.5l/s and 2.0l/s.

The average borehole yield recorded in the Eskom/GHT groundwater data base is 0.24 l/s, with maximum yield being 1.3 l/s and the minimum yield recorded as 0.0001l/s.

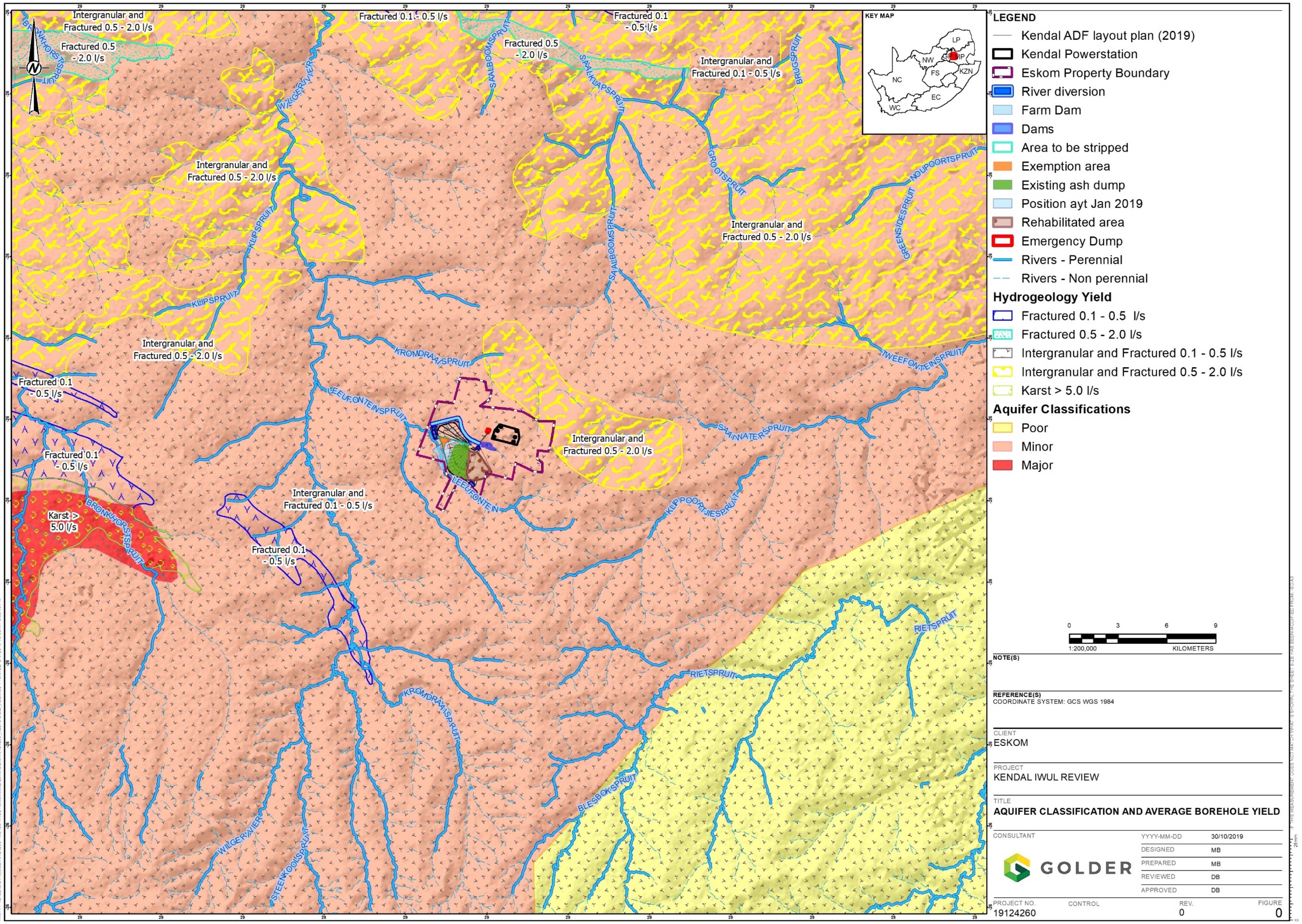

Figure 4: Aquifer Classification and Average Borehole Yield

4.6 Groundwater Levels and Flow direction

4.6.1 Deep Monitoring Boreholes

The maximum water level recorded during 2013 for the deep monitoring boreholes at the Kendal power station site is 17.16mbgl (metre below ground level), the minimum recorded is 1.06mbgl and the average groundwater level is 6.1mbgl.

Because of seasonal water level fluctuations and different measured dates, a groundwater piezometric contour map was constructed using only the deep water levels measured by GHT during 2013 and the water levels of the two hydrocensus boreholes (2013).

The correlation between the altitudes and water levels of the deep monitoring boreholes are 98% (Figure 5), therefore the assumption is made that the groundwater level will mimic the topography. The piezometric contour map was compiled using Bayesian kriging.

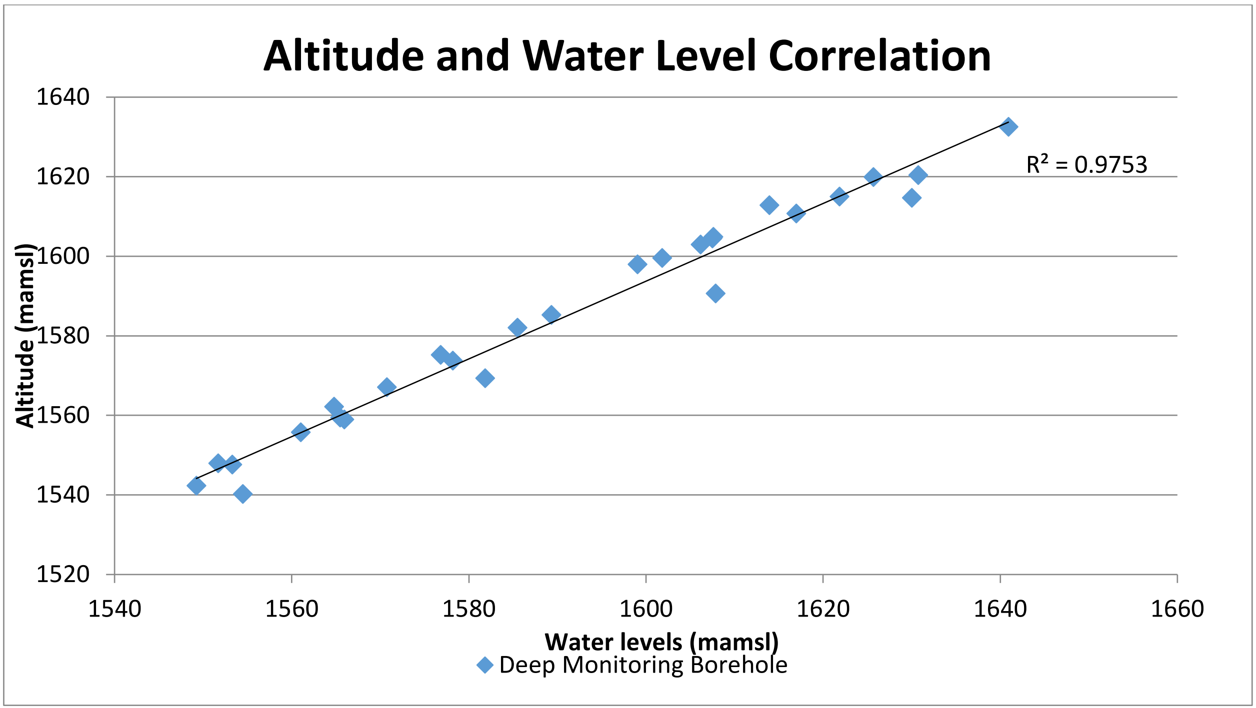

Figure 5: Correlation between Altitude and Water levels of Deep Monitoring Boreholes

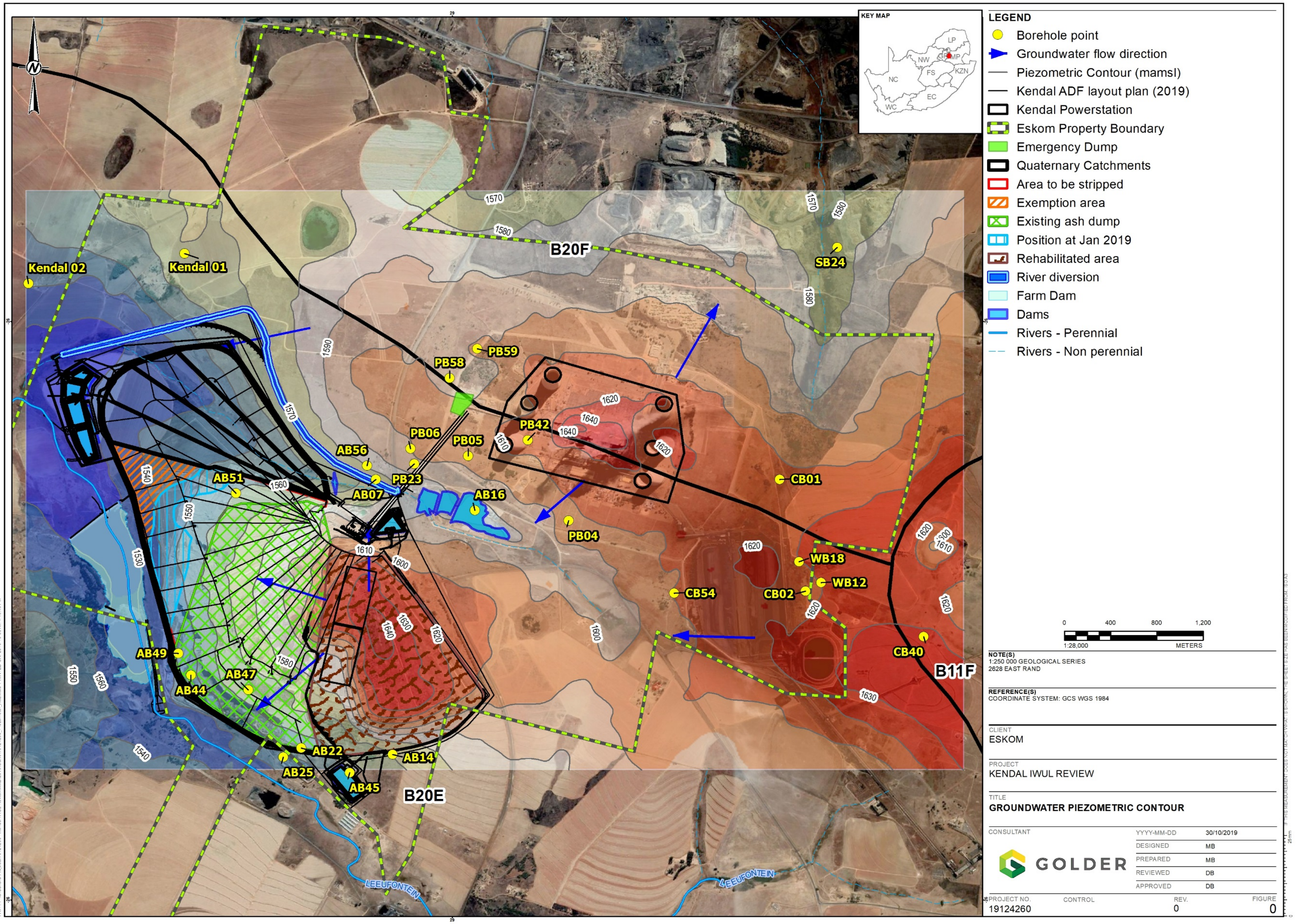

Figure 6: Groundwater Piezometric Contour Map (2014)

4.6.2 Shallow Monitoring Boreholes

Five pairs of deep and shallow monitoring boreholes are recorded as highlighted in pink and green in Table 5. Water level differences were measured in mbgl (AB52 and AB53) as well as at AB56 and AB57. Some of these measured differences were cancelled out, by calculating the water level as mamsl (AB56 and AB57). Borehole altitudes have been interpolated which could result in altitude inaccuracies, for a detailed piezometric contour map the altitudes of the monitoring boreholes need to be surveyed.

The maximum water level recorded during 2013 for the shallow monitoring boreholes at the Kendal power station site is 6.98mbgl (metre below ground level), the minimum recorded is 2.21mbgl and the average groundwater level is 4.45mbgl.

4.6.3 Groundwater Flow Direction

The groundwater flow mimics the topography and the direction of flow is towards the surface streams. The groundwater flow direction at the ADF is toward the west and towards the north away from the Kendal power station (Figure 6).

4.7 Existing Groundwater Monitoring Network

The positions of the existing monitoring boreholes are indicted on Figure 7. The groundwater monitoring network consists out of 45 monitoring boreholes (Table 5) which is maintained and operated by Eskom.

The positions of the existing monitoring boreholes around the existing and continuous ash extension disposal facility are well represented as monitoring facilities.

Table 5: Exiting Groundwater Monitoring Borehole Information

Borehole Number	Latitude	Longitude	SWL (mbgl)	SWL_2013 (mamsl)	SWL Date measured	Depth (m)	Yield (l/s)	Aquifer Monitoring Zone
B07A	26.09261229	28.95222	4.4	1574	2013/03/13	40	0.2	Deep
AB08	26.09001229	28.94752	2.07	-	2012/10/24	38	1.3	Deep
AB14	26.11401236	28.95352	12.45	1569	2013/03/12	30	-	Deep
AB15	26.10801238	28.93832	3.37	-	1987/05/21	26	1	Deep
AB16	26.09501228	28.95992	3.97	1585	2013/03/12	-	-	-
AB19	26.09801233	28.94402	5.6	-	2008/04/22	36	-	Deep
AB20	26.11011237	28.94392	-	-	-	31	0.01	Deep
AB21	26.0915123	28.94692	3.47	-	2009/11/12	30	0.01	Deep
AB22	26.11351238	28.94642	5.25	1556	2013/03/12	30	0.01	Deep
AB25	26.11421238	28.94502	5.66	1548	2013/03/12	-	-	-
AB44	26.10784238	28.93785	3.73	1548	2013/03/12	-	-	-
AB45	26.11541237	28.95020	6.88	1559	2013/03/12	-	-	-
AB47	26.10897237	28.94231	2.59	1559	2013/03/12	31	0.0001	Deep
AB48	26.10888237	28.94231	2.21	1562	2013/03/13	16	0.0001	Shallow
AB49	26.10615237	28.93687	6.93	1542	2013/03/13	31	0.0001	Deep
AB50	26.10610237	28.93694	6.98	1543	2013/03/13	16	0.0001	Shallow
AB51	26.09368232	28.94136	5.97	1559	2013/03/13	31	0.0001	Deep
AB52	26.0900023	28.94366	3.53	-	2012/10/24	31	0.015	Deep
AB53	26.0899623	28.94363	1.63	-	2012/10/24	6	-	Shallow
AB56	26.09154229	28.95155	3.43	1582	2013/03/13	31	0.0001	Deep
AB57	26.09155229	28.95144	2.38	1582	2013/03/13	11	-	Shallow
CB01	26.09261222	28.98362	1.06	1613	2013/03/13	38	0.1	Deep

Borehole Number	Latitude	Longitude	SWL (mbgl)	SWL_2013 (mamsl)	SWL Date measured	Depth (m)	Yield (l/s)	Aquifer Monitoring Zone
CB02	26.10131225	28.98562	15.3	1615	2013/03/13	40	1.3	Deep
CB03	26.10361227	28.98062	13.3	-	2008/11/14	40	0.1	Deep
CB09	26.09851226	28.97622	3.7	-	1987/05/20	19	-	Deep
CB13	26.09462923	28.98446	3.3	-	2009/11/11	26	0.15	Deep
CB17	26.0952122	28.99802	3.43	-	2012/10/24	-	-	-
CB40	26.10484224	28.99482	8.34	1633	2013/03/13	-	-	-
CB41	26.10505224	28.99490	-	-	-	-	-	-
CB54	26.10147227	28.97541	6.17	1611	2013/03/12	36	-	Deep
CB55	26.10147227	28.97541	6.23	1611	2013/03/12	11	-	Shallow
FBF04	26.09498228	28.96111	-	-	-	-	-	-
PB04	26.09581227	28.96722	2.73	1605	2013/03/12	40	0.3	Deep
PB05	26.09079227	28.95941	2.98	1605	2013/03/12	40	0.3	Deep
PB06	26.09021228	28.95492	2.22	1600	2013/03/12	40	0.1	Deep
PB23	26.09141228	28.95522	1.06	1598	2013/03/12	21	0.1	Deep
PB42	26.08956225	28.96405	6.81	1615	2013/03/13	-	-	
PB43	26.09014226	28.96445	-	-	-	-	-	
PB58	26.08473225	28.95796	17.16	1591	2013/03/13	31	-	Deep
PB59	26.08244224	28.96010	3.19	1603	2013/03/13	31	-	Deep
SB24	26.07456215	28.98811	1.54	1575	2013/03/12	31	0.1	
SB24S	26.07456215	28.98811	-	-	-	31	-	Deep
WB12	26.10064224	28.98684	10.28	1620	2013/03/12	30	-	Deep
WB18	26.09901224	28.98512	5.75	1620	2013/03/12	30	0.5	Deep
WB18S	26.09901224	28.98512	-	-	-	30	-	Deep

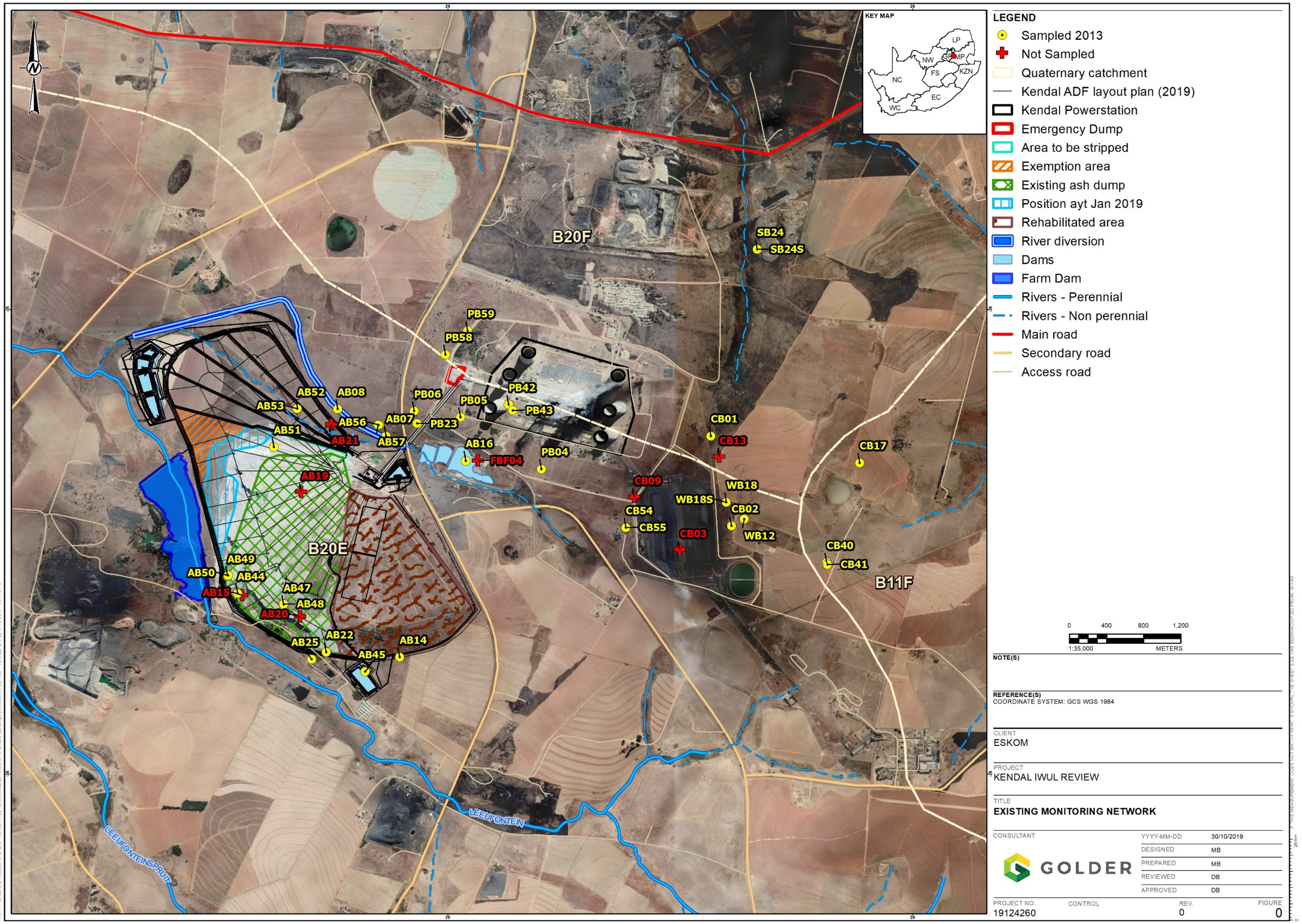

Figure 7: Groundwater Monitoring Network (2014)

4.8 Groundwater Conceptual Model

The initial groundwater conceptual model (Figure 8) that was constructed for Kendal power station is based on the 1:250 000 geology map series and the typical stratigraphic section of the area. The conceptual model forms the basis for the understanding of the groundwater occurrence and flow mechanisms in the area of investigation and is use as basis for future potential numerical groundwater modelling.

