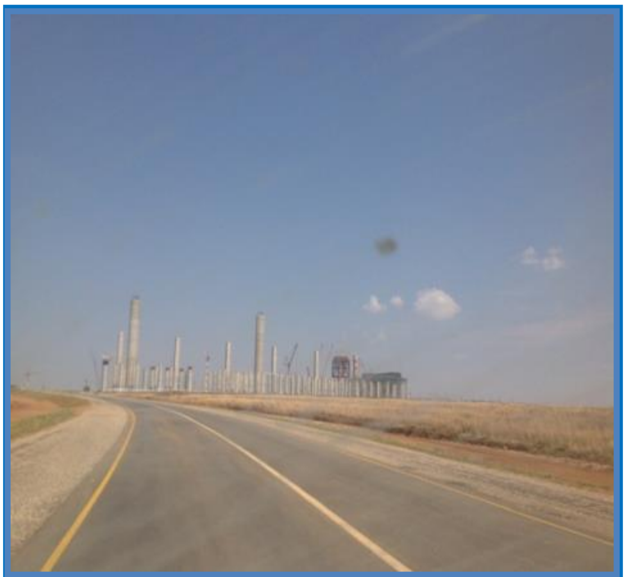

PROPOSED KUSILE ASH DISPOSAL FACILITY

Bio-physical study: Groundwater Assessment

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water earth life

February 2014

PROPOSED KUSILE ASH DISPOSAL FACILITY

Bio-physical study: Groundwater Assessment

FINAL

ZITHOLELE CONSULTING

Report Issue	Update with ADF leaking Scenarios (05)
Aqua Earth Reference Number	AEC0180/05/03-2014
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Title	Proposed Kusile Ash Disposal Facility. Biophysical study: Groundwater Assessment.

List of Abbreviations

AEC	Aqua Earth Consulting
EC	Electrical Conductivity
K	Hydraulic Conductivity
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NWA	National Water Act (Act 36 of 1998)
NEMA	National Environmental Management Act
EA	Environmental Assessment
S	Storativity
SA	South Africa
T	Transmissivity

Units of Measurement

a	annum
cm	centimetre
d	day
i	gradient
km^2	square kilometre
ℓ	litre
m	metre
m^2	square metre
m^3	cubic metre
mamsl	metres above mean sea level
mbgl	metres below ground level
mg/ℓ	milligrams per litre
mm	millimetre
mS	millisiemens
q	flux
s	second

Glossary

Abstraction: The act of removing water from a groundwater resource.

Alluvial Aquifer: An aquifer comprising unconsolidated material deposited by water, typically occurring adjacent to rivers and in buried paleo channels.

Aquifer: Aquifer means a geological formation which has structures or textures that hold water or permit appreciable water movement through them.

Aquifer Testing: Aquifer testing involves the withdrawal of measured quantities of water from or the addition of water to, a borehole(s); and the measurement of resulting changes in head in the aquifer both during and after the period of abstraction or addition.

Artesian Borehole: Boreholes that penetrate confined aquifers in which the piezometric surface is above ground level, so that the boreholes spontaneously discharge water without being pumped.

Baseflow: Sustained low flow in a river during dry or fair weather conditions, but not necessarily all contributed by groundwater; includes contributions from interflow and groundwater discharge.

Borehole: Includes a well, excavation, or any other artificially constructed or improved underground cavity which can be used for the purpose of intercepting, collecting or storing water in or removing water from an aquifer; observing and collecting data and information on water in an aquifer; or recharging an aquifer.

Borehole Log: A record of the geological and hydrogeological conditions encountered in the drilling of a borehole and the construction thereof.

Borehole Yield: The volume of water that can be abstracted from a borehole.

Catchment: Catchment in relation to watercourse or watercourses or part of a watercourse means the area from which any rainfall will drain into the watercourses, or part of a watercourse, through surface flow to a common point or points.

Conceptual Model: A conceptual model includes designing and constructing equivalent but simplified conditions for the real world problem.

Cone of Depression: The depression of hydraulic head around a pumping borehole caused by the withdrawal of water.

Contamination: The introduction of any substance into groundwater systems by the action of man.

Drawdown: The distance between the static water level and the surface of the cone of depression.

Dyke: A tabular or sheet-like body of igneous rock that cuts through and across the layering of adjacent rocks.

Electrical Conductivity (EC): Electrical conductivity is a measure of how well a material accommodates the transport of electric charge. The more salts dissolved in the water, the higher the EC value. It is used to estimate the amount of total dissolved salts, or the total amount of dissolved ions in the water.

Fault: A zone of displacement in rock formations resulting from forces of tension or compression in the earth's crust.

Fracture: Any break in a rock including cracks, joints and faults.

Fracture Flow: Water movement that occurs predominantly in fractures and fissures.

Hydraulic Conductivity: Measure of the ease with which water will pass through the earth's material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (m/d).

Hydraulic Gradient: The rate of change in the total hydraulic head per unit distance of flow in a given direction.

Hydraulic Head: Hydraulic head is the height above a datum plane such as sea level of the column of water that can be supported by the hydraulic pressure at a given point in a groundwater system.

Monitoring Borehole: A borehole used to measure groundwater trends.

Observation Borehole: A borehole used to measure the response of the groundwater system to an aquifer test.

Porosity: Porosity is the ratio of the volume of void space to the total volume of the rock or earth material.

Quaternary Catchment: A fourth order catchment in a hierarchal classification system in which a primary catchment is the major unit.

Recharge: The addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.

Remediation: Reduce the concentrations of contaminants in groundwater to some acceptable level.

Rest Water Level: The groundwater level in a borehole not influenced by abstraction or artificial recharge.

Saturated Zone: The subsurface zone below the water table, where interstices are filled with water under pressure greater than that of the atmosphere.

Semi-confined Aquifer: An aquifer that is partly confined by layers of lower permeability material through which recharge and discharge may occur.

Specific Yield (Sy): The ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium.

Transmissivity (T): The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.

Unconfined Aquifer: An aquifer where the water table is the upper boundary and with no confining layer between the water table and the ground surface. The water table is free to fluctuate up and down.

Unsaturated Zone: That part of the geological stratum above the water table where interstices and voids contain a combination of air and water, synonymous with zone of aeration or vadose zone.

Water table: The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is equal to that of the atmosphere.

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1 Introduction

1.1 Preamble

Aqua Earth Consulting cc (AEC) was commissioned by Zitholele Consulting (Pty) Ltd (Zitholele) to conduct groundwater assessment (specialist study) associated with the 60 years ash disposal facility of the Eskom's Kusile Power Station (EKPS).

The EKPS is under construction and is a coal fired power station with an estimated life greater than 60 years. The ash production at the EKPS is estimated between 530 and 796 Millions m^3 over 60 years. Appropriate sites are thus needed for the disposal of such amount of ash. Identification of feasible sites needs to be based on the Environment Assessment and WML which involve specialist studies as required by the "Impact assessment regulations 2010" in terms of Chapter 5 of the National Environmental Management Act, 1998[1] (NEMA).

The EKPS is located on the R545 road, within the farms Hartebeesfontein 537 JR and Klipfontein 566 JR near Emalahleni in Mpumalanga Province, at approximately 100 kilometres east of Pretoria. The R545 road is at approximately seven kilometres south of the N4 highway between Bronkhorspruit and Witbank.

The present document reports on the groundwater assessment conducted from November 2012 to November 2013, and associated with the 60 years ash disposal facility of EKPS.

1.2 Scope of the work

The present groundwater assessment is part of specialist studies for IRP and WUL and includes the following objectives:

- Characterize the prevailing groundwater situation,
- Define the water bearing strata in the area,
- Determine current groundwater levels distribution and flow directions,
- Determine baseline groundwater quality,
- A full description of potential impacts (direct and indirect) will be provided, relative to these specific developments.
- Practical mitigation measures will be recommended and discussed.
- If a need for the implementation of a monitoring programme in the EMP phase is evident, it will be highlighted and a programme proposed.
- 5x field surveys.

[1]Act No. 107 of 1998

- Buid a numerical groundwater flow and mass transport for the most two preferered scenarios

The present document report on these reached objectives.

1.3 Specific tasks

Subsequent to the above objectives, the following tasks have been proposed for the groundwater assessment:

- Desktop studies including review of existing monitoring data, maps and reports;
- Hydrocensus including locate existing boreholes and some major surface water bodies (Rivers and dams). Groundwater level measurement in the boreholes and sampling of water for portability analysis are also part of the hydrocensus;
- Geophysical surveys and interpretations for sitting of additional boreholes;
- Drilling of additional boreholes;
- Aquifer pump testing and interpretation;
- Comparative impacts risk Assessment;
- Geohydrological numerical modelling of the preferred site;
- Definition of the monitoring and management plan;
- Final Reporting;

1.4 Specialist details

Details of specialist and declaration of interest in respect of an application for authorisation in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended, and the Environmental Impact Assessment Regulations, 2010 are provided.

PROJECT TITLE

Proposed Kusile Ash Disposal Facility. Biophysical study: Groundwater Assessment.

Specialist:	AQUA EARTH CNSULTING		
Nature of specialist study compiled:	Groundwater Assessment.		
Contact person:	AHOKPOSSI D P		
Postal address:	PO.BOX :1747 North Riding		
Postal code:	2162	**Cell:**	0735721424
Telephone:	0117913490	**Fax:**	0115076612
E-mail:	Pacome@aquaearth.co.za		
Qualifications & relevant experience:	Msc Geohydrology (10 years)		
Professional affiliation(s) (if any)	SACNASP		

1.5 Declaration of Independence

Aqua Earth was appointed as subcontractor to conduct a specialist groundwater study as part of the Kusile 60 Years Ash Dam Disposal specialist studies for IRP and WUL and act as the independent specialists in this application. Aqua Earth will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant. Aqua Earth has the expertise in conducting the specialist report relevant to this application and will not engage in conflicting interests in the undertaking of this study. The specialist declaration is included in Appendix 1: Specialist Declaration.

1.6 Sources of Information

Information sourced for this study included (not limited to) the following data and literature:

- Kusile Power Station Construction and Operation Environment Management Plan (Task Order Number: 5407/10 ; Date: 14 October 2008);
- Surface and Groundwater Monitoring at Kusile Power Station – Report No: 12687 - May 2011;
- Surface and Groundwater Monitoring For Kusile Power Station Report No: 12687 - February 2012
- Surface and Groundwater Monitoring For Kusile Power Station Report No: 12687 – Summary Report – February 2012 ;
- Aquatic and Wetland Assessment - 2012 Monitoring Cycle - Report No: 12820 – A01- August 2012;
- Groundwater specialist study report. NEW LARGO/GROUNDWATER/VER-02/2012;
- New Largo Colliery – Final Environmental Impact Assessment Report-S0403-NLC-EIA-01-July 2012;
  Groundwater and surface water data (water levels and water quality) collected by Zitholele in June and July 2012 as part of contaminations investigation (monitoring) for the Kusile power station project;
- Groundwater data (water levels and water quality) in New Largo provided by Zitholele (April 2013);
- “1/250 000 Geological Series: 2528 Pretoria published in 1978 by the Government Printer;
- 1/250 000 Geological Series: 2628 East Rand” published in 1986 by the Government Printer.
- An Exploration of the 1:500 000 general hydrogeology map by H.C. Barnard – October 2000.

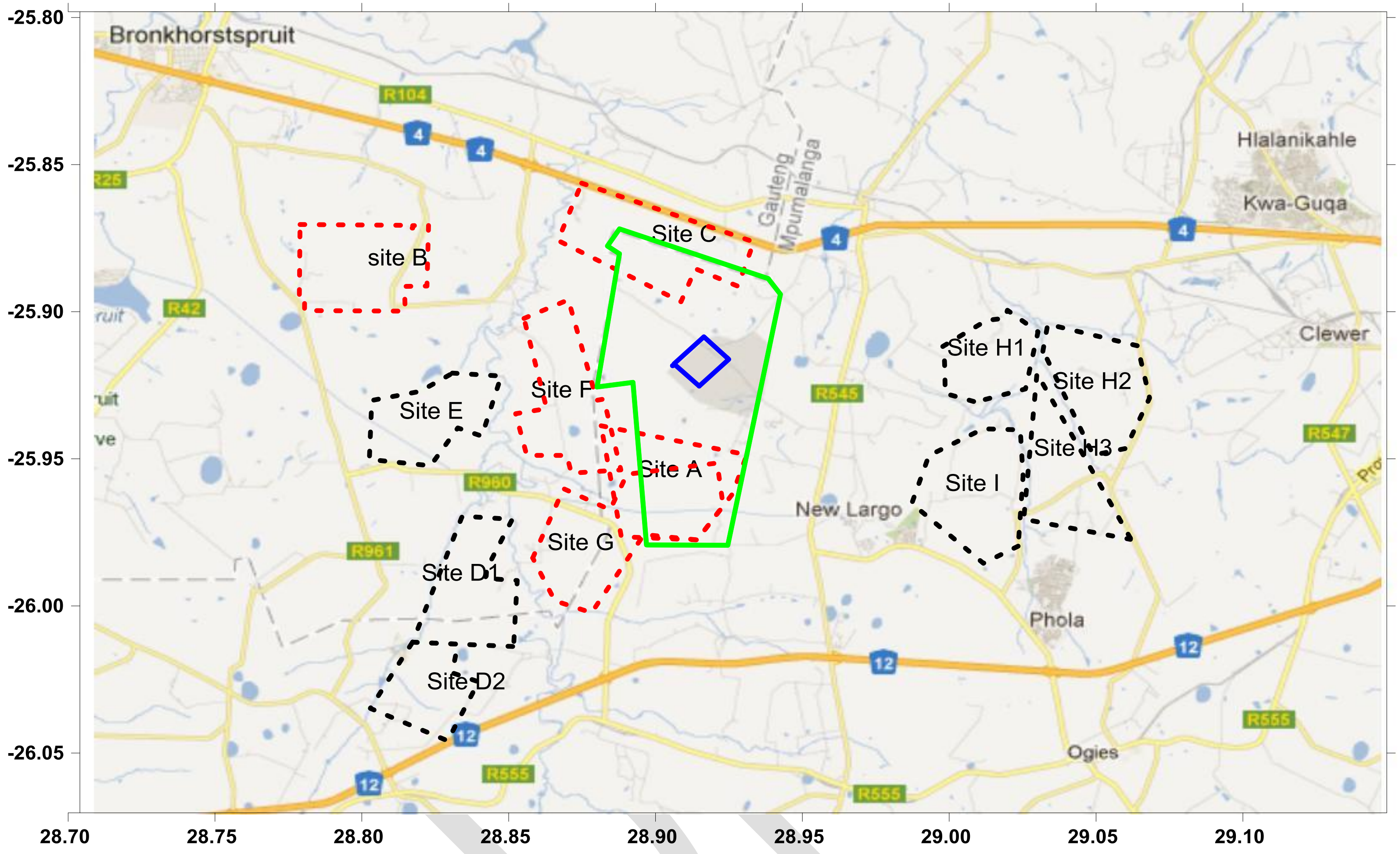
In addition of this sources, information (drawings, Power point presentation) presented by Zitholele during the workshop conducted late November 2012 to provide background to the project and for specialist briefing presentation have also been used in the present report.

2 Description of the Baseline Receiving Environment

2.1 Location

Preliminary studies (scoping report) have identified 12 potential areas (A, B, C, D1, D2, E, F, G, H1, H2, H3, I) that could be used to accommodate 60 years of produced ash as shown in figure 1. These sites are located at less than 15 km from the EKPS and vary in size from 1 300ha to 2 000ha. The study area is limited in the north by the N4 and in the south by the N12. The western and the eastern boundaries of the study area are located at approximately 15 km from the location of the power station and follow water divided.

By combining technical, environmental, and social rating elements, five (5) areas (A, B, C, F, and G) have been considered from the twelve (12) identified sites, for further investigations. With these five (5) alternative areas six (6) potentials disposal scenarios (A, B, C, F and small A, G and small A, and F and G have to be considered. The five (5) proposed alternatives areas fall into two (2) provinces and within the jurisdiction of different municipalities as is summarized in Table 1.



LOCATION OF THE STUDY AREA

LEGEND

- Provincial Boundary
- Alternative Sites
- Proposed Alternative Sites
- Kusile Power Station
- Eskom Property

water earth life

Projection: Geographic(Lat,Long) Hartebeesthoek 1994 (S.A) | Date : 18 11-2013 | Drawn by : AHOKPOSSI D P | Project : AEC0180

Figure 1: Locality map indicating possible ash dam disposal sites

Table 1: Proposed alternative positions

Area	Province	Municipality	Closest locality	Approximate Distance from EKPS (Direction)	Total Area	Farms Names
				Km	Km^2	
A	Mpumalanga	Delmas	Delmas Rural,	2.2 (South)	14.77	Klipfontein, Dwaalfontein,
B	Gauteng	Bronkhorstspruit	Kungwini Rural	9 (North-West)	13.35	Witklip, Nooitgedacht, Jakhalsfontein, Bossmanskraal
C	Gauteng; Mpumalanga	Bronkhorstspruit, Delmas	Kungwini Rural, Delmas Rural	1.7 (North)	15.29	Spitskop, Onverwacht, Kortfontein
F	Gauteng; Mpumalanga	Bronkhorstspruit, Delmas	Kungwini Rural, Delmas Rural	2.8 (West)	13.06	Bossmanskraal, Dwaalfontein, Witpoort
G	Gauteng; Mpumalanga	Bronkhorstspruit, Delmas	Kungwini Rural, Delmas Rural	3 (South)	18.65	Klipfontein, Dwaalfontein, Nooitgedacht, Witpoort

2.2 Climate

A description of the climate of the study area is based on the climate of the closest town, Bronkhorspruit. The climate of the study area is typical of the South African Highveld climatic zone with summer rainfall and cold winters. The average minimum and maximum monthly temperatures are shown in Figure 2 below.

Beronkhorspruit lies in the summer area of South Africa (Figure 3), therefore very little rain occurs in winter. It receives the lowest rainfall in June and highest rain fall in January. According to the SA explorer, Bronkhorspruit climate, the mean annual rainfall is approximately 570mm/a (Record from 2000 to 2011).

Long term precipitation records (50 to 92 years) at Ogies, Cologne, Clewer, and Vandyksdrif suggest mean annual rainfall values of 736, 676, 626, and 686 mm respectively.

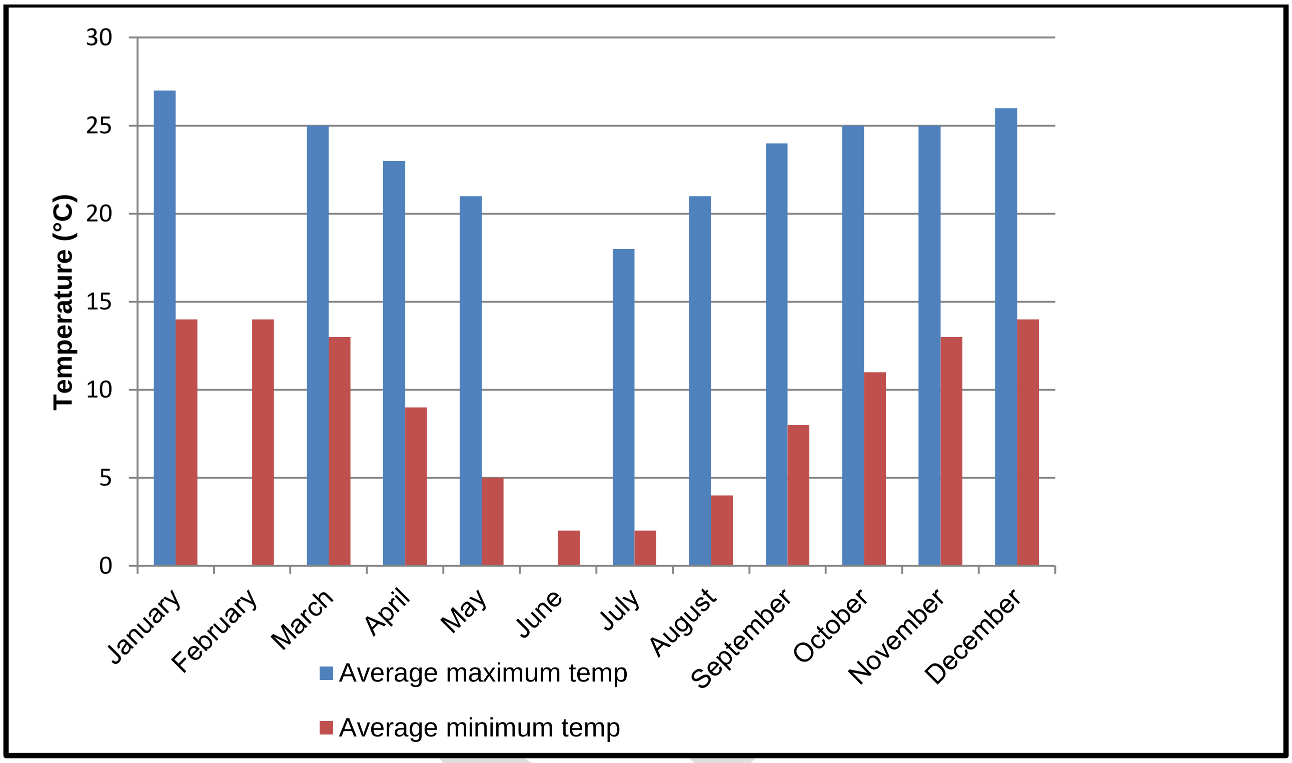


Figure 2: Average temperatures

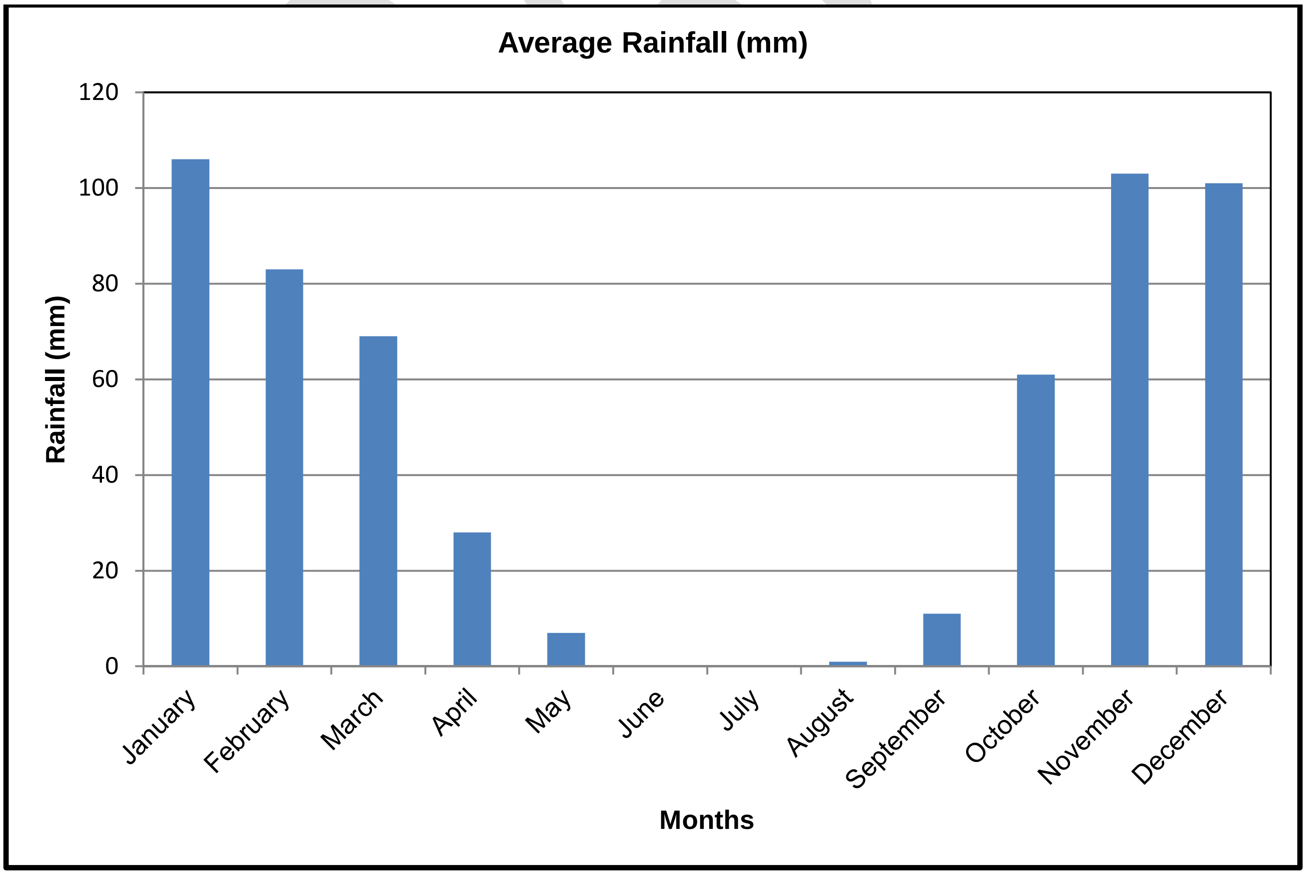


Figure 3: Average monthly rainfall

2.3 Topography and Drainage

The overall study area covers three quaternary catchments B20G, B20F, and B20D, (Surface Water Re-sources of South Africa, Volume 2, 1990: Drainage Regions A and B, WRC Report No. 298/2.1/94). These three quaternary catchments form part of Limpopo – Olifants primary drainage region. The Olifants River drains into Mozambique through Loskop Dam and the Kruger National Park, and also into the India Ocean through the Limpopo River. The five (5) areas proposed for the present investigation fall on the B20F with a small portion of the area B on the B20D (

Figure 4). Some characteristics of these catchments are given in Table 2.

