63 Wessel Road Rivonia 2128 PO Box 2597 Rivonia 2128 South Africa

Telephone: +27 (0)11 803 5726 Facsimile: +27 (0)11 803 5745
Web: www.gcs-sa.biz

Kusile Power Station Hydrogeological Investigation

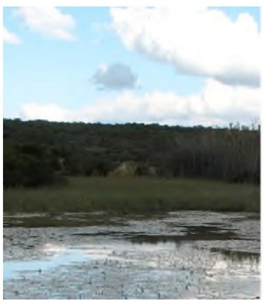
Report

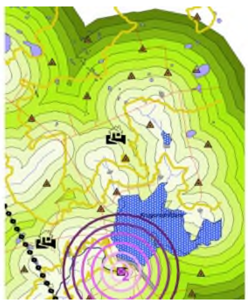
Version - 2

July 2014

Iliso Consulting

GCS Project Number: 13-427

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EXECUTIVE SUMMARY

Introduction

GCS undertook a hydrogeological study in October 2013, for the ESKOM Kusile Power Station which is a coal-fired power station close to the existing Kendal Power Station in the Nkangala District of the Mpumalanga Province. The Power station surface lease area is approximately 1 355 hectares , the infrastructure consist of the power station building, administration buildings (administrative, medical, maintenance, services) and the high voltage yard, which is located on the Hartbeesfontein and Klipfontein farms.

Site Specific Information

The Power Station is located between the towns of Bronkhorstspruit and Emalahleni, south of the N4 highway in the Mpumalanga Province. The proposed ash/gypsum disposal facility will be located directly south and adjacent to the Power Station.

The topography of the area slopes in a general north westerly direction towards the perennial Wilge River, located approximately 5km to the west of the proposed ash/gypsum disposal facility. The surrounding land use consists of agricultural land.

Previous Investigations

A water quality monitoring programme is currently being undertaken for the Kusile Power Station, since June 2008 by Zitholele Consulting. During this period a total of thirty-four (34) water samples were collected, which includes 16 boreholes and 16 surface water points and 2 duplicates. Fifteen of the 47 monthly monitoring sites were not sampled due to dried up springs, no flowing water, destroyed or collapsed boreholes.

Field Investigation

In total, 20 boreholes were identified during the hydrocensus from which data was collected, which included static water levels. The depths of the boreholes ranged from 16 to 60 metres. The static water levels recorded ranged between 0.59 to 25.34 mbgl (metres below ground level).

The short duration constant discharge test is used to determine the aquifer's response to stress (constant pumping) and to be able to calculate the aquifers hydraulic parameters i.e. transmissivity. The transmissivity in the two boreholes associated with the Dwyka Formation (10490-09 & 10490-10) ranged from 0.3 to 0.5 m^2/day.

The data obtained from borehole 10490-17 indicated insufficient results as minimal recovery was observed. This would be indicative of a very low yielding borehole with a low transmissivity value of less than 0.05 m^2/day. Borehole BH 27 (LGW-B4) indicated a high yielding borehole. In order to obtain accurate aquifer parameters for the borehole, long duration aquifer testing is recommended. Based on the results obtained, a transmissivity value ranging between 20 and 50 m^2/day was allocated for the borehole.

Hydrochemistry

The chemistry of majority of the boreholes indicated good water quality with very few parameters which were not compliant with the SANS 241-1:2011 drinking water quality standards.

Boreholes 10490-17 and BH3 indicated non-compliant manganese with concentrations of 4mg/l and 0.58mg/l respectively, which exceeded the SANS standard of 0.5mg/l. Borehole 10490-25 indicated non-compliance for fluoride with a concentration of 1.8mg/l which exceeded the SANS standard of 1.5mg/l.

Risk Assessment

A quantitative risk assessment methodology was used based on the data obtained during the field investigation. This method makes use of the basic risk assessment approach of deriving an expression for risk from the product of likelihood and consequences. It works by attributing absolute values to likelihood (probability) and consequences.

The hazards associated with the proposed ash/gypsum disposal facility and its impact on the groundwater environment include: Hydrocarbon contamination as well as poor quality water stored on site recharging the groundwater. The impact of hydrocarbon contamination on the soil and groundwater environment during construction indicates moderate environmental significance without mitigation in place and low environmental significance with mitigation in place.

Another negative impact envisaged is the result of poor quality artificial recharge from the ash/gypsum disposal facility. The mitigation measures would include lining the ash/gypsum disposal facility. This would reduce the impact on the groundwater environment as it inhibits the seepage of poor quality water into the aquifer. Mitigation measures would also include implementing the proposed groundwater monitoring programme as detailed in Section 10.

There are also negative impacts associated with the Flue Gas Desulphurisation Wastewater Treatment Plant and the possibility of poor quality water and waste impacting on the environment. The mitigation measures would include lining the area where the waste water will be stored on site.

Monitoring programme

A Groundwater Management Plan is required to ensure that the ash/gypsum disposal facility does not impact negatively on groundwater levels and quality to unacceptable levels. To ensure that the groundwater environment is protected, monitoring of water quality and levels is required on an on-going basis. The recommended monitoring includes groundwater level and groundwater quality monitoring as well as the visual inspection of the boreholes, as outlined below.

The following boreholes are currently being monitored by Zitholele Consulting on a monthly basis: 10490-09, 10490-10, 10490-17, 10490-21, 10490-25, 10490-27, BH2, BH3, BH11, BH25, BH27, BH30, GDF-6D, DWBH-06, DWBH-07 and DWBH-36 in order to comply with the conditions of the Environmental Authorisation (EA) issued by the Department of Environmental Affairs (DEA), and the Water Use License (WUL) from the Department of Water Affairs (DWA).

Based on the application for integrated waste management license, it is proposed by GCS that the boreholes should be sampled on a quarterly basis as per Table 10-1 which includes all boreholes sampled during this investigation. Boreholes should be sampled on a quarterly basis for indicator elements and a full analysis on a bi-annual basis.

Furthermore, it is recommended that leach tests are conducted on the ash/gypsum waste in order to determine the leachable concentrations of the waste samples and whether they are within acceptable limits. The results can also be used to assess the type of waste in accordance to in accordance with the National Environmental Management: Waste Act (NEMWA - Act 59 of 2008).

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1 INTRODUCTION

GCS undertook a hydrogeological study in October 2013, for the ESKOM Kusile Power Station which is a coal-fired power station close to the existing Kendal Power Station in the Nkangala District of the Mpumalanga Province. The Kusile power station covers approximately 2 500 ha of land, and is located on the Hartbeesfontein and Klipfontein farms. The hydrogeological assessment forms part of the requirement for the waste licence application for the following:

- The co-disposal facility and the Ash Dump Dirty Dam (ADDD);
- The Station Dirty Water Dam (SDD) and the station dirty dam settling tanks (SDD ST); and;
- Concrete and K3 Stockpile Areas.

The scope of work for the hydrogeological assessment was to carry out which included a desktop analyses, review of the existing monitoring reports and detailed a field investigation comprising of a hydrocensus, aquifer testing of selected boreholes and sampling of monitoring boreholes.

2 METHODOLOGY

2.1 Desktop Study

GCS assessed all available geological and hydrogeological data. All existing groundwater data was reviewed and assessed during the desktop study.

A study of the 1: 50 000 topographical, 1: 250 000 geological maps and satellite images were conducted during the desktop study. All relevant information was sourced from the client as well as from the relevant governmental departments where available. Any existing groundwater data captured in the National Groundwater Archive (NGA), obtained from the Department of Water Affairs was utilised.

The following data sources were used during the study:

- Topographic map (1:50 000): 2528DD;
- Geological map (1:250 000): 2528 Pretoria;

- The groundwater resources of the Republic of South Africa, sheets 1 and 2 (Vegter 1995);
- GRIP (Groundwater Resource Information Programme) data;
- GRDM, Groundwater Resource Directed Measures, GRDM Training Manual; and
- The National Groundwater Archive (NGA), Department of Water Affairs.
- Zitholele Consulting, 2013. Surface and Groundwater Monitoring for Kusile Power Station, Report No: 12820:7

2.2 Hydrocensus Investigation

A hydrocensus was conducted within a 2 km radius of the site area. The following information can be captured during the hydrocensus:

- GPS coordinates and elevation of existing boreholes or springs;
- Water levels of the boreholes, where accessible;
- Estimated abstraction volumes, where provided;
- Any other information regarding the water reliability or quality;
- Identifying surface water bodies and usage;
- Determine groundwater usage and identify groundwater users; and
- Selected boreholes identified during the hydrocensus will be incorporated within a monitoring plan to monitor groundwater quality.

2.3 Aquifer Testing

Short duration aquifer testing was conducted by way of constant discharge and recovery tests to determine the hydrogeological properties of the groundwater system. These tests allow better understanding of the aquifer hydraulic characteristics and the calculation of travel times of pollutants.

The constant rate tests were followed by recovery tests, where the rebound of the borehole water level was recorded to at least 90% recovery of the original water level. All four of the boreholes tested were sampled and stored in accordance with laboratory standards.

2.4 Groundwater Sampling

The hydrocensus/monitoring boreholes were sampled. The samples were submitted to M&L laboratory services a SANAS accredited laboratory based in Johannesburg, South Africa. A total of 10 samples were collected.

The hydrochemical sampling was carried out in accordance to the following publications:

- SABS ISO 5667-11:1993 Guidance on sampling of groundwater
- SABS ISO 5667-1:1980 Guidance on the design of sampling programs
- SABS ISO 5667-2:1991 Guidance on sampling techniques
- SABS ISO 5667-3:1994 Guidance on the preservation and handling of samples

The following parameters were analysed for, viz: anions, cations and selected metals. Water level measurements were recorded in all monitoring boreholes to create a groundwater contour map and to comment on the feasibility of the existing monitoring boreholes in place and to be used as future groundwater monitoring boreholes

3 SITE DESCRIPTION

3.1 Locality

The Power Station is located between the towns of Bronkhorstspruit and Emalahleni, south of the N4 highway in the Nkangala District of the Mpumalanga Province (refer to Figure 1). The proposed ash/gypsum disposal facility will be located directly south and adjacent to the Power Station.

3.2 Topography, Hydrology and Land Use

The topography of the area slopes in a general north westerly direction (Figure 1) towards the perennial Wilge River, located approximately 5km to the west of the proposed ash/gypsum disposal facility. The surrounding land use consists of agricultural land.