The conceptual model as discussed excludes any underground mining works and/or the linkage to underground mining works.

An aquifer system consisting out of three main aquifer zones which are commonly present in the Karoo, Bushveld Igneous Complex (BIC) and Transvaal Sequence (TS) are described namely:

- Upper weathered aquifer zone (Intergranular – DWAF 1996);
- Fractured aquifer zone (Fractured – DWAF 1996); and
- Deep fractured to fresh aquifer zones, controlled by geological structures and/or horizontal coal seams.

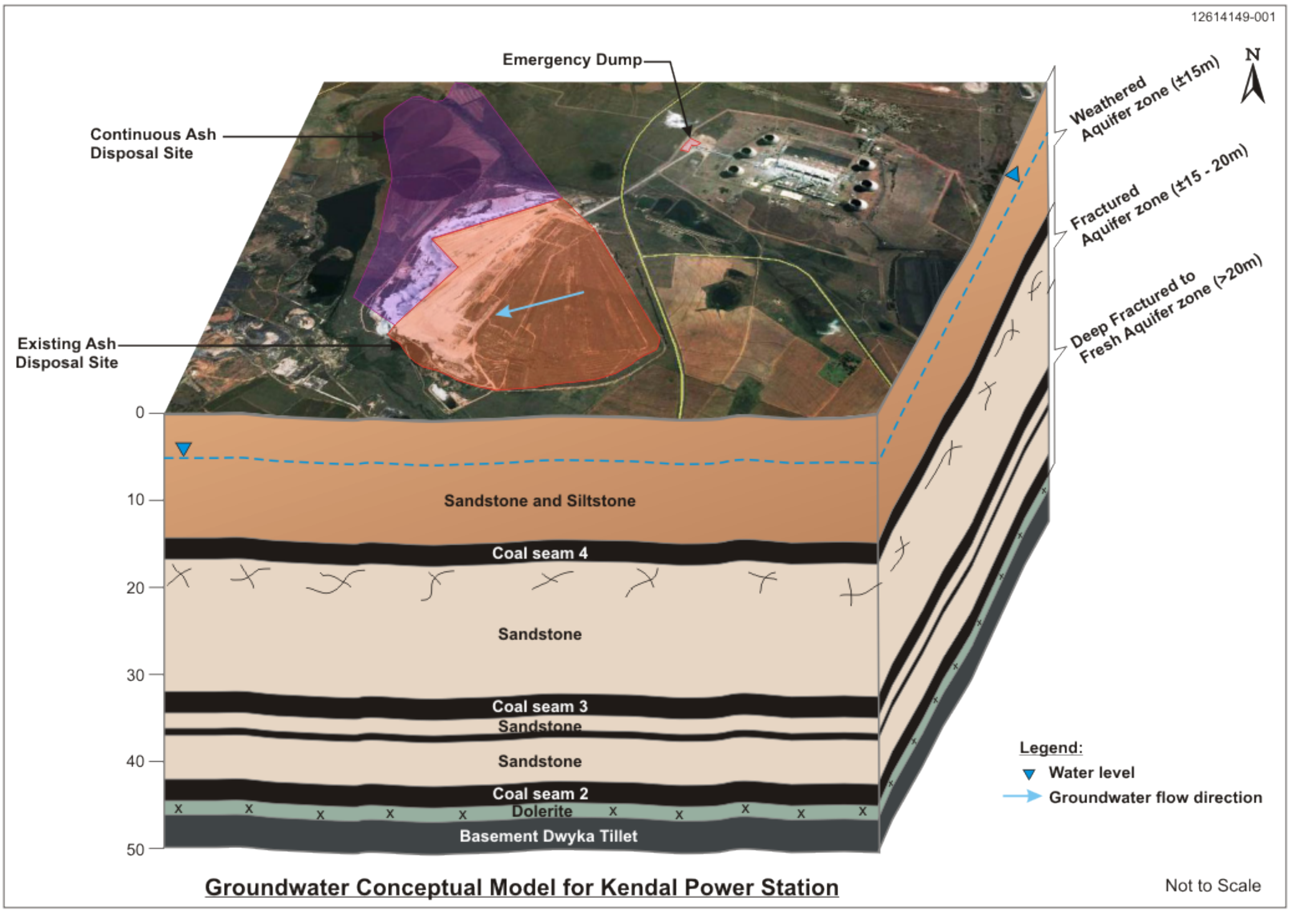

Figure 8: Initial Groundwater Conceptual Model

4.8.1 Weathered Aquifer Zone

From previous studies the average weathering depth of the Karoo sediments, BIC, dolerite sill and TS are commonly approximately 15m below surface. The aquifer conditions of the weathered aquifer zone could be unconfined but a perched water level could be present in areas underlain with an aquiclude formation (a formation, or part of formation through which virtually no groundwater moves), as noticeable at monitoring boreholes AB52 (Deep – 3.53mbgl) and AB53 (Shallow-1.63mbgl) and AB56 (Deep – 3.43mbgl) and AB57 (Shallow-2.38mbgl).

4.8.2 Fractured Aquifer Zone

The average depth of the fractured aquifer zone is commonly approximately from 15 to 20m below surface but need to be confirmed with future borehole logs. The aquifer conditions of the fractured aquifer zone are semi-confined where groundwater is associated with water-bearing fractures.

4.8.3 Deep Fractured to Fresh Aquifer Zone

The aquifer conditions of this aquifer zone can be described as semi-confined and being controlled by geological structures (dolerite intrusions and fault zones) and horizontal coal seam contact zones. There are no known geological structures present at ash dump facility. Geological structures will act as preferred groundwater flow paths.

4.9 Groundwater Quality (2014)

The 2014 groundwater quality results are discussed as two parts namely:

- The hydrocensus analytical results; and
- GHT Consulting Scientists analytical results 2012/ 2013.

4.9.1 Analytical Results

4.9.1.1 Hydrocensus Results 2014

The analytical results of the two hydrocensus boreholes were compared to the SANS 241-1 (2011) drinking water compliance standard, which specifies physical, aesthetic and chemical numerical limits for lifetime consumption as well as the South African Water Quality Guidelines (SAWQG), Volume 1: Domestic Use, Volume 4: Agricultural Use – Irrigation, and Volume 5: Agricultural Use – Livestock Watering (DWAF, 1996).

The major cations, anions and constituents of concern which exceeds these water compliance standards are highlighted in Table 6 and Table 7. The analytical result certificates are listed in Annexure C.

The groundwater quality of both hydrocensus samples are of essentially good quality except for elevated Nitrate (NO_3) and Manganese values at sampling position Kendal 01 which exceeds the SANS 241 (2011) compliance standard of 11mg/l and South African Water Quality Guidelines (SAWQG), Volume 1 – Domestic Use –Target Range of 6 mg/l for Nitrate and the South African Water Quality Guidelines (SAWQG), Volume 1 – Domestic Use –Target Range for Manganese of 0.05 mg/l. These elevated concentrations and lower pH of Kendal 01 is probably related to fertilizer used for irrigation purposes.

Table 6: Analytical Results of Hydrocensus Boreholes

Location	BH No.	pH	TDS mg/l	EC mS/m	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Fe mg/l	Mn mg/l	M Alk. mg/l	Cl mg/l	SO_4 mg/l	NO_3 as N mg/l	F mg/l	Al mg/l	Ni mg/l	Se mg/l
SANS 241-1 (2011 Drinking Water Compliance Limit		5-9.7	1200	170	-	-	200	-	0.3	0.1	-	300	250	11	1.5	3.0	0.7	0.01
South African Water Quality Guidelines (SAWQG), Volume 1 – Domestic Use – Target Range		6.0-9.0	450	70	32	30	100	50	0.1	0.05	-	100	200	6	1.0	0.15	-	0.05
South African Water Quality Guidelines (SAWQG), Volume 4 – Agricultural Use – Irrigation Target Range		6.5-8.4	260	40	-	-	70	-	5.0	0.02	-	100	-	-	2.0	5.0	0.2	0.02
South African Water Quality Guidelines (SAWQG), Volume 5 – Agricultural Use – Livestock Watering Target Range		-	1000	154	1000	500	2000	-	10	10	-	1500	1000	100	2.0	5.0	1.0	0.05
Kendal	Kendal 01	5.42	236	31.9	12.4	13.9	21.06	6.53	<0.05	0.099	5.8	33.1	12.2	22.1	<0.1	0.041	0.043	0.001
	Kendal 02	8.01	136	19.4	17.9	14.1	6.05	2.15	<0.05	0.008	96.5	1.54	1.32	4.23	<0.1	0.008	0.004	0.001

4.9.1.2 GHT 2012/2013 Groundwater Results

The results of 35 monitoring boreholes sampled by GHT in 2012 (Figure 7) were compared to the SANS 241-1 (2011) drinking water compliance standard, which specifies physical, aesthetic and chemical numerical limits for lifetime consumption as well as the South African Water Quality Guidelines (SAWQG), Volume 1: Domestic Use, Volume 4: Agricultural Use – Irrigation, and Volume 5: Agricultural Use – Livestock Watering (DWAF, 1996). (Table 7). These are the latest results (2012/2013) available from the monitoring data base (Aquabase format) as received from GHT Consulting Services.

The major cations, anions and constituents of concern which exceeds the SANS 241 (2011) drinking water compliance are listed in Table 7. Highlighted values exceed these standards.

The 2012/2013 (latest) analytical results were used to describe the 2014 groundwater quality. Most of the constituents of the GHT groundwater samples are below these standards. The following constituents however exceed the relevant standards:

Manganese (Mn) - Several monitoring boreholes CB01, AB07, AB08, WM12, AB16, AB22, SB24, PB42, AB45, AB48, AB51, AB52, CB55, AB57, PB59 and WB18S manganese (Mn) concentrations exceeds the SANS 241-1 (2011) drinking water compliance limit of 0.1 mg/l;

Boreholes PB04 and PB05 exceeds the South African Water Quality Guidelines (SAWQG), Volume 1 – Domestic Use –Target Range and Volume 4 Agricultural use for Irrigation Target range.

Sulphate (SO_4) - Monitoring borehole AB08 sulphate (SO_4) concentrations exceeds the SANS 241-1 (2011) drinking water compliance limit of 250 mg/l. This monitoring borehole is located to the north east of the existing and continuous as disposal site;

No groundwater analyses exceed the South African Water Quality Guidelines (SAWQG).

Fluoride (F) - Monitoring boreholes PB04, PB06, PB23, CB54 and PB58 fluoride (F) concentrations exceeds the South African Water Quality Guidelines (SAWQG)– Agricultural Use – Livestock Watering, irrigation and domestic use, Target Range, as well as the SANS 241-1 (2011) drinking water compliance limit.

Iron (Fe) Monitoring borehole AB08 and AB48 iron (Fe) concentrations exceeds the SANS 241-1 (2011) drinking water compliance lower limit of 0.3 mg/l as well as the South African Water Quality Guidelines (SAWQG)– domestic use, Target Range;

Other parameters Other parameters exceeding the South African Water Quality Guidelines (SAWQG) in some of the boreholes are limited to EC, Ca and B.

The elevated manganese concentrations reported are present in monitoring boreholes covering the Kendal power station site. It is therefore highly unlikely that the ash disposal facilities have an impact on the manganese concentrations of these monitoring boreholes. Groundwater quality results from surrounding groundwater users could confirm if this is a regional and natural trend or site specific.

The elevated sulphate level detected at AB08 is probably related to fertilizer used for irrigation purposes by surrounding landowners, and potentially from coal mining activities.

The elevated concentrations reported fluoride is probably related to the surrounding geology in the area comprising out of granite and diabase.

The high iron concentration reported need to be monitored in future to determine if there is a trend noticeable.

The latest analytical results confirm that presently the existing, continuous and emergency ash disposal facilities have very limited impact on the surrounding groundwater quality.

Table 7: 2013 Analytical Results of Monitoring Boreholes at Kendal

Location	BH No.	Latest Sampling	pH	TDS mg/l	EC mS/m	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Fe mg/l	Mn mg/l	M Alk.	Cl mg/l	SO4 mg/l	NO3 as N	Al mg/l	F mg/l	B mg/l	PO4 mg/l
SANS 241-1 (2011 Drinking Water Compliance Limit			5-9.7	1200	170	-	-	200	-	0.3	0.1	-	300	250	11	3.0	1.5	-	-
South African Water Quality Guidelines (SAWQG), Volume 1 –			6.0-9.0	450	70	32	30	100	50	0.1	0.05	-	100	200	6	0.15	1.0	-	-
South African Water Quality Guidelines (SAWQG), Volume 4 – Agricultural Use – Irrigation			6.5-8.4	260	40	-	-	70	-	5.0	0.02	-	100	-	-	5.0	2.0	0.5	-
South African Water Quality Guidelines (SAWQG), Volume 5 – Agricultural Use – Livestock Watering			-	1000	154	1000	500	2000	-	10	10	-	1500	1000	100	5.0	2.0	5.0	-
Groundwater Analytical Results 2012/2013																			
Kendal	CB01	20130313	7.4	-1	45.7	52.6	15.8	3.06	4.12	0.003	0.888	40	3.98	140	0.28	-1	0.32	0.01	0.02
	CB02	20130313	6.3	-1	4.93	1.18	1.45	0.493	1.16	0.003	0.001	2.48	0.42	1.17	2.57	-1	0.22	0	0.01
	PB04	20130312	8.2	-1	18	21	1.76	11.2	0.048	0.003	0.029	80.7	0.51	2.54	0.25	-1	3.01	0.01	0.02
	PB05	20130312	6.6	-1	9.55	4.8	2.08	4.58	1.56	0.003	0.06	28.6	1.59	1.66	0.58	-1	0.17	0	0.01
	PB06	20130312	8.4	-1	20.6	9.61	0.607	31.5	0.083	0.003	0.001	85.4	0.42	2.99	0.26	-1	5.05	0.06	0.01
	AB07	20130313	6.5	-1	7.48	6.06	1.36	2.12	1.12	0.003	0.386	23	1.83	1.89	0.25	-1	0.06	0	0.01

Location	BH No.	Latest Sampling	pH	TDS mg/l	EC mS/m	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Fe mg/l	Mn mg/l	M Alk.	Cl mg/l	SO4 mg/l	NO3 as N	Al mg/l	F mg/l	B mg/l	PO4 mg/l
	AB08	20121024	6.8	-1	97.1	173.28	54.29	36.52	4.22	0.983	0.796	56.1	14.9	634.77	0.19	-1	0.06	2.23	0.01
	WB12	20130312	7.3	-1	11.7	6.47	5.93	1.95	2.56	0.003	1.17	50.8	0.42	1.97	0.25	-1	0.13	0	0.01
	AB14	20130312	7	-1	6.8	4.83	1.99	1.52	0.773	0.003	0.001	20.7	0.61	2.59	0.3	-1	0.15	0	0.01
	AB16	20130312	6.7	-1	8.58	4.52	1.42	3.92	1.92	0.003	0.346	23.6	2.47	2.31	0.26	-1	0.26	0	0.01
	CB17	20130312	7.8	-1	26.1	29.7	7.05	9.42	2.37	0.003	0.001	107	9.2	4.73	1.67	-1	0.14	0	0.02
	WB18	20130312	6.9	-1	4.17	1.32	1.46	1.64	0.937	0.003	0.002	11	0.42	1.63	0.24	-1	0.32	0	0.01
	AB22	20130312	7.2	-1	43.6	56.2	8.48	11.7	3.43	0.003	0.125	101	11.4	80	0.27	-1	0.17	0.09	0.01
	PB23	20130312	9	-1	28.2	6.34	1.81	42	1.23	0.003	0.001	58.2	7.04	41.9	0.24	-1	3.67	0.04	0.01
	SB24	20130312	7.2	-1	57.3	45.3	27	29.8	1.17	0.003	0.481	235	8.7	42	0.27	-1	0.37	0.02	0.01
	AB25	20130312	6.2	-1	12.4	6.25	4.47	2.15	2.01	0.003	0.001	7.25	1.98	28.2	0.29	-1	0.26	0	0.01
	CB40	20130312	7.2	-1	15.6	11.5	6.39	1.94	2.4	0.003	0.001	26.2	1.21	2.27	8.88	-1	0.12	0	0.06
	PB42	20130313	6.5	-1	5.8	2.7	1.25	1.54	1.79	0.003	0.743	15.5	0.42	2.48	0.35	-1	0.17	0	0.01
	AB44	20130312	6.7	-1	9.27	7.45	3.13	1.04	0.786	0.003	0.001	29.2	1.96	2.86	0.26	-1	0.26	0	0.01
	AB45	20130312	6.4	-1	4.87	2.25	1.05	0.545	0.558	0.003	0.306	7.53	1.16	1.79	0.49	-1	0.26	0	0.01
	AB47	20130312	8.1	-1	17.6	6.97	3.85	17.3	1.58	0.003	0.001	56.2	11	2.67	0.26	0.003	0.39	0.02	0.01
	AB48	20130313	6.5	-1	25.8	13.1	7.71	18.6	3.14	0.973	0.498	81.9	14.7	17.4	0.27	0.003	0.49	0.07	0.01

Location	BH No.	Latest Sampling	pH	TDS mg/l	EC mS/m	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Fe mg/l	Mn mg/l	M Alk.	Cl mg/l	SO4 mg/l	NO3 as N	Al mg/l	F mg/l	B mg/l	PO4 mg/l
	AB49	20130313	7.4	-1	17.6	17.9	7.01	2.59	1.73	0.003	0.041	84.1	0.42	2.45	0.28	0.003	0.18	0	0.01
	AB50	20130313	6.6	-1	8.65	5.36	2.73	0.757	1.13	0.003	0.001	22.8	0.47	3.22	0.65	0.003	0.11	0.01	0.01
	AB51	20130313	7	-1	19.4	17.9	6.6	11.2	1.01	0.003	0.521	98	0.42	3.27	0.3	0.003	0.22	0	0.01
	AB52	20121024	7.7	-1	21	23.35	8.75	12.08	1.4	0.003	0.168	112.2	3.2	6.72	0.02	0.003	0.52	0	0.01
	AB53	20121024	7.3	-1	24.8	26.9	9.69	14.5	1.2	0.02	0.241	87.39	4.55	48.14	0.02	0.003	0.18	0	0.01
	CB54	20130312	8.2	-1	18.3	10.3	4.82	11.5	3.92	0.003	0.001	57.5	4.17	7.87	0.27	0.003	3.29	0	0.01
	CB55	20130312	6.7	-1	49.2	19.4	20.8	32.1	7.72	0.003	0.276	43.5	8.96	136	0.69	0.003	0.11	0	0.01
	AB56	20130313	9.5	-1	11.2	4.49	2.45	7.33	1.02	0.003	0.001	30.7	4.52	2.91	0.27	0.003	0.27	0	0.01
	AB57	20130313	7	-1	56	40.4	15.1	38.9	3.26	0.003	0.139	32.2	10.7	197	0.45	0.003	0.17	0.37	0.01
	PB58	20130313	7.6	-1	68	106	14.6	11.1	8.94	0.003	0.001	287	0.42	9.05	7	0.003	1.65	0.01	0.02
	PB59	20130313	6.7	-1	33.1	12	17	4.33	5.82	0.003	2.37	111	11.4	2.15	0.25	0.003	1.09	0	0.01
	WB18S	20130312	7.3	-1	3.93	1.45	1.21	0.539	0.639	0.003	0.115	8.41	0.47	1.38	0.25	-1	0.14	0	0.01
	SB24S	20130312	8.3	-1	52.9	37.3	27.7	33.4	0.854	0.003	0.001	257	10.7	2.57	0.26	-1	0.41	0.01	0.01

Note -1 indicates no available data

4.9.2 Expanded Durov Diagrams

Expanded Durov diagrams were used to present the groundwater quality types. Two sets of graphs were compiled, one set representing the hydrocensus groundwater chemistry and the second set representing the latest (2012/2013) groundwater chemistry.