Table 2: Characteristics of catchments

Catchment	Units	B20G	B20F	B20D
Area	**Km^2**	524.3	506	482.1
Mean Annual runoff	**mm/a**	44.1	33.3	36.1
Mean annual rainfall	**mm/a**	669.29	666.79	676.99

The “WILGE” is the principal (perennial) river that drains the quaternary catchment B20F (Figure 5). In the study area, it flows North-South at the West of the alternatives areas G, A, F, and C, and at East of the alternative area B. The details on the average distances of the alternatives areas from the WILGE, with the list of the tributaries (non perennial rivers) intersected by the AEC alternatives Area are summarized in Table 3. The topography in the catchment ranges in elevations between 1350 m and 1650 m above mean sea level. It drops gently SE-NW and SW-NE toward the WILGE River.

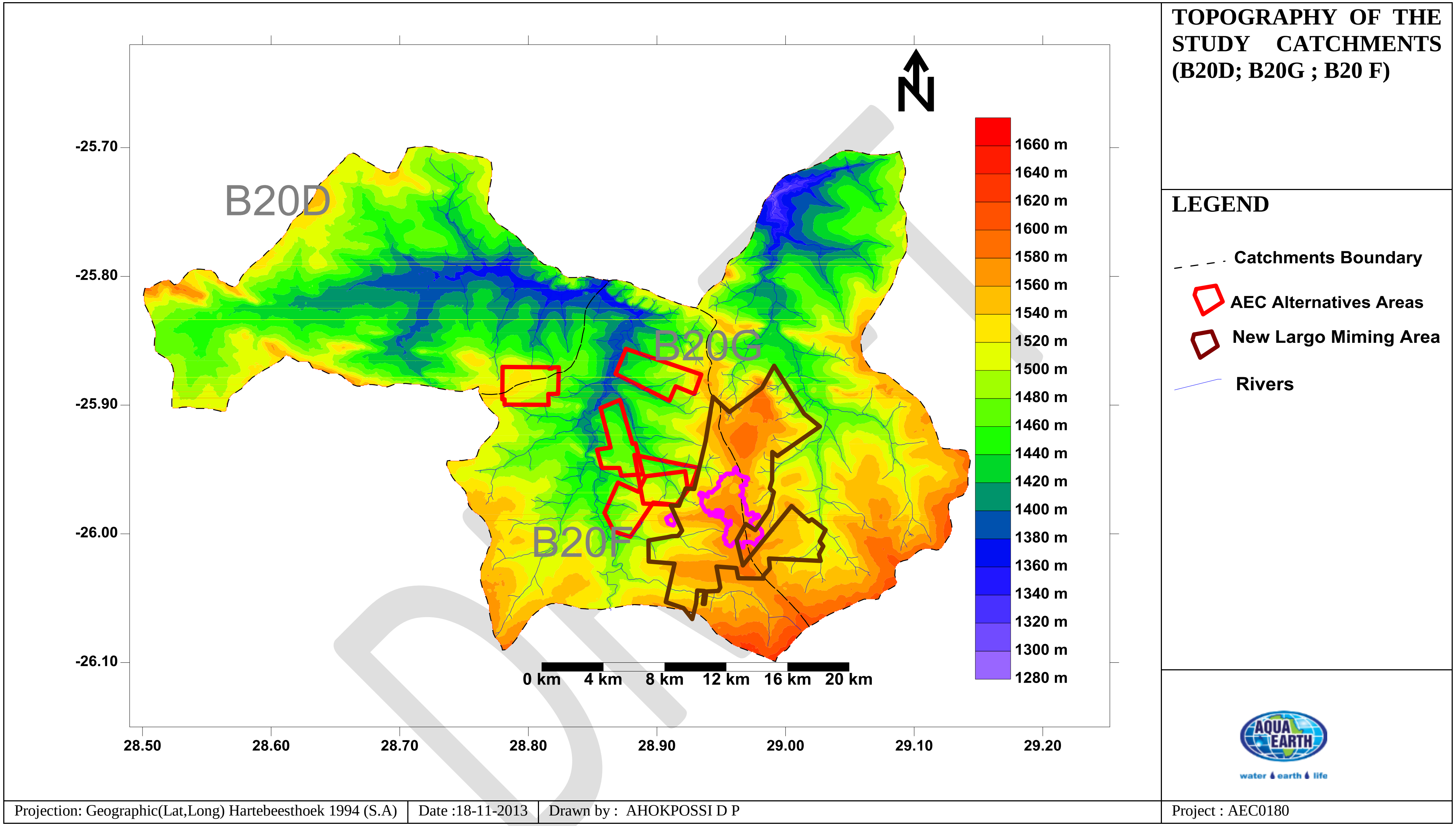


Figure 4: Topography of the study catchments

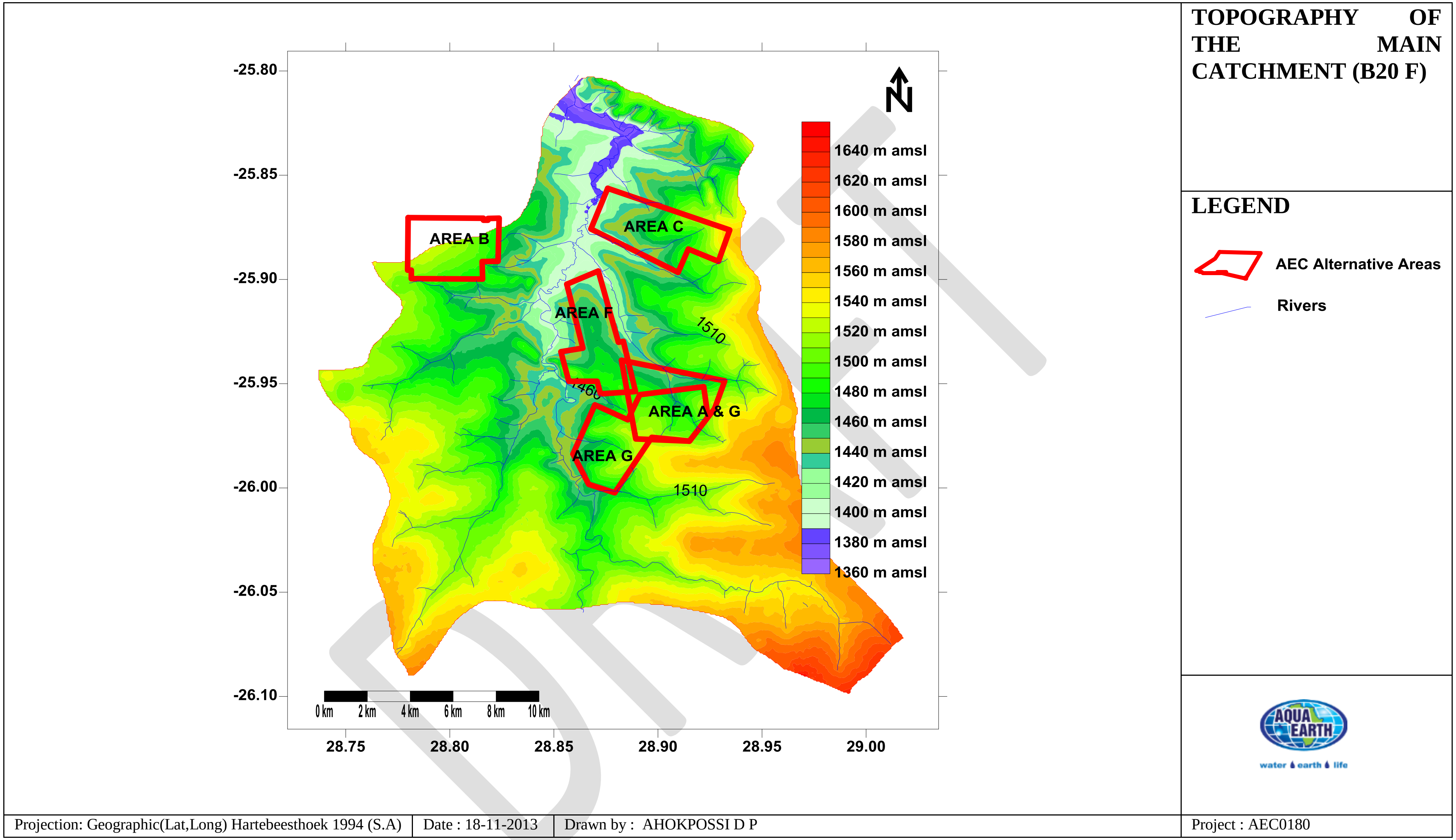


Figure 5: Topography of the main catchment (B20F)

Table 3: Summary of rivers intersected by proposed alternative sites

Alternatives Area	Distance to the Wilge River (km)	Number of Intersected Rivers	Intersected Rivers ID
Area A	3.20	8	Klipfonteinspruit; #002:57559; #002:57883; Holfonteinspruit; #002:57654; #002:57878; #002:57879; #002:57655
Area B	3.78	0	--
Area C	0.20	3	#002:58013 ; #002:58014; #002:57891
Area F	0.20	0	--
Area G	0.15	8	Holfonteinspruit; #002:57654; #002:57878; #002:57879; #002:57655; #002:57863; #002:57862; #015:132375

2.4 Geology

2.4.1 Regional Geology

The description of general geology is based on the analysis of the "1/250 000 Geological Series: 2528 Pretoria "and the "1/250 000 Geological Series: 2628 East Rand" published respectively in 1978 and in 1986 by the Government Printer.

Theses analysis reveals that the prevailing formations in the area are Ecca, Dwyka (found in the pre-Karoo topography), and Vryheid of the Karoo Sequence; Rayton, Magaliesberg, Sylverton, Daspoort, and Strubenkop of the Pretoria Group; and Loskop of the Rooiberg Group. The Karoo sequence in the area is associated with some shale, shaly sandstone, sandstone, conglomerate, tillite, and coal. The Pretoria Group in the area consists of quartzite, shale, subgraywacke, hornfels, carbonaceous, and chert. The Rooiberg Group is composed of agglomerate and lava. Some diabase sills have also been noticed in the study area during previous geological explorations, and are particularly associated with the Silverton formation. Some granite of the Bushveld Complex, and some Pyroxenite, gabbro, and anorthosite of the Dwarsfontein Suite are also expected as intrusive rocks in the south-west of the study area. The expected distribution of such lithologies in the study area is as shown in Figure 6.

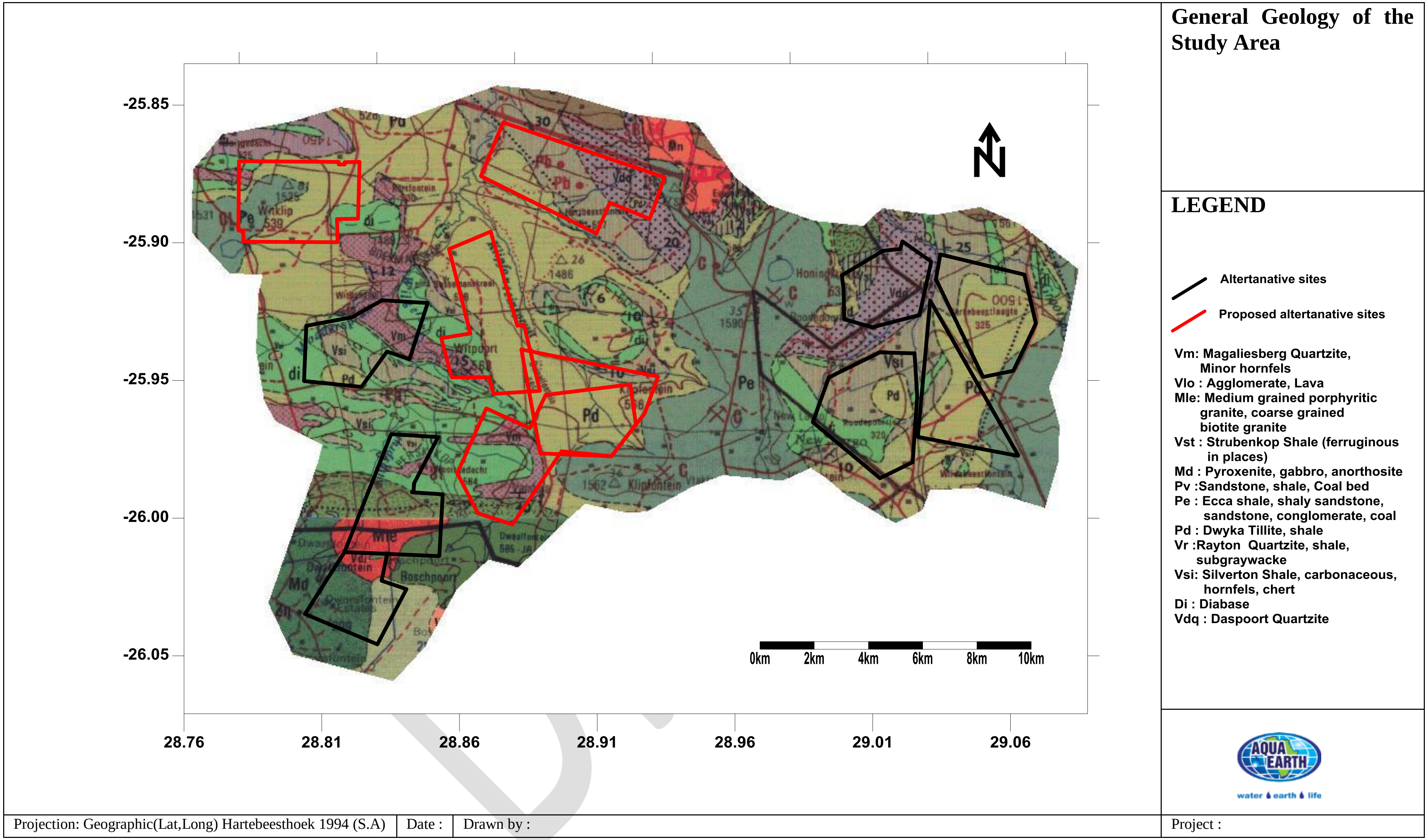


Figure 6: General geology of the study area

2.4.2 Sites Geology

The analysis of the Geological Series: 2528 Pretoria and 2628 East Rand have been used to identify the possible geology that may be encounter per proposed alternative sites. Table 4 and Table 5 summarize the geologic expectations derives from such analysis.

Table 4 : Expected geology at the proposed sites

Alternative Areas	Associated Lithology
Area A	Tillite, shale, carbonaceous, hornfels, chert, shaly sandstone, sandstone, conglomerate, coal
Area B	Tillite, shale, carbonaceous, hornfels, chert, shaly sandstone, sandstone, Diabase sills, Quartzite, Minor hornfels
Area C	Tillite, shale, carbonaceous, hornfels, chert
Area F	Tillite, shale, Diabase sills, Quartzite, Minor hornfels
Area G	Tillite, shale, Diabase sills, Quartzite, Minor hornfels, Pyroclasts, lava, granophyres

It has to be noted that some linear structure previously detected by landsat and aeromagnetic surveys, run NW—SE (alternative area C) and NE -- S (alternative areas H2 and H3) through the study area.

Table 5 : Geologic contacts at the proposed alternatives sites

Alternative areas	Associated apparent geologic boundary	Associated covered geologic boundary	Linear Structures
Area A	--	Vsi – Pd Pd -- Pe	--
Area B	--	Pe – Pd Pd – Di Di – Vm Vm – Pd	--
Area C	--	Pd – Vsi Vsi – Vm	SE-NW Lineaments in Vsi

Area F	Di – Vm (apparent)	Vsi – Pd Vsi – Di Di – Pd	--
Area G	--	Vls – Vm Vls – Di Di – Vm Vm -- Pd Pd – Di	--

No underground data (borehole or core logs) is available on the sites geology. Information collected during field underground investigation (boreholes drilling) have been used for the description of the sites geologies. The detail on the description is provided in the section 3.3 related to the drilling results.

2.5 Geohydrology

2.5.1 Regional Geohydrology

The description of general geohydrology is based on "Exploration of the 1:500 000 general hydrogeology map did by Barnard (2000).

The occurrence of groundwater is dictated by the rock type, nature of lithology contacts and the associated geologic structures (fissures, fractures zones, and intrusions). The analysis of the formations present in the study area suggests that ground water storage, flow (movement), recharge, and withdrawal are associated with two main natures of water-bearing rock formations: (1) Fractured aquifer system (Class B) and (2) inter-granular and fractured aquifer (Class D).

The general hydrogeological characterization of each geologic unit (formation) present in the study area is summarized in the Table 6. The very poor storage capacity due ortho-quartzite in the Daspoort formation, has to be noted. The occurrence of springs in the area originated from the Magaliesberg formation, or associated with contacts between sandstone and shale, along fault zones and along impermeable dolerite dykes in the Vryheid formation.

Very little information are found on recharge in the study area. Bredenkamp (1978) estimated an average recharge value of 8% by correlating groundwater levels fluctuation with rainfall in the Silverton formation. The recharge is estimated by Vegter et al (1968) at 4 to 5 % of the mean annual rainfall in Vryheid formation.

Table 6: Geological sequence with associated aquifer(s)

Formation	Class of aquifer	Groundwater occurrence	Maximum borehole yield	Range of water level
			l/s	(m) bgl
Daspoort		Faults; shear zones; contact zones of intrusive diabase sills with shale and quartzite horizons; occasional joints in fresh diabase	--	10 and 30
Magaliesberg	(B) Fractured aquifer	fractures, contact zones with diabase sills, faults and associated shear zones	9.30	10 and 40
Rayton	(D)Intergranular and fractured aquifer	zones of its different quartzite horizons and shale beds	--	20
Silverton	(D)Intergranular and fractured aquifer	shale brecciated (jointed) zones, contacts zones between intrusive diabase sheets and the shale.	20.00	10 – 80
Loskop	(D)Intergranular and fractured aquifer	fractures associated with the intrusion of acidic lava, contact zones between its different sediments	6.40	10 and 30
Dwyka	(D)Intergranular and fractured aquifer	upper weathered tillite	4.4	--
Vryheid	(D)Intergranular and fractured aquifer	weathered and fractured sedimentary rocks not associated with dolerite intrusion, indurated and jointed sedimentary rocks alongside dykes, narrow weathered and fractured dolerite dykes, weathered dolerite sills and jointed sedimentary rocks, weathered and fractured upper contact-zones of dolerite sills, weathered and fractured lower contacts-zones, and coal seams.	12.60	5 – 25
Ecca	(D)Intergranular and fractured aquifer	fractures and joints developed locally along bedding planes, contact zones between different lithologies, fault and associated shear zones, extensively developed fractures	9.20	--

2.5.2 Local geohydrological information in the study areas

Existing geohydrological information have been provided by Zitholele Consulting. Such information are collected from the existing groundwater and surface water monitoring network and include depths to groundwater levels in the boreholes, and waters (groundwater and Surface water) quality.

Information on 85 boreholes and 22 surface water points have been provided by Zitholele Consulting. The current KPS monitoring network has been designed and developed to comply with the recommendations and requirements of the EMP and existing EKPS Water Use Licenses and covers only a small part of the whole study area as is seen in Figure 7. The depths to water levels in the KPS area range from 1.48 to 28.94 m with an average of 9.48 m below ground level. Based on the unacceptable quality of 82 % of the samples, it have been concluded that groundwater resources at the KPS are not suitable for domestic water use as a result of high values for turbidity, iron, manganese, aluminium, and Coliforms concentration or a combination of any of these constituents.