Table 3-1: Hydrological Features in Close Proximity to the Site

Hydrological Feature	Distance from site	Direction
Klipfonteinspruit - Non perennial	650m	South of proposed ash/gypsum disposal facility – flows in a north westerly direction
Holfonteinspruit - Non perennial	2km	South of proposed ash/gypsum disposal facility – flows in a north westerly direction
Klipspruit	5km	West of proposed ash/gypsum disposal facility – flows in a northerly direction

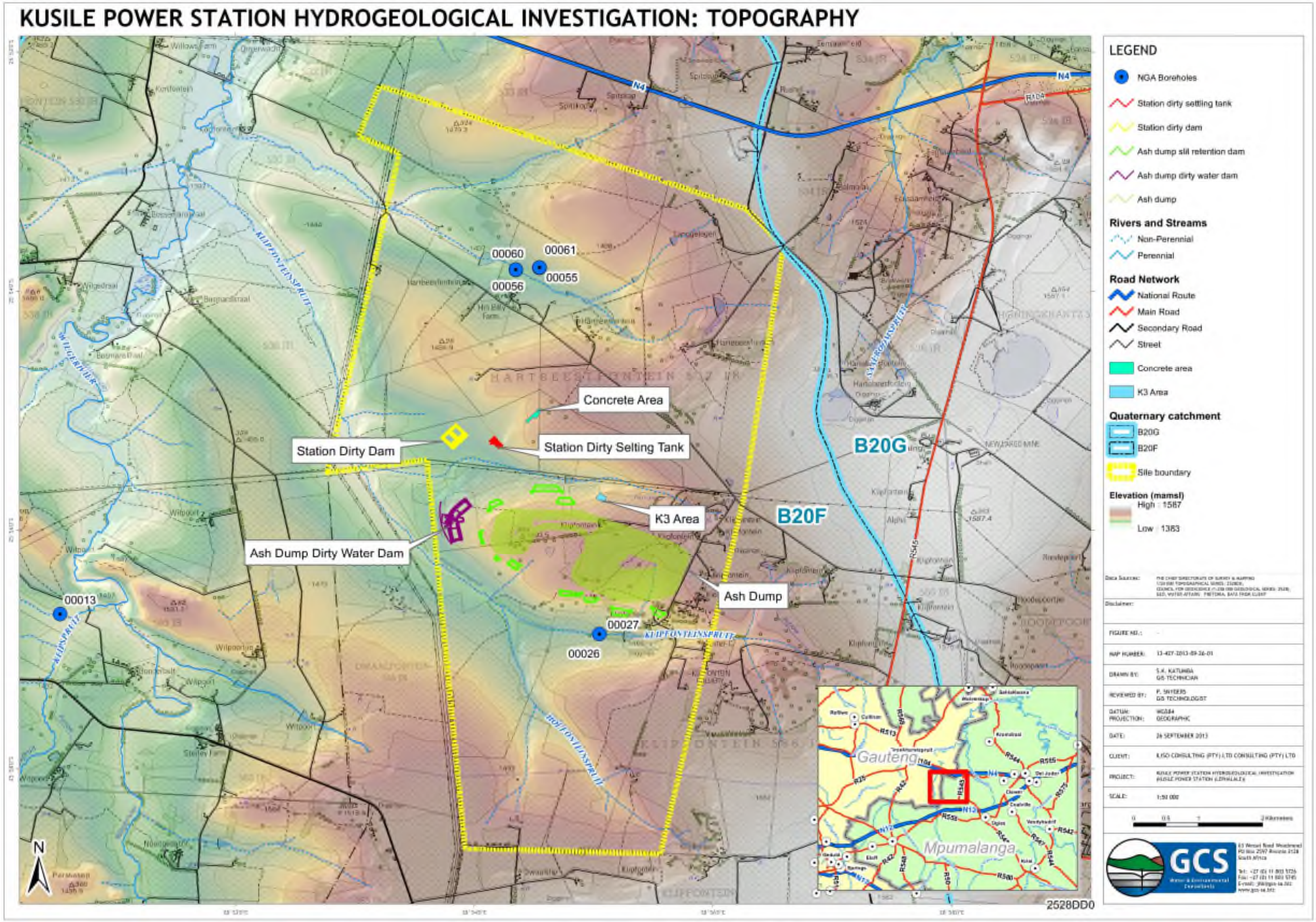

Figure 1: Kusile Power Station Topography Map

4 HYDROGEOLOGICAL DESKTOP STUDY

4.1 Quaternary Catchment

Data from relevant hydrogeological databases including, the National Groundwater Archive (NGA) was obtained from the Department of Water Affairs. The site area falls within quaternary catchment B20F as indicated in Table 4-1.

Table 4-1: Summarized Quaternary Catchment Information (GRDM, 2010)

Quaternary Catchment	Total Area (km^2)	Recharge mm/a	Current use Mm^3/a	Exploitation Potential Mm^3/a	Rainfall mm/a
B20F	504.2	58.82	0.21	4	667

4.2 General Geology and Hydrogeology

The geology and hydrogeology are described in general for the area. According to the 1:250 000 geological map for Pretoria (2528), the site is underlain by the following litholgies (refer to Figure 2):

Dwyka Formation of the Karoo Supergroup (Pd) – Tillite, shale
Ecca Formation of the Karoo Supergroup (Pe) – Shale, shaley sandstone, grit, sandstone, conglomerate, coal in places
Diabase (Di) – Intrusive
Silverton Formation – Pretoria Group (Vsi) – Shale, carbonaceous in places, hornfels, chert

According to the 1:500 000 Hydrogeological Map of Johannesburg 2526 (1999), the study area is mostly associated with fractured and intergranular aquifers based on the geology. The average groundwater yields associated with these aquifers, range from 0.1-0.5 l/s.

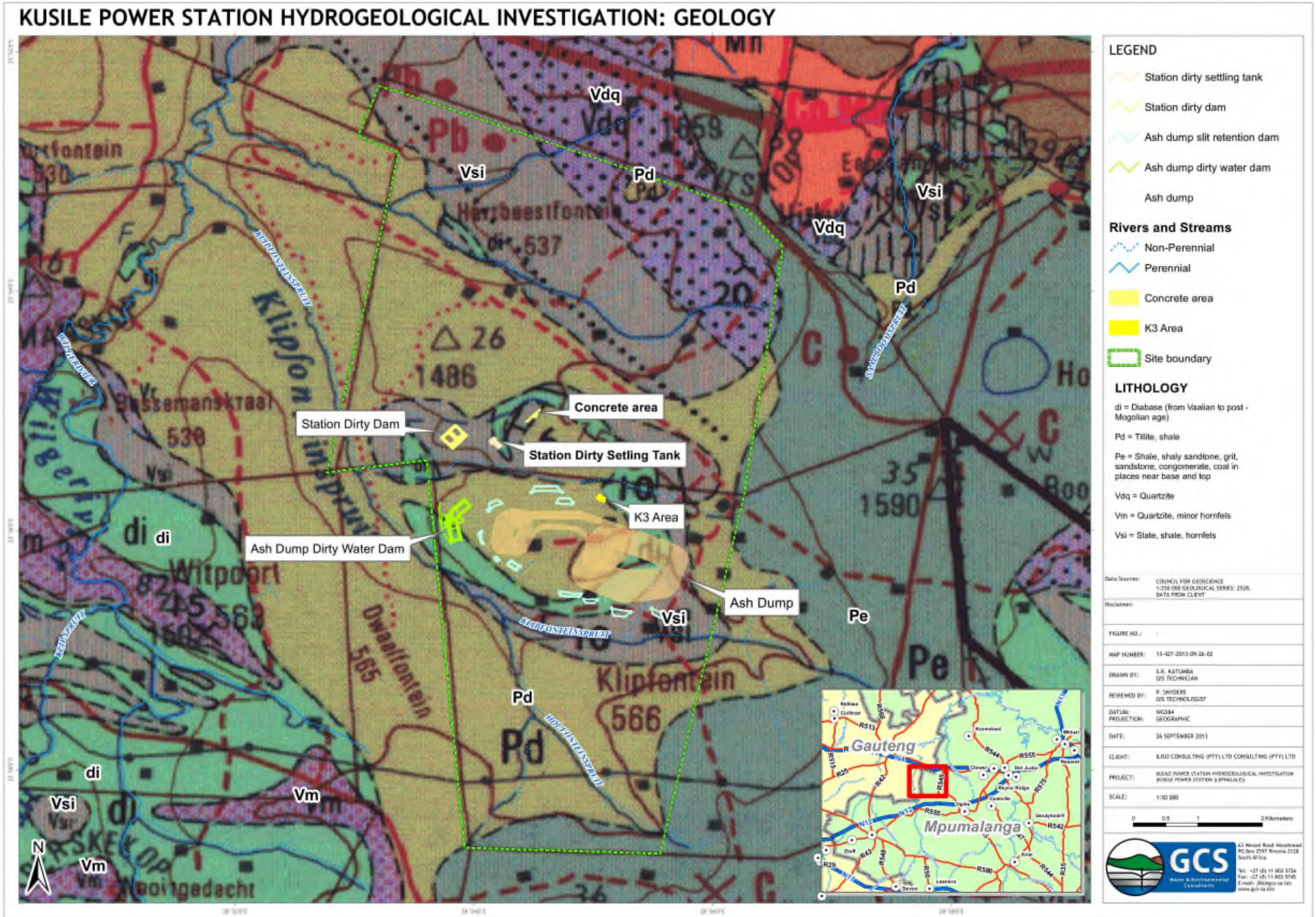

Figure 2: Geological Map

5 PREVIOUS GROUNDWATER MONITORING FOR KUSILE POWER STATION

A water quality monitoring programme is currently being undertaken for the Kusile Power Station, since June 2008 by Zitholele Consulting.

The overall objectives of the monitoring programme were to:

- Comply with the conditions of the Environmental Authorisation (EA) issued by the Department of Environmental Affairs (DEA), and the Water Use License (WUL) from the Department of Water Affairs (DWA);
- Determine the quality of water resources in the vicinity of the Kusile Power Station by:
    - sampling the surface and groundwater at pre-determined positions on a monthly basis;
    - recording the physical parameters at each sampling point when samples are taken;
    - sending the samples to a laboratory for analysis;
    - reporting the results of the aforementioned in a monthly monitoring report; and
    - Presenting the contents of the monitoring reports.

During this period a total of thirty-four (34) water samples were collected, which includes 16 boreholes and 16 surface water points and 2 duplicates. Fifteen of the 47 monthly monitoring sites were not sampled due to dried up springs, no flowing water, destroyed or collapsed boreholes.

6 FIELD INVESTIGATION

6.1 Hydrocensus

A hydrocensus was conducted within the perimeter of the Power Station as well as points located beyond the site boundary. All points as recorded in the Zitholele Consulting Surface and Groundwater Monitoring for Kusile Power Station Report were visited during this study.