Expanded Durov diagrams graphically represent the relative percentages of anions and cations in water samples. The cation percentages are plotted in the top part of the diagram and the anion percentages in the left part. A projection of these cation and anion percentages onto the central area presents the chemical signature of the major ion composition of the water. The chemical signature can be related to various hydro chemical environments and conditions.

4.9.2.1 Hydrocensus Groundwater Quality

The groundwater quality of the two boreholes surveyed during the hydrocensus was plotted on an expanded Durov diagram (Figure 9).

The expanded Durov diagram of the two hydrocensus samples (Figure 9) confirms two water types:

- Kendal 02 Is representative of magnesium bicarbonate type (Mg)$(HCO_3)_2$, these sample represent uncontaminated groundwater; and
- Kendal 01 is representative of magnesium chloride type (Mg) Cl, the plot position on the diagram indicates water with magnesium and chloride related contamination.

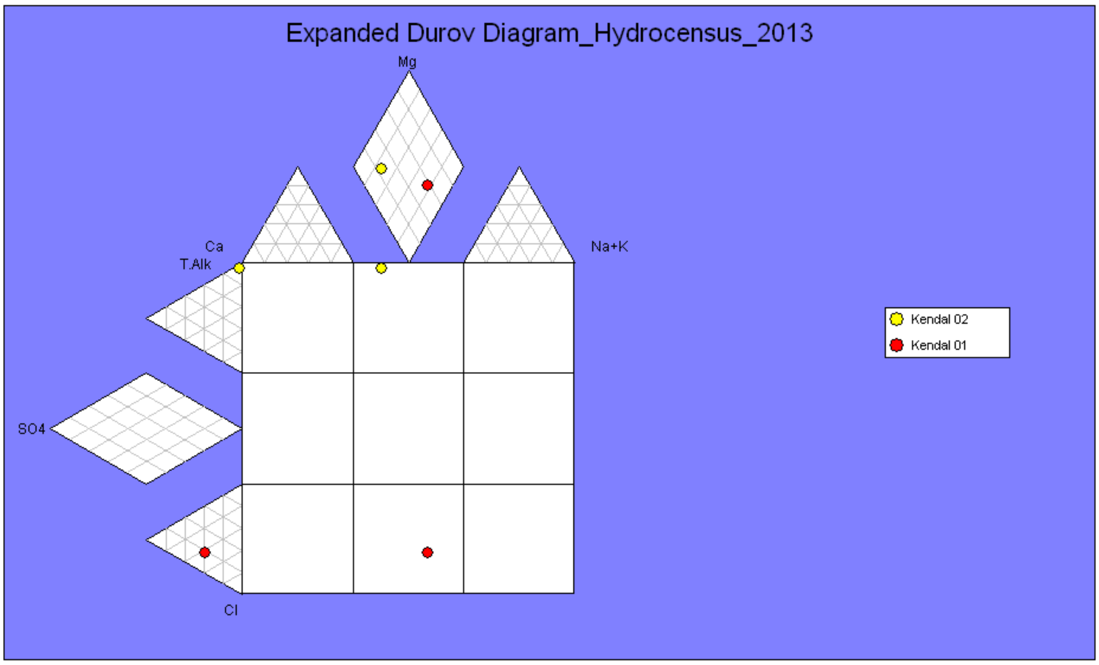

Figure 9: Expanded Durov Diagram of Hydrocensus Results

4.9.2.2 GHT 2012/2013 Analytical Results

The groundwater quality of 35 monitoring boreholes monitored by GHT was plotted on an expanded Durov diagram (Figure 10). These analytical results are representative of the latest analytical results (2012/2013) and were sampled during October 2012 and March 2013.

The expanded Durov diagram confirms four types of groundwater namely:

- Calcium, magnesium bicarbonate type (blue sector), (Ca, Mg)$(HCO_3)_2$;

- Sodium potassium bicarbonate type (green sector), (Na, K)$(HCO_3)_2$;
- Calcium sulphate type (red sector), (Ca)SO_4; and
- Magnesium sulphate type (yellow sector), (Mg)SO_4.

Discussion

- The majority of the monitoring boreholes are representative of calcium, magnesium bicarbonate type of water (Ca, Mg) $(HCO_3)_2$. These groundwater samples represent uncontaminated water;
- PB06, AB47 and PB23 and are representative of sodium potassium bicarbonate type of water (Na, K) $(HCO_3)_2$. The plot position on the diagram indicates minor sodium and potassium enrichment;
- CB01 and AB08 is representative of calcium sulphate (Ca)SO_4 type of water. The plot position on the diagram indicates water with calcium and sulphate related enrichment; and
- AB25, AB57 and CB55 are representative of magnesium sulphate (Mg)SO_4 type of water. The plot position on the diagram indicates water with magnesium and sulphate related enrichment;

Eight of the 35 (23%) 2012/2013 samples indicate probable contamination from site activity, related in terms of elevated sulphate, calcium, magnesium, potassium and sodium concentrations. The expanded Durov diagram also confirms that currently the ash disposal facilities have very limited impact on the surrounding groundwater quality.

The background groundwater quality is representative of calcium, magnesium bicarbonate type of water (Ca, Mg) $(HCO_3)_2$.

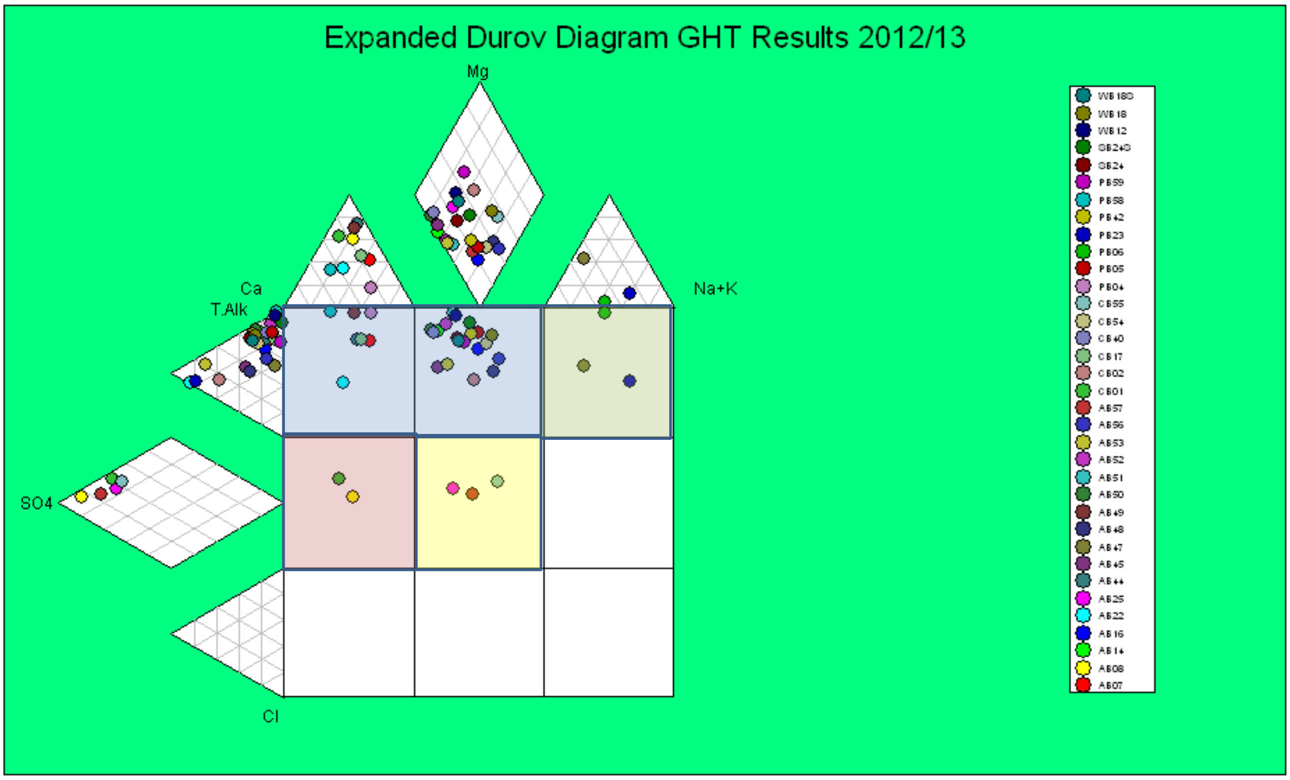

Figure 10: Expanded Durov Diagram – GHT Results2012_ 2013 Results

4.9.3 Groundwater Contamination Status

The groundwater chemistry of the 1012/2013 results of monitoring boreholes with constituents exceeding the SANS 241 (2011) drinking water compliance lowest limits are indicated on Figure 18. The chemical constituents exceeding the SANS 241 (2011) drinking water compliance lowest limits are Mn, F, Fe and sulphate and were plotted on the geology background.

The pH (Figure 19) and EC (Figure 20) values of the 2012/2013 analytical results of the monitoring boreholes were contoured to determine if the ADF have an impact on the surrounding groundwater quality. Increased pH values of around 9 is notable in the area near monitoring boreholes PB32, AB56 and PB 06 which are downstream of the conveyor belt system between the ash dump and the Power station. An increased in EC of maximum 90 mS/m is noticeable at monitoring position AB 08 which is still below SANS 241 (2011) Drinking Water Standard Lowest Compliance Limit.

From the analytical results the positions of monitoring boreholes constituents exceeding the SANS 241 (2011) drinking water compliance lowest limits, it can be concluded that the ADF currently has limited impact on the surrounding groundwater quality.

4.10 Background Groundwater Quality (2014)

The existing groundwater monitoring network consists of 45 monitoring boreholes (Figure 11). Twenty-seven of these boreholes are for the deep aquifer, five are shallow and there is no indication of the depth of the remaining boreholes.

The groundwater flows mimic the topography and is toward the surface streams. Figure 11 shows typical groundwater flow directions at KPS.

As part of the baseline assessment, the background water quality at the ADF is discussed below:

- Establish the background groundwater quality for Kendal power station (as a proxy for comparison between a pre-Eskom baseline and post-Eskom impacted groundwater); and
- Differentiate the impacts of the power station from those of the ADF.

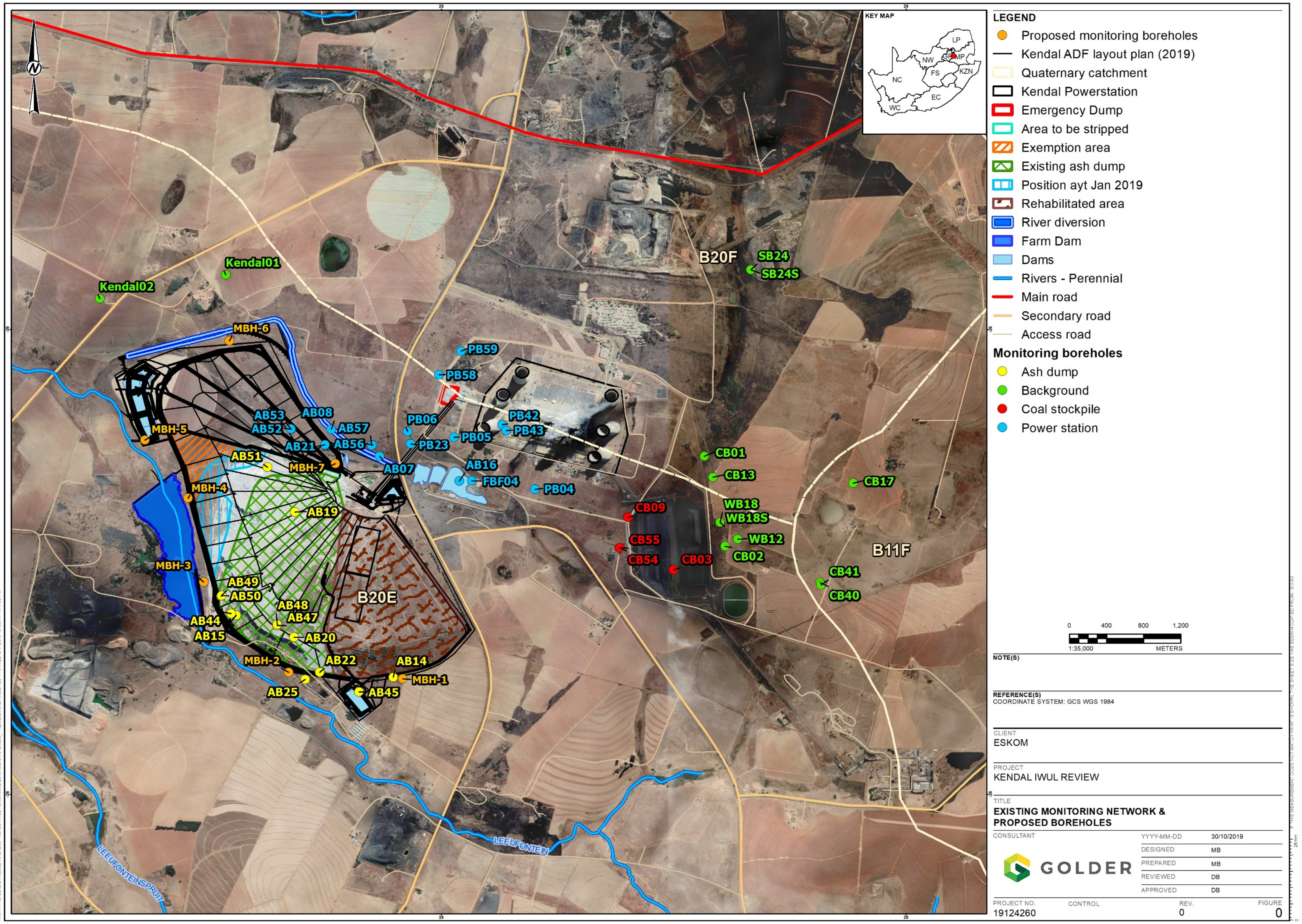

Figure 11: Existing Monitoring Network and Proposed new Monitoring Boreholes (2014)

4.10.1 Determination of background groundwater quality

The background groundwater quality was derived by calculating the mean and standard deviation for the concentrations of each parameter, using monitoring data from 1987 to 2013 for six boreholes which were determined as being located upstream of KPS facilities (CD02, CD17, CD40, WB12, WB18 and WB18S, see Figure 18 and a borehole identified during the hydrocensus (Kendal 02) that was found in the baseline study to represent unpolluted groundwater (Golder, 2013).

4.10.2 Results

The shallow and deep aquifer groundwater quality was compared against the baseline as determined in section 4.10. The gaps on the graphs signify absence of monitoring data. It appears from the piezometric contouring (Figure 18) that the groundwater flows divide in the area. Thus, groundwater and impacts from the ADF does not reach the power station and vice versa. The same applies for the power station and the colliery to the north east of the colliery. Thus, the boreholes with letters PB and AB, which occur across the river to the north and northeast of the ADF are considered to be monitoring impacts from the power station while all the other boreholes with letter AB are monitoring the impacts on groundwater around the ADF.

Generally, the pH of most boreholes around the ADF was within background over the past five years. Exceptions were boreholes AB25, AB22, AB47 and AB49, which were occasionally higher than the background levels (Figure 12).

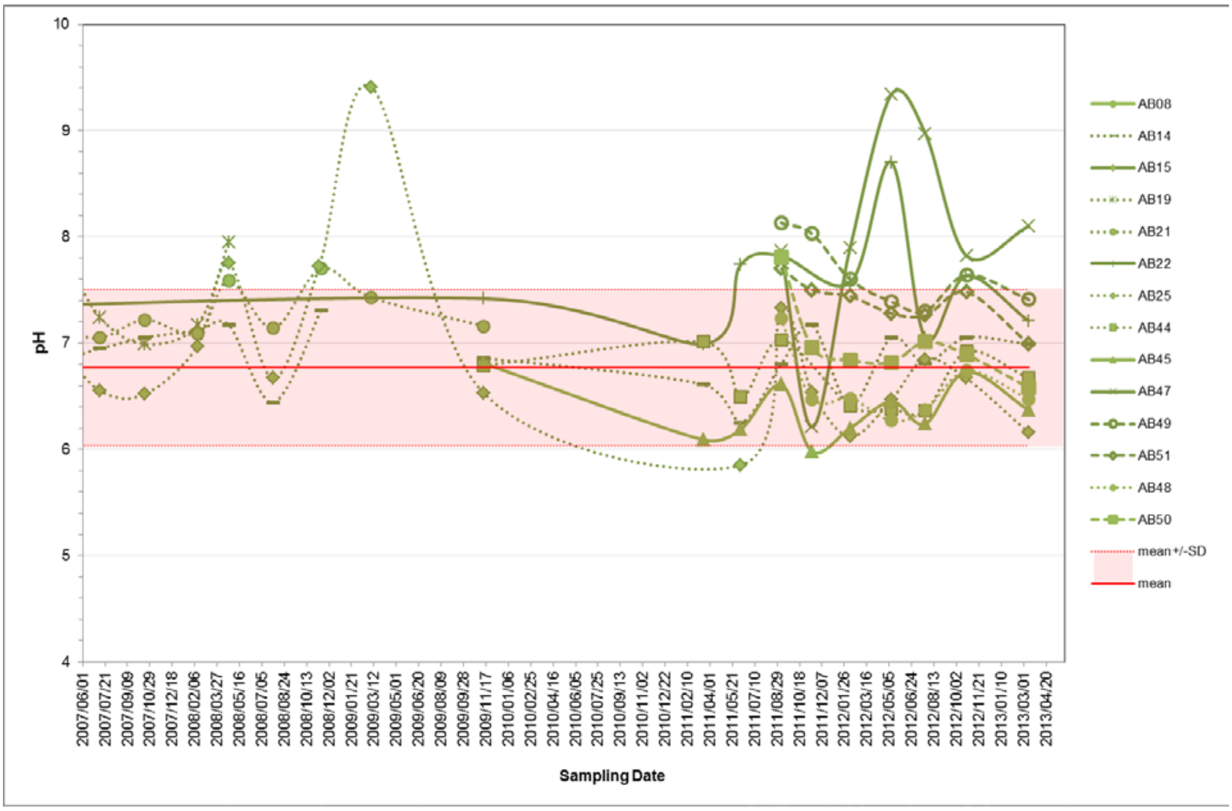

Figure 12: Variation of pH with time and against background values around the ADF

Five of the eleven monitoring boreholes around the power station (deep aquifer: AB56, PB23, PB06, PB04 and PB 58) were characterised by pH values that were above the background levels and have been increasing since 2011 (Figure 13).

The pH of shallow borehole (CB55) around the coal stockpile was consistently within background levels while the pH of the deep borehole (CB54) was consistently higher than the background levels since 2011.