Information from the Groundwater specialist study report for New Largo (conducted by JMA consulting - July 2012) have also been used to better understand the geohydrological conditions (aquifer mechanics and geo-hydrochemistry) in the study area, especially in the south-eastern side (around alternative sites A and G) of the present study area. This study reveals that the most prominent aquifer present in the New Largo is the unconfined to semi-unconfined laterally extensive shallow weathered zone aquifer within the Ecca, Dwyka, and Pretoria Geological Groups. The average thickness of this aquifer is of 20.77 m. Some non significant isolated perched aquifers have been identified in the north-eastern part of the New Largo. Depths to groundwater levels measured during JMA's study ranges from 2.14 m to 19.86 m below ground level, with an average of 8.78 m. The blow yields recorded from the aquifers at the New Largo ranges from 0.01 l/s to 3.33 l/s with an average of 0.23l/s. The transmissivity ranges from 0.02 to 42.22 with an average of 5.06 where as the average storativity is 0.002. The effective porosity at the New Largo site is estimated to vary from 0.01 to 0.07, with an average value of 0.05. The recharge to the groundwater has been estimated to be between 3% and 7 %.

Background water quality in the New Largo area has been described as calcium/magnesium bicarbonate water to slightly sodium bicarbonate/chloride water with HCO_3^- predominant anion. The background pH varies between 6.02 and 9.20 where as the background Electrical Conductivity (EC) varies between 1.5 mS/m to 34 mS/m

The presence of artificial aquifer associated with the old (historical) underground mining in the New Largo, has to be noted (Figure 7).

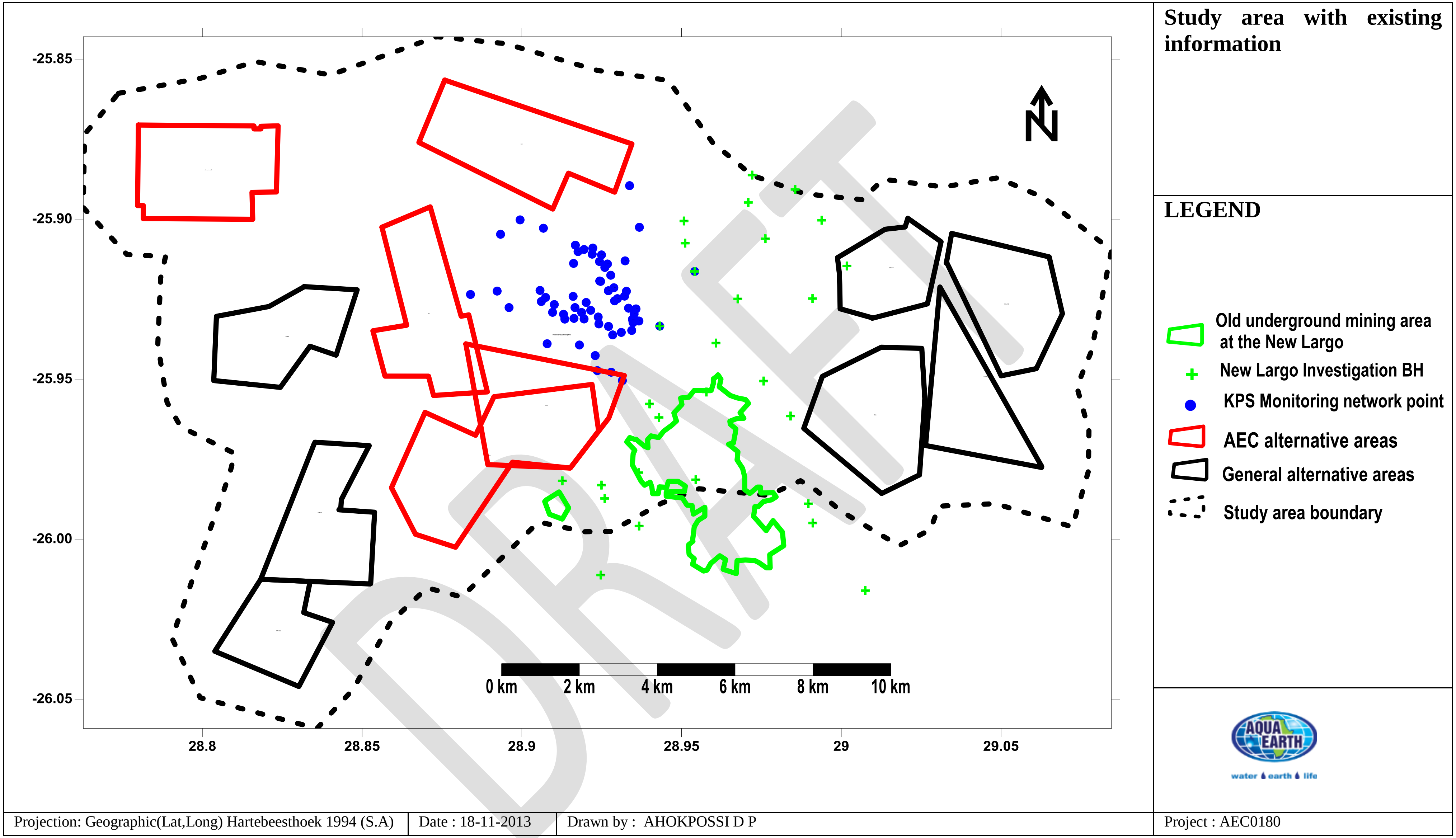


Figure 7: Location of existing geohydrological information in the study area

EC profiling collected from 3 boreholes (LGW-B15, LGW-B16, LGW-B24) in the new largo suggests some fresh water flowing at depths between 12.5 and 13.5 mbgl (Figure 8).

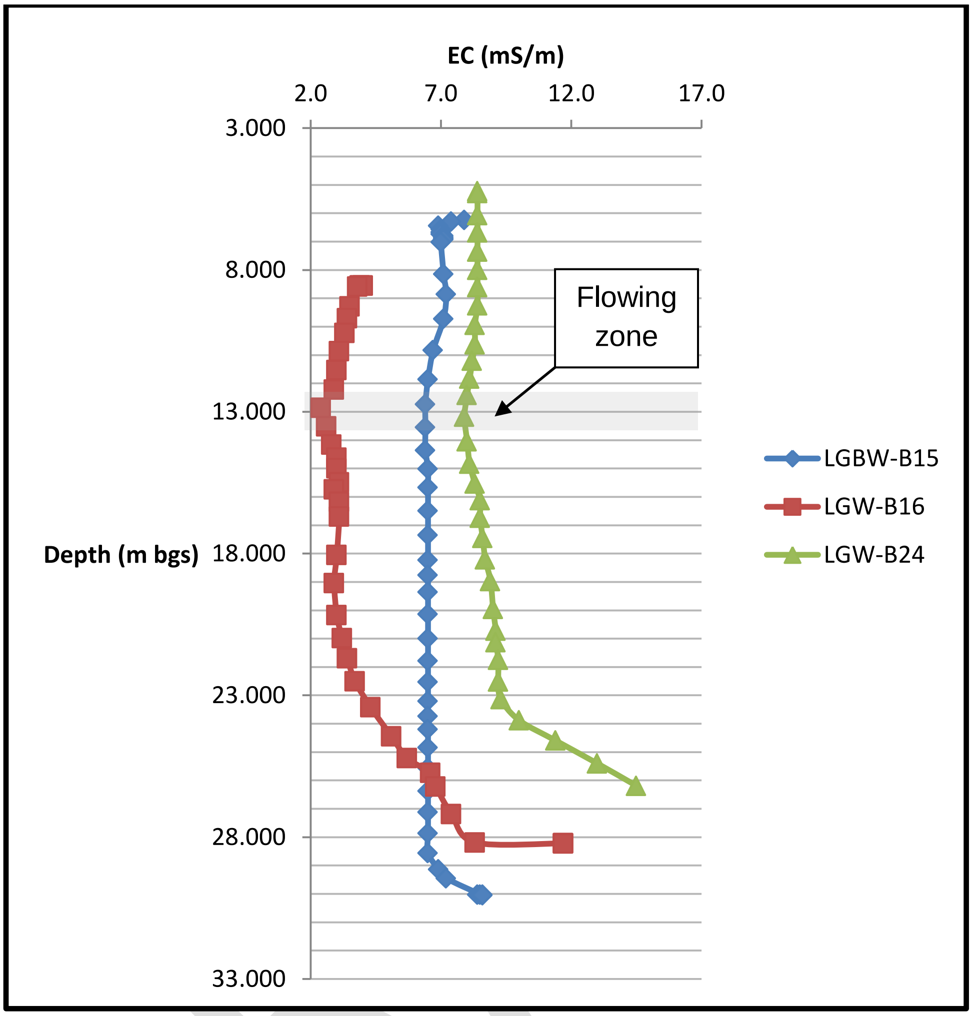


Figure 8: EC profiling showing flowing zone in the new largo

Analyses of the work done by Barnard (2000) have been used to identify possible groundwater occurrences per proposed alternative area (Table 7).

Table 7: Expected groundwater occurrences in the proposed alternative areas

Areas	Apparent geologic boundary	Covered geologic boundary	Linear Structures	Types of expected aquifers	Groundwater occurrence
Area A	--	Vsi : Silverton Pd : Dwyka Pe : Ecca	--	(D)Intergranular and fractured aquifer	1. Shale, brecciated (jointed) zones, contacts zones between intrusive diabase sheets and the shale. 2. Upper weathered tillite 3. Fractures and joints developed locally along bedding planes, contact zones between different lithology, fault and associated shear zones, extensively developed fractures
Area B	--	Pe : Pd Di : Vm Magaliesberg	--	(D)Intergranular and fractured aquifer (B) Fractured aquifer	1. Upper weathered tillite 2. Fractures and joints developed locally along bedding planes, contact zones between different lithology, fault and associated shear zones, extensively developed 3. Fractures, contact zones with diabase sills, faults and associated shear zones
Area C	--	Pd : Dwyka Vsi : Silverton Vm : Magalie	SE-NW Lineaments in Vsi	(D)Intergranular and fractured aquifer (B) Fractured aquifer	1. Fractures, contact zones with diabase sills, faults and associated shear zones 2. Shale, brecciated (jointed) zones, contacts zones between intrusive diabase sheets and the shale. 3. Upper weathered tillite

Areas	Apparent geologic boundary	Covered geologic boundary	Linear Structures	Types of expected aquifers	Groundwater occurrence
Area F	Di – Vm	Vsi ; Pd ; Di	--	(D)Intergranular and fractured aquifer	1. Shale, brecciated (jointed) zones, contacts zones between intrusive diabase sheets and the shale. 2. Upper weathered tillite
Area G	--	Vls : Vm Di : Pd	--	(D)Intergranular and fractured aquifer (B) Fractured aquifer	1. Fractures associated with the intrusion of acidic lava, contact zones between its different sediments 2. Fractures, contact zones with diabase sills, faults and associated shear zones 3. Upper weathered tillite

3 Geohydrological field investigations and findings

Several field investigations have been conducted by AEC from December to February (year??) as part of the groundwater investigations, to better understand the baseline geohydrological conditions (flow and quality). These works include hydrocensus, geophysical survey, boreholes drilling, and aquifer pumping tests.

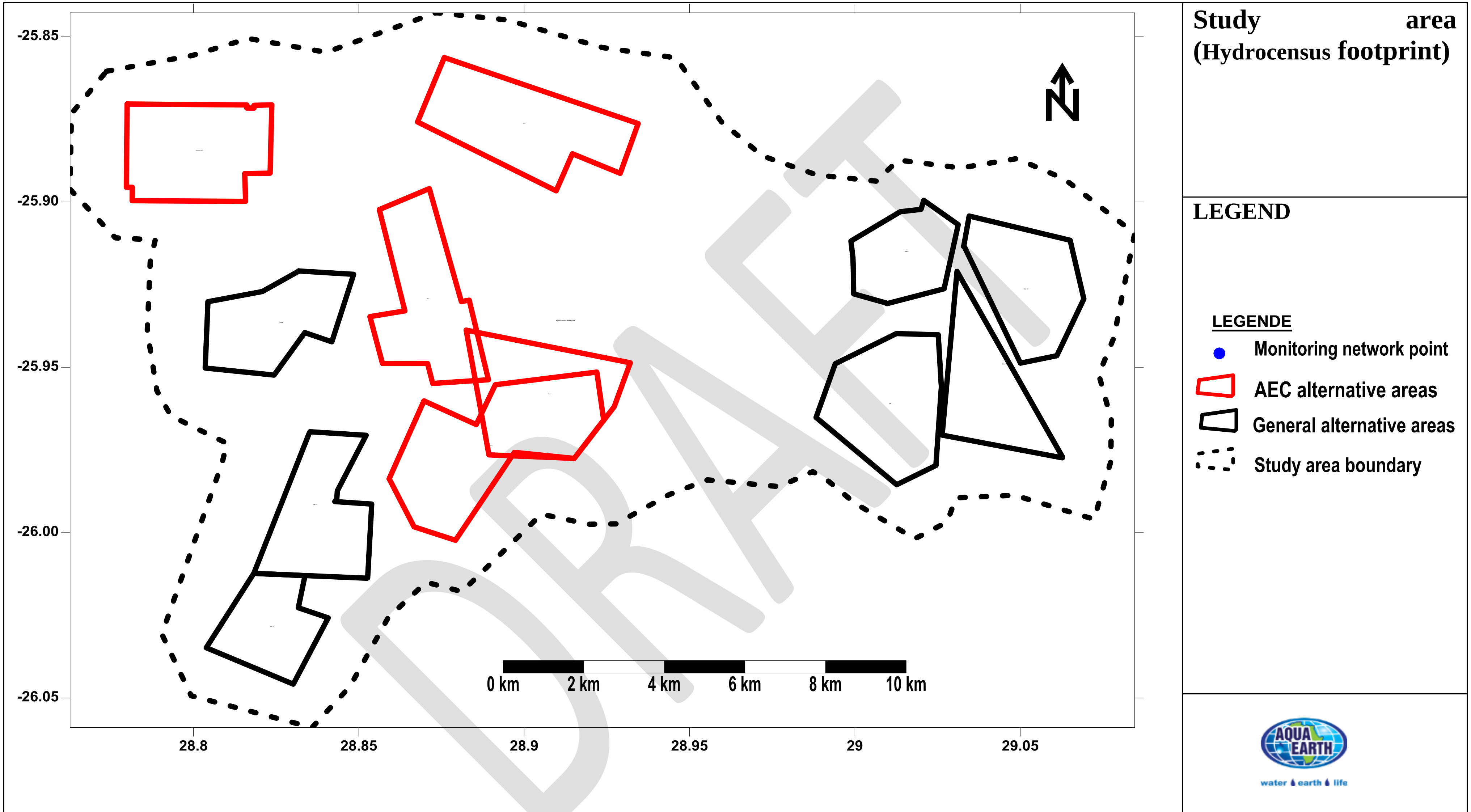
3.1 Hydrocensus

The Hydrocensus in the study area has been conducted in two phases (from 10-12-2012 to 12-12-2012 and from 8-12-2012 to 11-12-2012). Hydrocensus has been conducted in 2 km radius of all alternatives area, resulting in a hydrocensus footprint of 459.2 km^2 (Figure 9). A total of 131 (102 Boreholes, 2 natural springs, and 27 surface water points) water points have been considered during the hydrocensus as summarize in Table 8 and Table 9. The locations (GPS co-ordinates) were recorded and water samples were collected for all the identified water points. The depths to water levels in the boreholes, the type of pumps used, the borehole depths, and others information related to the water reliability and the quality were also recorded for groundwater points. The coordinates of each identified site was recorded on a handheld Garmin GPS and their locations were plotted on a map (Figure 10). Access to sites for water level measurements were determined and measured where possible.

Water samples have been collected by using “single-check valve weighed poly” nylon bailers (1.6” OD, 36 “Length) and a labelled rope. It has to be noted that, since the flowing points in the boreholes are not known, point-source sampling could not be performed, and that the quality of water will be representative of the average chemical and mass transport conditions in the boreholes, and not the quality of the flowing zone water. But disturbance that can be caused by pumping and purging were avoided as far as possible.

The bailer is lowered to the possible sample depth. As the bailer is being lowered, valve located at the bottom opens, allowing water to flow through the sampler. When, reaching the possible sampling depth, the bailer is raised using the support cable. The weight of water and upward movement of the bailer keep the ball valve closed. The bottom ball valve keeps the water in the bailer. Once at the surface, the bailer is emptied by opening the valve with a sample release device, and allowing the water to drain slowly through the sample release device into the sample container.

Water samples were collected in standard 1 litre plastic sample bottles. The samples were stored in a cooler box.



Projection: Geographic(Lat,Long) Hartebeesthoek 1994 (S.A) | Date :11-18-2013 | Drawn by : AHOKPOSSI D P | Project : AEC0180

Figure 9: Plan showing hydrocensus footprint

Table 8: AEC Hydrocensus Borehole

Farm owner(Contacts)	Borehole Number	Geographic coordinate WGS84 (DD)		Borehole Depths	Depth Water Encountered	Flow Rate	Groundwater Level	Type of pump	Use	Ph	E.C.
		Latitude	Longitude	(mbgl)	(mbgl)	(l/s)	(mbgl)				(mS/m)
--	KABH1	-25.88586	29.00654	--	--	--	--	--	Farming	6.71	89.4
--	KABH2	-25.89629	29.01278	--	--	--	--	--	Farming	--	--
--	KABH3	-25.90456	29.01873	--	--	--	--	--	Farming	6.43	156.5
--	KABH4	-25.89439	29.06008	--	--	--	--	--	Farming	--	--
--	KABH5	-25.95000	29.05542	--	--	--	--	--	Farming	5.57	35.4
--	KABH6	-25.96000	29.02322	--	--	--	--	--	Farming	7.26	175.6
Potter Truter	KABH7	-25.99245	28.88928	--	--	--	locked	submersible	domestic	7.03	106.2
Potter Truter	KABH8	-25.98607	28.88854	--	--	--	locked	submersible	domestic	6.31	54.4
Mike Hough	KABH9	-25.87328	28.9457	--	--	--	2	--	Farming	6.2	49.9
Stone	KABH10	-25.87015	28.93471	--	--	--	--	--	Farming	7.04	23
Stone	KABH11	-25.86975	28.93460	--	--	--	--	--	Farming	6.62	27.9

Stone	KABH12	-25.87052	28.93677	--	--	--	--	--	Farming	6.28	16.1
Stone	KABH13	-25.87116	28.93805	--	--	--	--	--	Farming	7.66	179
GHB Braak	KABH14	-25.86343	28.93486	--	--	--	17.51	--	Farming	6.93	91.9
Malehebre	KABH15	-25.86435	28.96401	--	--	--	--	--	Farming	7.23	161.3
Malehebre	KABH16	-25.86472	28.96354	--	--	--	--	--	Farming	6.08	482
MalebherBH3	KABH17	-25.90000	29.00000	--	--	--	--	--	Farming	7.51	297
Altes	KABH18	-26.01359	28.88345	--	--	--	7.45	Submersible	Domestic	6.57	571
Wessel	KABH19	-26.01756	28.85799	--	--	--	13.2	Submersible	Farming	7.82	146.6
Hylay farm	KABH20	-26.02345	28.84705	--	--	--	88.69	Submersible	Farming	7.03	185
Hylay farm	KABH21	-26.02683	28.84488	--	--	--	13	Submersible	Farming	6.61	127.7
Hylay farm	KABH22	-26.03476	28.83831	--	--	--	26.67	Submersible	Farming	7.04	157
Dieter (0823163566)	KABH12	-26.04766	28.81414	28	--	--	2.3	Submersible	Framing	6.87	288
Dieter (0823163566)	KABH13	-26.03941	28.80553	28	--	--	2.62	--	Framing	6.85	104.1
Koos(0825248301)	KABH14	-26.03130	28.81502	12	--	--	2.8	Submersible	Framing	7.3	373

Koos(0825248301)	KABH15	-26.03257	28.81314	30	--	6240L/H	5.69	Submersible	Framing	6.87	394
Van Zyl	KABH16	-25.87761	28.96579	--	--	--	broken	--	Framing	7.11	213
Van Zyl	KABH17	-25.87721	28.96567	--	--	--	--	--	Framing	--	--
Maraba	KABH18	-25.87838	28.96542	--	--	--	--	--	Framing	7.55	173.9
Maraba	KABH19	-25.87903	28.96330	--	--	--	broken	--	Framing	7	249
Maraba	KABH20	-25.87902	28.96161	--	--	--	broken	--	Framing	--	--
Eenzaheid	KABH21	-25.88142	28.96621	--	--	--	--	--	Framing	--	--
Top Brick	KABH22	-25.89630	28.95272	--	--	--	--	--	Framing	6.74	148.8
Top Bricks	KABH23	-25.89965	28.95667	--	--	--	broken	--	Framing	--	--
Hlumbane	KABH24	-25.89609	28.96478	--	--	--	--	--	Framing	--	--
Hlumbane	KABH25	-25.89744	28.96417	--	--	--	--	--	Framing	6.16	14.5
Balmaro	KABH26	-25.90582	28.97346	--	--	--	--	--	Framing	--	--
Sibongidawo primary school	KABH27	-25.92237	28.97018	--	--	--	--	--	Framing	5.62	15.6

--	KABH28	-25.94830	28.96638	--	--	--	--	--	Framing	--	--
Malchite	KABH29	-25.96071	28.93415	--	--	--	--	--	Framing	--	--
--	KABH30	-25.89466	28.97095	--	--	--	--	--	Framing	--	--
--	KABH31	-25.93141	28.96106	--	--	--	--	--	Framing	--	--
--	KABH32	-25.93153	28.96093	--	--	--	--	--	Framing	--	--
--	KABH33	-25.93045	28.96048	--	--	--	--	--	Framing	--	--
--	KABH34	-25.94109	28.95828	--	--	--	--	--	Framing	5.59	35.6
--	KABH35	-25.98125	28.95447	--	--	--	--	--	Framing	--	--
--	KABH36	-25.96739	28.97574	--	--	--	--	--	Framing	--	--
Chabangu	KABH37	-25.96302	29.00038	--	--	--	--	--	Framing	6.67	65.9
Van Der Merwe	KABH38	-25.96211	29.00810	--	--	--	--	--	Framing	7.15	95.7
Charles Le Maitre	KABH39	-25.87219	28.77249	--	--	--	locked	submersible	domestic	6.53	80.1
Charles Le Maitre	KABH40	-25.87000	28.77143	--	--	--	5.42	submersible	domestic	6.85	26.7
Charles Le Maitre	KABH41	-25.87019	28.77410	--	--	--	0	submersible	domestic	6.72	105.1
Charles Le Maitre(Tenents)	KABH42	-25.87293	28.77769	--	--	--	5.7	no pump	not used	5.55	23.8
River Le Maitre	KABH43	-25.87387	28.77547	--	--	--	--	--	Farming	6.65	113.3
Le Maitre	KABH44	-25.88650	28.77285	--	--	--	locked	submersible	domestic	6.05	53.5