The borehole details are presented in Table 6-1 for all boreholes identified during the hydrocensus. Several boreholes, namely 10490-01, 10490-04, 10490-05, 10490-07, 10490-08, 10490-23, 10490-24, BH6, DWBH-05 and DWBH-06 have been destroyed on site. The location of the boreholes have been presented on

In total, 20 boreholes were identified from which data was collected, which included static water levels and field parameters (EC, pH, temperature and TDS). The depths of the boreholes ranged from 16 to 60 metres. The static water levels recorded ranged between 0.59 to 25.34 mbgl (metres below ground level).

According to the data presented in the Zitholele Consulting Surface and Groundwater Monitoring report, 8 springs are present within the site area which were all visited. However, one spring could not be accessed as it is located on Anglo American's property. Five springs were dry and therefore no data was collected for these. The remaining two indicated water present with the field a parameters presented in Table 6-2.

Thirteen surface water points were included in the Zitholele Consulting Surface and Groundwater Monitoring report, which were included in this study. The details recorded are presented in Table 6-3.

Table 6-1: Hydrocensus Details - Boreholes

Borehole ID	Type	Co-Ordinates S	Co-Ordinates E	Depth (m)	Collar Height (M)	SWL (mbgl)	pH	EC (mS/cm)	TDS (ppm)	Temperature (ºC)	Water Description	Remarks
10490-01	Borehole	-25.91899	28.92437	Destroyed (construction)								
10490-04	Borehole	-25.9239	28.91605	Destroyed (construction)								
10490-05	Borehole	-25.9258	28.92013	Destroyed (construction)								
10490-07	Borehole	-25.9136	28.91619	Destroyed (construction)								
10490-08	Borehole	-25.90990	28.91759	30	0.32	25.34	6.72	0.203	144	21.1	Clear	Next to main road
10490-09	Borehole	-25.92740	28.91664	25	N\A	5.41	5.81	0.14	60	20.5	Clear	On construction site
10490-10	Borehole	-25.92740	28.89600	25	0.19	0.59	5.75	0.05	20	19.1	Clear	On construction site
10490-17	Borehole	-25.93989	28.90533	25	0.35	4.34	6.14	0.12	60	19.5	Clear	Within the proposed ash/gypsum disposal
10490-21	Borehole	-25.94276	28.92275	36	0.31	11.1	6.69	0.232	164	19.4	Clear	None
10490-23	Borehole	-25.99263	28.92903	Destroyed (construction)								
10490-24	Borehole	-25.9223	28.93273	Destroyed (construction)								
10490-25	Borehole	-25.92330	28.88393	16	0.99	1.57	7.86	0.448	316	19.2	Clear	None
10490-27	Borehole	-25.91280	28.93232	30	0.37	15.92	6.2	0.06	20	21	Clear	None
ATS-BH01	Borehole	-25.95428	28.95462	No access Fence (Anglo American)								
BH 10	Borehole	-25.93286	28.93286	No access Fence (Anglo American)								
BH 11	Borehole	-25.95020	28.93147	35	N\A	7.46	6.51	0.04	10	-	Clear	Equipped
BH 2	Borehole	-25.90260	28.90675	41	0.36	8.25	7.18	0.129	92.3	19.2	Clear	None
BH 24	Borehole	-25.90000	28.89945			12.67	Equipped, pump not working, next to a windmill					
BH 25	Borehole	-25.90450	28.89334	41	0.24	15.86	6.05	0.06	30	19.4	Clear	None
BH 27 (LGW-B4)	Borehole	-25.93319	28.94313	32	0.53	8.37	7.55	0.036.5	25.9	19.2	Clear	Near road
BH 3	Borehole	-25.91234	28.90014	40	N\A	6.45	7.09	0.151	106	18.2	Clear	None

BH 30 (LGW-B11)	Borehole	-25.91610	28.95413	30	0.66	3.34	7.15	0.086	61.7	19.5	Clear	Near residence
BH 6	Borehole	-25.93286	28.93286	Destroyed (construction)								
DWBH-05	Borehole	-25.91791	28.92511	Destroyed(construction)								
DWBH-10	Borehole	-25.91791	28.92511	Destroyed(construction)								
DWBH-36	Borehole	-25.91445	28.91236	32	N\A	7.26	5.88	0.17	80	21.4	Clear	Next to road
DWBH-06	Borehole	-25.92171	28.92613	45	0.12	11.99	6.55	0.05	20	20	Clear	-
DWBH-07	Borehole	-25.92496	28.93006	30	0.51	9.22	7.07	0.584	41.1	19.6	Clear	On site
GDF-6D	Borehole	-25.90808	28.92886	51	0.15	12.94	5.59	0.16	80	19.5	Clear	-
KP-05	Borehole	-25.91958	28.93214	60	0.4	16.77	6.03	0.07	30	20.5	Clear	On site
LGW-B6	Borehole	-25.98190	28.91268	30	0.57	8.79	8.79	0.193	138	20.5	Clear	Next to coal mine

Table 6-2: Hydrocensus Details - Springs

Spring ID	Type	Co-Ordinates S	Co-Ordinates E	pH	EC (mS/cm)	TDS (ppm)	Temperature (°C)	Water Description	Remarks
Spring 1	Spring	-25.90230	28.93680	Dry					
Spring 10	Spring	-25.95428	28.95462	No access Fence (Anglo American)					
Spring 11	Spring	-25.93110	28.93460	Dry					
Spring 12	Spring	-25.94236	28.91466	Dry					
Spring 2	Spring	-25.88930	28.93372	Dry					
Spring 3	Spring	-25.97322	28.90632	Dry					
Spring 4	Spring	-25.94449	28.88893	6.7	0.0859	60.7	16.6	Clear	-
Spring 6	Spring	-25.94760	28.92797	6.35	0.42	220	26.5	Clear	-

Table 6-3: Hydrocensus Details - Surface Water

Surface Water ID	Type	Co-Ordinates S	Co-Ordinates E	pH	EC (µS/cm)	TDS (ppm)	Temperature (°C)	pH	Remarks
SW 1	Surface Water	-25.92000	28.88306	7.85	1010us	781	17.2	Brown	Flow slow
SW 16	Surface Water	-25.90237	28.85132	8.34	275us	196	20	Clear	Flow fast
SW 17	Surface Water	-25.87476	28.86313	7.91	307us	220	19.8	Clear	Flow fast
SW 2	Surface Water	-25.85330	28.86847	7.44	231us	163	22	Brown	Flow fast
SW 3	Surface Water	-25.88810	28.88915	7.9	158.3us	117	21.6	Brown	Flow fast
SW 4	Surface Water	-25.89090	28.89269	8.26	139.4us	99	18.9	Brown	Medium flow
SW 5	Surface Water	-25.94410	28.90410	6.28	336us	240	20.3	Clear	Medium flow
SW 6	Surface Water	-25.88797	28.88723	8.44	149.1us	104	17.4	Brown	Next to the bridge,fast flow
SW 7	Surface Water	-25.92518	28.8935	7.5	300us	213	25.6	Brown	No flow
SW 8	Surface Water	-25.8946	28.90094	7.95	130.9us	94.1	18.5	Brown	Dam
SW 9	Surface Water	-25.90245	28.91739	7.6	125.1us	88.5	19.9	Brown	Bridge, fast flow
SW 10	Surface Water	-25.87853	28.86982	8.42	149.2us	106	20.2	Brown	Fast flow
SW 11	Surface Water	-25.88439	28.8617	7.8	294us	209	19	Brown	Fast flow

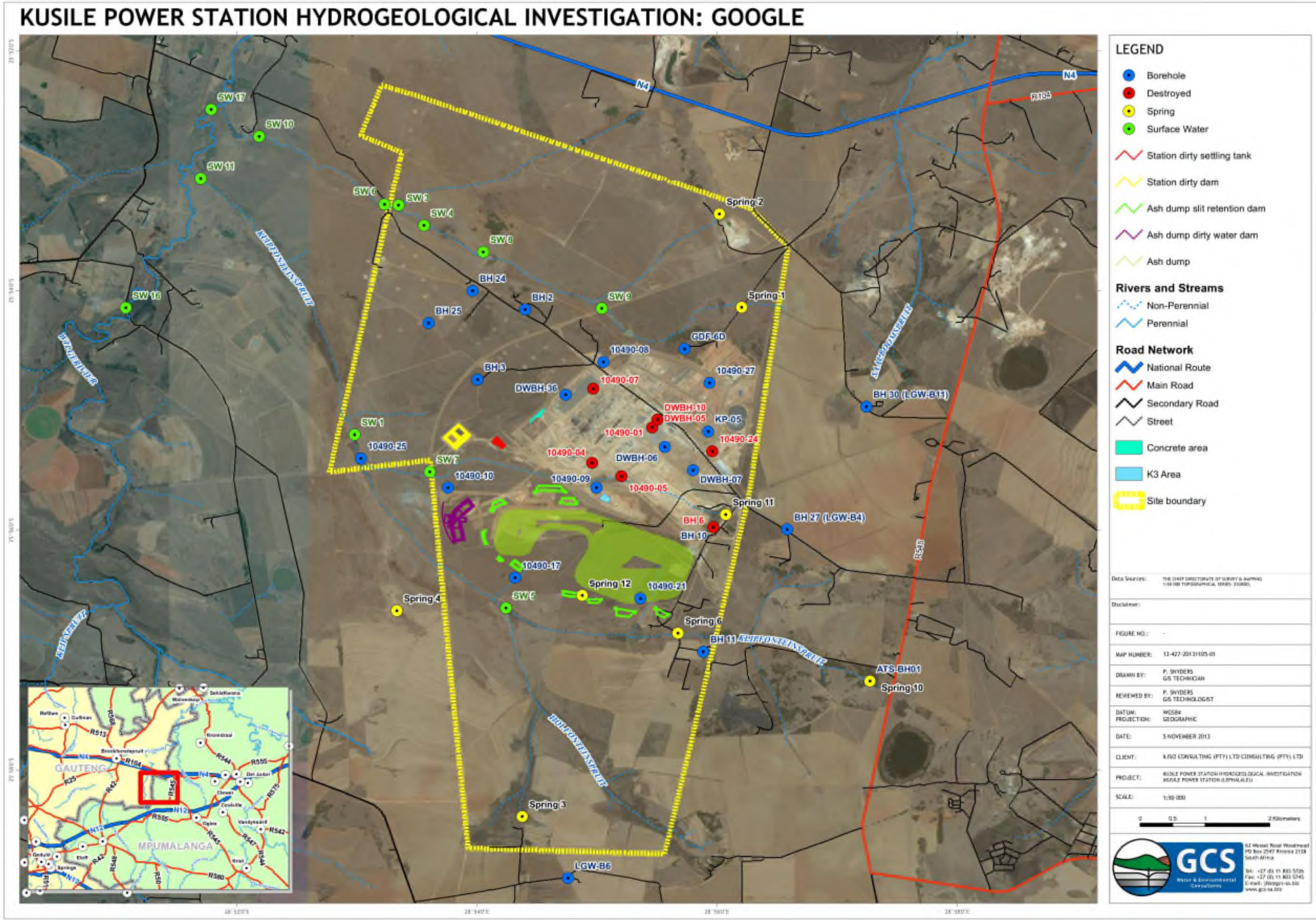

Figure 3: Hydrocensus Map

6.2 Groundwater Levels

The groundwater level data obtained from the newly drilled boreholes on site, was used to contour the groundwater levels over the site area. The groundwater level contour map is presented in Figure 4 below. The groundwater contours indicate that the groundwater flows in a north westerly/westerly direction across the site area. This indicates that the groundwater mimics the topography and flows towards the perennial river to the west.