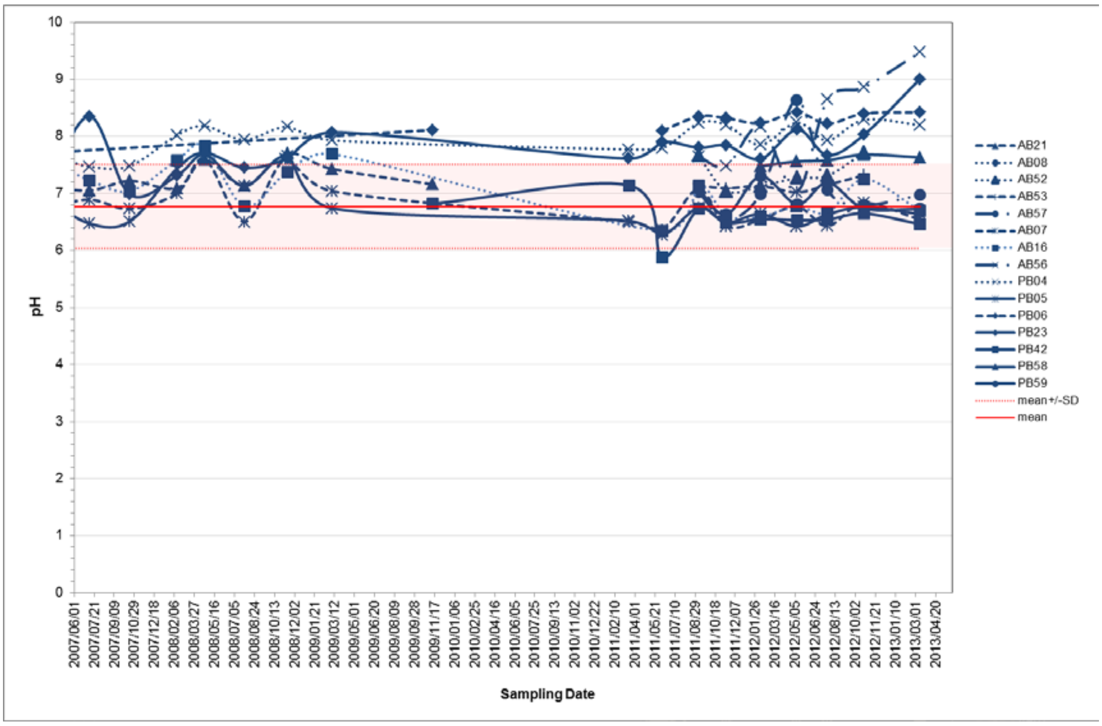

Figure 13: Variation of pH with time and against background values around the power station

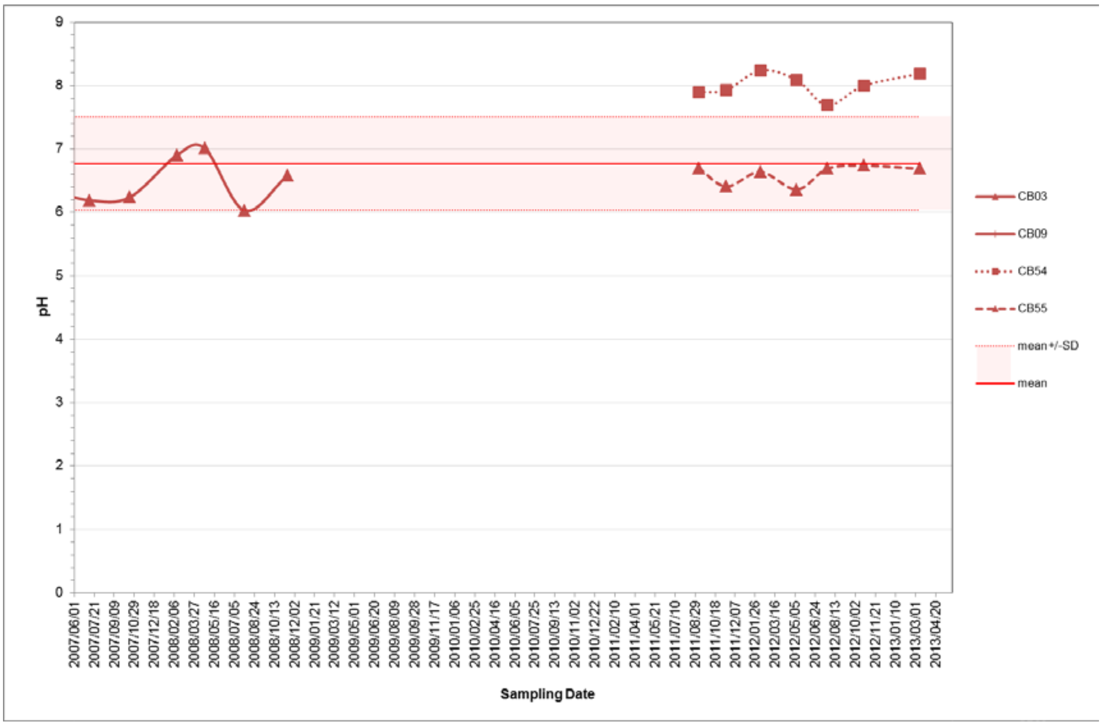

Figure 14: Variation of pH with time and against background values around the coal stockpile

The sulphate concentrations in most boreholes around the ADF were within the background concentrations over the past five-year monitoring period. Exceptions were two shallow aquifer boreholes (AB48 and AB53), one deep borehole (AB22) and unspecified borehole (AB25), in which sulphates were consistently above the background levels (Figure 15).

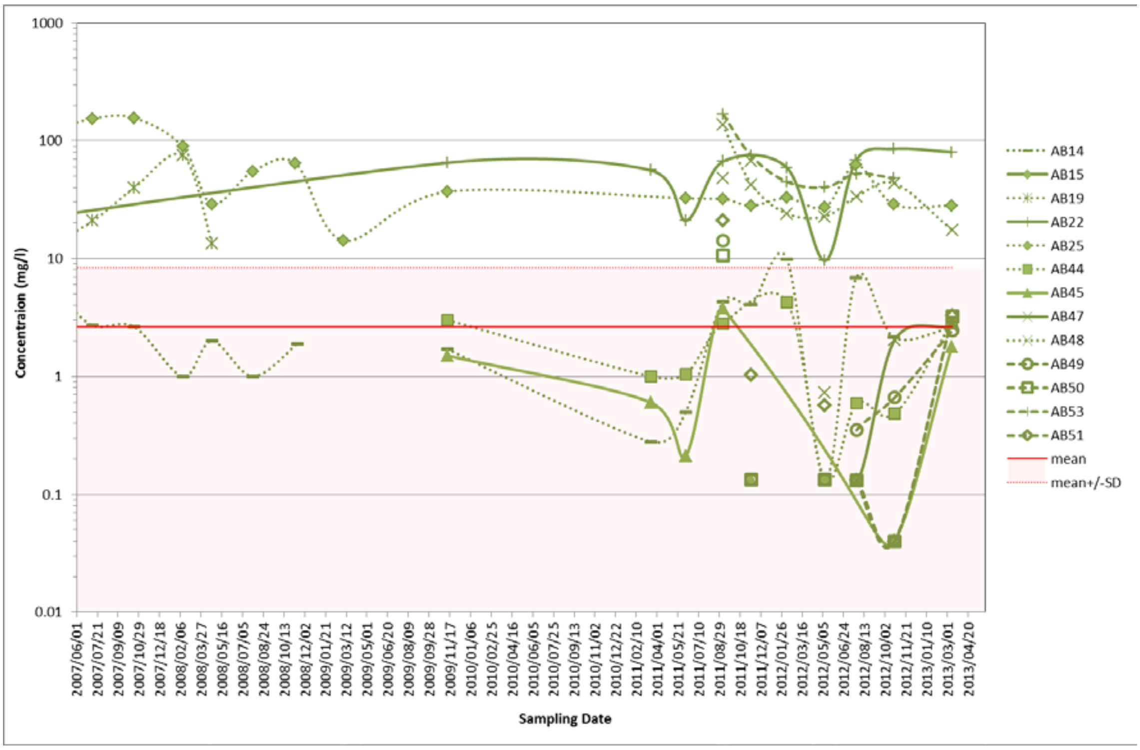

Figure 15: Variation of sulphates with time and against background values around the ADF

The concentration of sulphate in most of the boreholes around the power station was within the background levels (Figure 15). Exceptions were five deep aquifer boreholes (AB56, AB52, AB58, PB23 and AB21) and one shallow aquifer borehole (AB57). Monitoring was not consistent around the coal stockpile over the past five years. The available data indicate exceedances of the background sulphate concentrations in deep aquifer borehole CB03 from 2011 onwards (Figure 17).

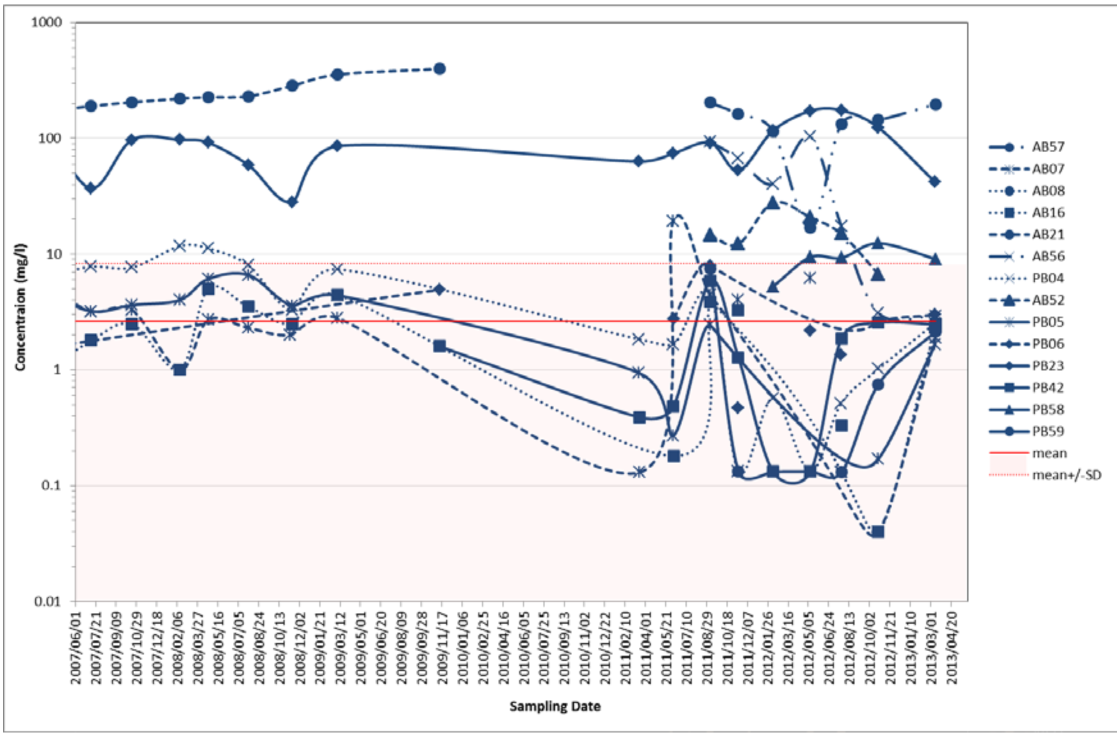

Figure 16: Variation of Sulphates with time and against background values around the power station

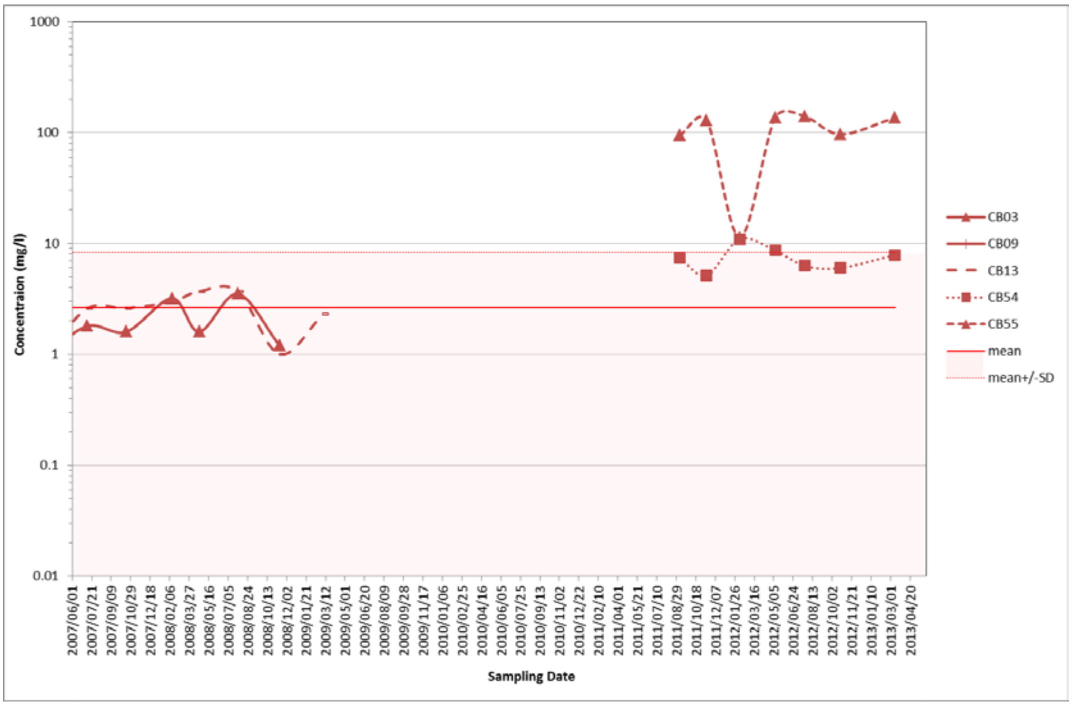

Figure 17: Variation of Sulphates with time and against background values around the ADF

Seven of the monitoring boreholes around the power station (boreholes PB04, PB58, PB59, PB06, PB21, AB52 and AB53) exceeded the background alkalinity concentration over the last five years. Only three of the monitoring boreholes around the ADF (AB49, AB44 and AB22) had alkalinity concentrations above the background levels and all boreholes around the coal stockpile were all within the background concentrations.

Fluoride concentrations exceeded the background in seven of the monitoring boreholes around the power station (PB06, PB04, PB23, PB58, PB59, AB16 and AB 52), one borehole (AB48) around the ADF and none of the boreholes around the coal stockpile.

Manganese concentrations were occasionally exceeded in four of the monitoring boreholes around the power station (PB59, AB53, AB52 and PB42) and rarely in some the boreholes around the ADF (AB48, AB51 and AB47) and coal stockpile (CB55).

Trace metals were generally not monitored (e.g. As, Hg and Cd) or monitored inconsistently (e.g. Ni, Cu and Zn). Generally, the data available indicates concentrations of trace metals that are within the background levels around all the facilities. Marginal exceedances of Ni, Cu and Pb were noted in boreholes CB03 and CB09 from the coal stockpile area and also noted around the power station from boreholes PB04, PB05 and AB08. Exceedances of Ni, Cu and Pb concentrations were occasionally noted in boreholes AB14 and AB15 around the ADF. The results are summarised in Table 8.

Table 8: Summary of Groundwater Qualities at Kendal Power Station

Source	Groundwater Chemistry Signature
Background	Near neutral pH, low concentration of alkalinity, sulphate, fluoride and trace metals.
Power station	Generally, exceeds background levels of pH, sulphate, alkalinity, fluoride, Mn, Ni, Cu, Pb and Zn in up to half of the boreholes.

Source	Groundwater Chemistry Signature
Ash disposal facility	Generally, exceeds background levels of alkalinity, and exceeds sulphate in 4 of 14 boreholes. Occasionally exceeds background levels of pH and fluoride and rarely Mn, Ni, Cu, Pb and Zn in 2 boreholes.
Coal stockpile	Occasionally exceeds background levels of pH, sulphate, and Cu, Ni, Pb and Zn in 2 boreholes. Rarely exceeds fluoride and manganese background levels.

4.10.3 Background Groundwater Quality Conclusions

Generally, the boreholes around the ADF differ from background concentrations in alkalinity and sulphate generally exceeding background alkalinity levels and exceeding background sulphate levels in over a third of the boreholes, as well as occasional exceedances of the background concentration of fluoride, Mn, Ni, Cu, Pb and Zn in a minority of the boreholes. For those parameters where (occasional) exceedances of the background concentrations are recorded, the levels in the boreholes around the ADF are within DWAF domestic water use guideline levels, except for fluoride at AB48 and rare exceedances of pH, Mn, Cu and Pb.

From the available data and assessment thereof, it is concluded that the current ADF (that has been in operation for more than 25 years) has currently an insignificant impact on the local groundwater quality if compared to the background levels and DWAF Water quality guidelines for Domestic use.

Other potential constituents of concern from ash disposal facilities (such as Hg, Cd and As) were not previously monitored, but are included in the Kimopax 2019 analyse.

4.11 Groundwater recharge

From the published hydrogeological maps (DWAF 1996) the average recharge for the study area is shown as between 50mm to 75mm per annum as indicated on Figure 21.

4.12 Groundwater Vulnerability

Groundwater vulnerability gives an indication of how susceptible an aquifer is to contamination. Aquifer vulnerability is used to represent the intrinsic characteristics that determine the sensitivity of various parts of an aquifer to being adversely affected by an imposed contaminant load.

A national scale groundwater vulnerability map of South Africa was prepared by the WRC (Water Research Commission), using the DRASTIC methodology that includes the following components:

- **D**epth to groundwater;
- **R**echarge due to rainfall;
- **A**quifer media;
- **S**oil media;
- **T**opography;
- **I**mpact of the vadose zone; and
- Hydraulic **C**onductivity.

Groundwater vulnerability was classified into six classes ranging from very low to very high.

Groundwater vulnerability at the Kendal continuous and emergency ash site is shown on the national groundwater vulnerability map as low to medium (Figure 22). The probability that disposal of ash on existing and continuous and emergency site will have an impact on the groundwater is limited but needs to be monitored.