Le Maitre	KABH45	-25.88659	28.77236	--	--	--	6.77	submersible	domestic	6.41	61.4
Le Maitre	KABH46	-25.88532	28.77368	--	--	--	--	--	domestic	5.82	72.6
Le Maitre	KABH47	-25.87920	28.77310	--	--	--	6,25	--	domestic	6.6	77.6
Karel Raghrt	KABH48	-25.92117	28.81916	--	--	--	4.65	submersible	domestic	6.56	130.8
Karel Raghrt	KABH49	-25.92212	28.81849	--	--	--	7.08	submersible	domestic	6.29	123.7
Hans van Rensburg	KABH50	-25.91854	28.80387	--	--	--	locked	submersible	domestic	--	--
Hans van Rensburg	KABH51	-25.91775	28.80466	--	--	--	13.32	submersible	domestic	6.5	79.7
Hans van Rensburg	KABH52	-25.92500	28.80733	--	--	--	12.34	--	Framing	6.48	131.1
Hans van Rensburg	KABH53	-25.92399	28.80838	--	--	--	10.2	submersible	domestic	6.56	268
Hans van Rensburg	KABH54	-25.90941	28.79350	--	--	--	locked	submersible	domestic	--	--
Glitzer	KABH55	-25.85640	28.86374	--	--	--	locked	submersible	domestic	--	--
Glitzer	KABH56	-25.85569	28.86452	--	--	--	locked	submersible	domestic	6.18	75.6
Dykefeld	KABH57	-25.86530	28.85611	--	--	--	locked	submersible	domestic	6.45	123.7
Dykefeld	KABH58	-25.86642	28.85541	--	--	--	--	submersible	domestic	6.34	99.7
Dykefeld	KABH59	-25.86652	28.85546	--	--	--	--	submersible	Farming	--	--
Topigs	KABH60	-25.88638	28.85047	--	--	--	7.72	submersible	domestic	6.53	79.5
Topigs	KABH61	-25.88753	28.84827	--	--	--	locked	submersible	domestic	--	--
Topigs	KABH62	-25.87192	28.85451	--	--	--	9.67	submersible	domestic	6.35	189.5
Topigs	KABH63	-25.89683	28.83920	--	--	--	17.64	submersible	domestic	6.63	40.1

HP Sharp	KABH64	-25.86271	28.87523	--	--	--	--	submersible	domestic	7.15	91.4
HPG Tereblanche	KABH65	-25.86378	28.87621	--	--	--	11.16	--	Farming	--	--
Misty lake-Kunene	KABH66	-25.85944	28.88387	--	--	--	locked	--	Farming	7.56	176
Misty lake-Kunene	KABH67	-25.87504	28.88036	--	--	--	locked	--	livestock	--	--
RM Kgosana Family Trust	KABH68	-25.87739	28.86799	--	--	--	7.7	submersible	domestic	--	--
RM Kgosana Family Trust	KABH69	-25.82858	28.82185	--	--	--	locked	submersible	domestic	6.06	27.4
Johan Ernest	KABH70	-25.82840	28.82171	--	--	--	8.65	no pump	not used	6.33	39.2
Du Plesis	KABH71	-25.82881	28.82692	--	--	--	--	--	Farming	7.79	194.7
Du Plesis	KABH72	-25.85119	28.83409	--	--	--	locked	--	domestic	--	--
Jakalsfointein river	KABH73	-25.85887	28.80731	--	--	--	locked	--	domestic	7.05	250
Hans van Rensburg	KABH74	-25.85781	28.80487	--	--	--	6.7	pump not working	Farming	6.47	212
Roelf van Rensburg	KABH75	-25.85292	28.82025	--	--	--	5.45	no pump	Farming	6.64	104.3
Roelf van Rensburg	KABH76	-25.85495	28.81410	--	--	--	--	--	Farming	--	--
Roelf van Rensburg	KABH77	-25.87638	28.82228	--	--	--	locked	--	Farming	7.48	18.2
Roelf van Rensburg	KABH78	-25.87123	28.82210	--	--	--	locked	--	Farming	6.21	53.7
Andreas Moll	KABH79	-25.87056	28.81559	--	--	--	locked	--	Farming	6.05	57
Andreas Moll	KABH80	-25.86712	28.81800	--	--	--	locked	--	Farming	6.3	48.4
Andreas Moll	KABH81	-25.86686	28.81764	--	--	--	locked	--	Farming	--	--

Andreas Moll	KABH82	-25.87113	28.81625	--	--	--	--	--	Farming	6.08	201
Andreas Moll	KABH83	-25.86646	28.82160	--	--	--	locked	--	Farming	6.98	155.2
Vander walt	KABH84	-25.98423	28.81473	27	20	2000 L/H	10.26	Submersible	Farming	6.45	803
Pierre Pieter (0824608773)	KABH85	-25.98455	28.82322	--	--	--	11.03	Submersible	Farming	6.9	323
Backhof (0731703390)	KABH86	-25.97387	28.80029	--	--	--	6.88	Submersible	Farming	6.38	412
Viskus(0823279449)	KABH87	-25.95940	28.79332	--	--	--	38.76	Submersible	Farming	6.09	25.3
Hannesand Thera	KABH88	-25.96293	28.81763	--	--	--	8.53	Submersible	Farming	7.15	138.8
Public	KABH89	-25.93998	28.79164	--	--	--	--	--	Farming	7.3	293
--	KABH90	-25.93289	28.79512	--	--	--	--	--	Farming	--	--
825705725	KABH91	-25.95235	28.80521	30	20	6000L/H	--	Submersible	Farming	6.95	190.5
Hendrick Kok (0720214393)	KABH92	-25.96389	28.86266	--	--	--	5.22	Submersible	Farming	6.83	286
Boshoff (0829219462)	KABH93	-25.93209	28.86296	--	--	--	46.5	Submersible	Farming	7.29	234
Hendrik JPD (0823882592-0823882591-0823882595)	KABH94	-25.97859	28.85871	15	12	2083.3L/H	5.49	Submersible	Farming	7.63	434
Lencass (0828925119)	KABH95	-25.99472	28.84747	65	45	2000L/H	5.6	Submersible	Farming	6.25	182
HS Pernaar (0825766678)	KABH96	-25.95391	28.84973	100	85	--	9.76	Submersible (2.5Kw)	Farming	--	--

Table 9: AEC surface water Hydrocensus

Farm Owner(Contacts)	Borehole Number	Geographic coordinate WGS84		Type of pump	Use	ph	E.C.
		Latitude	Longitude				(mS/m)
--	KASW1	-25.88882	29.01084	--	--	--	--
--	KASW2	-25.89608	29.01476	--	--	--	--
--	KASW3	-25.89958	29.01519	--	--	--	--
--	KASW4	-25.89748	29.06518	--	--	--	--
--	KASW5	-25.90879	29.06530	--	--	--	--
--	KASW6	-25.96768	29.02672	--	--	--	--
Potter Truter	KASW7	-25.99342	28.88816	--	--	7.66	100.3
Potter Truter	KASW8	-26.00212	28.88710	--	--	7.88	147.6
--	KASW9	-26.00420	28.95883	--	--	9.22	534
Abie	KASW10	-25.96803	28.96049	--	--	7.16	2450
Municipality	KASW11	-26.00628	28.86108	Submersible	Framing	8.12	480
Maraba	KASW12	-25.87986	28.96421	--	--	6.89	119.2
Top Bricks	KASW13	-25.89492	28.95440	--	--	6.73	135.1
Top Bricks	KASW14	-25.90203	28.95962	--	--	6.97	74.4
Top Bricks	KASW15	-25.89897	28.95201	--	--	6.7	74.6
Balmaro	KASW16	-25.90758	28.97601	--	--	--	--
--	KASW17	-25.96848	28.95778	--	--	--	--
Malachite	KASW18	-25.95529	28.93852	--	--	--	--
Malachite	KASW19	-25.94946	28.93820	--	--	7.83	57.8
Karel Raghrt	KASW20	-25.91863	28.82403	--	water sports	6.75	109.8
Andreas Moll fountain	KASW21	-26.02275	28.81314	--	--	7.1	195
825705725	KASW22	-25.95125	28.80483	--	Farming	6.93	50.9
Hendrik JPD (0823882592-0823882591-0823882595)	KASW23	-25.96068	28.87877	--	Farming	--	--

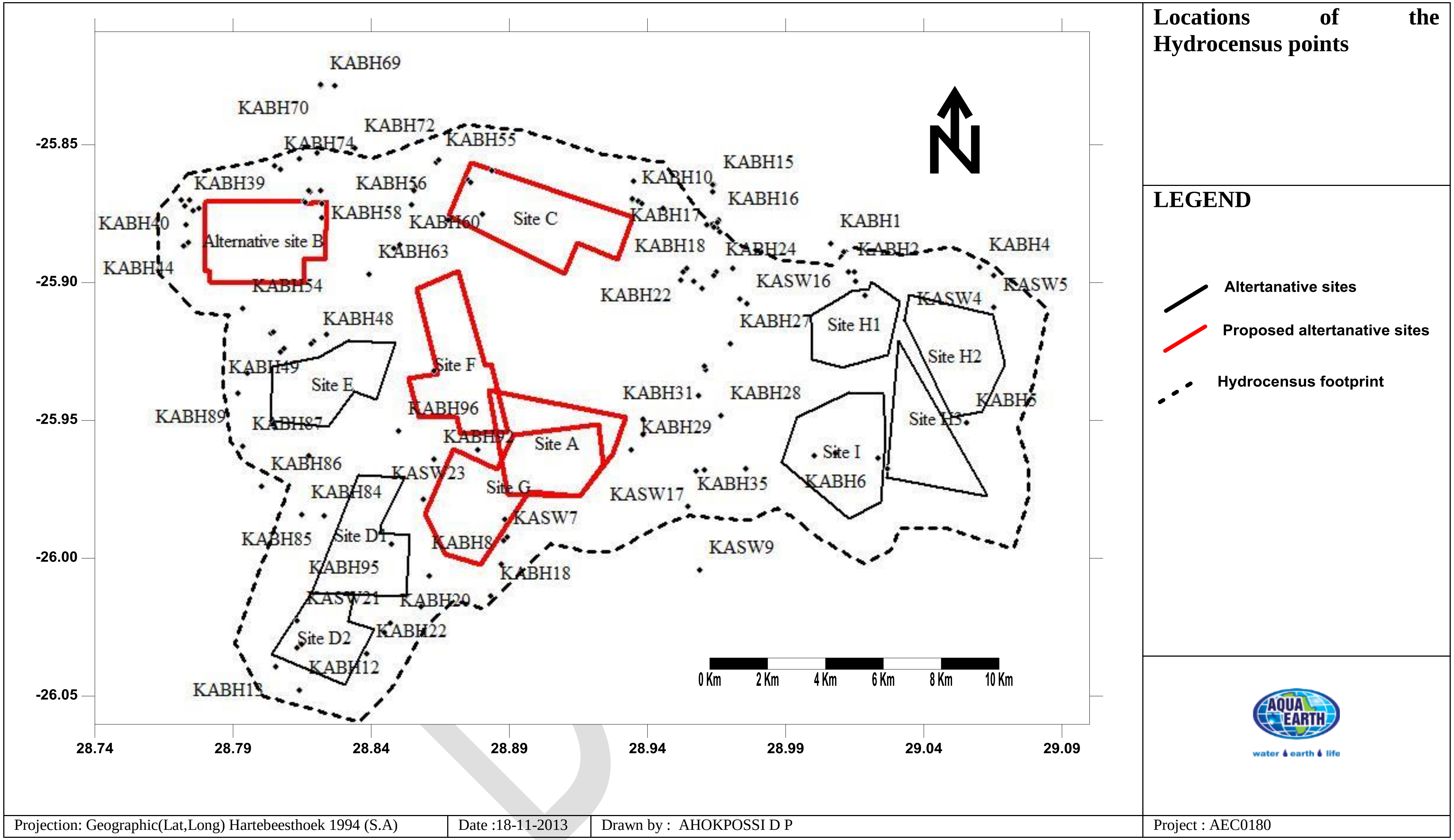


Figure 10: Plan showing hydrocensus points locations

3.1.1 Water use

Information on groundwater use are collected firstly from hydrocensus, but also from existing reports in the area. Groundwater in the area, is used to supply water for different size of livestock, crop farming, garden, sand washing, and domestic use.

Based on the information from hydrocensus, 72% of the existing boreholes are for crop farming and livestock, 23 % are for domestic use, 5% for other purposes. Some indicative groundwater pumping rates can be consulted in Table 8.

3.1.2 Water level

Depths to water levels collected during the hydrocensus (41), data provided by Zitholele Consulting (43), and data collected for New Largo have been processed together to understand the general groundwater drainage in the study area. Available depths to groundwater levels are used to generate groundwater levels contour map (Figure 12).

Ground surface elevations collected from the SRTM digital elevation model of the study area for the hydrocensus points, and the one surveyed for the KPS water monitoring network have been used together with the elevation of the investigated boreholes at the New Largo, measured depths to water levels (84) and boreholes collar height, to determined groundwater elevations in 84 boreholes in the study area.

The plot of these available elevations against the ground surface elevations indicates a correlation of 98.83 % (Figure 11), suggesting a semi-confined to unconfined aquifers types in the study area. The high correlation also indicates that groundwater drainage in the study area mimics the one of surface water as a function of topography, and that the Bayesian interpolation technique can be used to generate water elevations where water levels could not be used. Few deviations from typical characteristic (correlation) are observed and may be related to over pumping from some boreholes (KABH93, KABH87, KABH20), and geologic heterogeneity. The low water elevations due to over pumping have been removed from the correlation calculation. The groundwater drainage resulting from the Bayesian interpolation is shown in Figure 13.

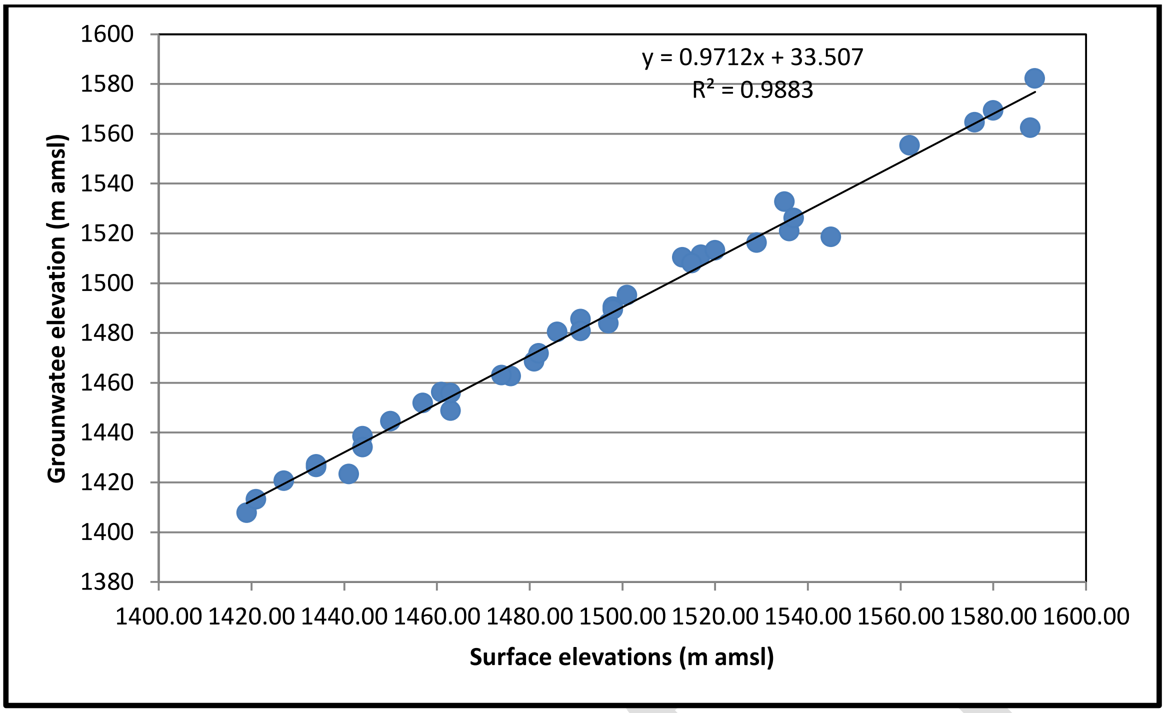
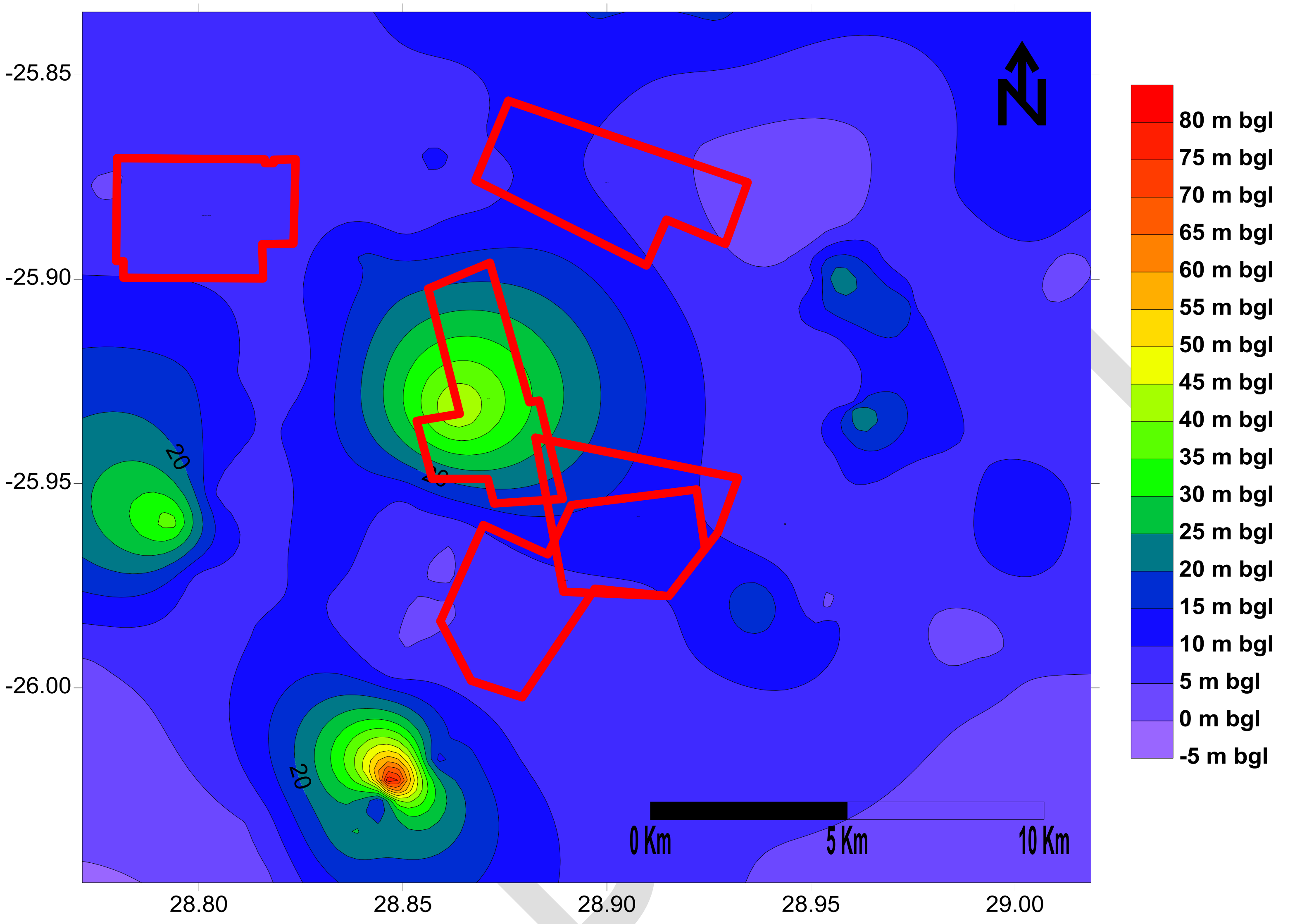


Figure 11: Surface water elevations and Groundwater elevations correlation



Depths to Groundwater levels contour map

LEGEND

Proposed altertanative sites

Projection: Geographic(Lat,Long) Hartebeesthoek 1994 (S.A)	Date : 18-11-2013	Drawn by : AHOKPOSSI D P	Project : AEC0180

Figure 12: Depths to groundwater levels contour map

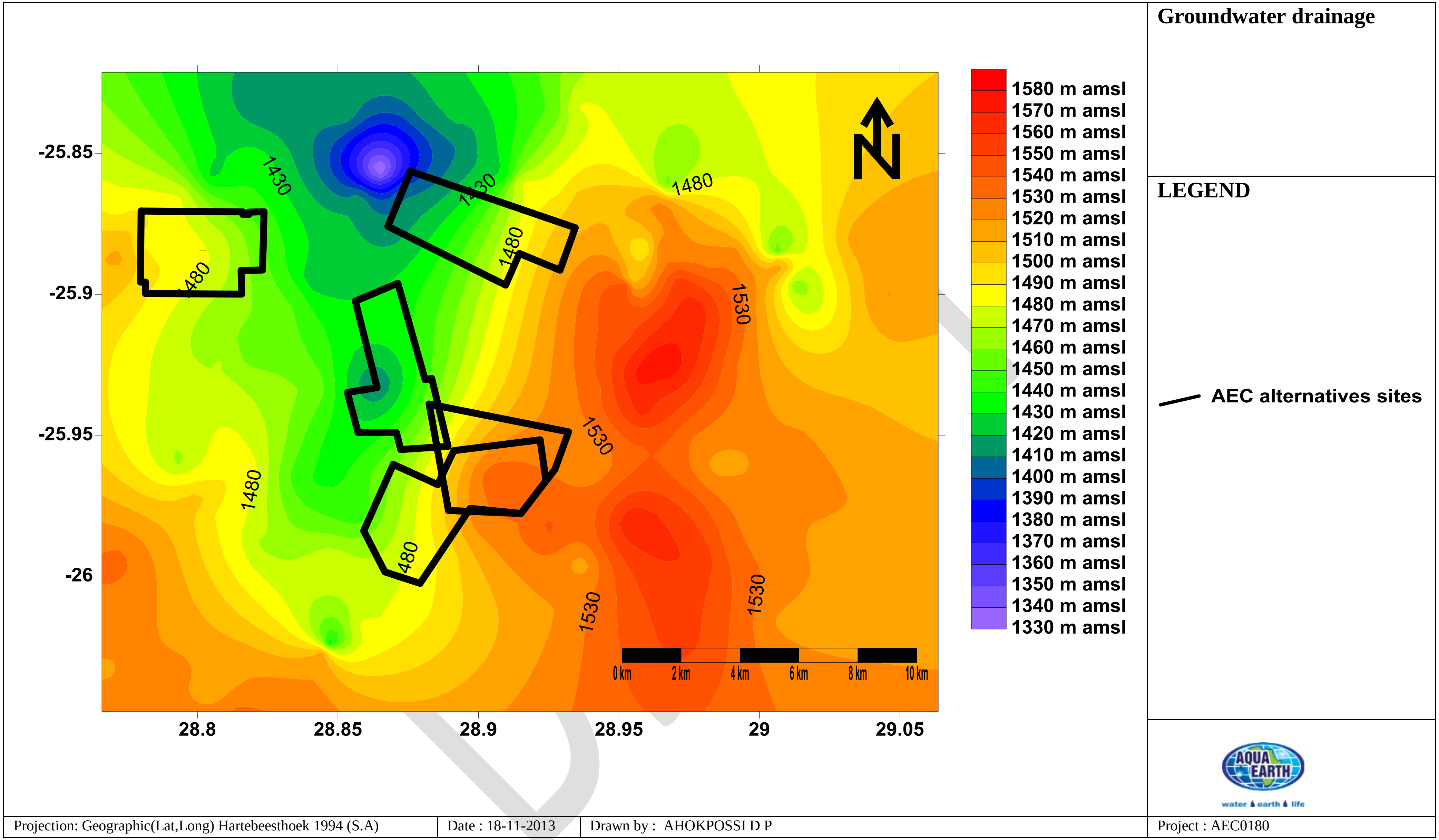


Figure 13: Groundwater drainage

Groundwater elevations, in general fluctuate between 1330 m and 1580 m above mean see level. The analysis of the depths to groundwater levels and groundwater elevation maps, suggests that the groundwater uses (quantitative) in and surrounding the different alternative sites, does not dramatically impact on the natural groundwater drainage, except in the alternative site F where a clear cone of depression can be seen around KABH93.