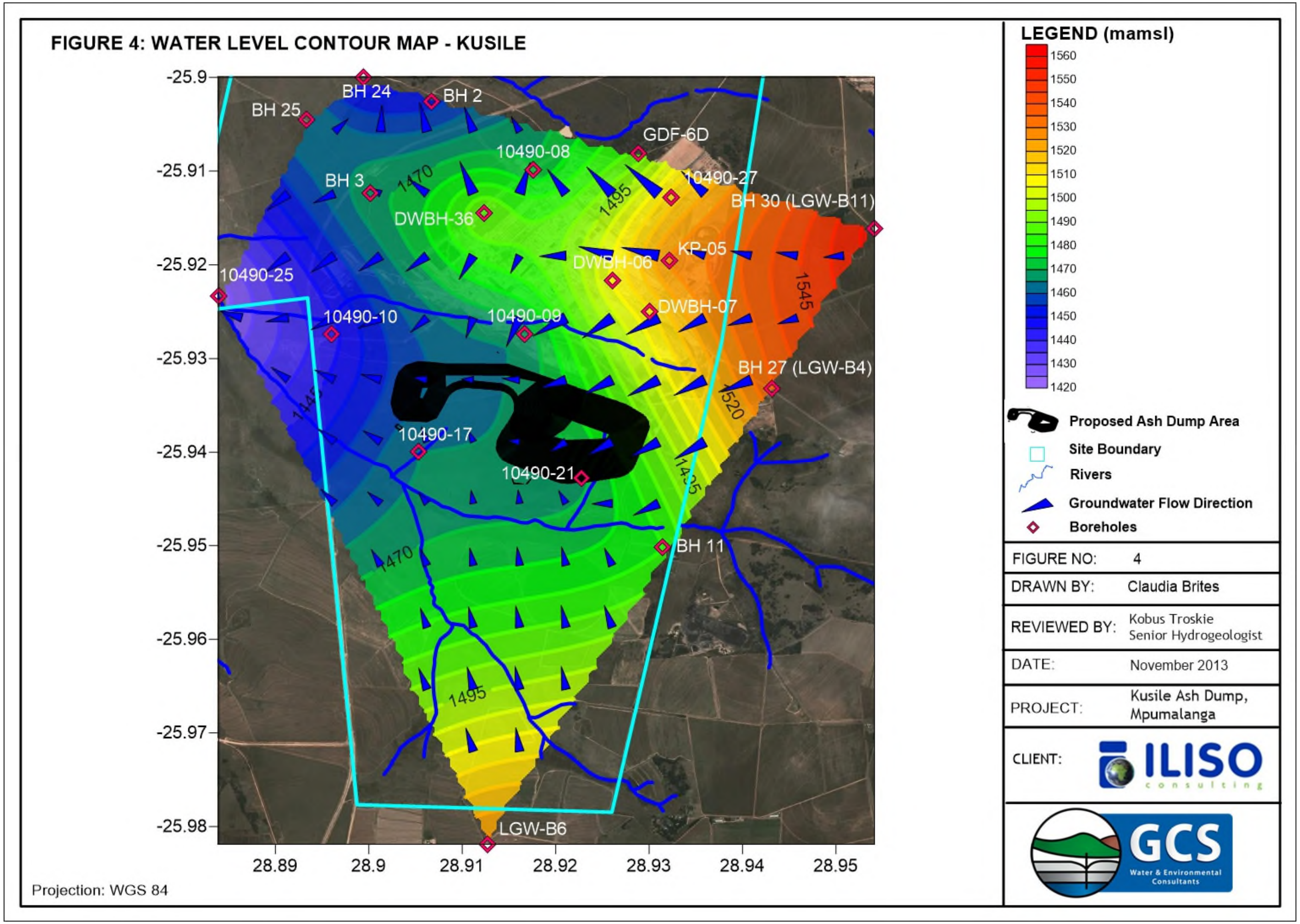

Figure 4: Groundwater Level Contour

6.3 Aquifer Testing

Short duration aquifer testing was carried out on the four boreholes on site, (10490-09, 10490-10, 10490-17 and BH 27 (LGW-B4)). The aquifer testing was conducted from the 29th October until the 1st November 2013. This allows for a better understanding of the aquifer hydraulic characteristics of the geological formations and the calculation of travel times of pollutants and the risk of contamination.

The short duration constant discharge test is used to determine the aquifer's response to stress (constant pumping) and to be able to calculate the aquifers hydraulic parameters i.e. transmissivity and storativity. The testing also allows for the identification of impermeable or recharge boundaries. The test involves monitoring the drawdown of the water level in the borehole while the discharge is kept constant.

The recovery test provides an indication of the ability of a borehole and groundwater system to recover from the stress of abstraction. This ability can again be analysed to provide information with regards to the hydraulic properties of the groundwater system.

The duration of the tests varied, based on how fast the borehole was pumped dry after which recovery was measured up until 90%. The results of the aquifer testing are presented in Table 6-4.

Table 6-4: Aquifer Test Results

Borehole ID	Borehole SWL (mach)	Borehole Depth (m)	Test (min)	Recovery Test (min)	Test Rate (l/s)	Transmissivity Theis residual drawdown/recovery method (m^2/day)
10490-09	5.39	25	12	90	0.8	0.5
10490-10	0.67	25	40	70	0.58	0.2
10490-17	4.45	25	7	120	0.8	-
BH 27 (LGW-B4)	8.96	32	120	15	0.92	-

The transmissivity of the aquifer unit was determined using Aqtesolv and is tabulated above. The transmissivity in the two boreholes associated with the Dwyka Formation (10490-09 & 10490-10) ranged from 0.3 to 0.5 m^2/day. The data obtained from borehole 10490-17 indicated insufficient results as minimal recovery was observed. This would be indicative of a very low yielding borehole with a low transmissivity value of less than 0.05 m^2/day. Borehole BH 27 (LGW-B4) indicated a high yielding borehole. In order to obtain accurate aquifer parameters for the borehole, long duration aquifer testing is recommended. Based on the results obtained, a transmissivity value ranging between 20 and 50 m^2/day was allocated for the borehole. The analysis of the aquifer test data is presented in Appendix A and Appendix B.

6.4 Groundwater Sampling

In total 10 hydrocensus boreholes were sampled. The samples were submitted to M&L laboratory services, a SANS accredited laboratory based in Johannesburg, South Africa.

Field observations for each sampling point, consisting of the following information, were recorded on field data sheets:

- Date of sampling;
- Coordinates of each borehole;
- Depth of water level;
- In-situ measurements for each sampling point, namely pH, electrical conductivity (EC), Total Dissolved Solids (TDS) and temperature;
- General characteristics of the water samples such as colour, turbidity and smell as well as visual observations of the sample site.

The hydrochemical sampling was carried out in accordance to the following publications:

- SABS ISO 5667-11:1993 Guidance on sampling of groundwater
- SABS ISO 5667-1:1980 Guidance on the design of sampling programs
- SABS ISO 5667-2:1991 Guidance on sampling techniques
- SABS ISO 5667-3:1994 Guidance on the preservation and handling of samples

Each sample was analysed according to the Table 6-5 below.

Table 6-5: Constituents required for analysis

Conductivity mS/m @ 25°C	Calcium, Ca
pH at 25°C	Magnesium, Mg (mg/l)
Total Dissolved Solids	Potassium, K
Ammonia as NH4	Sodium, Na
Bicarbonate, HCO_3	Aluminium as Al
Carbonate, CO_3	Manganese, Mn
Chloride, Cl	Iron, Fe
Fluoride, F	Zinc as Zn
Hexavalent Chromium as Cr6+	Lead, Pb
Hydroxide alkalinity as OH-	Copper as Cu
Nitrate as N	Chromium as Cr
Nitrate, NO_3	Arsenic
Nitrite as N	Nickel as Ni
Phenolic Compound as Phenol	Selenium as Se
Phosphate as PO4	Mercury as Hg
Sulfate, SO_4	Cobalt as Co
Total Alkalinity as $CaCO_3$	

The water qualities measured within the boreholes are tabulated in Table 6-6 and were compared to the SANS 241-1:2011 drinking water quality standards for domestic use. Many chemical substances in water are essential as part of the daily intake required, however at high concentrations they make water unpalatable and may cause illnesses.

The chemistry data provides baseline conditions in order to make comparisons too in the future to determine if the water quality has deteriorated based on the influence of the ash/gypsum disposal facility.