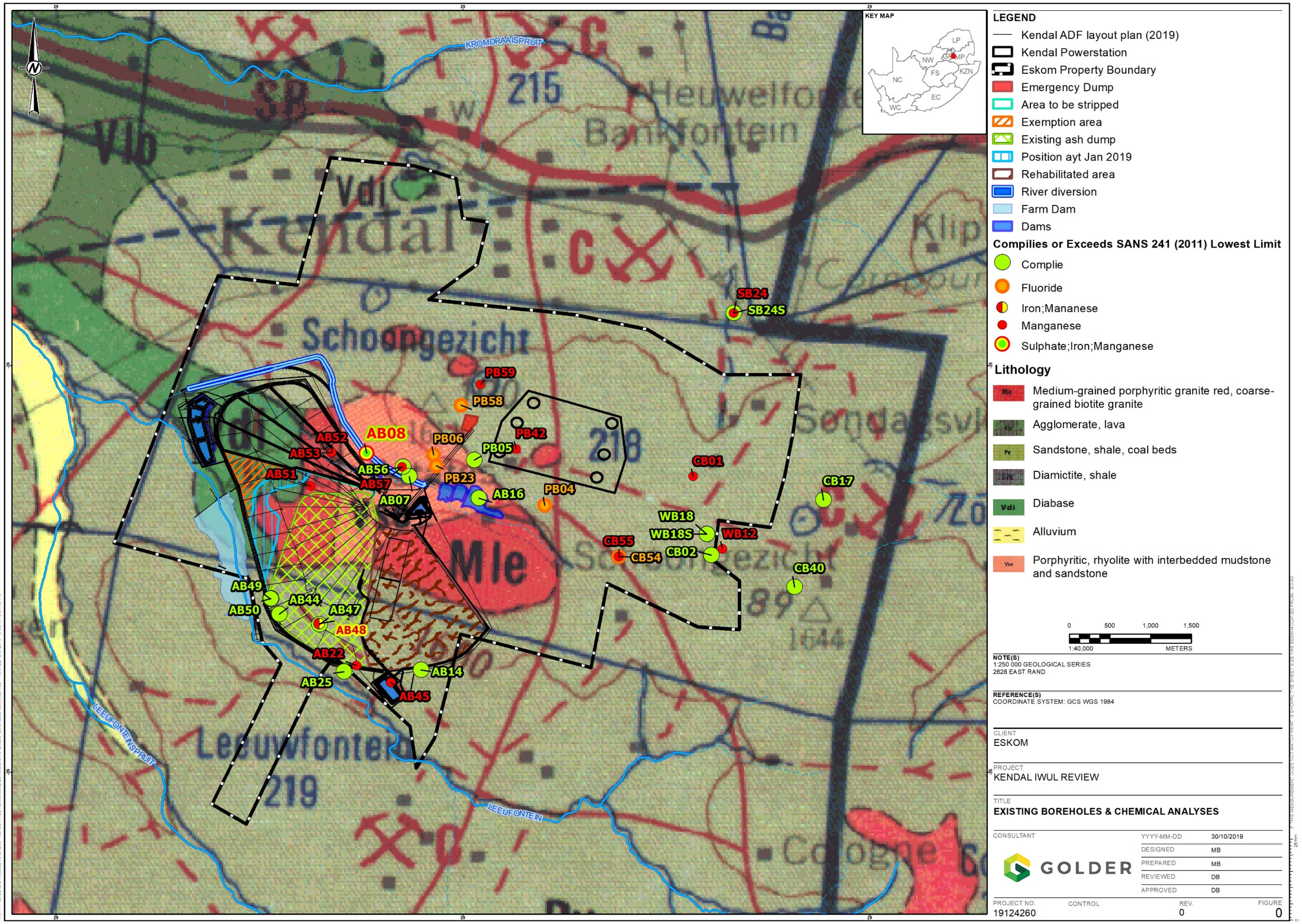

Figure 18: Groundwater Inorganic Chemical Determinants Compared to SANS 241:2011(2014)

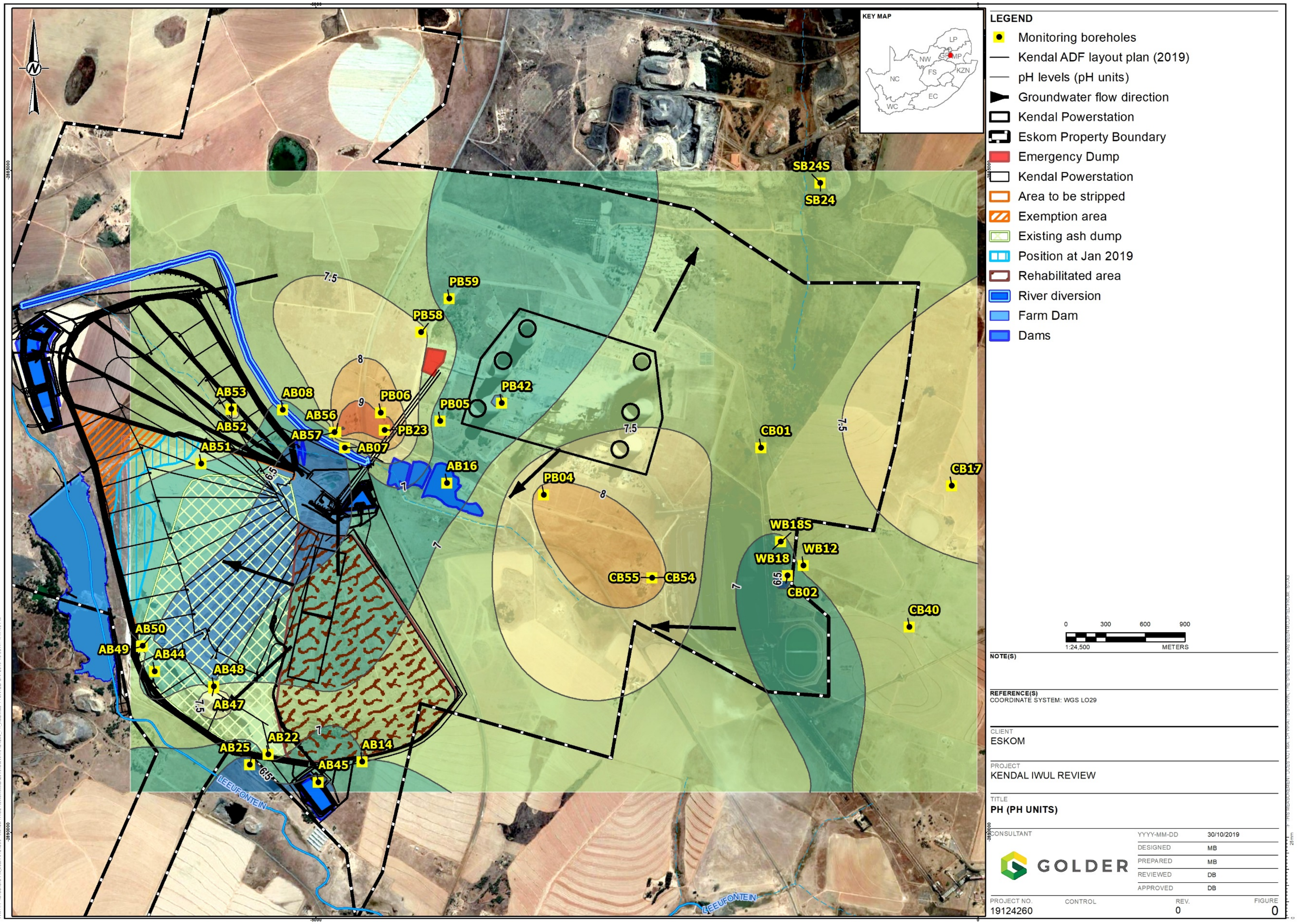

Figure 19: Contour map pH as of 2012 chemical results (2014)

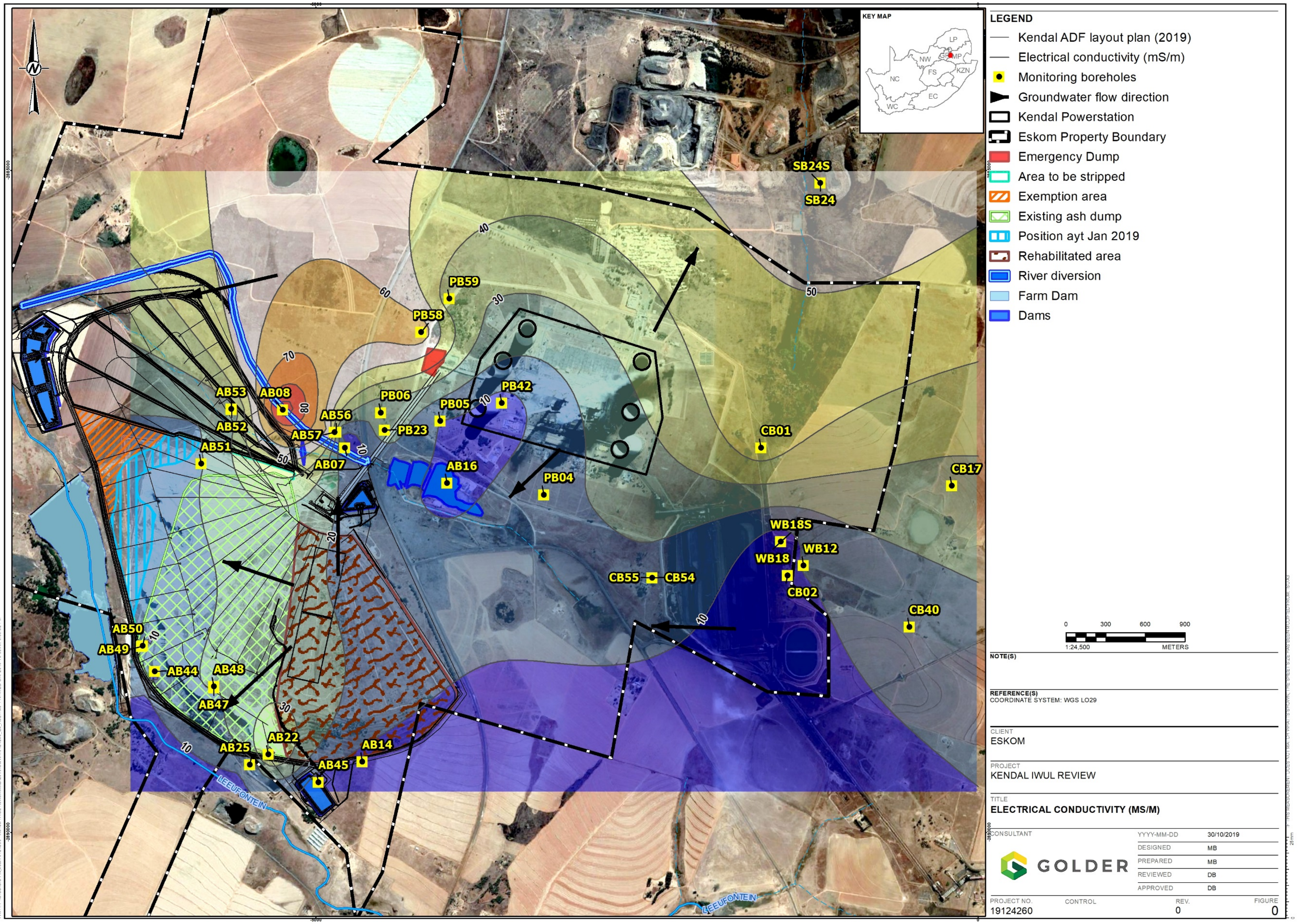

Figure 20: Contour map of electrical conductivity as of 2012 chemical results (2014)

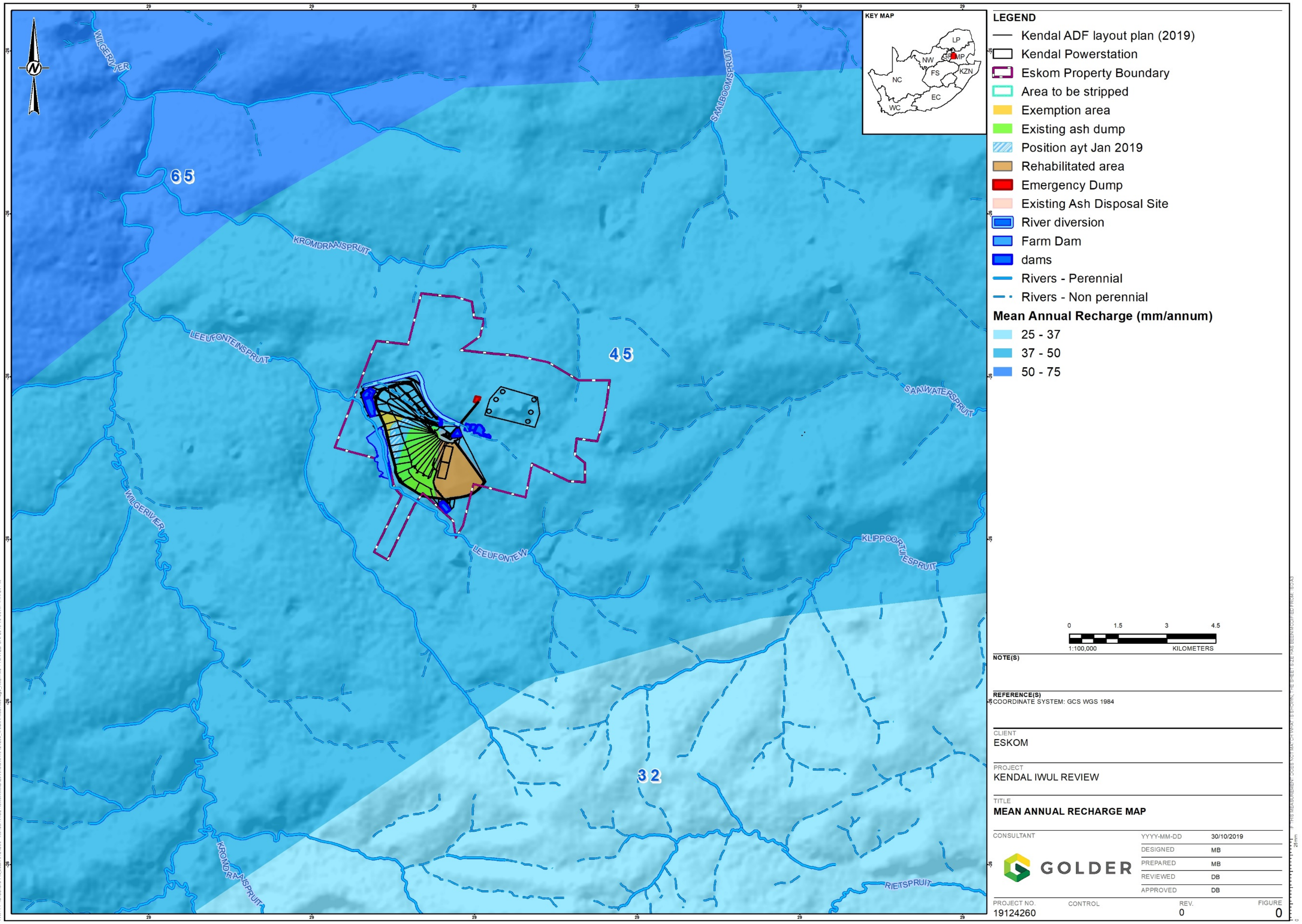

Figure 21: Mean Annual Groundwater Recharge

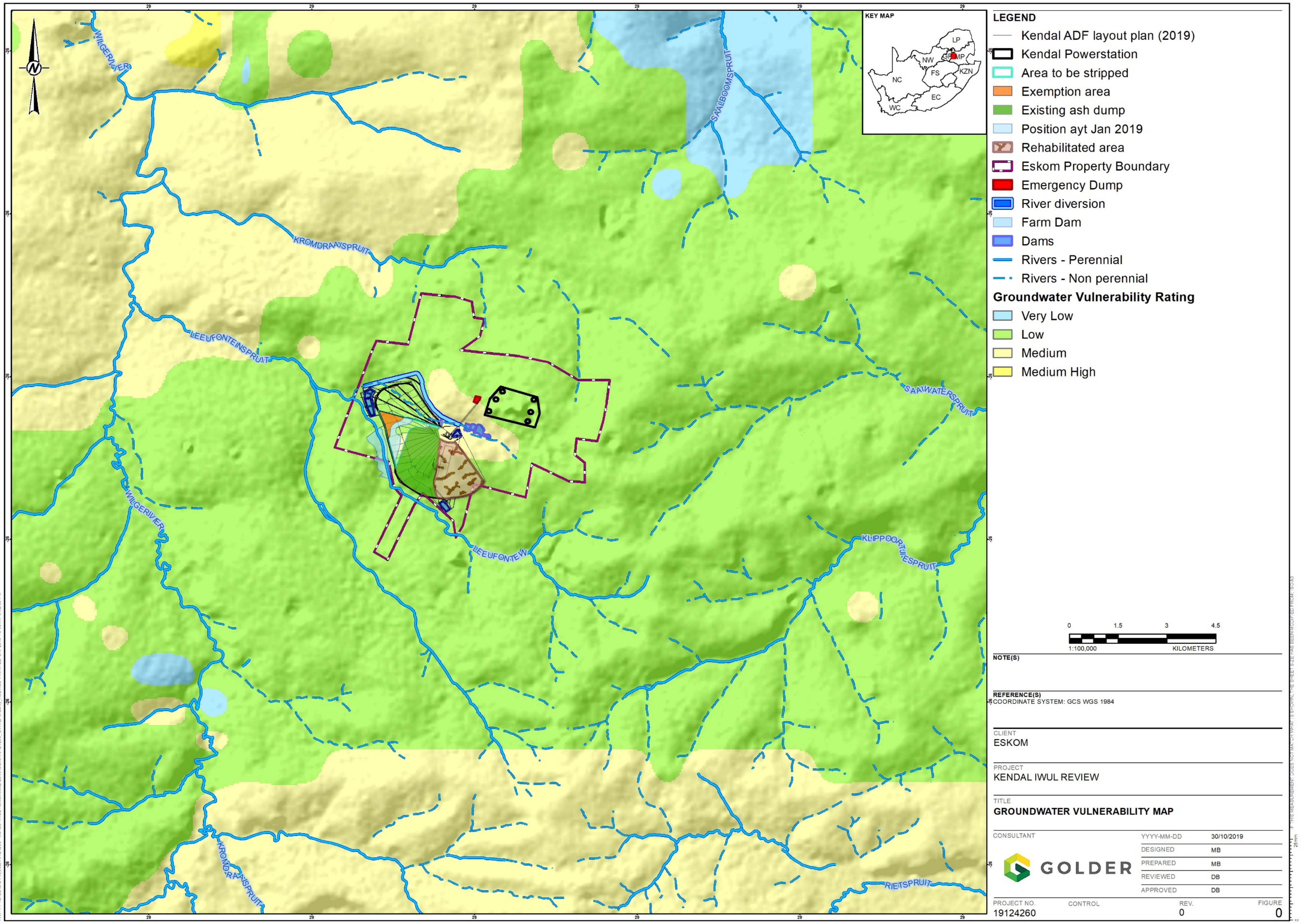

Figure 22: Groundwater Vulnerability Map

5.0 GROUNDWATER QUALITY - 2019

5.1 Groundwater Sampling

Kimopax's Surface and Groundwater Monitoring Report Phase 87 (July 2019) was used to discuss the existing groundwater quality.

A total of 43 monitoring boreholes were surveyed during the Phase 87 (July 2019) monitoring programme by Kimopax, as listed in Table 9 and 33 groundwater samples were collected (Figure 25). Water samples were submitted to a SANAS accredited laboratory aQualande Laboratories for water quality analysis.

Table 9: Kendal Power Station groundwater water monitoring sites (Kimopax 2019)

Monitoring point	Longitude	Latitude	ELEV	Site Description
CB01	28,98809	-26,10108	1617,55	Borehole north of the coal stockyard.
CB13	28,98912	-26,10269	1615,77	Borehole north-east of the coal
CB02	28,98999	-26,10983	1631,61	Borehole southeast of coal stockyard
PB04	28,97166	-26,10437	1600,98	Borehole south of the power station
PB05	28,96415	-26,09874	1600,06	Borehole at dirty water dams PP03 &
PB42	28,96883	-26,09751	1611,63	Borehole north of PP07.
PB58	28,96268	-26,09270	1606,02	Borehole west of emergency ash
PB59	28,96483	-26,09039	1606,27	Borehole north of emergency ash
AB47	28,94702	-26,11696	1545,48	Deep borehole south of ash stack
AB48	28,94700	-26,11692	1545,46	Shallow borehole south of ash stack.
AB62	28,93947	-26,10059	1542,04	Deep borehole north west of ash stack
AB63	28,93950	-26,10061	1545,99	Shallow borehole north west of ash
CB54	28,98008	-26,10944	1612,67	Deep borehole west of coal stock
CB55	28,98009	-26,10949	1610,00	Shallow borehole west of coal stock
AB44	28,94263	-26,11572	1540,09	Borehole in south-western corner of
AB64	28,93636	-26,09795	1534,73	Deep borehole north west of ash

Monitoring point	Longitude	Latitude	ELEV	Site Description
AB65	28,93633	-26,09792	1532,05	Shallow borehole located north west
AB66	28,94632	-26,09427	1549,89	Deep borehole north of ash stack,
AB67	28,94630	-26,09425	1549,42	Shallow borehole north west of ash
PB06	28,95936	-26,09877	1582,51	Borehole west of clean water dam
PB23	28,95987	-26,09943	1579,40	Borehole west of clean water dam
WB12	28,99136	-26,10861	1635,87	Borehole east of domestic waste site
WB18	28,98979	-26,10702	1623,64	Borehole north-east of domestic waste
AB07	28,95666	-26,10117	1588,03	Borehole north of ash stack and west
AB08	28,95199	-26,09856	1563,17	Borehole at north-western corner of
AB16	28,96461	-26,10299	1600,53	Borehole south of dirty water dam at
AB22	28,95129	-26,12172	1547,34	Borehole south of return water dam.
CB40	28,99949	-26,11281	1644,74	Borehole 1 km south east from coal
SB24	28,99281	-26,08254	1572,86	Borehole east of sewage plant.
AB14	28,95828	-26,12202	1569,60	Borehole south of rehabilitated ash
AB25	28,94791	-26,11822	1544,82	Borehole south of stream near mining
AB45	28,95492	-26,12342	1552,39	Borehole South of ash s tack next to
AB49	28,94162	-26,11412	1539,53	Deep borehole west of ash stack.