However analysis of the groundwater level time series data (May 2009 to May 2013) obtained from the monthly water monitoring at the Kusile Power Station (by Zitholele), shows in general, a clear downward trend. This implies a general reduction in groundwater storage during this monitoring period. The reason of this decreasing trend in groundwater storage is unclear, but a combination of natural processes (climate) and man-made stresses are suspected.

3.1.3 Background water quality

All the water samples collected during the hydrocensus have been analysed for the basics indicator parameters (pH, and TDS, and EC) in the AEC office laboratory. These results were used to draw water quality contour maps (Figure 15, Figure 16) and used as first descriptions of the water quality variation in the study area. The pH contour map reveals slightly alkaline water occurring at the south-east of sites A and G (New Largo), within the boundaries and east of site C. Opencast mining areas (rehabilitated and not) were noticed at the east of site C during the hydrocensus, and may be the source of alkaline waters.

By considering the groundwater drainage patterns and the locations of the five (5) recommended alternative areas, sixteen (16) groundwater samples and 4 surfaces water samples were selected and submitted to UIS Laboratory, a SANAS accredited laboratory (South African National Accreditation Standards) in Pretoria on the 18 January 2013. A list of twenty (20) samples is presented in Table 10 and their positions are shown in Figure 14.

Table 10: List of hydrocensus samples submitted to the Laboratory (UIS)

Surface waters samples	Groundwater samples
KASW7; KASW20; KASW23; KABH19	KABH44;KABH96; KABH93; KABH62; KABH94; KABH18; KABH66; KABH73; KABH78; KABH10; KABH8; KABH22; KABH63; KABH56; KABH67; KABH42

Table 11 provides the list of constituent measurements requested from the laboratory. The analytical methods used to measure all these constituents are given in the attached appendices, with raw analyses results (Appendix 2: Laboratory measurements).

Table 11: List of constituents measured for the hydrocensus samples

Physical constituents	Macro-constituents	Micro-constituents
pH, Electrical Conductivity (EC), Dissolved Solids.	Dissolved Oxygen, Total Alkalinity as CaCO3, Fluoride (F), Sodium (Na), Potassium (K), Chloride (Cl), Nitrite (NO2), Nitrate (NO3), Sulphate (SO4), Calcium (Ca), Magnesium (Mg), Phosphate (PO4), (NO3 as N).	Aluminium (Al), Iron (Fe), Manganese (Mn), Silicon (Si).

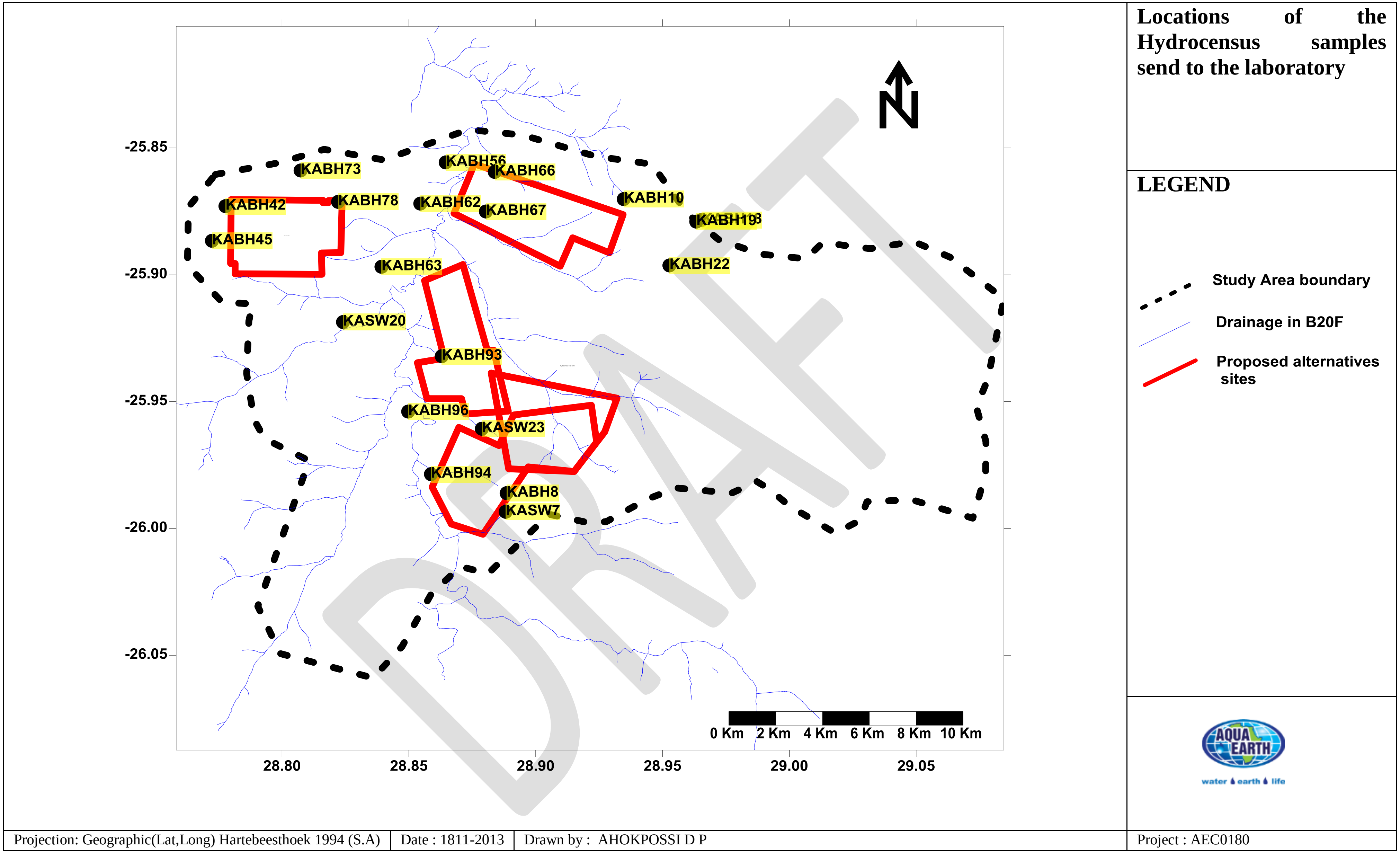


Figure 14: Locations of the hydrocensus samples submitted to the laboratory

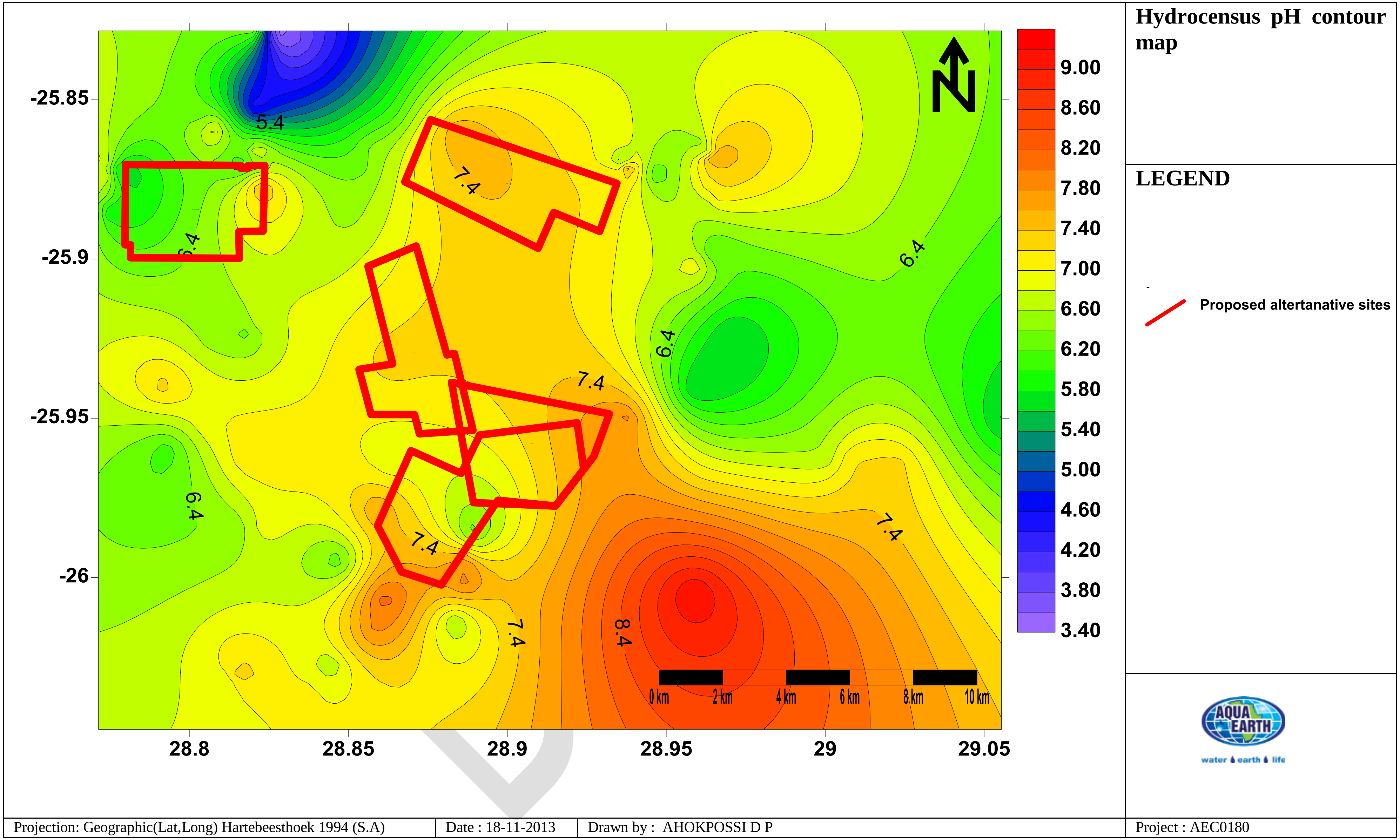


Figure 15: Hydrocensus results: pH contours

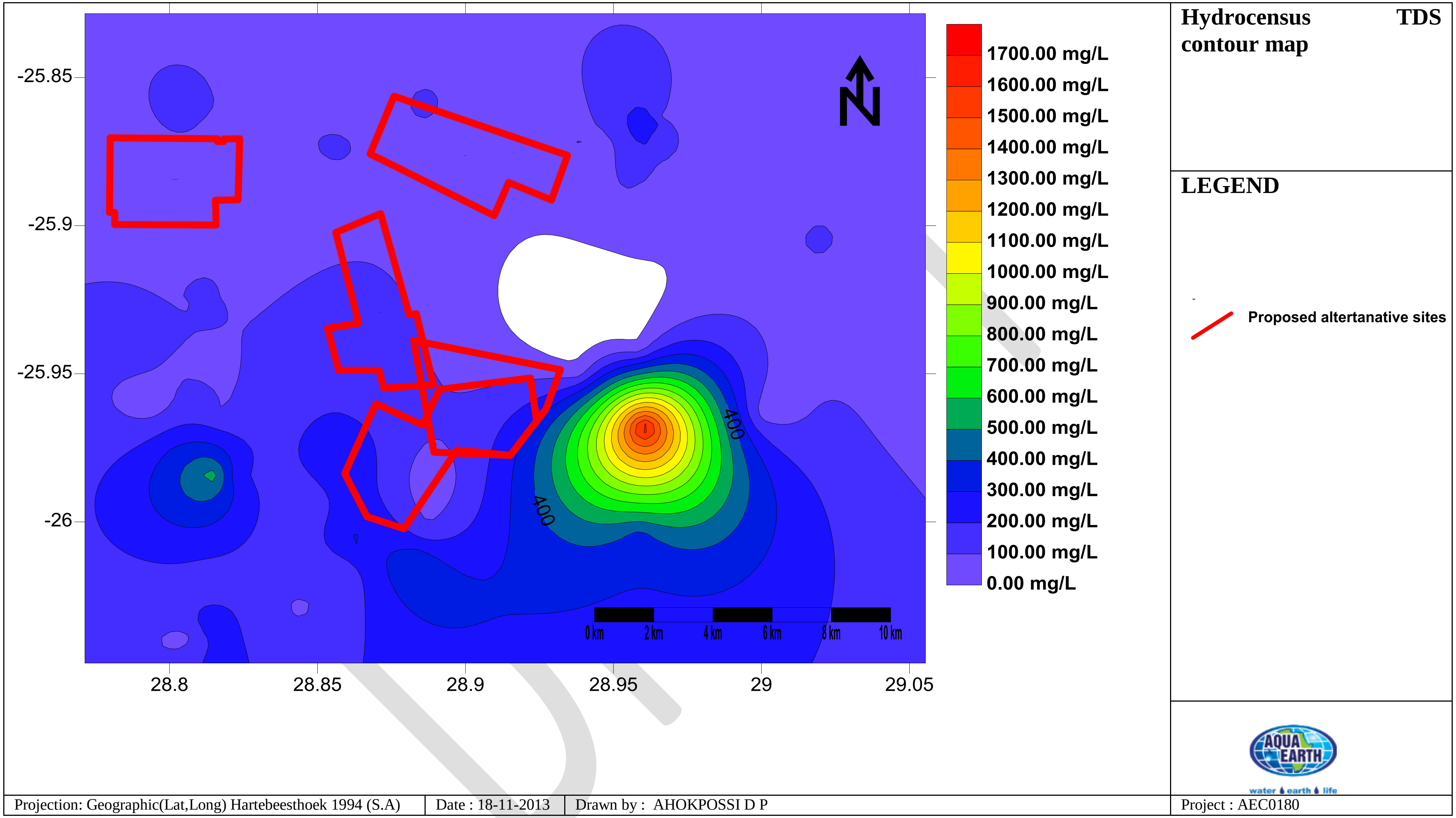


Figure 16: Hydrocensus results: TDS contours

The chemical results received from the laboratory, are interpreted by making use of the Windows Interpretation System for Hydrogeologists (WISH) and the SANS 241: 2005 (South African National Standards) for domestic use.

All the surface water samples indicates water quality that falls within the recommended operational limits for all the constituents measured, except for KASW20 for which the iron (Fe) content falls above the operational allowable limit (

Sample Number	Ph	EC mS/m	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO4 mg/l	NO3-N mg/l	F mg/l	Fe mg/l
KABH44	6.03	6	50	2.39	3.24	5.87	3.79	3.31	3.66	3.53	<0.1	<0.05
KABH96	7.59	54.2	404	58.8	26.8	34.3	0.95	41.7	117	<0.3	<0.1	<0.05
KABH93	7.1	25.2	212	25.2	11.9	17.2	2.56	18.9	5.96	4.76	0.183	<0.05
KABH62	5.86	13.8	108	7.14	5.22	11.8	6.46	17.3	10.2	4.54	<0.1	<0.05
KABH94	7.29	44	370	36	42.4	13.1	0.66	13.2	61.4	3.71	0.137	<0.05
KABH18	6.59	20.9	180	19.2	9.01	16.8	1.99	12.1	7.18	7.3	0.206	<0.05
KABH66	7.05	10.5	70	10.7	4.7	8.79	2.25	1.81	4.86	0.31	<0.1	<0.05
KABH73	7.12	6.8	56	7.62	5.01	3.43	0.88	0.965	4.23	<0.3	0.138	<0.05
KABH78	6.84	5.7	64	4.79	2.56	5.45	2	1.56	3.66	2.44	<0.1	<0.05
KABH10	6.72	3.4	32	2.15	0.78	6.09	1.99	1.08	3.95	1.15	0.39	<0.05
KABH8	6.27	6.7	60	4.27	3.89	5.34	1.83	2.19	4.34	4.52	<0.1	<0.05
KABH22	6.65	14.4	98	14.1	8.5	10.8	0.8	1.29	11.6	0.97	0.298	<0.05
KABH63	6.43	6.7	60	5.07	6.03	3.92	0.47	2.12	4.14	1.56	<0.1	<0.05
KABH56	6.61	8	76	4.26	4.03	8.26	1.69	6.05	4.53	4.6	<0.1	<0.05
KABH67	7.52	27.6	198	21.7	15	29.8	0.96	3.56	5.71	<0.3	0.591	<0.05
KABH42	5.69	2.9	<30	1.51	1.17	4.56	1.23	3.38	4.92	1.14	<0.1	<0.05
KASW19	7.04	24.1	172	19.9	17	17.1	0.84	3.52	15.2	1.43	0.276	<0.05
KASW23	6.67	6.1	60	2.85	3.21	7.01	2.41	4.97	7.77	<0.3	0.247	0.07
KASW7	6.98	10.8	82	5.99	8.55	8.08	2.69	7.38	6.93	<0.3	0.242	0.13
KASW20	6.88	12.7	94	7.09	8.1	10.1	4.17	9.89	16.2	0.48	0.273	0.78
SANS 241; 2005												
ASS I: mmended onal Limit	5-9.5	<150	<1000	<150	<70	<200	<50	<200	<400	<10	<1	<0.2
S II: Max wable	4.0-10	150-370	1000 - 2400	150-300	70-100	200-400	50-100	200-600	400-600	10.0-20	1-1.5	0.2-2
e Class II mits	>10	>370	2400>	>2400	>100	>400	>100	>600	>600	>20	>1.5	>2

Table 13).

Table 12: Water quality of the hydrocensus samples

3.1.3.2	Sample Number	Ph	EC mS/m	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO4 mg/l	NO3-N mg/l	F mg/l	Fe mg/l	Mn mg/l
Groundwater	KABH44	6.03	6	50	2.39	3.24	5.87	3.79	3.31	3.66	3.53	<0.1	<0.05	<0.05
	KABH96	7.59	54.2	404	58.8	26.8	34.3	0.95	41.7	117	<0.3	<0.1	<0.05	0.1
	KABH93	7.1	25.2	212	25.2	11.9	17.2	2.56	18.9	5.96	4.76	0.183	<0.05	<0.05
	KABH62	5.86	13.8	108	7.14	5.22	11.8	6.46	17.3	10.2	4.54	<0.1	<0.05	<0.05
	KABH94	7.29	44	370	36	42.4	13.1	0.66	13.2	61.4	3.71	0.137	<0.05	<0.05
	KABH18	6.59	20.9	180	19.2	9.01	16.8	1.99	12.1	7.18	7.3	0.206	<0.05	<0.05
	KABH66	7.05	10.5	70	10.7	4.7	8.79	2.25	1.81	4.86	0.31	<0.1	<0.05	<0.05
	KABH73	7.12	6.8	56	7.62	5.01	3.43	0.88	0.965	4.23	<0.3	0.138	<0.05	<0.05
	KABH78	6.84	5.7	64	4.79	2.56	5.45	2	1.56	3.66	2.44	<0.1	<0.05	<0.05
	KABH10	6.72	3.4	32	2.15	0.78	6.09	1.99	1.08	3.95	1.15	0.39	<0.05	<0.05
	KABH8	6.27	6.7	60	4.27	3.89	5.34	1.83	2.19	4.34	4.52	<0.1	<0.05	<0.05
	KABH22	6.65	14.4	98	14.1	8.5	10.8	0.8	1.29	11.6	0.97	0.298	<0.05	<0.05
	KABH63	6.43	6.7	60	5.07	6.03	3.92	0.47	2.12	4.14	1.56	<0.1	<0.05	<0.05
	KABH56	6.61	8	76	4.26	4.03	8.26	1.69	6.05	4.53	4.6	<0.1	<0.05	<0.05
	KABH67	7.52	27.6	198	21.7	15	29.8	0.96	3.56	5.71	<0.3	0.591	<0.05	<0.05
	KABH42	5.69	2.9	<30	1.51	1.17	4.56	1.23	3.38	4.92	1.14	<0.1	<0.05	0.06
Surface water	KASW19	7.04	24.1	172	19.9	17	17.1	0.84	3.52	15.2	1.43	0.276	<0.05	<0.05
	KASW23	6.67	6.1	60	2.85	3.21	7.01	2.41	4.97	7.77	<0.3	0.247	0.07	<0.05
	KASW7	6.98	10.8	82	5.99	8.55	8.08	2.69	7.38	6.93	<0.3	0.242	0.13	<0.05
	KASW20	6.88	12.7	94	7.09	8.1	10.1	4.17	9.89	16.2	0.48	0.273	0.78	<0.05
SANS 241; 2005														
CLASS I: Recommended Operational Limit		5-9.5	<150	<1000	<150	<70	<200	<50	<200	<400	<10	<1	<0.2	< 0.1
CLASS II: Max Allowable		4.0-10	150-370	1000 - 2400	150-300	70-100	200-400	50-100	200-600	400-600	10.0-20	1-1.5	0.2-2	0.1-1
Above Class II Limits		>10	>370	2400>	>2400	>100	>400	>100	>600	>600	>20	>1.5	>2	>1

Except the Manganese (Mn) concentration of KABH96 situated south-west of site F, which falls within class 2 maximum allowable limits, all the groundwater samples, indicates water quality that falls into the recommended operational limits.