Table 6-6: Chemistry Analysis of the Boreholes Sampled

Parameter (mg/l)	Units	SANS 241-1: 2011	10490-09	10490-10	10490-17	10490-21	10490-25	BH11	BH27	BH3	BH30	LGW-B6
pH	pH units	5-9.7	6.8	6.5	7	7.4	8	6.9	6.4	7	6.8	8.1
Conductivity	mS/m @25°C	170	11	7.2	10.8	19.6	30.5	8.5	7.8	12.8	7.7	16.3
Total Dissolved Solids	mg/l	1200	86	50	54	122	166	16	6	74	30	84
Calcium	mg/l Ca	NV	8.7	5	5.8	15.7	18.4	2.3	0.84	9.2	5	18.1
Calcium Hardness as CaCO3	mg/CaCO3		22	12.5	14.5	39	46	5.7	2.1	23	12.5	45
Magnesium	mg/l Mg	NV	5	2.7	3.9	11.5	11.2	1.8	0.9	7.2	3.5	9.6
Magnesium Hardness as CaCO3	mg/CaCO3		21	11.1	16.1	47	46	7.4	3.7	30	14.4	40
Sodium	mg/l Na	200	9.2	6.9	9.1	19.9	48	4.5	2.2	7.2	2.7	6
Potassium	mg/l K	NV	2.8	1.6	4.2	1.2	3.2	2.2	0.96	5.2	2	7.2
T. Alkalinity	mg/l $CaCO_3$	NV	47	29	50	119	194	15	5.5	64	22	87
Phosphate	mg/l PO3	NV	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
Bicarbonate	mg/l HCO_3	NV	57	35	61	145	237	18.3	6.7	78	27	106
Carbonate	mg/l CO_3	NV	0	0	0	0	0	0	0	0	0	0
Chloride	mg/l Cl	300	2	3.7	1.7	0.9	2	2	0.4	2.6	1.6	1.6
Sulphate	mg/l SO_4	500	0.5	2.4	1.7	0.9	1.1	1.1	2.7	<0.2	1	0.2
Nitrate, NO3	mg/NO3	NV	13.2	0.7	<0.1	0.1	0.2	4	4.7	0.2	17.3	0.1
Nitrate	mg/l N	11	3	0.2	<0.1	<0.1	<0.1	0.9	1.1	<0.1	3.9	<0.1
Nitrite as N	mg/l N	0.9	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.2	<0.10
Fluoride	mg/l F	1.5	0.1	0.1	0.2	0.1	1.8	0.1	0.1	0.1	0.1	0.5
Ammonia	mg/l NH3	1.5	<0.10	<0.10	0.7	<0.10	0.1	<0.10	<0.10	0.7	0.4	0.5
Arsenic as As (µg/l)	mg/l As	0.01	0.001	<0.001	0.02	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
Aluminium	mg/l Al	0.3	0.03	0.22	<0.003	<0.003	0.006	0.14	0.009	0.007	0.03	0.01
Manganese	mg/l Mn	0.5	0.17	0.15	4	0.05	0.07	0.001	0.13	0.58	0.15	0.007
Cobalt	mg/l Co	0.5	0.001	0.001	<0.001	<0.001	0.001	0.001	0.001	0.001	0.001	0.001
Chromium	mg/Cr	0.05	0.005	<0.003	0.003	0.003	<0.003	0.003	<0.003	0.004	0.003	0.006
Sum of Cations	meq/ℓ	NV	1.318	0.816	1.11	2.62	4.015	0.515	0.235	1.502	0.711	2.138
Sum of Anions	meq/ℓ	NV	1.224	0.75	1.415	2.427	4.053	0.455	0.181	1.303	0.794	1.843
% Error	-	NV	3.698	4.215	-6.791	3.783	-0.471	6.846	-4.665	4.852	-5.263	5.665
Iron	mg/l Fe	2	0.18	0.12	0.1	0.07	0.36	0.13	0.03	0.03	0.11	0.05
Vanadium	mg/l V	0.2	0.02	0.01	0.01	0.04	0.04	0.007	0.003	0.02	0.01	0.03
Zinc	mg/l Zn	5	0.01	0.006	0.01	<0.005	<0.005	0.01	0.009	0.03	0.01	0.01
Lead	mg/l Pb	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/l Cu	2	0.01	0.009	0.01	0.01	0.02	0.02	0.007	0.009	0.01	0.02
Hydroxide Alkalinity as OH-	mg/l	NV	0	0	0	0	0	0	0	0	0	0

Values in red indicate concentration higher than SANS 241-1:2011

The chemistry of majority of the boreholes indicated very good water quality with very few parameters which were not compliant with the standards.

Boreholes 10490-17 and BH3 indicated non-compliant manganese with concentrations of 4mg/l and 0.58mg/l respectively, which exceeded the SANS standard of 0.5mg/l.

Borehole 10490-25 indicated non-compliance with the fluoride concentration of 1.8mg/l which exceeded the SANS standard of 1.5mg/l.

7 AQUIFER CLASSIFICATION

The aquifer associated with the ash/gypsum disposal area (Dwyka Formation) can be classified as a minor-aquifer system based on the hydrogeological data gathered during the field investigation as well as the Aquifer Classification Map of South Africa as published by the Department of Water Affairs (2012).

The aquifer classification is based on the Parson Aquifer Classification System (Parsons, R, 1995). A Minor Aquifer System comprises of fractured or potentially fractured rocks which do not have high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and supplying base flow to rivers.

However, based on the high transmissivity value from borehole BH 27 (LGW-B4), the aquifer associated with the Ecca Formation may be considered a major aquifer system.

8 ASH/GYPSUM DISPOSAL FACILITY LEACHATE

Drawing on research that has been done in South Africa on the impacts of ash from coal-fired power stations on specifically groundwater the following conclusions can be made. Numerous mitigation measures and best environmental practises are available for implementation:

- Without lining of the facility, the salt load in the groundwater will definitely increase, originating mainly from the process water waste streams co-disposed with the ash, together with evaporation processes to cool the power plant.
- The concentration of metals in the coal type determines the concentration of metals in the ash and therefore the leachate.
- Studies on South African sites show contamination of soils and groundwater directly under the ash disposal facility, with limited plume development and movement at well selected sites.
- Shallower water tables will develop as a mound under the disposal site, driving the groundwater flow in the direction of streams or other discharge points.
- Over the long term life of the ash disposal facility, the pH tends to decrease to around 7 and the mobilization of metals becomes problematic from below pH 9.
- Acid leaching will take place from the coal stockpiles (if not mitigated), increasing the overall potential for groundwater contamination.

Table 8-1: Major elements found in groundwater due to leaching from different ash disposal sites in South Africa (Adapted from M. Kolosa (2012))

Power Station	Wet/ Dry	Elements of concern from site monitoring	Geology	Status
Tutuka	Dry	Na, Cl, Ca and SO4	The site falls within the Carboniferous to early Jurassic aged Karoo Basin. Sediments here fall within the Permo-Triassic aged Northern facies of the Ecca Series	In use
Duvha	Wet	Salinity, SO_4, Na, Mg, Al, B, As, Cr, Fe, Ni, Se and Zn	Karoo environment consisting of sandstone, siltstone, mudstone and shale.	In use
Hedrina	Wet	Na, Ca, SO4, K, Cl	Karoo Supergroup, comprising of the Ecca Group and Dwyka Formation.	In use
Kragbron (Taaibos and Highveld)	Wet	SO_4	Underlain by the Karoo Super sedimentary rocks of the Ecca and Beaufort groups	20 years old not in use
Matimba	Dry	Na, Ca, Mg, K, Cl, SO4, Fe, Mn and B.	Coal occurs in both Vryheid and Grootegeluk formation of the Karoo Supergroup	In use
Majuba	Wet	Na, SO4, F and B	Built on Ecca and Beaufort sedimentary formation of the Karoo Supergroup	In use

9 QUANTITATIVE RISK ASSESSMENT

A quantitative risk assessment methodology was used for the risk assessment. This method makes use of the basic risk assessment approach of deriving an expression for risk from the product of likelihood and consequences. It works by attributing absolute values to likelihood (probability) and consequences as presented in Figure 5.

The main objective of the risk assessment is to identify the negative impacts that can be avoided and/or mitigated and the benefits of the positive impacts during the construction and operation phases of the co-disposal facility on the environment.

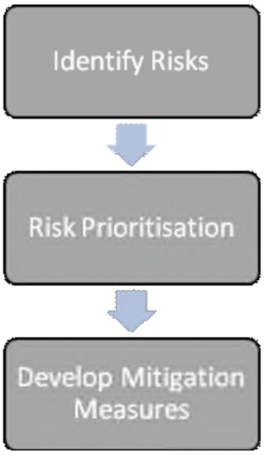

Figure 5: Summary of Quantitative Risk Assessment Methodology

9.1 Phase 1: Identification of Risks

The hazards identified with the proposed ash/gypsum disposal facility and its impact on the groundwater environment are as follows:

- Hydrocarbon Contamination
- Poor quality water leaching from ash/gypsum disposal facility on site recharging the groundwater;

9.2 Impact Assessment

The ash disposal facility may have the following impacts on the groundwater environment. A detailed description of possible impacts identified is discussed below.

9.2.1 Construction Phase - Hydrocarbon contamination

During the construction phase, hydrocarbon contamination is possible due to the presence of heavy machinery on site. Spillages may occur which may impact both the soil and groundwater environment. The impacts are costly and difficult to clean up, however, only small amounts envisaged.

9.2.2 *Operational Phase - Poor quality artificial recharge from the ash/gypsum disposal facility*

The major potential impacts of ash/gypsum disposal on groundwater resources are generally associated with changes in the pH of the water, the increase in salt content and the concentration of the potentially toxic trace elements. The most important factor in determining the resulting pollution impact of the ash/gypsum is the way in which it is stored.

During dry disposal, the ash still has a moisture content of up to 15% as this water is added to suppress the dust during transport and deposition.

Fly ash mainly consists of small, glassy hollow particles and contains all the natural elements, and in comparison with the parent material is enriched in trace elements. Studies show that trace elements are usually concentrated in the smaller ash particles. The ash is usually enriched in arsenic, boron, calcium, molybdenum, sulphur, selenium and strontium.

By understanding the chemistry of the ash, a better insight into its reactions with various other elements can be reached. The pH of the ash is normally elevated due to the abundance of calcium oxide. Calcium oxide usually constitutes about 8 % of the ash and is of great importance in the forming of the pozzolanic layer. As stated above, another factor that plays an important role is the presence of water in the ash. If there is enough water to isolate the ash from the atmosphere (as is the case with wet disposal) the ash will not be able to react with the oxygen in the air and the pozzolanic layer will not be able to form.

Should the ash be wetted and dried cyclically, the ash will have time to react with the atmosphere. This will cause a reaction between calcium oxide and the carbon dioxide that will then lead to the crystallisation of calcium carbonate (limestone). Another reaction that occurs is that between calcium and sulphate that results in the crystallisation of gypsum.

These two minerals (calcium carbonate and gypsum) form the so-called pozzolanic layer, which is a layer of very low permeability. The layer can be expected to occur in the upper 0.5 m of the ash disposal infrastructure. It is thus evident that the formation of the

pozzolanic layer is mostly confined where wetting and drying of ash occurs, during deposition in the wet process and near the surface on a dry ash pile.
Leaching from these ash/gypsum disposal sites may occur. Leaching experiments show that the element composition of the leachate does not necessarily reflect that of the whole ash sample proportionally. This suggests that for some elements a correlation of leachate quality to whole ash properties cannot be made. This is because the rate at which these elements will leach from the ash is dependent on:

- The form in which the element is present within the ash;
- The location of the element within the ash matrix; and
- Whether the element has been absorbed on to the ash particle surface.

Parts of the ash spheres are chemically stable in the environment and are resistant to weathering due to the alumino silicate matrix. Any element present in this matrix will be less readily available for leaching. However, elements absorbed onto the surface of the ash spheres will be more readily leached. Un-combusted mineral material may account for the presence of high concentrations of certain elements in the whole ash analysis. Leachate generated from these ashes may however, not reflect the high concentrations because the extraneous material associated with the ash are not in a form that is susceptible to leaching.

Water contained in the ash material during deposition can leach constituents from the ash disposal facility and transport it to the surrounding environment. Additional water that is recharged from rainfall will supplement the interstitial water and contribute to the leaching of elements. The water that migrates through the facility can either daylight along the edge of the ash disposal facility and enter the surrounding environment as surface water, or migrate vertically to the bottom of the disposal facility and enter the underlying soil from where it can recharge and contaminate the aquifers.