Monitoring point	Longitude	Latitude	ELEV	Site Description
AB50	28,94163	-26,11409	1539,06	Shallow borehole west of ash stack.
AB56	28,95616	-26,09948	1579,86	Deep borehole below settling dam
AB57	28,95612	-26,09951	1579,74	Shallow borehole below settling dam
AB52	28,94334	-26,09269	1537,27	Deep borehole southeast of PP05.
AB53	28,94331	-26,09265	1539,53	Shallow borehole southeast of PP05.
AB60	28,93634	-26,10117	1539,06	Deep borehole west of ash stack,
AB61	28,93633	-26,10121	1579,86	Shallow borehole west of ash stack,
CB17	28,99770	-26,09790	1545,23	Borehole upstream from coal
AB68	28,94092	-26,09018	1537,27	Deep Borehole northwest of the Ash
AB69	28,94090	-26,09011	1539,53	Shallow Borehole northwest of the

5.2 Water Quality Standards and Analytical Results

5.2.1 Groundwater WUL Quality Parameter Limits

The groundwater quality parameters for Kendal Power Station as per WUL (licence no.04/B20E/BCEG/1048) are listed in Table 10.

Table 10: Groundwater WUL parameter Limits (WUL licence no.04/B20E/BCEG/1048)

Variables	Limits
pH	6.5-8.4
Electrical Conductivity	40 mS/m
Sodium	20 mg/l
Magnesium	20 mg/l
Calcium	25 mg/l
Chloride	20 mg/l
Sulphate	30 mg/l
Nitrate	6 mg/l
Phosphate	0.05 mg/l
Iron	1 mg/l
Manganese	0.18 mg/l
Aluminium	0.02 mg/l
E coil	130 mg/l

5.2.2 Analytical Results

The 33 boreholes sampled during Phase 87; analytical results were compared to the:

- SANS 241-1 (2015) water compliance standard, which specifies aesthetic, operational, chronic and acute health limits (Table 11). Values exceeding specified limits are highlighted accordingly; and
- Kendal Power Station WUL (licence no.04/B20E/BCEG/1048) limits (Table 12). Values highlighted in red exceeds the maximum allowable WUL limit.

The major cations, anions and constituents of concern which exceeds the SANS 241-1 (2015) water compliance standard are listed in Table 11. Values exceeding specified limits are highlighted accordingly.

Most of the constituents of the groundwater samples are below SANS 241-1 (2015) water compliance standard limits. The following constituents however exceed the relevant standards:

- Manganese (Mn;
- Sodium (Na);
- Sulphate (SO_4);

- Ammonia as N;
- Iron (Fe); and
- Turbidity.

The elevated manganese concentrations reported are present in monitoring boreholes covering the Kendal Power Station site and are probably related to the geology. It is therefore highly unlikely that the ash disposal facilities have an impact on the manganese concentrations of these monitoring boreholes.

The elevated concentration of sodium (AB 57) is probably related to the surrounding geology in the area comprising out of granite and diabase.

The elevated sulphate levels detected at AB08, AB69, AB57 and PB23 is probably related to pollution from fertilizer used for irrigation purposes by surrounding landowners as these boreholes are located upgradient (east) of the ADF and groundwater flow is towards the west.

Ammonia may be present in groundwater as a result of the degradation of natural occurring organic matter or manmade sources. The elevated ammonia measured as N (AB22, PB59 and CB01) are probably related to a combination of natural and mining activities (P59 is located at KPS, whereas AB22 and CB01 are located to the south and east of the ADF respectively).

The high iron concentrations are probably related to the geology. reported need to be monitored in future to determine if there is a trend noticeable.

The turbidity present in the sampled boreholes are probably related to borehole construction.

Only monitoring borehole CB02 was found to be within the WUL limits, whereas the remaining 32 samples exceed one or more of the parameters as listed in Table 10. These boreholes are probably impacted by mining activities as the ash stack, coal stockyard, settling dam, dirty water dams, ash water return dam and other mining activities (Kimopax 2019).

The 2019 analytical results confirm that presently the existing, continuous and emergency ash disposal facilities have very limited impact on the surrounding groundwater quality. These results correlate with the 2014 groundwater study findings.

Table 11: Groundwater Phase 87 2019 Analytical Results - compared to SANS:241-2015

Sample Date	Borehole ID	EC 25° C in mS/m	pH at 25° C	Turbidity as NTU	Total Dissolved Solids	Nitrate NO_3 as N	Nitrite as N	Free chlorine as Cl2	Chlorides as Cl	Total Alkalinity as $CaCO_3$	Sulphate as SO_4	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Iron as Fe	Manganese as Mn	Aluminium as Al	Free and Saline Ammonia as N	Zinc as Zn	Copper as Cu	Lead as Pb	Fluoride as F
		mS/m	Units	NTU	Mg/l																		
	Aesthetic	170	No limit	5	1200	No limit	No limit	No limit	300	No limit	250	No limit	No limit	200	No limit	0.3	0.1	No limit	1.5	5	No limit	No limit	No limit
	Operational	No limit	5 to 9.7	1	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	0.3	No limit	No limit	No limit	No limit	No limit
	Chronic health	No limit	No limit	No limit	No limit	No limit	No limit	5	No limit	No limit	No limit	No limit	No limit	No limit	No limit	2	0.4	No limit	No limit	No limit	2	0.01	1.5
	Acute health	No limit	No limit	No limit	No limit	11	0.9	No limit	No limit	No limit	500	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit
20-05-2019	SB24	50.8	7.48	190	287	1.37	0.03	0.12	6.21	246.3	26.4	44.16	27.13	35.85	1.55	13.7907	0.43374	0.01229	**BDL**	0.01401	**BDL**	**BDL**	0.0004
20-05-2019	PB58	53	7.27	23.4	286	2.18	0.04	0.03	**BDL**	274.2	**BDL**	100.18	11.66	13.93	4.55	1.62846	0.90412	0.1242	**BDL**	0.03244	**BDL**	**BDL**	0.0015
20-05-2019	CB23	6.29	7.37	44.6	**BDL**	2.05	0.03	0.02	**BDL**	24.7	**BDL**	2.99	2.31	4.89	0.27	1.80874	0.85574	0.02421	**BDL**	0.02464	**BDL**	**BDL**	**BDL**
20-05-2019	WB18	5.59	6.91	55.3	**BDL**	0.81	0.03	**BDL**	**BDL**	25.8	**BDL**	2.66	1.87	4.19	**BDL**	3.05729	0.85574	0.00856	**BDL**	0.01361	**BDL**	**BDL**	**BDL**
20-05-2019	CB40	17.49	6.96	2	192	10.7	0.05	0.02	4.43	29.8	**BDL**	13.87	7.49	4.28	3.42	0.11339	0.04528	0.01335	**BDL**	0.02918	**BDL**	**BDL**	**BDL**
21-05-2019	AB45	7.3	6.78	140	**BDL**	3.44	0.09	0.23	2.6	31.8	1.7	4.16	2.7	**BDL**	0.9	1.30617	0.57317	0.00982	0.55	0.01317	0.00218	**BDL**	**BDL**
21-05-2019	AB14	6.33	6.87	271	**BDL**	3.44	0.03	0.23	2.1	31	1.6	70.48	24.11	128.29	3.39	0.60338	0.57317	**BDL**	**BDL**	0.00087	**BDL**	0.00389	**BDL**
21-05-2019	AB07	8.48	6.44	276	46	3.77	0.06	0.07	1.8	40.9	1.7	3.87	1.74	1.87	1.29	11.6044	0.57317	0.01581	**BDL**	0.00883	**BDL**	0.00113	**BDL**
21-05-2019	AB08	102.9	7.68	47.2	687	3.44	0.04	**BDL**	21.2	18.1	590.8	1.82	2.18	**BDL**	0.77	1.24837	0.57317	**BDL**	**BDL**	0.00398	**BDL**	**BDL**	**BDL**
21-05-2019	AB68	37.5	7.42	29.7	192	4.03	0.13	0.06	20.5	77	77.3	23.08	14.13	35.86	**BDL**	1.19166	0.57317	0.02771	**BDL**	0.03237	0.00302	0.00536	**BDL**
21-05-2019	AB69	91.2	6.92	392	594	3.63	0.04	0.45	19.5	74.3	364.9	72.27	45.55	80.54	**BDL**	8.02489	0.57317	**BDL**	**BDL**	0.00588	**BDL**	0.00504	**BDL**
21-05-2019	AB66	26.1	8.41	8.75	89	3.15	0.03	0.02	11.7	117.5	1.6	4.96	5.8	43.27	0.62	0.22323	0.00534	0.0075	0.52	0.00401	0.00242	**BDL**	0.0005
21-05-2019	AB67	43.5	8.05	112	258	2.96	0.03	0.48	19.2	138.8	54.8	34.97	15.81	41.66	0.54	2.29592	0.15913	0.07692	**BDL**	0.01602	0.00287	**BDL**	0.0003
21-05-2019	AB65	15.13	7.35	229	123	3.08	0.03	0.17	3.1	72.3	1.9	15.95	8.38	**BDL**	0.74	0.70203	1.40558	**BDL**	**BDL**	0.00902	0.0029	**BDL**	**BDL**

Sample Date	Borehole ID	EC 25° C in mS/m	pH at 25° C	Turbidity as NTU	Total Dissolved Solids	Nitrate NO_3 as N	Nitrite as N	Free chlorine as Cl2	Chlorides as Cl	Total Alkalinity as $CaCO_3$	Sulphate as SO_4	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Iron as Fe	Manganese as Mn	Aluminium as Al	Free and Saline Ammonia as N	Zinc as Zn	Copper as Cu	Lead as Pb	Fluoride as F
21-05-2019	AB64	25.1	7.46	37.9	111	3.02	0.04	0.05	4.2	102.4	6.6	22.44	15.8	2.66	1.44	3.52272	0.98617	**BDL**	**BDL**	0.01024	**BDL**	0.00265	**BDL**
22-05-2019	AB44	14.74	5.89	12.8	59	3.01	0.02	0.03	8.6	14.5	35.8	7.85	5.12	4.71	1.61	0.6267	0.09764	0.0072	**BDL**	0.00724	0.00248	0.00275	**BDL**
22-05-2019	AB48	61.8	6.52	243	322	2.96	0.02	0.26	23.8	147.7	123.5	34.25	21.54	58.11	6.22	30.1407	2.43975	0.00821	1.04	0.00714	0.00242	0.00511	**BDL**
22-05-2019	AB47	60.8	6.51	236	345	3.17	0.03	0.32	20.7	144.8	114.4	33.95	20.57	57.24	5.31	19.6972	1.82864	**BDL**	0.97	0.00403	0.00223	0.00202	**BDL**
22-05-2019	AB25	20.1	7.91	74.9	93	3.14	0.02	0.18	1.7	102.8	1.6	22.15	8.03	4.74	2.72	0.99175	0.04506	0.0158	**BDL**	0.00479	0.00352	0.00194	0.0005
22-05-2019	AB22	18.86	8.78	24.5	40	3.2	0.08	0.11	9.9	71.4	4.3	8.39	3.09	12.75	5.93	0.86949	0.01538	0.17959	3.59	0.02869	0.00423	**BDL**	**BDL**
22-05-2019	PB04	18.86	8.78	5.62	94	3	0.03	0.05	1.7	74.8	2.5	20.27	1.63	14.6	**BDL**	0.59998	0.06907	0.03675	**BDL**	0.00329	0.00222	**BDL**	0.0023
22-05-2019	AB57	116.1	7.45	99.1	745	2.95	0.03	0.39	13.4	37.8	501.7	33.3	10.66	214.03	3.72	2.86604	0.02204	0.08108	**BDL**	0.01251	0.00303	**BDL**	**BDL**
22-05-2019	AB56	10.73	9.18	5.87	**BDL**	3.03	0.02	0.03	8.6	30.1	3.7	0.85	1.11	8.88	1.13	0.28396	**BDL**	0.01834	**BDL**	0.00772	**BDL**	**BDL**	**BDL**
22-05-2019	PB06	20.4	8.35	10.4	100	3.37	0.04	0.04	3.2	84.1	3.5	8.82	0.83	35.69	**BDL**	1.37461	0.00964	0.0608	**BDL**	0.00604	0.00291	**BDL**	0.0049
22-05-2019	PB05	9.35	6.42	400	79	2.62	0.02	0.63	3.1	33.5	2.6	4.44	2.4	5.32	1.69	35.5093	0.31469	0.04161	**BDL**	0.00842	0.00187	0.00297	**BDL**
22-05-2019	CB55	16.79	7.38	78	62	3.02	0.03	0.11	6.2	61.4	12.5	7.58	4.38	16.46	1.8	3.9568	0.31202	0.03128	**BDL**	0.00918	0.00234	**BDL**	**BDL**
22-05-2019	CB54	12.82	7.5	18	55	3.16	0.03	0.03	5.6	43.7	2.5	5.63	3.47	7.28	3.28	1.19945	0.10635	0.02594	**BDL**	0.00605	0.00234	**BDL**	0.0027
23-05-2019	PB59	60.2	7.09	244	335	3.08	0.03	0.12	9.3	248.4	55.2	60.58	32.31	20.02	5.58	4.43996	1.14878	0.01687	1.67	0.01418	0.00593	0.00374	0.0003
23-05-2019	PB42	7.38	6.38	426	**BDL**	3	0.03	0.29	1.9	34.6	1.4	1.73	2.25	1.83	3.02	2.96426	1.21606	0.01955	**BDL**	0.01419	0.00304	**BDL**	**BDL**
23-05-2019	CB01	16.24	7.17	113	45	2.99	0.02	0.18	2.7	78.5	1.8	9.29	4.94	2.73	1.52	1.93296	1.02258	**BDL**	1.59	0.00018	**BDL**	**BDL**	**BDL**
23-05-2019	CB02	4.91	6.08	23.2	60	5.34	0.02	0.05	1.3	9.7	1.4	**BDL**	1.39	**BDL**	1.32	0.3876	0.09404	0.00458	**BDL**	0.00296	**BDL**	**BDL**	**BDL**
23-05-2019	AB16	8.02	6.57	251	35	3.12	0.02	0.17	4.9	31.8	1.3	2.41	1.27	5.75	1.67	2.82027	0.29524	0.01191	**BDL**	0.01234	0.00295	**BDL**	0.0003
23-05-2019	PB23	76.9	7.1	117	432	2.97	0.02	0.05	9.4	73.5	269.6	28.08	8.49	125.26	4.06	5.09835	0.54243	0.00849	**BDL**	0.00902	0.00253	0.00613	0.0006

Notes: BDL: Below Detection limit

Table 12: Analytical Results compared to WUL Limits (WUL licence no.04/B20E/BCEG/1048)

BH ID	Date	pH	EC	Ca	Mg	Na	Cl	SO_4	NO_3-N	PO_4	Al	Fe	Mn
		pH units	mS/m	mg/l									
WUL limits		6,5-8,4	40	25	20	20	20	30	6,0	0,05	0,02	1	0,18
SB24	20-05-2019	7.48	50.8	44.16	27.13	35.85	6.21	26.4	1.37	BDL	0.0123	13.7907	0.4337
PB58	20-05-2019	7.27	53	100.18	11.66	13.93	BDL	BDL	2.18	BDL	0.1242	1.6285	0.9041
CB23	20-05-2019	7.37	6.29	2.99	2.31	4.89	BDL	BDL	2.05	BDL	0.0242	1.8087	0.2822
WB18	20-05-2019	6.91	5.59	2.66	1.87	4.19	BDL	BDL	0.81	BDL	0.0086	3.0573	0.355
CB40	20-05-2019	6.96	17.49	13.87	7.49	4.28	BDL	BDL	10.7	BDL	0.0134	0.1134	0.0453
AB45	21-05-2019	6.78	7.3	4.16	2.7	BDL	2.6	1.7	3.44	BDL	0.0098	1.3062	0.5732
AB14	21-05-2019	6.87	6.33	70.48	24.11	128.29	2.1	1.6	3.44	BDL	BDL	0.6034	0.1841
AB07	21-05-2019	6.44	8.48	3.87	1.74	1.87	1.8	1.7	3.77	BDL	0.0158	11.6044	0.4046
AB08	21-05-2019	7.68	102.9	1.82	2.18	BDL	21.2	590.8	3.44	0.2	BDL	1.2484	0.2581
AB68	21-05-2019	7.42	37.5	23.08	14.13	35.86	20.5	77.3	4.03	BDL	0.0277	1.1917	0.0588
AB69	21-05-2019	6.92	91.2	72.27	45.55	80.54	19.5	364.9	3.63	0.12	BDL	8.0249	0.1792
AB66	21-05-2019	8.41	26.1	4.96	5.8	43.27	11.7	1.6	3.15	0.11	0.0075	0.2232	0.0053
AB67	21-05-2019	8.05	43.5	34.97	15.81	41.66	19.2	54.8	2.96	BDL	0.0769	2.2959	0.1591
AB65	21-05-2019	7.35	15.13	15.95	8.38	BDL	3.1	1.9	3.08	BDL	BDL	0.702	1.4056
AB64	21-05-2019	7.46	25.1	22.44	15.8	2.66	4.2	6.6	3.02	BDL	BDL	3.5227	0.9862
AB44	22-05-2019	5.89	14.74	7.85	5.12	4.71	8.6	35.8	3.01	**0.21**	0.0072	0.6267	0.0976
AB48	22-05-2019	6.52	61.8	34.25	21.54	58.11	23.8	123.5	2.96	0.2	0.0082	30.1407	2.4398
AB47	22-05-2019	6.51	60.8	33.95	20.57	57.24	20.7	114.4	3.17	BDL	BDL	19.6972	1.8286
AB25	22-05-2019	7.91	20.1	22.15	8.03	4.74	1.7	1.6	3.14	0.1	0.0158	0.9918	0.0451
AB22	22-05-2019	8.78	18.86	8.39	3.09	12.75	9.9	4.3	3.2	0.2	0.1796	0.8695	0.0154
PB04	22-05-2019	8.78	18.86	20.27	1.63	14.6	1.7	2.5	3	0.25	0.0368	0.6	0.0691
AB57	22-05-2019	7.45	116.1	33.3	10.66	214.03	13.4	501.7	2.95	0.1	0.0811	2.866	0.022
AB56	22-05-2019	9.18	10.73	0.85	1.11	8.88	8.6	3.7	3.03	BDL	0.0183	0.284	BDL

BH ID	Date	pH	EC	Ca	Mg	Na	Cl	SO_4	NO_3-N	PO_4	Al	Fe	Mn
		pH units	mS/m	mg/l									
WUL limits		6,5-8,4	40	25	20	20	20	30	6,0	0,05	0,02	1	0,18
PB06	22-05-2019	8.35	20.4	8.82	0.83	35.69	3.2	3.5	3.37	BDL	0.0608	1.3746	0.0096
PB05	22-05-2019	6.42	9.35	4.44	2.4	5.32	3.1	2.6	2.62	BDL	0.0416	35.5093	0.3147
CB55	22-05-2019	7.38	16.79	7.58	4.38	16.46	6.2	12.5	3.02	BDL	0.0313	3.9568	0.312
CB54	22-05-2019	7.5	12.82	5.63	3.47	7.28	5.6	2.5	3.16	BDL	0.0259	1.1995	0.1064
PB59	23-05-2019	7.09	60.2	60.58	32.31	20.02	9.3	55.2	3.08	BDL	0.0169	4.44	1.1488
PB42	23-05-2019	6.38	7.38	1.73	2.25	1.83	1.9	1.4	3	BDL	0.0196	2.9643	1.2161
CB01	23-05-2019	7.17	16.24	9.29	4.94	2.73	2.7	1.8	2.99	BDL	BDL	1.933	1.0226
CB02	23-05-2019	6.08	4.91	BDL	1.39	BDL	1.3	1.4	5.34	BDL	0.0046	0.3876	0.094
AB16	23-05-2019	6.57	8.02	2.41	1.27	5.75	4.9	1.3	3.12	BDL	0.0119	2.8203	0.2952
PB23	23-05-2019	7.1	76.9	28.08	8.49	125.26	9.4	269.6	2.97	BDL	0.0085	5.0984	0.5424

Notes: Red indicated parameters above WUL Limits and BDL: Below Detection limit

5.3 Groundwater Classification

The groundwater quality results of the sampled boreholes are visually represented on an expanded Durov and Piper diagrams to distinguish between the different water quality classes/types.