Groundwater samples KABH73, KABH63, KABH22, KABH93, KABH94, KABH66, KABH67, KABH18, KABH56, KABH44, and KABH78 are shown on a Piper diagram (Figure 17) as calcium/magnesium bicarbonate waters, and are interpreted as unpolluted water by using the expanded Durov diagram (Figure 18).

KABH10, situated north-east of site C, indicates sodium bicarbonate/ chloride water quality, which may be related to waste water discharge, as can be seen from the expanded Durov diagram. The location of the site, in close proximity to Lynnville, supports this suggestion; but this quality could also be related to either irrigation return flow or seepage from high extraction underground coalmine area, located approximately 700 m west of KABH10. KABH42, situated close to the north-western corner of site B, and KABH62 indicates calcium/sodium, sulphate water quality, suggesting opencast coal mine waters.

All the surface water samples are interpreted as calcium magnesium waters by using a piper diagram (Figure 19), and can be considered as unpolluted water if the expanded Durov diagram (Figure 20) is considered.

Table 13: Hydrocensus samples water quality as compared to the SANS

	Sample Number	Ph	EC mS/m	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO4 mg/l	NO3-N mg/l	F mg/l	Fe mg/l	Mn mg/l
Groundwater	KABH44	6.03	6	50	2.39	3.24	5.87	3.79	3.31	3.66	3.53	<0.1	<0.05	<0.05
	KABH96	7.59	54.2	404	58.8	26.8	34.3	0.95	41.7	117	<0.3	<0.1	<0.05	0.1
	KABH93	7.1	25.2	212	25.2	11.9	17.2	2.56	18.9	5.96	4.76	0.183	<0.05	<0.05
	KABH62	5.86	13.8	108	7.14	5.22	11.8	6.46	17.3	10.2	4.54	<0.1	<0.05	<0.05
	KABH94	7.29	44	370	36	42.4	13.1	0.66	13.2	61.4	3.71	0.137	<0.05	<0.05
	KABH18	6.59	20.9	180	19.2	9.01	16.8	1.99	12.1	7.18	7.3	0.206	<0.05	<0.05
	KABH66	7.05	10.5	70	10.7	4.7	8.79	2.25	1.81	4.86	0.31	<0.1	<0.05	<0.05
	KABH73	7.12	6.8	56	7.62	5.01	3.43	0.88	0.965	4.23	<0.3	0.138	<0.05	<0.05
	KABH78	6.84	5.7	64	4.79	2.56	5.45	2	1.56	3.66	2.44	<0.1	<0.05	<0.05
	KABH10	6.72	3.4	32	2.15	0.78	6.09	1.99	1.08	3.95	1.15	0.39	<0.05	<0.05
	KABH8	6.27	6.7	60	4.27	3.89	5.34	1.83	2.19	4.34	4.52	<0.1	<0.05	<0.05
	KABH22	6.65	14.4	98	14.1	8.5	10.8	0.8	1.29	11.6	0.97	0.298	<0.05	<0.05
	KABH63	6.43	6.7	60	5.07	6.03	3.92	0.47	2.12	4.14	1.56	<0.1	<0.05	<0.05
	KABH56	6.61	8	76	4.26	4.03	8.26	1.69	6.05	4.53	4.6	<0.1	<0.05	<0.05
	KABH67	7.52	27.6	198	21.7	15	29.8	0.96	3.56	5.71	<0.3	0.591	<0.05	<0.05
	KABH42	5.69	2.9	<30	1.51	1.17	4.56	1.23	3.38	4.92	1.14	<0.1	<0.05	0.06
Surface water	KASW19	7.04	24.1	172	19.9	17	17.1	0.84	3.52	15.2	1.43	0.276	<0.05	<0.05
	KASW23	6.67	6.1	60	2.85	3.21	7.01	2.41	4.97	7.77	<0.3	0.247	0.07	<0.05
	KASW7	6.98	10.8	82	5.99	8.55	8.08	2.69	7.38	6.93	<0.3	0.242	0.13	<0.05
	KASW20	6.88	12.7	94	7.09	8.1	10.1	4.17	9.89	16.2	0.48	0.273	0.78	<0.05
SANS 241; 2005														
CLASS I: Recommended Operational Limit		5-9.5	<150	<1000	<150	<70	<200	<50	<200	<400	<10	<1	<0.2	< 0.1
CLASS II: Max Allowable		4.0-10	150-370	1000 - 2400	150-300	70-100	200-400	50-100	200-600	400-600	10.0-20	1-1.5	0.2-2	0.1-1
Above Class II Limits		>10	>370	2400>	>2400	>100	>400	>100	>600	>600	>20	>1.5	>2	>1

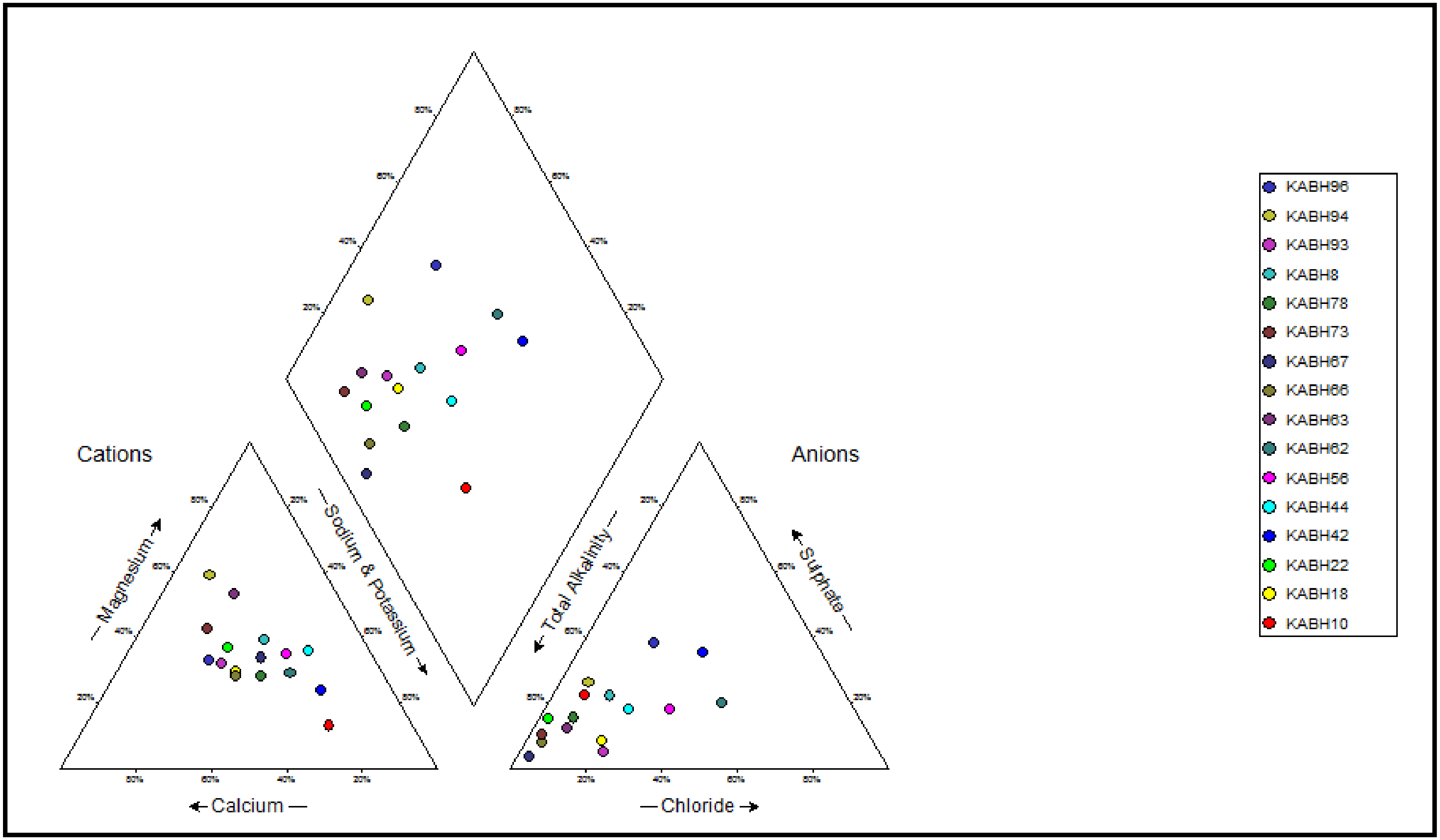


Figure 17: Piper diagram of the groundwater samples

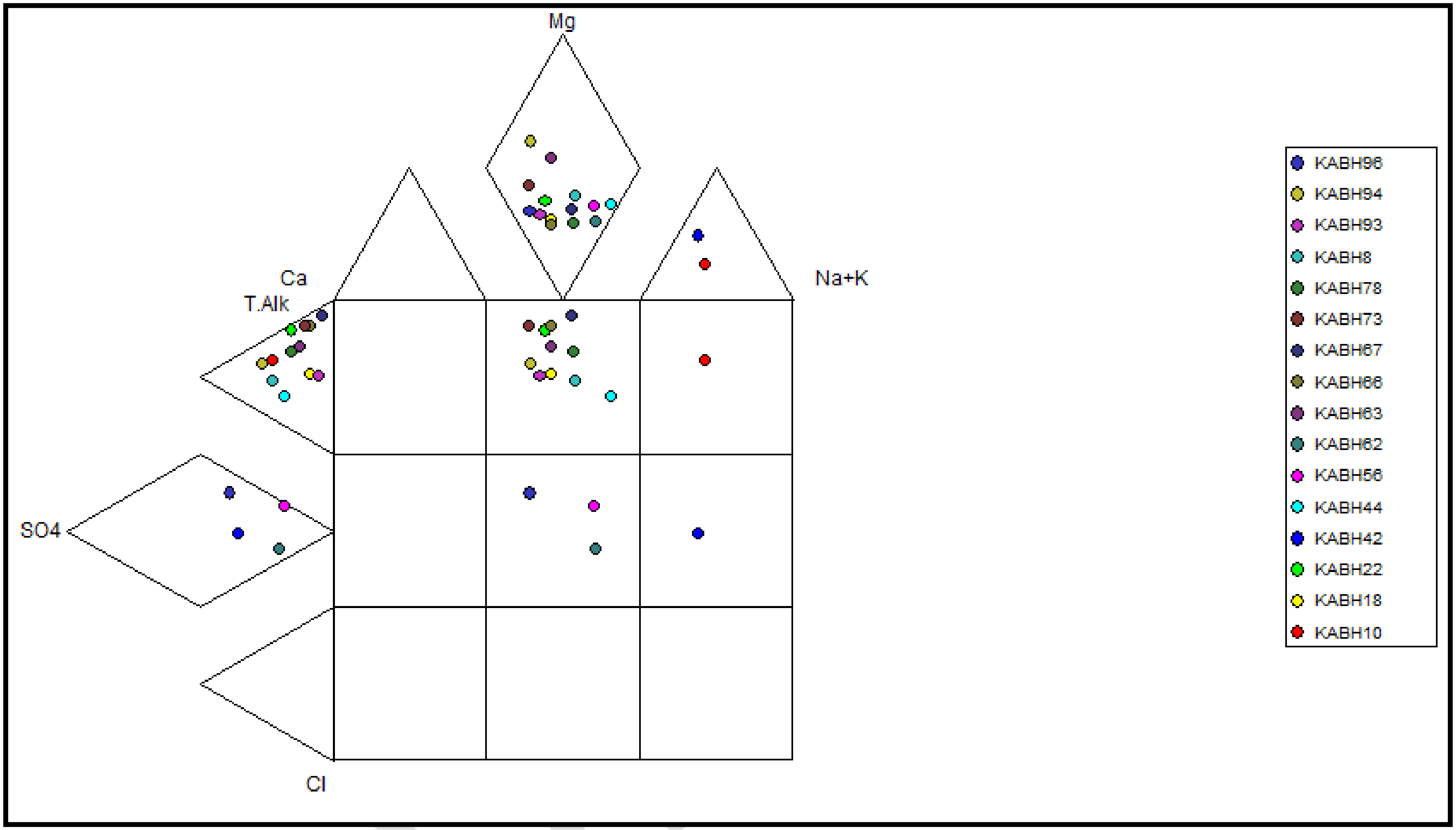


Figure 18 : Expanded Durov Diagram of the groundwater samples

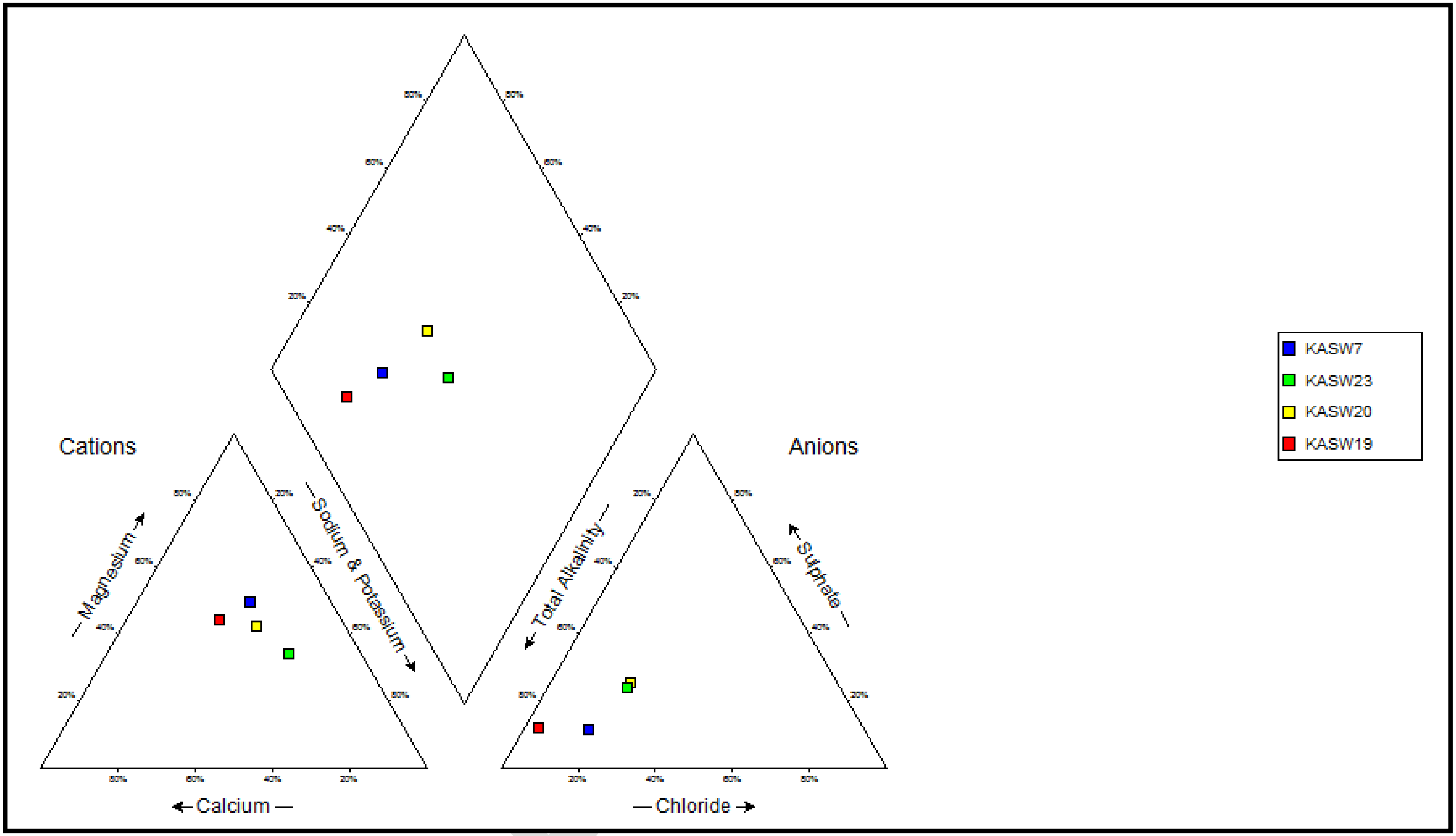


Figure 19: Piper diagram of the surface water samples

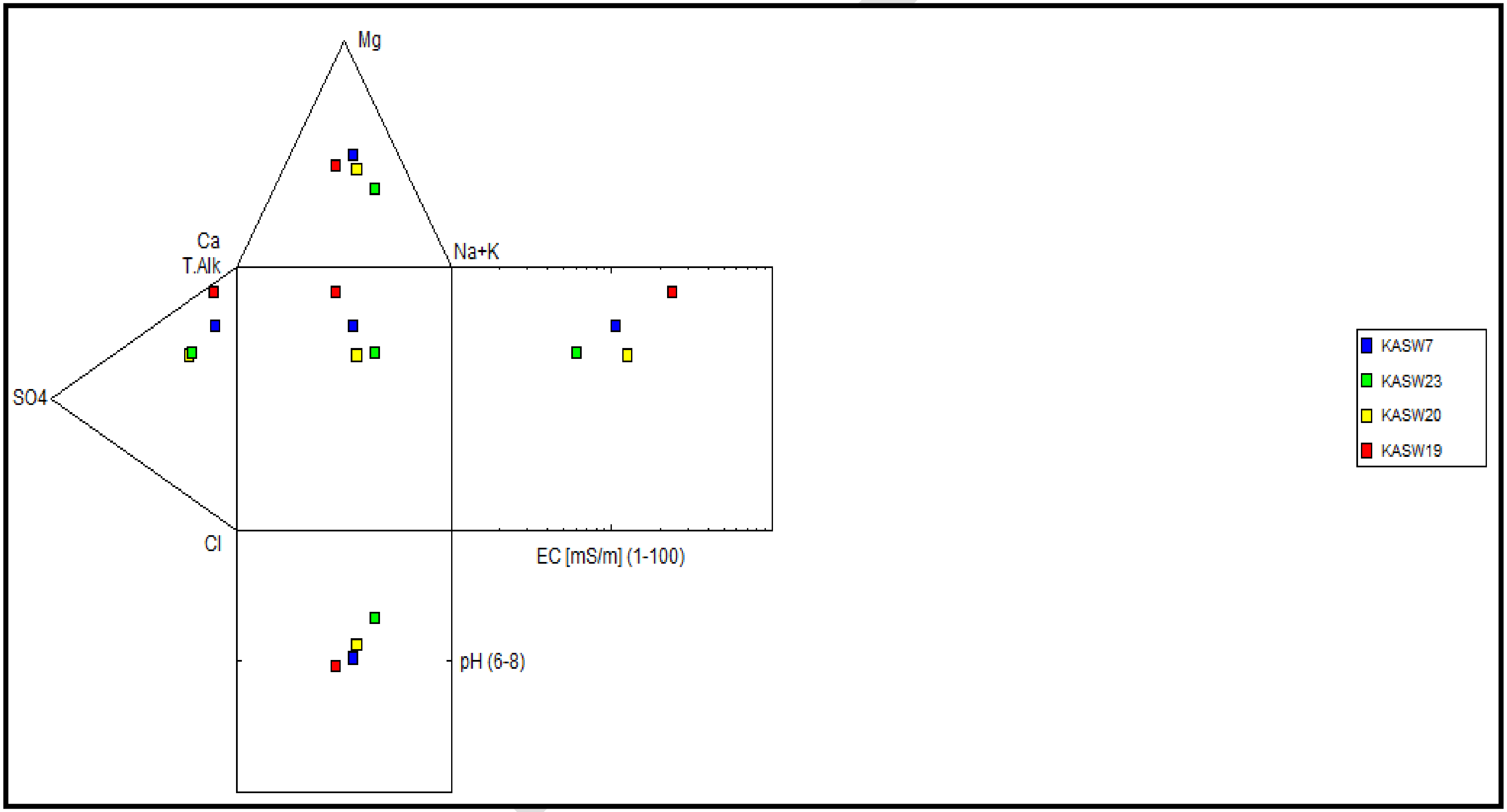


Figure 20: Expanded Durov diagram of the groundwater samples.

3.2 Geophysical surveys

A site walkover and geophysical survey was carried out in January 2013. Areas where no boreholes could be identified during hydrocensus have been prioritized for new monitoring borehole drilling. In these areas, the features associated with groundwater occurrence as listed in Table 7 were targeted in or around each proposed alternative site. These targets have been used in combination with the accessibility to the sites and location of boundary fences to define the geophysical traverses. In total, 10 geophysical surveys line were conducted, using the magnetic method and Very-Low-Frequency (VLF) Electromagnetic Method .

Magnetometers are instruments used for measuring the magnetic field and by virtue of their sensitivity and range are able to measure the changes of field between two rock types with only small differences in magnetic content.

VLF surveying is a continuous-wave (frequency domain) electromagnetic technique that uses low-frequency radio transmissions as the source. When these intersect a buried conductor they induce currents that generate a secondary magnetic field concentric around the source of the currents. VLF surveys involve measuring the orientation of this field. Eleven major transmitters located across the globe generate these transmissions, providing a range of frequencies from 3 kHz to 24 kHz.

The geophysical traverses were set out in the following manner:

- Lines were set out perpendicular or close to the possible structures as indicated on the geological map,
- Lines were walked with a station spacing of 10m and 5m in areas where the possible structure could be intersected.
- Coordinates were taken at the beginning and end of each line.
- Danger tape and white wash (chalk) was used to mark the lines.

Hydrogeological maps and geophysical data in this area has shown that the probability of striking water is greater where the weathering extends to below the piezometric level and on the fractured and contact zones.

Description of the traverses is given in Table 14 while the various positions are shown in Figure 21. The geophysical survey results are indicated in Appendix 3: Geophysical data. The majority of sites where selected using the magnetometer survey results. All sites indicated anomalies which were delineated as possible structures (lineaments) and/or contact zones between different geological formations.