Co-disposal of ash and neutralised regeneration effluents must always be disposed of as a semi-homogeneous mixture and spread across the ash pile. Prolonged disposal of neutralised regeneration effluents in one location can compromise the pozzolanic characteristics of the ash (due to high sulphate concentrations), which will increase the risk of leaching.

The quality of the water seeping from the ash/gypsum facility is determined by performing leach and element enrichment testing. This includes a distilled water leachate test and acid-base accounting tests to determine the acid-neutralising and acid-generating capacity of the ash from which the net neutralising potential is calculated. The volume of water that will seep from the ash/gypsum disposal facility in the long term will be affected by the recharge from rainfall.

9.2.3 Operational Phase - Poor quality water from the Flue Gas Desulphurisation Wastewater Treatment Plant

An assessment of the potential impacts envisaged with the use of FGD technology on the water resources was conducted to assist in making decisions and developing management plans. The hazards identified with the use of FGD technology at a power station are related to the use of water in the emissions reduction process, the creation and storage of poor quality water and waste, and its impact on the groundwater environment.

Flue Gas Desulphurisation (FGD) waste will be dewatered and the poor quality water stored on site for reuse in the FGD process. The possibility exists that artificial recharge will occur through permeable soil and weathered material and contaminate the aquifer. At this stage, the details regarding where the waste water will be stored prior to treatment is not known. The dam/storage area where the waste water will be stored, must be lined

9.3 Phase 2: Quantitative Risk Assessment (Risk Prioritisation)

The risk assessment will involve the quantification of the risks associated with the project. The potential significance of potential environmental risks identified should be determined using the significance rating as described below. The terminology has been taken from the Guideline Documentation on EIA Regulations as follows:

- Severity / magnitude;
- Reversibility;
- Duration of impact; and
- Spatial extent.

Table 9-1 provides the criteria upon which the rating of the impacts are determined.

Table 9-1: Consequence and probability ranking

Severity/ magnitude (S)	Reversibility R	Duration (D)	Spatial extent E	Probability (P)
5 - Very high/ don't know	1 - Reversible (regenerates naturally)	5 - Permanent	5 - International	5 - Definite/ don't know

4 - High		4 - Long term (impact ceases after operational life)	4 - National	4 - High probability
3 - Moderate	3 - Recoverable (needs human input)	3 - Medium term (5 - 15 years)	3 - Regional	3 - Medium probability
2 - Low		2 - Short term (0 - 5 years)	2 - Local	2 - Low probability - negligible
1 - Minor	5 - Irreversible	1 - Immediate	1 - Site only	1 - Improbable
0 - None				0 - None

The maximum value which can be obtained is 100 significance points. The risks will be rated as High, Moderate or Low significance by combining the consequence of the impact and the probability of occurrence:

Consequence = severity + reversibility + duration + spatial scale

Consequence X Probability = Significance

- More than 60 significance points indicate High environmental significance;
- Between 30 and 60 significance points indicate Moderate environmental significance;
- Less than 30 significance points indicate Low environmental significance.
- The abovementioned criteria will be used to generate likelihood (probability) and consequence for the construction and operation phases of the project as follows:

Table 9-2: Quantitative Risk Assessment for Construction Phase

Construction Phase														
	Rating Before Mitigation Measures							Rating After Mitigation Measures						
Risk	S	R	D	E	C	P	Significance = C*P	S	R	D	E	C	P	Significance = C*P
Hydrocarbon contamination associated with heavy machinery on site	3	3	3	2	11	3	33	3	3	3	2	11	2	22

Table 9-3: Quantitative Risk Assessment for Operation Phase

Operational Phase														
	Rating Before Mitigation Measures							Rating After Mitigation Measures						
Risk	S	R	D	E	C	P	Significance = C*P	S	R	D	E	C	P	Significance = C*P
Poor quality artificial recharge from the ash gypsum co-disposal facility	4	3	4	2	13	4	52	3	3	4	2	12	3	36
Artificial recharge to groundwater	3	3	4	2	12	4	48	2	3	4	2	11	3	33
Poor quality water emanating from the Flue Gas Desulphurisation Wastewater Treatment Plant	4	3	4	1	12	4	48	2	3	4	1	10	3	30

9.3.1 Construction Phase - Hydrocarbon contamination

During the construction phase, hydrocarbon contamination is possible due to the presence of heavy machinery on site. Spillages may occur which may impact both the soil and groundwater environment. The impacts are costly and difficult to clean up, however, only small amounts envisaged.

Table 9-2 tabulates the impact of hydrocarbon contamination on site and the impacts on the soil and groundwater environment. The associated ratings and scores of the impact after mitigation measures are in place are detailed below. The score of 33 points results in a moderate environmental significance with mitigation in place.

The mitigation measures would include secondary containment for all fuel stored on site. Mitigation measures would also include implementing the proposed groundwater monitoring programme as detailed in Section 10. This would allow for the early detection of water quality deterioration associated with the site. Accurate oil records must be kept (purchased, disposal, and recycled). Ensure clean up protocols in place and followed. The score of 22 points results in a low environmental significance with mitigation in place.

9.3.2 Operational Phases - Poor quality artificial recharge from the ash/gypsum co-disposal facility

Table 9-3 tabulates the impact of poor quality artificial recharge from the ash/gypsum co-disposal facility and the associated ratings and scores of the impact before mitigation measures are in place. The score of 52 points results in a moderate environmental significance without mitigation in place.

The mitigation measures would include lining the ash/gypsum co-disposal facility. This would reduce the impact on the groundwater environment as it inhibits the seepage of poor quality water into the aquifer. Mitigation measures would also include implementing the proposed groundwater monitoring programme as detailed in Section 10. This would allow for the early detection of water quality deterioration associated with the site. The score of 36 points results in a moderate environmental significance with mitigation in place.

Furthermore, it is recommended that leach tests are conducted on the ash/gypsum waste in order to determine the leachable concentrations of the waste samples and whether they are within acceptable limits. The results can also be used to assess the type of waste in accordance to in accordance with the National Environmental Management: Waste Act (NEMWA - Act 59 of 2008).

9.3.3 Operational Phases - Artificial recharge to groundwater

Table 9-3 tabulates the impact of artificial recharge from the dirty water dams and station dirty dam and the associated ratings and scores of the impact before mitigation measures are in place. The score of 48 points results in a moderate environmental significance without mitigation in place.

The mitigation measures would include lining the raw water dams. This would reduce the impact on the groundwater environment as it inhibits the seepage of poor quality water into the aquifer. Mitigation measures would also include implementing the proposed groundwater monitoring programme as detailed in Section 10. This would allow for the early detection of water quality deterioration associated with the site. The score of 33 points results in a moderate environmental significance with mitigation in place.

9.3.4 Operational Phase - Poor quality water from the Flue Gas Desulphurisation Wastewater Treatment Plant

Table 9-3 tabulates the impact of poor quality from the Flue Gas Desulphurisation Wastewater Treatment Plant and the associated ratings and scores of the impact before mitigation measures are in place. The score of 48 points results in a moderate environmental significance without mitigation in place.

The mitigation measures would include a closed system for the Flue Gas Desulphurisation Wastewater Treatment Plant. Ensuring the area where the waste water is to be stored is lined, will reduce the impact on the groundwater environment as it inhibits the seepage of poor quality water into the aquifer. Additionally, the water will be treated, as the site is a zero-liquid effluent discharge site. The treatment is a three step process, which involves pre-treatment, evaporation, concentration and crystallisation. The clean water is then re-used and the waste is deposited on the ash/gypsum disposal facility. Mitigation measures would also include implementing the proposed groundwater monitoring programme as detailed in Section 10. This would allow for the early detection of water quality deterioration associated with the site. The score of 30 points results in a moderate environmental significance with mitigation in place.

10 PROPOSED GROUNDWATER MANAGEMENT PLAN

A Groundwater Management Plan is required to ensure that the ash/gypsum disposal facility does not impact negatively on groundwater levels and quality to unacceptable levels. To ensure that the groundwater environment is protected, monitoring of water quality and levels is required on an on-going basis. The recommended monitoring includes groundwater level and groundwater quality monitoring as well as the visual inspection of the boreholes, as outlined below.

The Kusile Power Station has sufficient amounts of monitoring boreholes surrounding the site, including the area of the proposed ash disposal facility, given that none of the existing boreholes are destroyed during construction and operation of the ash/gypsum disposal facility. It is imperative that these boreholes are monitored on a regular basis.

It is important that if any boreholes located on the site footprint is destroyed, that the borehole is backfilled using a cement – bentonite slurry so as to prevent direct migration of potentially poor quality water into the aquifers, before any ash is deposited in the area surrounding the borehole.

The following boreholes are currently being monitored by Zitholele Consulting: 10490-09, 10490-10, 10490-17, 10490-21, 10490-25, 10490-27, BH2, BH3, BH11, BH25, BH27, BH30, GDF-6D, DWBH-06, DWBH-07 and DWBH-36 in order to comply with the conditions of the Environmental Authorisation (EA) issued by the Department of Environmental Affairs (DEA), and the Water Use License (WUL) from the Department of Water Affairs (DWA).

Based on the application for integrated waste management license, it is proposed that the boreholes should be sampled on a quarterly basis as per Table 10-1, which are presented on Figure 3. The monitoring programme should also be in line with the requiremnets of the Water Use license issued by the Department of Water Affairs. This includes all boreholes sampled during this investigation.

Table 10-1: Monitoring Schedule

Borehole Name	Proposed Sampling Frequency	Analysis
10490-09	Quarterly for indictor elements and a full analysis on an bi-annual basis	Indicator elements include TDS, SO4, Na, Cl, Mg, Al, B, As, Cr, Fe, Ni, Se and Zn As per Table 6.6 for bi-annual analysis
10490-10		
10490-17		
10490-21		
10490-25		

BH11		
BH 27 (LGW-B4)		
BH 3		
BH 30 (LGW-B11)		
LGW-B6		

A significant data set is currently in place for baseline data as the groundwater monitoring is already in place. Therefore all new data collected from the existing boreholes must be compared to the existing data to identify any trends in the groundwater levels and chemistry over time. Long-term groundwater monitoring at similar ash disposal facilities have indicated varying degrees of groundwater quality deterioration.

Typically groundwater monitored within boreholes adjacent to ash/gypsum disposal facilities indicates a rise in the salt content of the groundwater due to seepage from surface sources and also because of the dissolution of salt from the previously unsaturated zones. The increase in salinity is, therefore, a combination of artificial recharge from poor quality (saline) surface water sources and the mobilisation of salts in the exposed zones in the boreholes.

The rate of salts leaching into the subsurface depends on the ash/gypsum disposal facility (wet versus dry), liners, soil /geology and depth to water level. Typically very slow migration of salts and metals are expected if the site is well selected and managed.