5.3.1 Expanded Durov

Expanded Durov diagrams graphically represent the relative percentages of anions and cations in water samples. The cation percentages are plotted in the top part of the diagram and the anion percentages in the left part. A projection of these cation and anion percentages onto the central area presents the chemical signature of the major ion composition of the water. The chemical signature can be related to various hydrochemical environments and conditions.

The majority of the samples plot on blue sector of the diagram and represent background groundwater quality, calcium magnesium bicarbonate type of water (Ca,Mg)(HCO_3)$_2$).

The green sector of the diagram is representative of sodium potassium bicarbonate type of water Na/K–(HCO_3)$_2$. The plot position on the diagram indicates minor sodium enrichment diluted by precipitation.

The red sector of the diagram is representative of sodium potassium sulphate water type (i.e. Na/K–SO_4). The plot position on the diagram indicates water with minor sodium and sulphate enrichment (PB23 and AB57).

The yellow sector of the diagram is representative of magnesium sulphate type of water (Mg)SO4. The plot position on the diagram indicates impacted water with magnesium and sulphate enrichment.

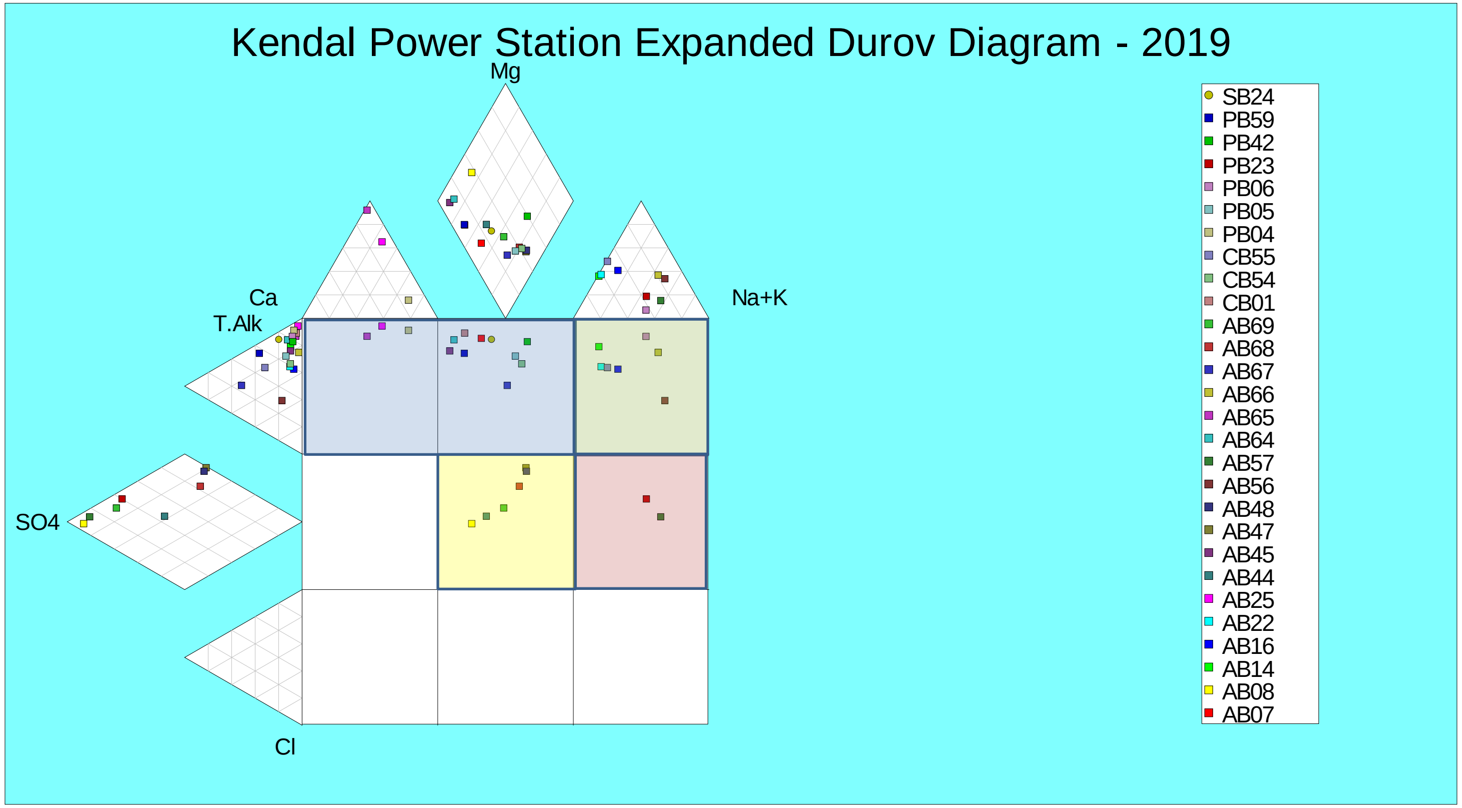

Figure 23: Expanded Durov Diagram - 2019

5.3.2 Piper Diagram

Piper diagrams graphically represent the relative percentages of anions and cations in water samples. The cation percentages are plotted in the left triangle and the anion percentages in the right triangle. A projection of these cation and anion presentations onto the central diamond presents the chemical signature of the major ion composition of the water.

The majority of the samples plot on blue sector of the Piper diagram and show a signature of calcium magnesium bicarbonate type of water $(Ca,Mg)(HCO_3)_2$. This type of water is associated with recent rainfall recharge and not impacted groundwater (viz. polluted).

The red sector in the Piper Diagram represents a typical sodium chloride (Na–Cl) water type.

The yellow sector of the Piper Diagram shows a signature of calcium/sodium sulphate type of water (PB23 and AB57).

The green sector represents a sodium bicarbonate (i.e. $Na–(HCO_3)_2$) water type signature and follows the typical dynamic groundwater flow evolution.

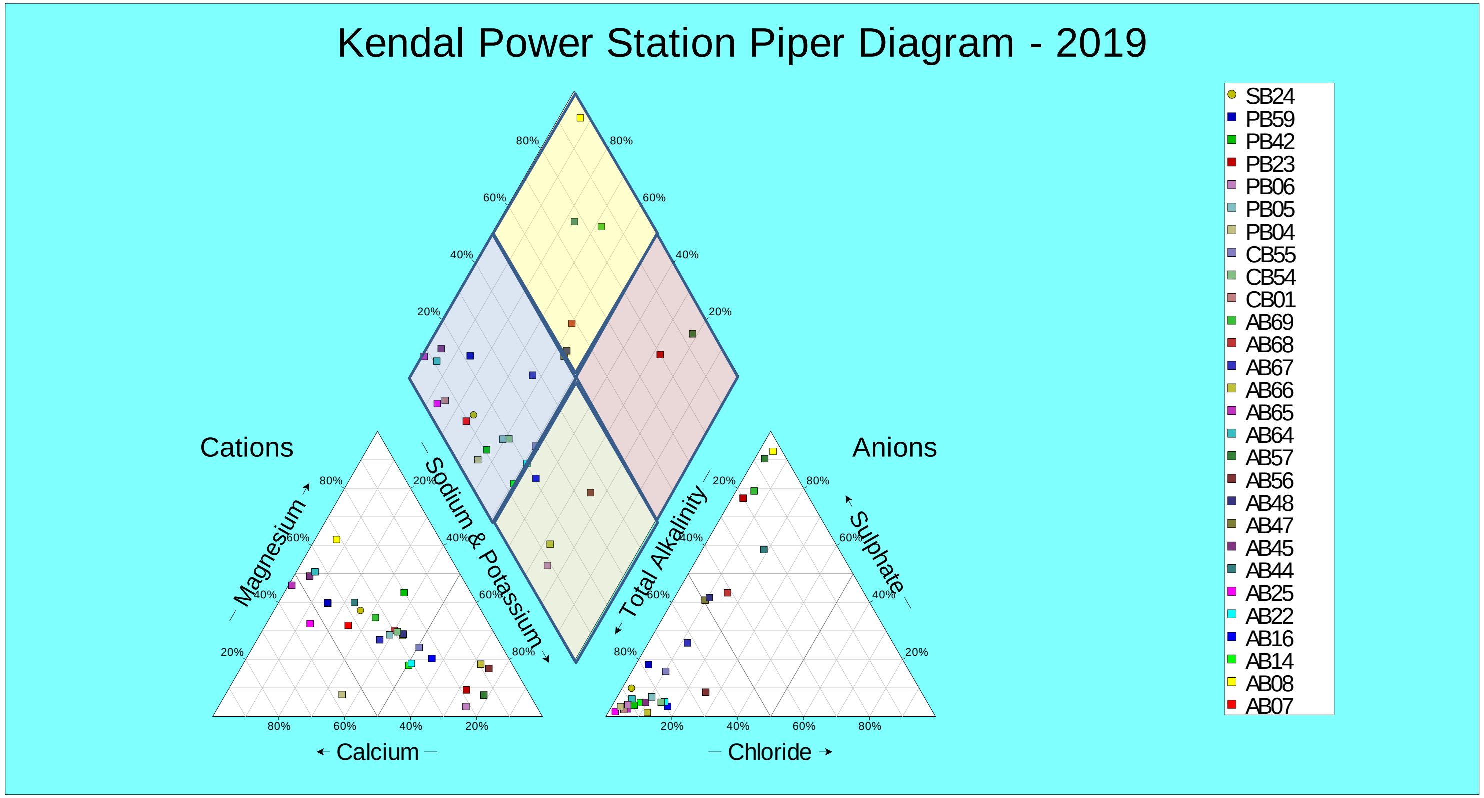

Figure 24: Piper Diagram - 2019

5.4 Groundwater Levels and Flow Directions

The minimum and maximum water levels reported by Kimopax during the phase 87, 2019 monitoring round range between 0.74 mbgl to 14.03 mbgl. The Kimopax groundwater contour map was adapted to illustrate the 2019 groundwater flow direction (Figure 25).

The groundwater flow mimics the topography and the direction of flow are towards the surface streams. The groundwater flow direction at the ADF is toward the west and towards the north away from the Kendal Power Station and correlates with the 2014 study results.

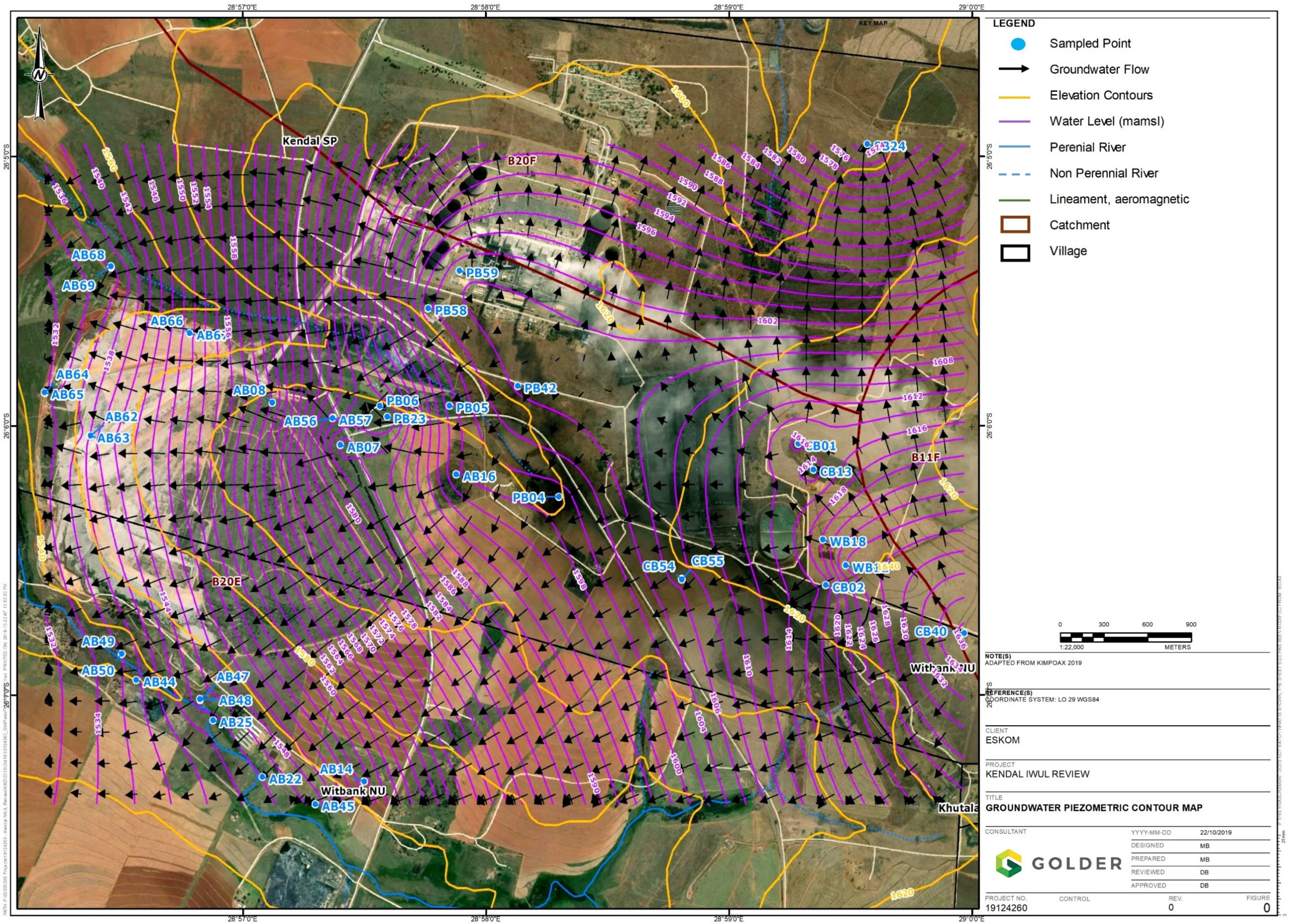

Figure 25: 2019 - Groundwater Piezometric Contours and sampled boreholes (Adapted from Kimopax Phase 87)

6.0 GROUNDWATER QUALITATIVE IMPACT ASSESSMENT

The impact assessment was conducted to determine how the proposed continuous ashing on the existing exemption area footprint will affect the state of the groundwater. The following Impact assessment methodology was followed in order to ensure uniformity as described below:

6.1 Impact Assessment Methodology

A standard impact assessment methodology was utilised so that a wide range of impacts can be compared with each other. The impact assessment methodology makes provision for the assessment of impacts against the following criteria:

- Significance;
- Spatial scale;
- Temporal scale;
- Probability; and
- Degree of certainty.

A combined quantitative and qualitative methodology is used to describe impacts for each of the aforementioned assessment criteria. A summary of each of the qualitative descriptors along with the equivalent quantitative rating scale for each of the aforementioned criteria is given in Table 13.

Table 13: Quantitative rating and equivalent descriptors for the impact assessment criteria

Rating	Significance	Extent Scale	Temporal Scale
1	VERY LOW	*Isolated sites / proposed route*	Incidental
2	LOW	*Study area*	Short-term
3	MODERATE	*Local*	Medium-term
4	HIGH	*Regional / Provincial*	Long-term
5	VERY HIGH	*Global / National*	Permanent

A more detailed description of each of the assessment criteria is given in the following sections.

6.1.1 Significance Assessment

Significance rating (importance) of the associated impacts embraces the notion of extent and magnitude but does not always clearly define these since their importance in the rating scale is very relative. For example, the magnitude (i.e. the size) of area affected by atmospheric pollution may be extremely large (1 000 km^2) but the significance of this effect is dependent on the concentration or level of pollution. If the concentration is great, the significance of the impact would be HIGH or VERY HIGH, but if it is diluted it would be VERY LOW or LOW. Similarly, if 60 ha of a grassland type are destroyed the impact would be VERY HIGH if only 100 ha of that grassland type were known. The impact would be VERY LOW if the grassland type was common. A more detailed description of the impact significance rating scale is given in Table 14 below.

Table 14: Description of the significance rating scale

Rating		Description
5	Very high	Of the highest order possible within the bounds of impacts which could occur. In the case of adverse impacts: there is no possible mitigation and/or remedial activity which could offset the impact. In the case of beneficial impacts, there is no real alternative to achieving this benefit.
4	High	Impact is of substantial order within the bounds of impacts, which could occur. In the case of adverse impacts: mitigation and/or remedial activity is feasible but difficult, expensive, time-consuming or some combination of these. In the case of beneficial impacts, other means of achieving this benefit are feasible but they are more difficult, expensive, time-consuming or some combination of these.

Rating		Description
3	Moderate	Impact is real but not substantial in relation to other impacts, which might take effect within the bounds of those which could occur. In the case of adverse impacts: mitigation and/or remedial activity are both feasible and fairly easily possible. In the case of beneficial impacts: other means of achieving this benefit are about equal in time, cost, effort, etc.
2	Low	Impact is of a low order and therefore likely to have little real effect. In the case of adverse impacts: mitigation and/or remedial activity is either easily achieved or little will be required, or both. In the case of beneficial impacts, alternative means for achieving this benefit are likely to be easier, cheaper, more effective, less time consuming, or some combination of these.
1	Very low	Impact is negligible within the bounds of impacts which could occur. In the case of adverse impacts, almost no mitigation and/or remedial activity are needed, and any minor steps which might be needed are easy, cheap, and simple. In the case of beneficial impacts, alternative means are almost all likely to be better, in one or a number of ways, than this means of achieving the benefit. Three additional categories must also be used where relevant. They are in addition to the category represented on the scale, and if used, will replace the scale.
0	No impact	There is no impact at all - not even a very low impact on a party or system.

6.1.2 Spatial Scale

The spatial scale refers to the extent of the impact i.e. will the impact be felt at the local, regional, or global scale. The spatial assessment scale is described in more detail in Table 15.

Table 15: Description of the spatial scale

Rating		Description
5	Global/National	The maximum extent of any impact.
4	Regional/Provincial	The spatial scale is moderate within the bounds of impacts possible and will be felt at a regional scale (District Municipality to Provincial Level).
3	Local	The impact will affect an area up to 10 km from the proposed route.
2	Study Area	The impact will affect an area not exceeding the Eskom servitude.
1	Isolated Sites / proposed route	The impact will affect an area no bigger than the power line pylon footing.

6.1.3 Duration Scale

In order to accurately describe the impact, it is necessary to understand the duration and persistence of an impact in the environment. The temporal scale is rated according to criteria set out in Table 16.

Table 16: Description of the temporal rating scale

Rating		Description
1	Incidental	The impact will be limited to isolated incidences that are expected to occur very sporadically.
2	Short-term	The environmental impact identified will operate for the duration of the construction phase or a period of less than 5 years, whichever is the greater.
3	Medium term	The environmental impact identified will operate for the duration of life of facility.
4	Long term	The environmental impact identified will operate beyond the life of operation.
5	Permanent	The environmental impact will be permanent.