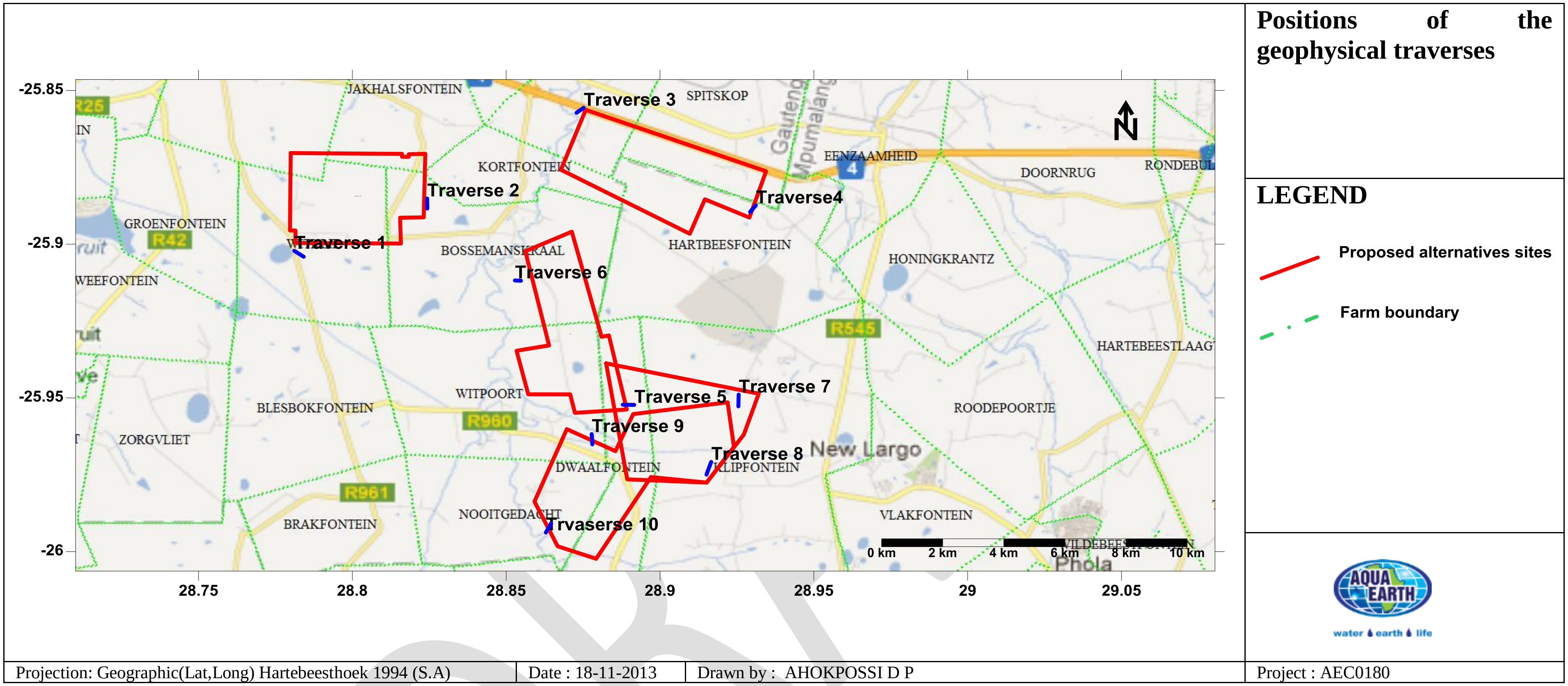


Figure 21: Positions of the geophysical traverses

Table 14: Summary on the geophysical traverses

Traverse name	Farm	Start			End			Total Length	General Direction
		Point name	Latitude	Longitude	Point name	Latitude	Longitude	(m)	
Traverse 1	Witklip	KAM1S	-25.9041	28.7842	KAM1E	-25.90217	28.78113	314	SE-NW
Traverse 2	Bosmanskraal	KAM2S	-25.8884	28.82436	KAM2E	-25.88515	28.82430	360	S-N
Traverse 3	Dwaalfointein	KAM3S	-25.85564	28.875186	KAM3E	-25.85726	28.87287	293	SW-NE
Traverse 4	Bosmanskraal	KAM4S	-25.8874	28.93116	KAM4E	-25.88950	28.92928	299	SW-NE
Traverse 5	Witpoort	KAM5S	-25.95227	28.8916	KAM5E	-25.95220	28.88790	371	W-E
Traverse 6	Klipfointein	KAM6S	-25.91188	28.8548	KAM6E	-25.91181	28.85284	197	W-E
Traverse 7	Onverwacht	KAM7S	-25.95274	28.92547	KAM7E	-25.94893	28.92557	422	S-N
Traverse 8	Klipfointein	KAM8S	-25.97494	28.9151	KAM8E	-25.97082	28.91663	482	SW-NE
Traverse 9	Klipfointein	KAM9S	-25.96509	28.878	KAM9E	-25.96178	28.87780	367	N-S
Traverse 10	Spitskop	KAM10S	-25.99082	28.8646	KAM10E	-25.99377	28.86290	369	SW-NE

Table 15: Locations of the targets for potential monitoring boreholes

Borehole Name	Farm	Geographic Coordinates (WGS84)		Position on the relevant traverse
		Latitude	Longitude	
KAM1	**Witklip**	-25.90271	28.78231	Position 55
KAM2	**Bosmanskraal**	-25.88652	28.82448	Position 50
KAM3	**Dwaalfointein**	-25.99264	28.86341	Position 95
KAM4	**Bosmanskraal**	-25.91160	28.85381	Position90
KAM5	**Witpoort**	-25.96304	28.87806	Position100
KAM6	**Klipfointein**	-25.95180	28.88964	Position120
KAM7	**Onverwacht**	-25.85620	28.87372	Position130
KAM8	**Klipfointein**	-25.97253	28.91623	Position40
KAM9	**Klipfointein**	-25.95048	28.92550	Position 280
KAM10	**Spitskop**	-25.88815	28.92983	Position 150

3.3 Drilling

Borehole drilling was carried out in February 2013 using an air percussion drill rig with a 900cfm compressor under full time supervision of a Geohydrologist. All the boreholes were drilled and completed at a diameter of 6.5 inches. A total of thirteen (13) boreholes were drilled on the target sites listed in Table 15. All the boreholes were drilled to the final depth of 30m except for borehole KAM4 and KAM9 (Error! Reference source not found.).

During the drilling the following information was recorded:

- Penetration rates;
- Samples were collected at 1m intervals during drilling;
- Water strikes;
- Borehole construction information;
- Geological formations intersected during drilling.

During the drilling phase; boreholes KAM4, KAM7 and KAM9 were re-drilled due to difficult geological conditions encountered at these sites. Borehole KAM4 collapsed at the first and second attempt and was re-drilled to final depth of 19m, boreholes KAM7 and KAM9 were re-drilled to final depth of 30m and 28m due to problems encountered during the pumping test.The observation/monitoring boreholes were constructed as follows:

- Start with 215mm diameter drilling and complete with 165mm;
- Install 110mm PVC solid and perforated casing;
- Insert gravel pack to the top;
- Install bentonite seal;
- Complete the hole with a sanitary seal, concrete block, stand pipe and lockable cap.

The drilling information (location, depth, main water strike depth, static water level) are summarised in Table 16. Detailed drilling and construction logs with the different penetration rates are presented in Appendix 4: Drilling data.

Table 16: Summary of the Drilled boreholes

Borehole Name	Location	Lat	Long	Depth (mbgl)	Water Strike (mbgl)	S.W.L. (m)
KAM1	Kusile Power Station	-25.90271	28.78231	30	8	6.0
KAM2	Kusile Power Station	-25.88813	28.92965	30	24	6.0
KAM3	Kusile Power Station	-25.85620	28.87372	40	19	14.1
KAM4	Kusile Power Station	-25.88813	28.92965	20	14	1.9
KAM5	Kusile Power Station	-25.95180	28.88964	20	21	2.23
KAM6	Kusile Power Station	-25.91160	28.85381	30	26	21.0
KAM7	Kusile Power Station	-25.95048	28.92550	30	19	2.23
KAM8	Kusile Power Station	-25.97253	28.91623	30	7	10.17
KAM9	Kusile Power Station	-23.98065	28.90853	28	19	4.97
KAM10	Kusile Power Station	-24.02409	28.90513	30	No water strike	--

Blow yields could not be measured in all of the drilled boreholes, due to the low yields intercepted, the measured blow yields in boreholes KAM2, KAM6, and KAM7 indicates a number of very low values, ranging between 0.016 l/sec to 1.9 l/s.

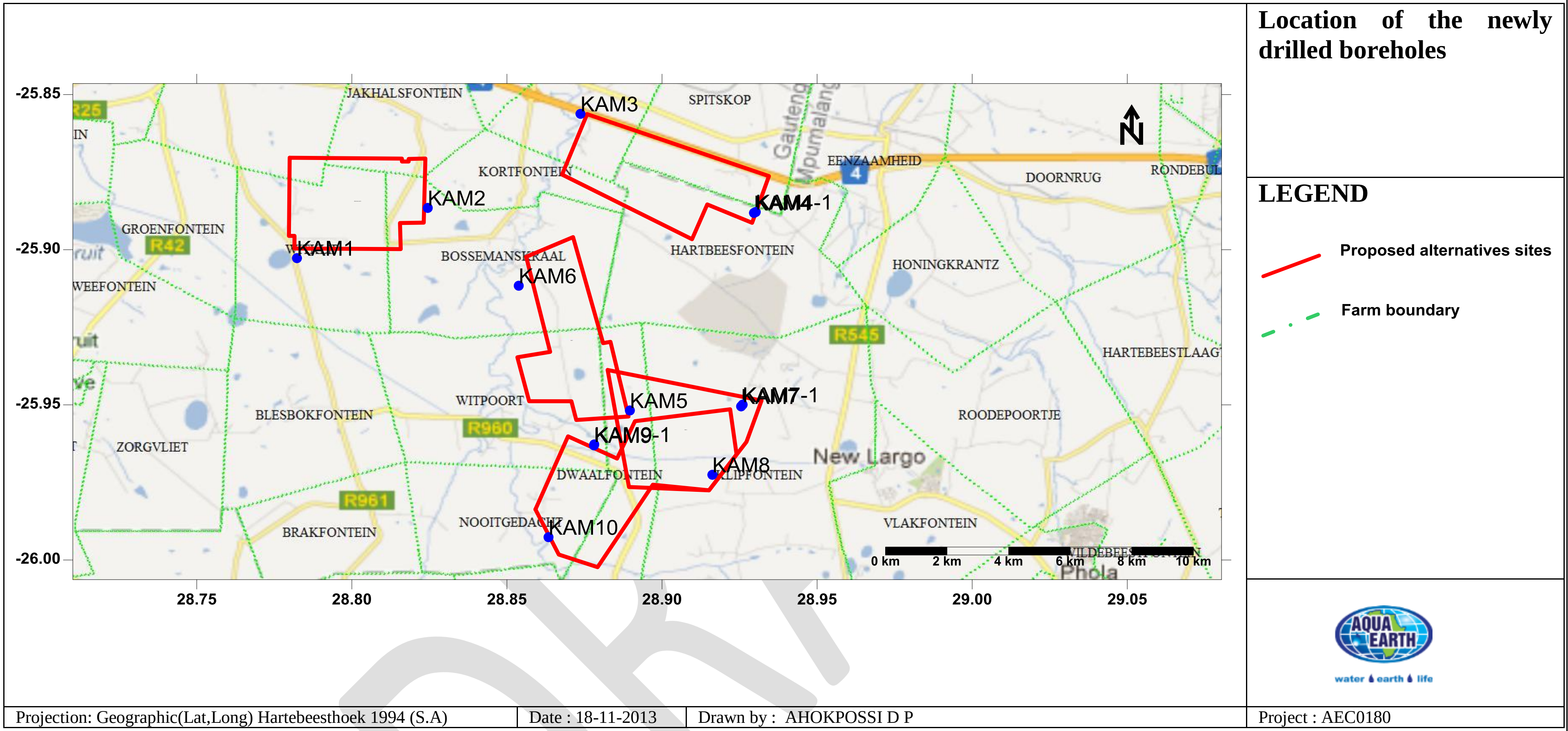


Figure 22: Locations of the newly drilled boreholes

Table 17: Typical lithology at the proposed alternative sites

<table>
<tr><th>Depth</th><th colspan="5">Lithology</th></tr>
<tr><th>(m)</th><th>Site B</th><th>Site C</th><th>Site A</th><th>Site F</th><th>Site G</th></tr>
<tr><td>1</td><td rowspan="2">Top loamy soil mixed with yellowish fine Shale</td><td rowspan="3">TOPSOIL: Angular, Fractured yellowish dry shale</td><td rowspan="2">TOPSOIL: Reddish white fine to medium grained sandstone with quarts</td><td rowspan="3">Yellowish finely pulverised by hammer-Shale</td><td rowspan="4">TOPSOIL: Brownish to reddish overburden red sandstone</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td><td rowspan="6">Shale yellowish to red</td><td rowspan="2">Fine grained heavily weathered yellowish shale</td></tr>
<tr><td>4</td><td rowspan="3">Shale: Fine grained yellowish to brown, dry</td><td>Angular, black fractured particles and laminated shale</td></tr>
<tr><td>5</td><td rowspan="6">Sandstone: Dry, Very fine light heavily weathered</td><td rowspan="4">Weathered yellowish finely powdered shale</td><td rowspan="5">Shale: Yellowish, fine grained</td></tr>
<tr><td>6</td></tr>
<tr><td>7</td><td rowspan="16">Shale: Yellowish, rounded to subrounded, fractured and dry</td></tr>
<tr><td>8</td></tr>
<tr><td>9</td><td rowspan="22">Very fine grained brownish to yellowish weathered sandstone</td><td rowspan="13">Fine to medium grained sand particles in the sandstone,angular fractured greyish to lightish sandstone</td></tr>
<tr><td>10</td><td rowspan="14">Shale:Brown, weathered , fresh broken angular chips</td></tr>
<tr><td>11</td><td rowspan="15">Shale: Fine to medium grained, lightly yellowish, rounded to angular fresh</td></tr>
<tr><td>12</td></tr>
<tr><td>13</td></tr>
<tr><td>14</td></tr>
<tr><td>15</td></tr>
<tr><td>16</td></tr>
<tr><td>17</td></tr>
<tr><td>18</td></tr>
<tr><td>19</td></tr>
<tr><td>20</td></tr>
<tr><td>21</td></tr>
<tr><td>22</td><td rowspan="7">Darkish to maroon sandstone with fine to medium grained sand particles, sub rounded fractured particles</td></tr>
<tr><td>23</td><td rowspan="7">Shale: Greyish to black, Angular ,medium sized chips, Fresh</td></tr>
<tr><td>24</td><td rowspan="7">Shale:Heavely weathered, very fine grained, greyish and dry</td></tr>
<tr><td>25</td></tr>
<tr><td>26</td><td rowspan="2">Shale: Moist yellowish very fine</td></tr>
<tr><td>27</td></tr>
<tr><td>28</td><td rowspan="3">Shale: Moist, very fine grained, greyish</td></tr>
<tr><td>29</td><td rowspan="2">Maroon angular fractured fresh (layered) shale</td></tr>
<tr><td>30</td><td>Shale: Angular, Fine to medium grained, Greyish, wet</td></tr>
</table>

Groundwater samples were collected from the newly drilled boreholes and submitted to UIS analytical services laboratory on the 19-02-2013 for analysis. The list of constituent measurements requested from the laboratory is given in Table 18. These constituents listed are selected based on constituents measured in the water monitoring program for Kusile power station. The raw results of the analyses of these samples as received from the laboratory are summarised in Appendix 2: Laboratory measurements.

Table 18: List of constituents analyzed for the drilled boreholes samples

Physical constituents	Macro-constituents	Micro-constituents	Microbiological constituents
pH, Electrical Conductivity (EC), Turbidity, Dissolved Solids, Suspended Solids	Chemical Oxygen Demand (COD), Dissolved Oxygen, Total Alkalinity as CaCO3, Total Hardness as CaCO3, Fluoride (F), Sodium (Na), Potassium (K), Chloride (Cl), Nitrite (NO2), Nitrate (NO3), Sulphate (SO4), Calcium (Ca), Magnesium (Mg), Ammonia as N	Aluminium (Al), Arsenic (As), Barium (Ba), Beryllium (Be), Boron (B), Bromide (Br), Cadmium (Cd), Cesium (Cs), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Lithium (Li), Manganese (Mn), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Selenium (Se), Silver (Ag), Strontium (Sr), Tellurium (Te), Thallium (Tl), Tin (Sn), Titanium (Ti), Tungsten (W), Uranium (U), Vanadium (V)	Total Coliforms; Faecal Coliforms; and *E.Coli*

Table 19: New drilled boreholes water quality as compared to SANS

Sample Number	pH	EC	TDS	Ca	Mg	Na	K	Cl	SO4	NO3-N	F	Fe	Mn
		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
KAM5	7.35	9	58	6.42	4.23	5.96	4.11	0.895	1.19	0.48	<0.1	<0.01	0.006
KAM2	8.08	10.5	72	8.93	6.62	5.3	1.61	0.761	0.92	<0.3	<0.1	<0.01	0.001
KAM6	8.02	34.9	236	24.1	14.6	41	1.41	2.27	9.39	<0.3	0.871	<0.01	0.014
KAM3	7.3	17	112	13.9	9.61	12.2	1.02	2.21	0.993	0.31	0.538	0.351	0.009
KAM7	9.07	32.7	226	3.76	1.01	78.9	1.03	3.26	3.94	0.49	10.1	0.322	0.005
KAM9	7.02	15.3	108	12	10.8	3.8	1.67	5	0.697	6.99	0.178	<0.01	0.009
KAM8	5.89	5.9	50	2.15	3.25	4.23	1.3	3.16	<0.3	4.89	<0.1	0.39	0.012
KAM10	9.89	16.2	100	19.6	0.39	14	1.64	3.99	29.5	0.66	0.669	0.067	0.002
KAM1	6.92	12.8	92	2.55	2.12	22.8	5.36	4.28	6.84	<0.3	<0.1	0.01	0.013
SANS													
CLASS I: Recommended Operational Limit	5-9.5	<150	<1000	<150	<70	<200	<50	<200	<400	<10	<1	<0.2	< 0.1
CLASS II: Max Allowable	4.0-10	150-370	1000 - 2400	150-300	70-100	200-400	50-100	200-600	400-600	10.0-20	1-1.5	0.2-2	0.1-1
Above Class II Limits	>10	>370	2400>	>2400	>100	>400	>100	>600	>600	>20	>1.5	>2	>1

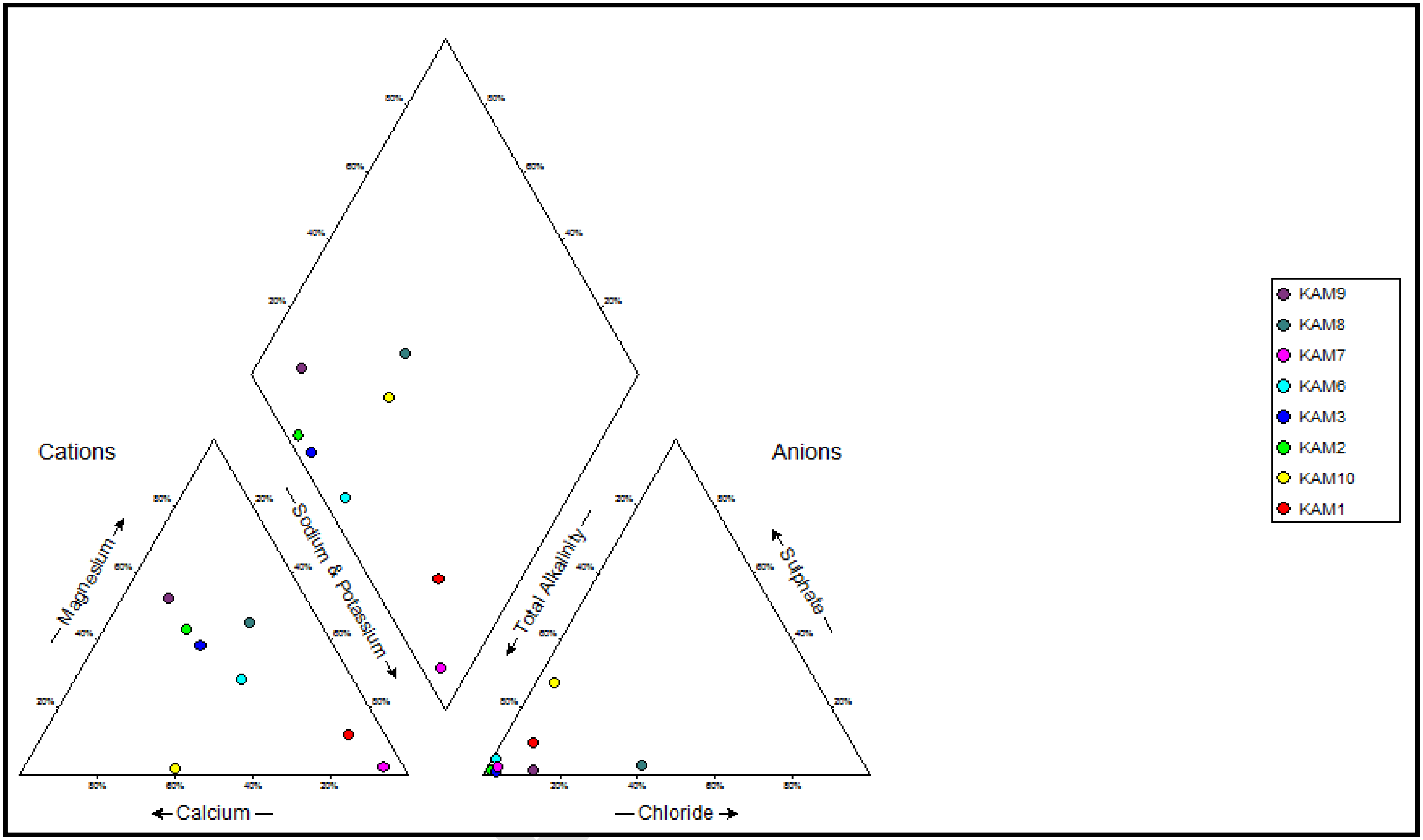


Figure 23: Piper diagram of the water quality collected from the new drilled boreholes