Water levels are in general are expected to rise due to the availability of water on the site and increase in recharge from both the clean water and dirty water systems. This will cause a flow gradient away from the site, even in slight upgradient direction of groundwater flow.

If the monitoring data indicates the need for corrective action, the magnitude of the impact must be assessed by an appropriately qualified and experienced specialist and the necessary measures put forward based on the magnitude of the impact.

11 CONCLUSIONS AND RECOMMENDATIONS

GCS undertook a hydrogeological study in October 2013, for the ESKOM Kusile Power Station is a coal-fired power station close to the existing Kendal Power Station in the Nkangala District of the Mpumalanga Province.

The hydrogeological investigation included a hydrocensus, evaluation of existing data, aquifer testing of existing monitoring boreholes as well as sampling of the monitoring boreholes.

In total, 20 boreholes were identified during the hydrocensus from which data was collected, which included static water levels. The depths of the boreholes ranged from 16 to 60 metres. The static water levels recorded ranged between 0.59 to 25.34 mbgl (metres below ground level).

The transmissivity in the two boreholes associated with the Dwyka Formation (10490-09 & 10490-10) ranged from 0.3 to 0.5 m^2/day. The data obtained from borehole 10490-17 indicated insufficient results as minimal recovery was observed. This would be indicative of a very low yielding borehole with a low transmissivity value of less than 0.05 m^2/day. Borehole BH 27 (LGW-B4) indicated a high yielding borehole and the pump test results indicated insufficient drawdown based on the pump capacity.

The chemistry of majority of the boreholes indicated good water quality with very few parameters which were not compliant with the SANS 241-1:2011 drinking water quality standards for domestic use.

Boreholes 10490-17 and BH3 indicated non-compliant manganese with concentrations of 4mg/l and 0.58mg/l respectively, which exceeded the SANS standard of 0.5mg/l. Borehole 10490-25 indicated non-compliance with the fluoride concentration of 1.8mg/l which exceeded the SANS standard of 1.5mg/l.

A quantitative risk assessment methodology was used for the risk assessment. This method makes use of the basic risk assessment approach of deriving an expression for risk from the product of likelihood and consequences. It works by attributing absolute values to likelihood (probability) and consequences.

The hazards associated with the proposed ash/gypsum co-disposal facility and its impact on the groundwater environment include: Hydrocarbon contamination as well as poor quality water stored on site recharging the groundwater. The impact of hydrocarbon contamination on the soil and groundwater environment during construction indicates moderate environmental significance without mitigation in place and low environmental significance with mitigation in place.

Another negative impact envisaged is the result of poor quality artificial recharge from the ash/gypsum disposal facility. The mitigation measures would include lining the ash/gypsum disposal facility. This would reduce the impact on the groundwater environment as it inhibits the seepage of poor quality water into the aquifer. Mitigation measures would also include implementing the proposed groundwater monitoring programme as detailed in Section 10.

There are also negative impacts associated with the Flue Gas Desulphurisation Wastewater Treatment Plant and the possibility of poor quality water and waste impacting on the environment. The mitigation measures would include lining the area where the waste water will be stored on site.

A groundwater management plan is required to ensure that the ash/gypsum disposal facility does not impact negatively on groundwater levels and quality to unacceptable levels. To ensure that the groundwater environment is protected, monitoring of water quality and levels is required on an on-going basis. The recommended monitoring includes groundwater level and groundwater quality monitoring as well as the visual inspection of the boreholes, as outlined below.

The following boreholes are currently being monitored by Zitholele Consulting: 10490-09, 10490-10, 10490-17, 10490-21, 10490-25, 10490-27, BH2, BH3, BH11, BH25, BH27, BH30, GDF-6D, DWBH-06, DWBH-07 and DWBH-36 in order to comply with the conditions of the Environmental Authorisation (EA) issued by the Department of Environmental Affairs (DEA), and the Water Use License (WUL) from the Department of Water Affairs (DWA).

Based on the application for integrated waste management license, it is proposed by GCS that the boreholes should be sampled on a quarterly basis as per Table 10-1 which includes all boreholes sampled during this investigation. Boreholes should be sampled on a quarterly basis for indicator elements and a full analysis on a bi-annual basis.

Furthermore, it is recommended that leach tests are conducted on the ash/gypsum waste in order to determine the leachable concentrations of the waste samples and whether they are within acceptable limits. The results can also be used to assess the type of waste in accordance to in accordance with the National Environmental Management: Waste Act (NEMWA - Act 59 of 2008).

12 REFERENCES

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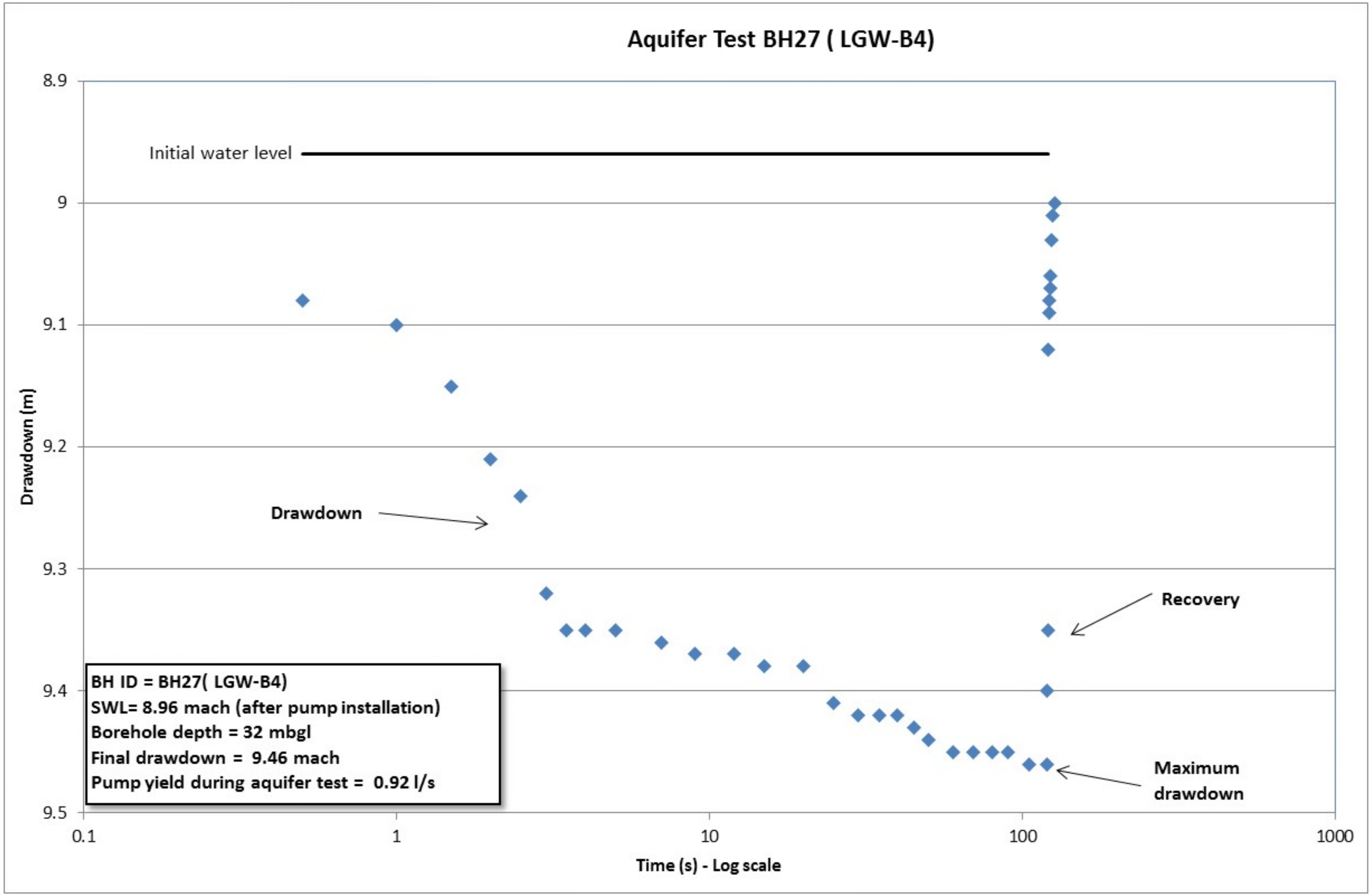
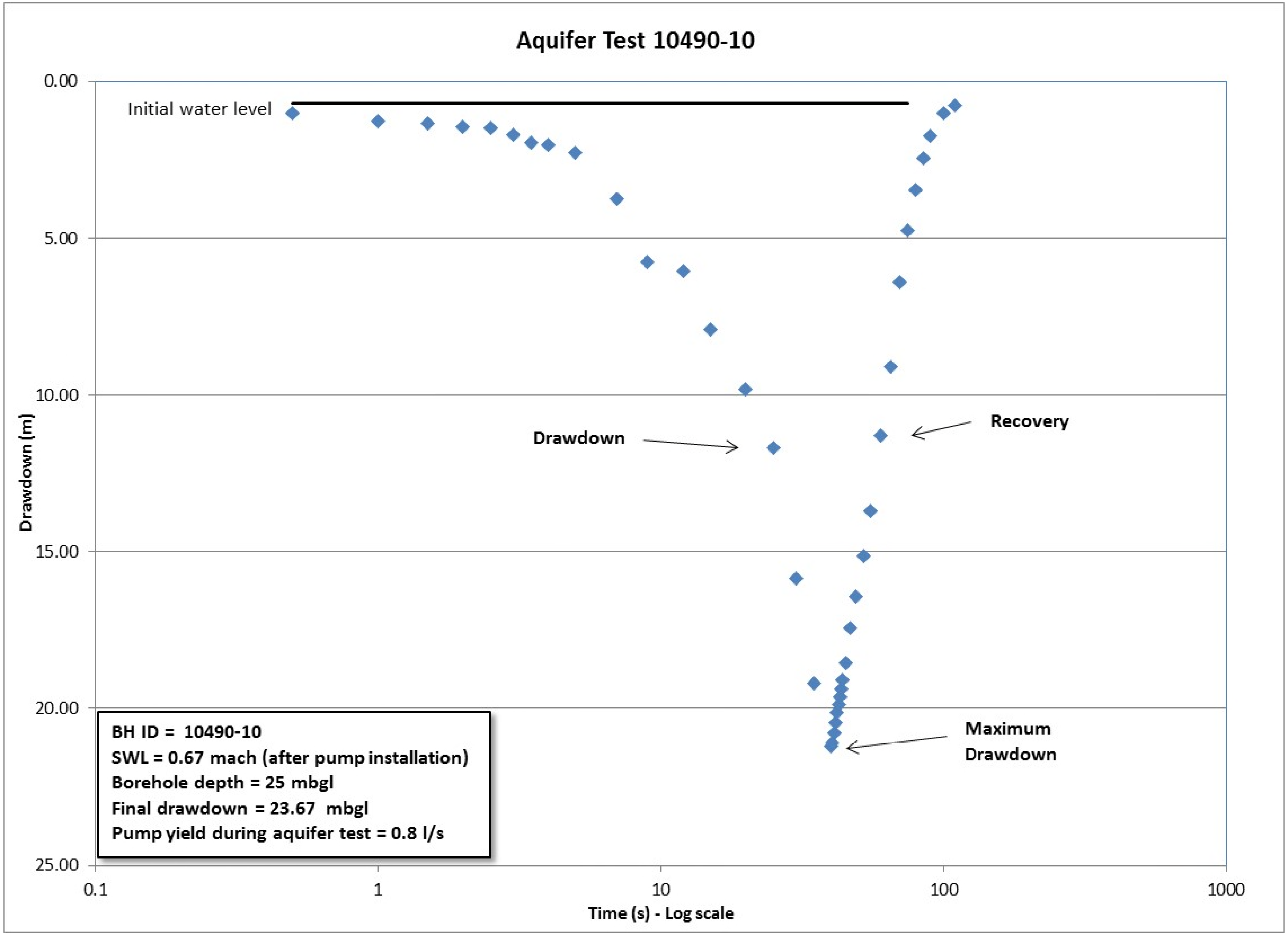
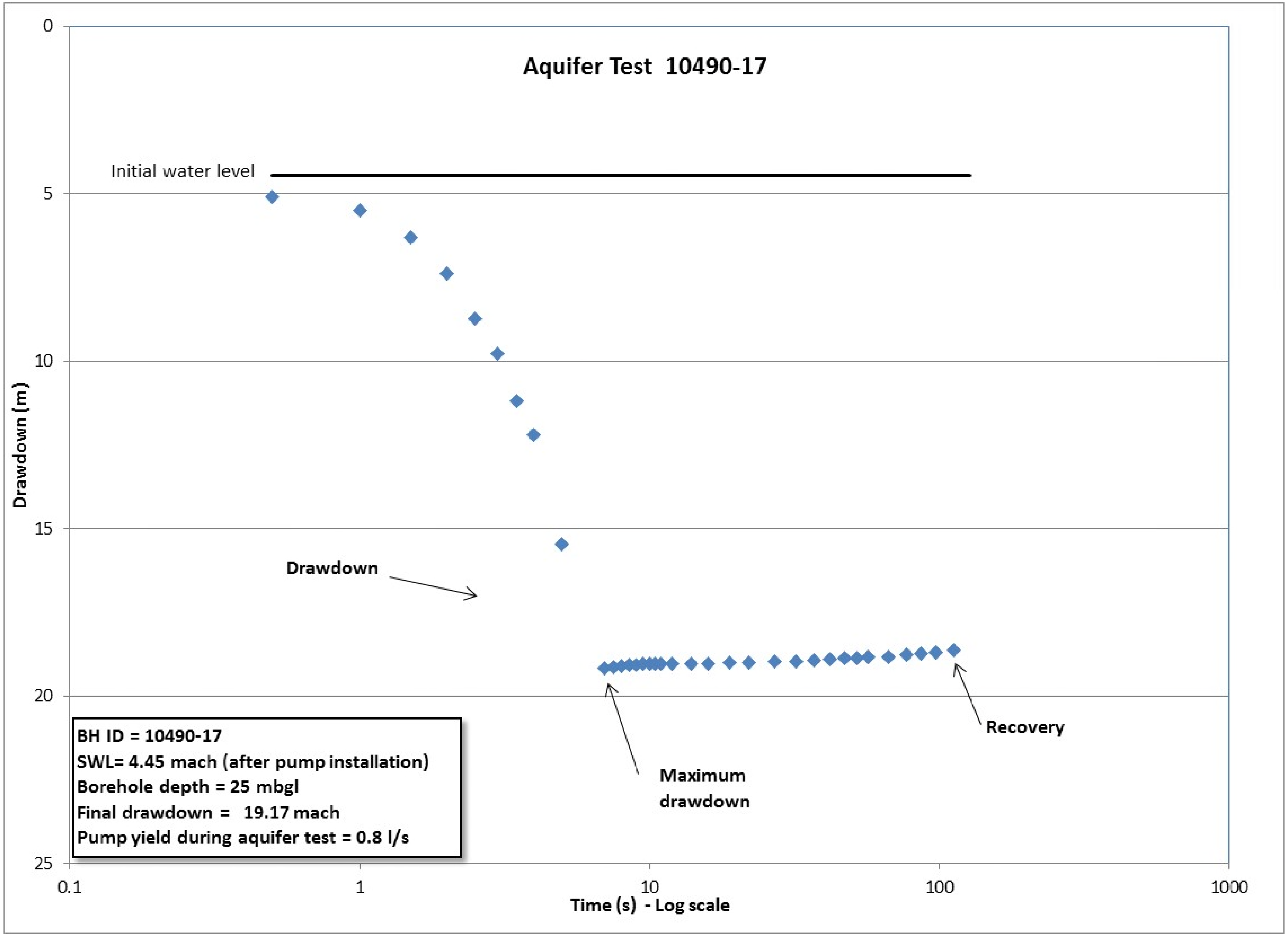
Zitholele Consulting, 2013. Surface and Groundwater Monitoring for Kusile Power Station, Report No: 12820:7