6.1.4 Degree of Probability

Probability or likelihood of an impact occurring are described as shown in Table 17 below.

Table 17: Description of the degree of probability of an impact occurring

Rating	Description
1	Practically impossible
2	Unlikely
3	Could happen
4	Very Likely
5	It's going to happen / has occurred

6.1.5 Degree of Certainty

As with all studies it is not possible to be 100% certain of all facts, and for this reason a standard "degree of certainty" scale is used as discussed in Table 18. The level of detail for specialist studies is determined according to the degree of certainty required for decision-making. The impacts are discussed in terms of affected parties or environmental components.

Table 18: Description of the degree of certainty rating scale

Rating	Description
Definite	More than 90% sure of a particular fact.
Probable	Between 70 and 90% sure of a particular fact, or of the likelihood of that impact occurring.
Possible	Between 40 and 70% sure of a particular fact or of the likelihood of an impact occurring.
Unsure	Less than 40% sure of a particular fact or the likelihood of an impact occurring.
Can't know	The consultant believes an assessment is not possible even with additional research.
Don't know	The consultant cannot, or is unwilling, to make an assessment given available information.

6.1.6 Quantitative Description of Impacts

To allow for impacts to be described in a quantitative manner in addition to the qualitative description given above, a rating scale of between 1 and 5 was used for each of the assessment criteria. Thus, the total value of the impact is described as the function of significance, spatial and temporal scale as described below:

Impact Risk = ((SIGNIFICANCE **+** *Spatial* **+** Temporal) ÷ 3) **X** (Probability ÷ 5)

An example of how this rating scale is applied is shown below Table 19.

Table 19: Example of Rating Scale

Impact	Significance	Spatial Scale	Temporal Scale	Probability	Rating
	LOW	Local	Medium-term	Could Happen	
Impact to air	**2**	**3**	**3**	**3**	**1.6**

Note: The significance, spatial and temporal scales are added to give a total of 8, that is divided by 3 to give a criteria rating of 2, 67. The probability (3) is divided by 5 to give a probability rating of 0, 6. The criteria rating of 2, 67 is then multiplied by the probability rating (0, 6) to give the final rating of 1, 6.

The impact risk is classified according to five classes as described in the table Table 20 below.

Table 20: IMPACT RISK CLASSES

Rating	Impact Class	Description
0.1 – 1.0	1	Very Low
1.1 – 2.0	2	Low
2.1 – 3.0	3	Moderate
3.1 – 4.0	4	High
4.1 – 5.0	5	Very High

Therefore, with reference to the example used for air quality above, an impact rating of 1.6 will fall in the Impact Class 2, which will be considered to be a low impact.

6.1.7 Cumulative Impacts

It is a requirement that the impact assessments take cognisance of cumulative impacts. In fulfilment of this requirement the impact assessment will take cognisance of any existing impact sustained by the operations, any mitigation measures already in place, any additional impact to environment through continued and proposed future activities, and the residual impact after mitigation measures.

It is important to note that cumulative impacts at the national or provincial level will not be considered in this assessment, as the total quantification of external companies on resources is not possible at the project level due to the lack of information and research documenting the effects of existing activities. Such cumulative impacts that may occur across industry boundaries can also only be effectively addressed at Provincial and National Government levels.

6.2 Groundwater Impacts

The emergency, existing ash disposal facilities at Kendal Power Station are unlined facilities and pose a risk of contamination of the aquifers.

The use of the emergency, existing and continuous ash disposal facilities at Kendal Power Station can probably have the following impact on groundwater:

- The impact on the quality of the groundwater.

6.2.1 Assessment of Groundwater Impact

6.2.1.1 Significance Assessment

The significance rating of the impact on groundwater is 2 (Low) (Table 14).

6.2.1.2 Spatial Scale

The spatial scale rating of the impact on groundwater is 2 (Study area) (Table 15).

6.2.1.3 Duration Scale

The duration scale rating of the impact on groundwater is 4 (Long Term) (Table 16).

6.2.1.4 Degree of Probability

The degree of probability of the impact on groundwater is 3 (Could happen) (Table 17).

6.2.1.5 Degree of Certainty

The degree of certainty of the impact on groundwater is possible and is between 40 and 70% sure of a particular fact or the likelihood of an impact occurring (Table 18).

6.2.1.6 Quantitative Description of Impacts

The quantitative description for impact of the ash disposal facilities on groundwater is calculated as follows:

Impact Risk = ((SIGNIFICANCE **+** *Spatial* **+** Temporal) ÷ 3) X (Probability ÷ 5)

= ((8) ÷ 3) X (3 ÷ 5)

= (2.7) X (0.6)

=1.62

Table 21: Impact on Groundwater existing Ash Facility (unlined)

Impact	Significance	Spatial Scale	Duration Scale	Probability	Rating
	LOW	Study Area	Long-term	Could Happen	Low
Impact on Groundwater Quality	**2**	**2**	**4**	**3**	**1.62**

The impact risk is on groundwater quality is classified according to the impact risk classes (Table 20) as class 2 with a low impact.

The impacts from the unlined ADF is listed in Table 21 , the new lined ADF in Table 22 and the lined and existing unlined ash facility in Table 23.

Table 22: Impacts of new Continues Ash Facility only and Lined (After Mitigation)

Impact	Significance	Spatial Scale	Duration Scale	Probability	Rating
	Very Low	Study Area	Long-term	Unlikely	Very Low
Impact on Groundwater Quality	**1**	**2**	**4**	**2**	**0.93**

Table 23: Impact of new Continues Ash Facility lined and existing unlined ash facility (Cumulative Assessment)

Impact	Significance	Spatial Scale	Duration Scale	Probability	Rating
	Low	Local	Long-term	Could Happen	Low
Impact on Groundwater Quality	**2**	**3**	**4**	**3**	**1.80**

6.2.2 Mitigation Measures

The following mitigation measures are proposed for the continuous ashing on the exemption area:

- Lining and sealing of proposed new continuous ash disposal facility as per engineering designs will reduce the risk of groundwater contamination;
- Additional mitigation measures that can be implemented are summarised below:
  - Scavenger borehole system at the two water quality outliers (AB08 and AB57) may contain/deplete the development of these local plumes although the source of potential contamination needs to be investigated;
  - Part of the mitigation and management could include a deeper (intersecting the groundwater level ~3.5m below surface) subsoil drainage collection trench between the ash dump and the stream to the west thereof. This is only necessary if contamination migration from the ADF to the stream is noticed. At this stage it is recommended that this subsurface drain should be designed but not installed. If contamination is noticed during monitoring it can be installed at specific contamination flow zones (determined by monitoring). The design must be as such that the inflow in the trench is limited to upstream and below and not from the downstream side. Thus, impermeable layers at the stream side of the trench;

- Although existing groundwater monitoring is sufficient as baseline, expansion/optimisation of the groundwater monitoring network is recommended on the continuous ADF area to form part of the mitigation and management of the ash dump, to cover the outline of the proposed CADF area. This will be included in the monitoring network and will be used as a warning system for contaminant migration.

7.0 CONCLUSIONS

The following groundwater conclusions are made for Kendal Power Station ashing on the exemption area footprint:

- The site is mainly underlain by sub–horizontal sediments of the Karoo Sequence comprising of shale, carbonaceous shale, sandstone and coal layers of the Vryheid formation of the Ecca group;
- The initial regional groundwater conceptual model identifies three aquifer zones namely weathered, fractured and deep fractured to fresh aquifer zones, but needs to be confirmed and updated, from future test pumping and borehole logs;
- The average groundwater levels of the deep monitoring boreholes for 2014 are 6.1 mbgl and for the shallow monitoring boreholes 2.21mbgl;
- The minimum and maximum water levels reported by Kimopax during the phase 87 2019 monitoring round range between 0.74 mbgl to 14.03 mbgl.
- The groundwater flow mimics the topography and the direction are towards the surface streams;
- The background groundwater quality of the Kendal Power Station are representative of calcium, magnesium bicarbonate type of water (Ca, Mg)$(HCO_3)_2$.;
- The following inorganic constituents exceed the SANS 241 (2015) drinking water compliance standards manganese, iron, sulphate, sodium, ammonia as N and turbidity;
- The 2014 and 2019 analytical results confirm the existing, continuous and emergency ash disposal facilities have limited impact on the surrounding groundwater quality;
- Groundwater vulnerability at the Kendal continuous and emergency ash site is shown on the national groundwater vulnerability map as **low** to medium; and
- According to qualitative groundwater impact assessment for the exemption area footprint, the impact risk on the groundwater quality is classified as class 2 with a **low impact**, therefore it can be concluded that the exemption area has a low impact on the groundwater quality.

8.0 RECOMMENDATIONS

The following recommendations are made for Kendal Power Station ashing on the exemption area footprint:

- Based on the outcome of the groundwater impact assessment for the exemption area footprint, the impact risk on the groundwater quality is classified as class 2 with a low impact and the impacts on the groundwater are not exceed the current conditions. The application for the exception extension therefore could be granted;
- Groundwater monitoring in and around Kendal Power Station must continue, to enable early warnings where changing trends are noted and ensure mitigation is implemented timeously;
- The following monitoring tasks should be conducted to be consistent with the existing WUL (Licence No.: 04/B20E/ABCEGI/3888):
  - **Quarterly monitoring** of groundwater levels and quality;
  - **Purged groundwater sampling;**

- The analytical suite for groundwater samples should include determinants as listed in Table 24: and

Table 24: Analytical Suite as per existing WUL

Variable	Units
pH	pH Units
Electrical Conductivity	mS/m
Total Dissolved Solids (TDS)	mg/l
Total Alkalinity	mg/l
Major cations (Na, K, Mg, Ca)	mg/l
Major anions (Cl, F, SO_4)	mg/l
Nitrate (NO_3 as N)	mg/l
Nitrite (NO_2 as N)	mg/l
Chemical Oxygen demand (COD)	mg/l
Orthophosphate	mg/l
Turbidity (as N.T.U)	mg/l
Trace elements by ICP-OES scan including Fe, Mn, Al, Cu, B, Pb, Zn, Hg, Cd and As	mg/l
Total Chromium (as Cr)	mg/l
Cyanides (as CN)	mg/l
Silica (as SIO_2)	mg/l
Free and saline Ammonia NH3 (as N)	mg/l
E. coli	In cfu/100ml

- A proposed mitigation trench between the ash dump and the stream to the west thereof, should only be implemented if contamination migration from the dumps to the stream is noticed.

9.0 REFERENCES

- Golder Associates (2014). Groundwater Baseline Study at Kendal Power Station – Continuous Ash Disposal. Report No.: 12614149-12075-1.
- GHT Consulting Scientists (2012). Kendal Power Station, Routine Monitoring Phase 58, February 2012. GHT Consulting Scientists Report No: RVN 601.11/1286.
- Kimopax (2019a), Phase 85 Annual Surface and Groundwater Monitoring, Eskom Kendal, Mpumalanga, January 2019. Project Number: Kim-Wat-2017-146.
- Kimopax (2019b), Phase 86 Surface and Groundwater Monitoring, Eskom Kendal, Mpumalanga, March 2019. Project Number: Kim-Wat-2017-146.
- Kimopax (2019c), Phase 87 Quarterly Surface and Groundwater Monitoring, Eskom Kendal, Mpumalanga, July 2019. Project Number: Kim-Wat-2017-146.

Signature Page

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https://golderassociates.sharepoint.com/sites/110013/project files/6 deliverables/groundwater final/19124260-328866-2_kendal_groundwater_rep_final_311019.docx

APPENDIX A

Analytical Results 2013

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FINAL CERTIFICATE OF ANALYSIS

Report Date	2013-03-05
Date Required	2013-02-25
Contract No	
Order/Ref No	76380

sanas Testing Laboratory T0184

12614149 301PT 000010 Kendel

Notes
The results relate specifically to the items tested.
The report shall not be reproduced except in full, without the written approval of the laboratory.
¹ SANAS accredited analysis included in the SANAS Schedule of Accreditation for this laboratory.
² Not SANAS accredited analysis and not included in the SANAS schedule of accreditation for this laboratory.
³ Outsourced not performed by this laboratory.

Request ID: 7117 **Sample ID:** 330712 **Received:** 2013-02-15 **Matrix:** Water **Page:** 1 / 3
Sample Number: KENDAL/1/13/02/2012/10:30 **Revision Number:** 0

Method: ¹UIS-EA-T001(pH) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit
¹pH	5.42		¹pH Temperature	21.9	Deg C

Method: ¹UIS-EA-T001(Electrical Conductivity) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit
¹Total Conductivity	31.9	mS/m	¹TC Temperature	21.9	Deg C

Method: ²UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit
²TDS by EC * 6.5	207	mg/l	²TDS by EC * 7	223	mg/l

Method: ¹UIS-EA-T005(Total Dissolved Solids) **Completed:** 2013-02-28

Parameter	Value	Unit
¹Total Dissolved Solids	236	mg/l

Method: ²UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2013-02-28

Parameter	Value	Unit
²TDS by Summation	209	mg/l

Method: ¹UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit
¹P Alkalinity	<0.6	mg/l CaCO3	¹Total (M) Alkalinity	5.8	mg/l CaCO3

Method: ²UIS-TEA-T001(Disolved Cations in Water by ICP-OES) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
²Ca	12.4	mg/l	²Fe	<0.05	mg/l	²K	6.53	mg/l
²Mg	13.9	mg/l	²Na	21.7	mg/l	²Si	7.69	mg/l

Method: ²UIS-EA-T008(Anions by Ion Chromatography) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
¹F	<0.1	mg/l	¹Cl	33.1	mg/l	¹NO2	<0.2	mg/l
¹NO3	97.9	mg/l	¹NO3 as N	22.1	mg/l	²PO4	<0.8	mg/l
¹SO4	12.2	mg/l						

Method: ²UIS-CP-T002(Ion Balance Error) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
²Sum of Cations	2.92	me/l	²Sum of Anions	3.41	me/l	²Ion Balance Error	-7.8	%

Method: [1]UIS-EA-T009(Ammonium by Ion Chromatography (IC)) **Completed:** 2013-02-28

Parameter	Value	Unit
[1]NH4	<2.5	ppm

Method: [2]UIS-AC-T100(Trace elements in liquids by ICP-MS) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ag	<0.001	mg/l	[2]Al	0.041	mg/l	[2]As	<0.001	mg/l
[2]Au	<0.001	mg/l	[2]B	0.005	mg/l	[2]Ba	0.954	mg/l
[2]Be	0.001	mg/l	[2]Bi	<0.001	mg/l	[2]Cd	0.0003	mg/l
[2]Ce	0.001	mg/l	[2]Co	0.015	mg/l	[2]Cr	<0.001	mg/l
[2]Cs	0.002	mg/l	[2]Cu	0.013	mg/l	[2]Ga	<0.001	mg/l
[2]Ge	<0.001	mg/l	[2]Hf	<0.001	mg/l	[2]Hg	<0.0001	mg/l
[2]Ho	<0.001	mg/l	[2]Ir	<0.001	mg/l	[2]La	0.001	mg/l
[2]Li	0.049	mg/l	[2]Mn	0.099	mg/l	[2]Mo	<0.001	mg/l
[2]Nb	<0.001	mg/l	[2]Nd	0.001	mg/l	[2]Ni	0.043	mg/l
[2]Pb	0.001	mg/l	[2]Pt	<0.001	mg/l	[2]Rb	0.03	mg/l
[2]Sb	0.001	mg/l	[2]Sc	0.002	mg/l	[2]Se	0.001	mg/l
[2]Sn	<0.001	mg/l	[2]Sr	0.33	mg/l	[2]Ta	<0.001	mg/l
[2]Te	<0.001	mg/l	[2]Th	<0.0001	mg/l	[2]Ti	<0.05	mg/l
[2]Tl	<0.001	mg/l	[2]U	<0.0001	mg/l	[2]V	<0.001	mg/l
[2]W	<0.001	mg/l	[2]Y	0.003	mg/l	[2]Zn	0.088	mg/l
[2]Zr	<0.001	mg/l						

Request ID: 7117 **Sample ID:** 330713 **Received:** 2013-02-15 **Matrix:** Water **Page:** 2 / 3
Sample Number: KENDAL/2/13/02/2013/11:23 **Revision Number:** 0

Method: [1]UIS-EA-T001(pH) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	8.01		[1]pH Temperature	21.9	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit
[1]Total Conductivity	19.4	mS/m	[1]TC Temperature	21.9	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC * 6.5	126	mg/l	[2]TDS by EC * 7	136	mg/l

Method: [1]UIS-EA-T005(Total Dissolved Solids) **Completed:** 2013-02-28

Parameter	Value	Unit
[1]Total Dissolved Solids	136	mg/l

Method: [2]UIS-CP-T003(Calculated Total Dissolved Solids by Summation) **Completed:** 2013-02-28

Parameter	Value	Unit
[2]TDS by Summation	125	mg/l

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	96.5	mg/l CaCO3

Method: [2]UIS-TEA-T001(Disolved Cations in Water by ICP-OES) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca	17.9	mg/l	[2]Fe	<0.05	mg/l	[2]K	2.15	mg/l
[2]Mg	14.1	mg/l	[2]Na	6.05	mg/l	[2]Si	4.8	mg/l

Method: [2]UIS-EA-T008(Anions by Ion Chromatography) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]F	<0.1	mg/l	[1]Cl	1.54	mg/l	[1]NO2	<0.2	mg/l
[1]NO3	18.7	mg/l	[1]NO3 as N	4.23	mg/l	[2]PO4	<0.8	mg/l
[1]SO4	1.32	mg/l						

Method: [2]UIS-CP-T002(Ion Balance Error) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	2.39	me/l	[2]Sum of Anions	2.32	me/l	[2]Ion Balance Error	1.47	%

Method: [1]UIS-EA-T009(Ammonium by Ion Chromatography (IC)) **Completed:** 2013-02-28

Parameter	Value	Unit
[1]NH4	<2.5	ppm

Method: [2]UIS-AC-T100(Trace elements in liquids by ICP-MS) **Completed:** 2013-02-28

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ag	<0.001	mg/l	[2]Al	0.008	mg/l	[2]As	<0.001	mg/l
[2]Au	<0.001	mg/l	[2]B	0.013	mg/l	[2]Ba	0.124	mg/l
[2]Be	<0.001	mg/l	[2]Bi	<0.001	mg/l	[2]Cd	0.0002	mg/l
[2]Ce	<0.001	mg/l	[2]Co	0.002	mg/l	[2]Cr	0.007	mg/l
[2]Cs	<0.001	mg/l	[2]Cu	0.003	mg/l	[2]Ga	<0.001	mg/l
[2]Ge	<0.001	mg/l	[2]Hf	<0.001	mg/l	[2]Hg	<0.0001	mg/l
[2]Ho	<0.001	mg/l	[2]Ir	<0.001	mg/l	[2]La	<0.001	mg/l
[2]Li	0.069	mg/l	[2]Mn	0.008	mg/l	[2]Mo	<0.001	mg/l
[2]Nb	<0.001	mg/l	[2]Nd	<0.001	mg/l	[2]Ni	0.004	mg/l
[2]Pb	0.001	mg/l	[2]Pt	<0.001	mg/l	[2]Rb	0.008	mg/l
[2]Sb	0.001	mg/l	[2]Sc	0.004	mg/l	[2]Se	0.001	mg/l
[2]Sn	<0.001	mg/l	[2]Sr	0.12	mg/l	[2]Ta	<0.001	mg/l
[2]Te	<0.001	mg/l	[2]Th	<0.0001	mg/l	[2]Ti	<0.05	mg/l
[2]Tl	<0.001	mg/l	[2]U	<0.0001	mg/l	[2]V	0.002	mg/l

²W	<0.001 mg/l	²Y	<0.001 mg/l	²Zn	0.072 mg/l
²Zr	<0.001 mg/l				

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AUTHORISED SIGNATORY

APPENDIX B

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