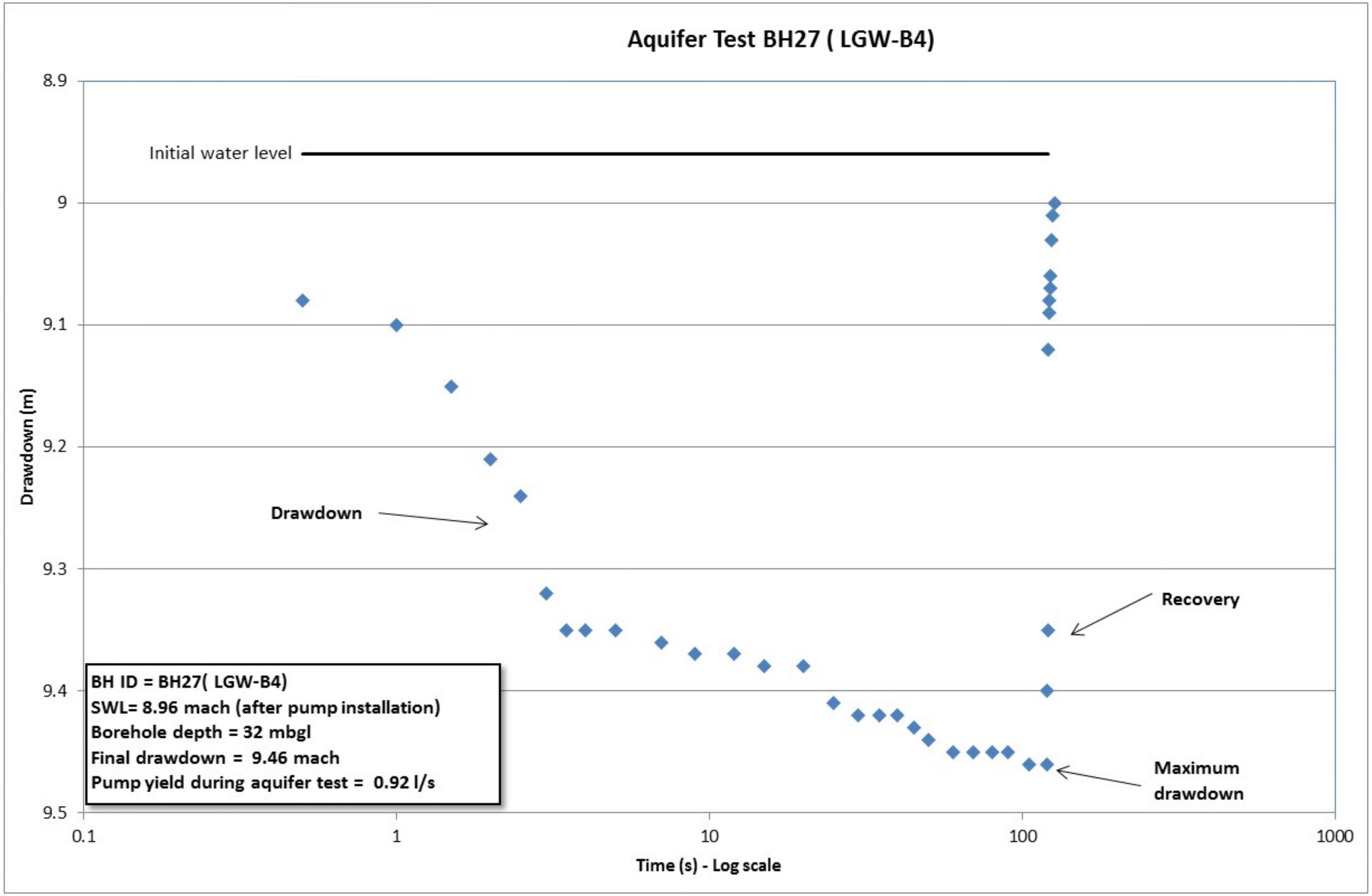
APPENDIX A
AQUIFER TEST DATA





Aquifer Test 10490-10
0.00
5.00
10.00
15.00
20.00
25.00
Drawdown (m)
Initial water level
Drawdown
Recovery
Maximum Drawdown
BH ID = 10490-10
SWL = 0.67 mach (after pump installation)
Borehole depth = 25 mbgl
Final drawdown = 23.67 mbgl
Pump yield during aquifer test = 0.8 l/s
0.1
1
10
100
1000
Time (s) - Log scale


Aquifer Test 10490-17
Initial water level
Drawdown
Maximum drawdown
Recovery
BH ID = 10490-17
SWL= 4.45 mach (after pump installation)
Borehole depth = 25 mbgl
Final drawdown = 19.17 mach
Pump yield during aquifer test = 0.8 l/s
Drawdown (m)
0
5
10
15
20
25
0.1
1
10
100
1000
Time (s) - Log scale


Aquifer Test BH27 (LGW-B4)
8.9
9
9.1
9.2
9.3
9.4
9.5
Drawdown (m)
Initial water level
Drawdown
Recovery
Maximum drawdown
BH ID = BH27(LGW-B4)
SWL= 8.96 mach (after pump installation)
Borehole depth = 32 mbgl
Final drawdown = 9.46 mach
Pump yield during aquifer test = 0.92 l/s
0.1
1
10
100
1000
Time (s) - Log scale

APPENDIX B
AQUIFER TEST ANALYSIS

APPENDIX C
LABORATORY CHEMISTRY