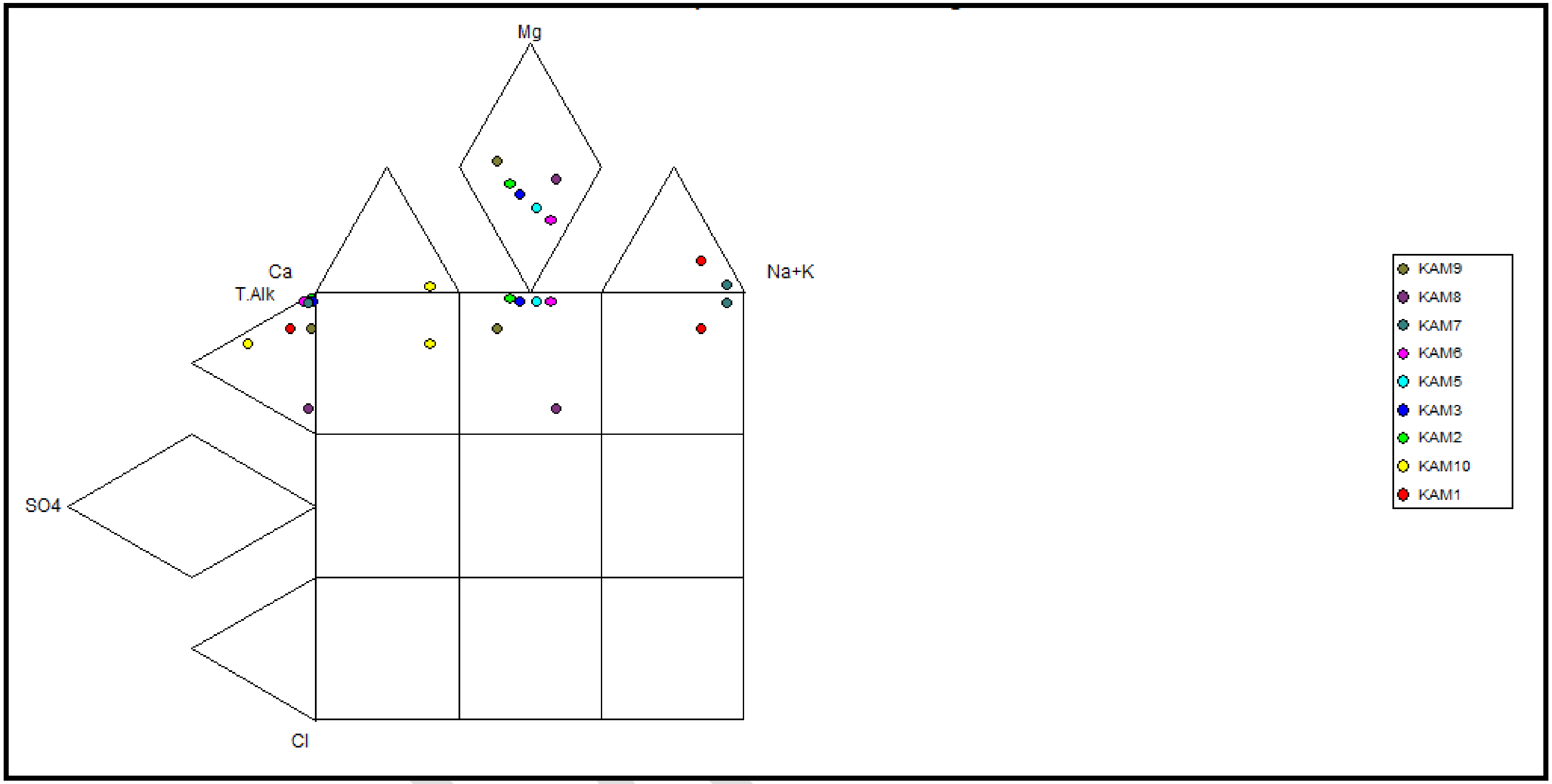


Figure 24: Expanded Durov diagram of water quality collected from the new drilled boreholes

The Iron (Fe) concentrations of samples from KAM8, KAM7, and KAM3, as well as the pH of samples KAM10 fall into the SANS class 2 maximum allowable limit. The fluoride concentration of sample KAM7 falls above the SANS class 2 maximum allowable limit. Except the high concentration of iron and fluoride as noticed (Table 19), all the other groundwater samples show water quality that falls within the class 1 recommended SANS limits.

Based on the Piper diagram (Figure 23), groundwater samples from KAM5, KAM2, KAM8, KAM9, KAM10, KAM3, and KAM6 are of calcium/magnesium bicarbonate waters (zone B), and are interpreted as unpolluted groundwater using the Expanded Durov diagram (Figure 24). The groundwater samples from KAM7 and KAM1 fall into sodium bicarbonate / chloride waters quality zone (zone C) on the Piper diagram, and are interpreted as polluted waters using the Expanded Durov diagram.

Elevated concentrations in KAM7 may be related to the historical underground coal mine activities in the New Largo mining area. This may also explain the slight concentration changes of iron in KAM7 and KAM8, and of fluoride in KAM7.

The location of KAM1 (close to a pan) suggests that the source of the pollution in this borehole may be related to either waste water discharge or irrigation return flow. The same assumptions are made for the alkaline water in the KAM10 and the high concentration of water in KAM3 which are respectively located close to the Wilge River.

3.4 Aquifer pump testing and results

The newly drilled boreholes were to be test pumped in order to determine the sustainable yield and the basic hydraulic parameters of the aquifer. The test pumping was conducted by Aqua Earth Consulting using a variable speed drive submersible test unit capable of yielding up to 4l/s.

Constant rate tests were conducted on all the boreholes drilled. These tests were conducted with the purpose of determining bulk aquifer flow parameters mainly the Transmissivity (T), and the Storativity (S) values for the surrounding country rocks. Details of pump tests are provided in Table 20.

The response (drawdown) of the aquifer during the aquifer constant pumping tests are analysed with different methods provided in the program Flow Calculation (FC) developed at the Institute of Groundwater Studies (IGS/UFS), and the results are compiled in Table 21. Detailed test data as well as the fitted curves are presented in Appendix 5: Aquifer test data interpretation. JMA consulting has estimated the shallow aquifer average storativity to 0.002, which is comparable to 0.0012 estimated by AEC.

Table 20: Summary on the pumping tests

Borehole Number	Pump Depth	Pumping Rate	Length of Pumping Phase	Drawdown	Length of Recovery Phase	Residual Drawdown
	(m)	(l/s)	(min)	(m)	(min)	(m)
KAM1	20	0.05	70	12.44	180	6.69
KAM2	20	1.67	480	14.53	360	1.56
KAM3	22	0.15	70	12.78	240	0.84
KAM4	10	0.2	42	9.03	40	6.45
KAM5	24	0.06	720	17.13	420	1.84
KAM6	28	0.07	360	3.52	120	0.90
KAM7	22	0.08	480	9.74	120	0.17
KAM8	24	0.11	360	5.05	30	0.02
KAM9	22	0.13	480	6.91	120	0.20
KAM10	25	0.07	160	20.63	780	0.46

Table 21: Calculated borehole-aquifers parameters

Borehole Number	Cooper - Jacob Method		Theis		Recovery vs Rise W/L Method	Logan 1964 Method
	T (m^2/day)	S	T (m^2/day)	S	T (m^2/day)	T (m^2/day)
KAM1	0.2	0.146	1	0.2	0.20	0.40
KAM2	4	1.88	7	0.2	0.10	0.40
KAM3	0.10	2.59E-05	..	..	0.10	0.40
KAM4	0.40	1.48E-05	..	..	0.20	0.60
KAM5	0.10	0.286	1	0.2	0.10	0.30
KAM6	0.50	9.08E-05	..	..	0.70	1.50
KAM7	0.30	0.776	1	0.18	0.10	0.50
KAM8	0.40	2.12	2	0.056	0.20	1.00
KAM9	0.8	0.178	1	0.088	0.20	0.80
KAM10	0.10	3.86E-05	..	..	0.10	0.30

3.5 Groundwater recharge

Vegter (1995) estimated the water recharge to groundwater to range between 32mm/a and 65mm/a. This relates to a recharge ranging from 5.03 % to 10.24 % of mean annual precipitation (considering 635mm/a). The JMA study at the New Largo used 37mm/a in their geohydrological calculations.

Groundwater recharge (*R*) variation in the area was also calculated using the chloride method (Bredenkamp *et al.*, 1995), and is expressed as a percentage of the Mean Annual Precipitation (MAP). The average chloride in rainfall for the area is considered to be approximately 1mg/l (inland areas). The variation in groundwater chloride concentration as measured from the current groundwater investigation, as well as previous investigations, (Zitholele monitoring programme at Kusile, JMA investigation on New Largo) has been used to estimate groundwater recharge sensitivity in the study area. Any elevated groundwater chloride concentrations in the data were considered as contaminated water and were not included in the recharge calculation.

Although the chloride method is subject to limitations, this method is preferred at the present stage of our study, using the available data. And the results will be used for recharge sensitivity. The results help us to depict at least the areas with more recharge potential in the study area (Figure 25). The generated map suggests that 80 % to 90 % of sites B and C, as well as the northern part of site F, indicates the relatively higher recharge sensitivity in the study area. These sites may constitute potential recharge areas. A SE-NW corridor of relatively higher recharge sensitivity runs from the north-eastern corner of site A to the centre of site C. This corridor position and orientation coincides with a SE-NW lineament depicted during geological analysis and possibly suggests a preferential flow zone.

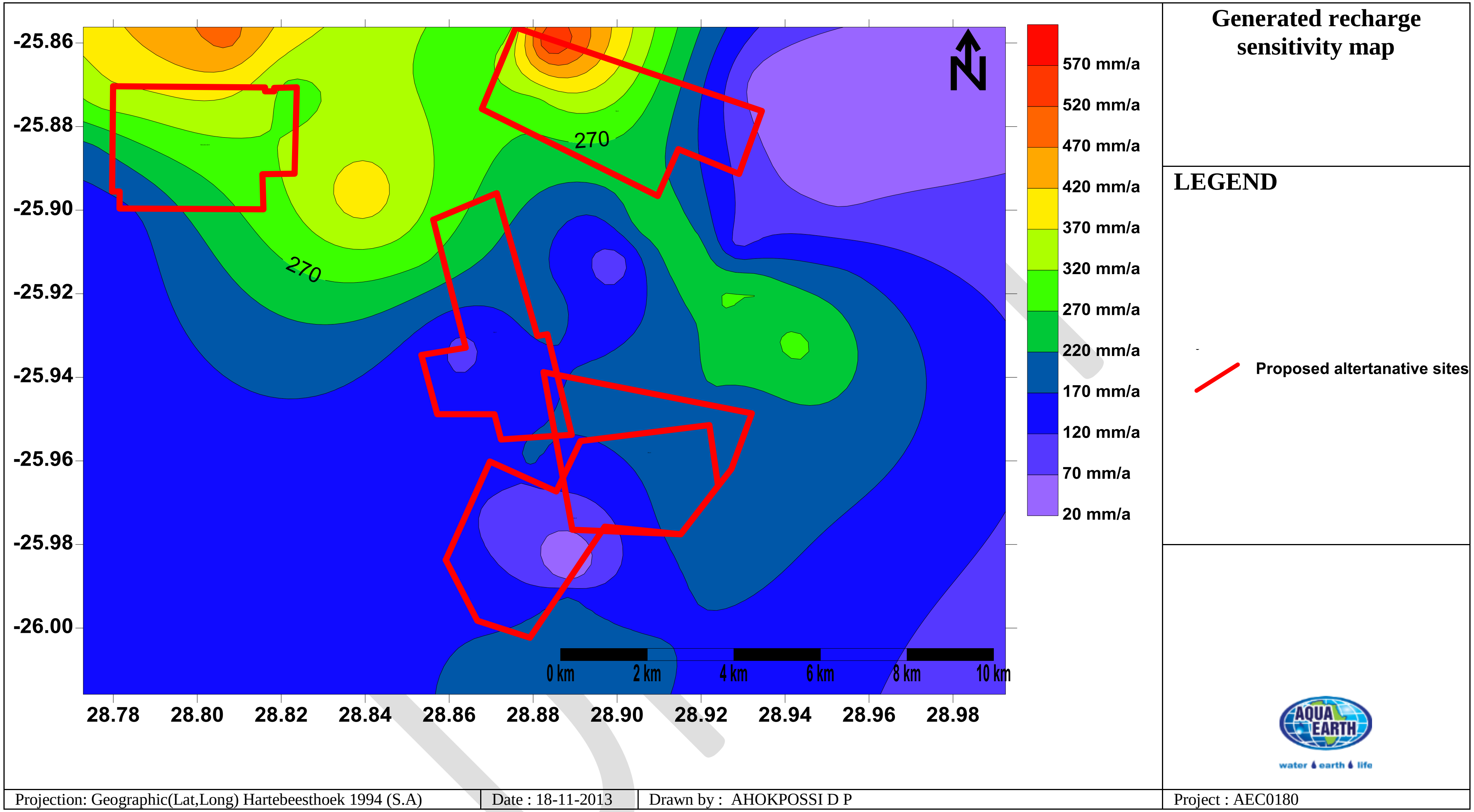


Figure 25: Generated recharge to groundwater sensitivity map (Chloride method)

3.6 Groundwater reserve

Preliminary groundwater quantity and quality reserve determination was prescribed by DWA through previous water use licenses (Ref: 28/8/3/3/36; 26/8/3/3/36). Table 22 and Table 23 present the existing reserve prescriptions.

Table 22: Summary of the Reserve

Catchment	Area	Recharge	Population	Base flow	EWR	BHN	Reserve as % Recharge
	km^2	Mm^3/a		Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a
B20F	504	16.81	5000	6.28	2.2	0.05	13.38

Table 23: Summary on the groundwater quality reserve

Parameters	Units	Basics human needs	Groundwater quality reserve
General chemistry			
Sodium	mg/l	<200	6.81
Magnesium	mg/l	<100	3.81
Calcium	mg/l	<150	5.39
Chloride	mg/l	<200	3.87
Sulphate	mg/l	<400	3.37
Nitrate	mg/l	<10	0.69
Fluoride	mg/l	<1	0.11
Physical parameters			
pH		5-9.5	7.89
Electrical conductivity	mS/m	150	9.90

4 Site sensitivity analysis and ranking of the alternatives sites

The five (5) alternative areas offer six (6) potential disposal scenarios (A, B, C, F and small A (referred "FA"), G and small A (referred "GA"), and F and G that need to be assessed in terms of groundwater sensitivity.

The most important groundwater components are zones of shallow groundwater systems or fractured zones (preferential flow paths) also including wetlands (riparian zones). These components constitute the zones where groundwater is most easily recharged, polluted or depleted.

Detailed sensitivity analysis requires flow (drawdown, contribution to base flow) and mass transport (plumes) simulations based on modelling (numerical) tools. The groundwater model will only be developed for the preferred scenario after comparative assessments.

The findings from the desktop studies and the different field investigations conducted were used to analyse the sensitivity of the proposed alternative sites in terms of groundwater and surface water. The geology (mainly of the unsaturated zone), the depths to groundwater levels, the aquifer characteristics, the recharge potential, the number of intersected rivers, and the distance to the Wilge River, were all used in the sensitivity assessment of the proposed alternative sites.

Site sensitivity was classified broadly according to the following criteria described below:

- Very low sensitivity (1)
- Low Sensitivity (2) ;
- Moderate Sensitivity (3);
- High Sensitivity (4);
- "No – Go" Areas (5).

Table 24: Proposed alternative sites rating and ranking

Sensitivity criteria		Alternative sites					
Criteria	**Detail on the criteria**	**A**	**B**	**C**	**AF**	**AG**	**FG**
Geology	Top lithology to water strike	3	2	3	3	3	3
	Contacts zones	2	3	2	5	4	5
	Linear sructures	1	1	4	1	1	1
	Combining geology	2	2	4	4	3	4
Depths to water level	--	4	4	2	4	4	2
Aquifers characterics	--	2	2	4	5	3	5
Recharge potential	--	2	5	5	3	2	3
Surface water	Distance from Wilge River	2	1	4	4	5	5
	Number of intersected rivers	4	4	4	4	4	4
	Combining surface water	3	3	4	3	5	5
Combining rating	--	13	16	19	19	17	19
Ranking	--	**1**	**2**	**4**	**4**	**3**	**4**

Based on the present geohydrological sensitivity ranking, the alternative scenario A appears to be the scenario that will be less sensitive in terms of the groundwater flow regime and quality depletion.

5 Comparative impacts assessment and choice of the preferred sites

The potential effects on groundwater are part of the primary environmental concerns when a landfill is proposed for waste disposal. Such effects are of particular importance in the case of residual coal ash landfill (disposal). In general, the quality and the quantity of the groundwater system underlying and down gradient to the disposal may be affected.

The current identification of the potential impacts of the ash disposal on groundwater follows the criteria as suggested by DWA Best Practice Guideline – Water Management for Mine Residue Deposits (DWA, 2008):

- Impact on downstream water users;
- Impacts on sensitive or protected areas;
- Impacts on any open-cast or underground workings, shafts or occupied premises; the stability of the underground/excavated workings can be affected by possible seepage and the mass of the MRD;
- Effects of seepage on dump stability;
- Groundwater quality impacts.

5.1 Potential project impacts

The potential impacts on groundwater are associated with activities during the construction phase, operation phase, and the closure and post-closure phases of the ash disposal facility.

5.1.1 Construction phase

The clearing of topsoil for footprint areas associated with ash disposal construction can increase infiltration rates of water to the groundwater system and decrease buffering capacity of soils to absorb contaminants from spills on surface. Groundwater recharge from surface may increase, especially in the potential recharge area.

During construction phase, it would be necessary to divert the stream and if required dewater the site to allow construction to proceed. Any river running across the ash disposal area will need to be diverted. The cut and fill activities associated with the construction of the ash disposal facility, may intercept shallow (or perched) groundwater. In cases where the construction will intercept groundwater (mainly perched aquifer), lowering of the groundwater level by dewatering may be needed during construction. This will cause localise cones of groundwater depressions around the ash dam area.

The construction activities are likely to increase the possibility of accidental spills of hydrocarbons (oils, diesel etc), and other potentially hazardous chemicals during the construction phase. The diversion and the demolition of a fuel pipe crossing the construction area is also a concern. Such spills together with the construction waste can infiltrate and cause contamination of the groundwater system.

The footprint area of the ash facility (minimum 822 ha) together with the DWA minimum requirements in terms of liner (ash disposal, pollution control dam) construction will result in the reduction of the recharge potential at selected site(s). The impact on the groundwater quantity is expected to be progressive as construction of the total terrace will be through multiple phases (sequences) over 60 years.

The following impacts have been considered and quantified during the construction phase:

- Increasing of infiltration rates;
- Decreasing of the soils buffering capacity;
- Deterioration of groundwater quality due to construction waste (toxic construction material);
- Deterioration of groundwater quality due to hydrocarbon spills from storage, and diversion of fuel pipes (organic contaminants);
- Altered Flow systems.

5.1.2 Operational phase

During operation of the Ash Disposal Facility (ADF), any spillages (along the conveyor) of ash during transport represent a potential source of pollution of groundwater. Seepage from the ash may infiltrate through the soil and reach the underlain shallow water table aquifer.
When the operation starts, liner, pollution control dams, and other water management infrastructures (drainage trenches) would already be constructed. Any contact of water (rainfall) with the ash in the ash disposal facility constitutes a direct potential risk of groundwater pollution as a result seepage and leachate (leaking of liners) from:

- ADF;
- contaminated water trenches;
- Pollution control dams.

Although large volumes of water is expected to be used for dust suppression and irrigation of rehabilitated areas during operational phases, such water use is not expected to impact on the groundwater drainage, since the required water volume will unlikely be sourced from groundwater. It is understood that the required water will be sourced from the power station during dry periods where there is no water in the surrounding dams.

After thirty (30) years of operations it expected that half of the terrace will be constructed. The reduction seepage potential at the selected site(s) would start to affect the water table elevations (and the groundwater drainage) at and surrounding the selected site.

The following impacts have been considered and quantified during the operational phase:

- Groundwater pollution due to potential seepage, leachate infiltration (leak of liner) from ADF, contaminated water trenches and pollution control dams;
- Alteration of the groundwater flow system due to groundwater pumping (different uses).

5.1.3 Closure (Decommissioning) phase

After 5 years of ash deposits on the first cell (lined terrace), the first phase of decommissioning and closure will be implemented in terms of the project plan requirements. The final cover is projected to stabilize the waste and prevent infiltration of precipitation. It would consist of placement of a buffer of top soil layers. All the water protection and management infrastructure will be operating and should continue.

Generally decommissioning is too short to see significant impacts on the groundwater levels, but in the present context where decommissioning will be progressive (per cell), significant reduction of impacts could occur even before the last discharge (60 years) of coal ash at the selected site. The risk of such impacts will be reduced over time as the potential contaminants are diluted and or naturally attenuated over time. With strong management options, the risk is expected to reduce even further. The following impacts have been considered and quantified during the closure phase:

- Deterioration of groundwater quality due to waste, and spills related to closure activities;
- Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ADF, contaminated water trenches and pollution control dams;
- Alteration of the groundwater flow system due to groundwater pumping (different uses).

It is recommended that the top soil layers be followed by installation of a linear low-density polyethylene (LLDPE) geomembrane.

5.1.4 Post closure phase

After closure (decommissioning), the selected site will be left with the rehabilitated coal ADF, and associated water management infrastructures (drainage, trenches, dams, monitoring and pumping well, ect.). The seepage reduction at the foot print of the ADF will reach its maximum level.

Even after the ceasing of the mining activities, the following may impact the groundwater conditions (quality and quantity) and have been quantified during for post-closure phase:

- Groundwater pollution due leachate (leak) from the ADF, Contaminated water trenches and other contaminated water storage facilities
- Reduction of infiltration rates
- Alteration of the groundwater flow system due to groundwater pumping (different uses)

5.2 Comparative impacts assessments

The methodologies (categories and ranking criteria) used for the quantification of the impacts per alternative sites have been provided by Zitholele and can be consulted in Appendix 6: Impacts assessment methodology, as provided. A matrix (Excel spreadsheet) was developed by Zitholele using given categories and ranking criteria, and has been availed to each specialist. Figure 26 through Figure 53 show the results of the geohydrological impacts and associated mitigation measures assessments.

5.2.1 Construction phase

Without any mitigation, the overall (combined impacts) impact risks that the construction of the coal Ash Disposal Facility would have on the groundwater systems are very low, irrespective to the scenario. However, it is worthy to mention that the risk impacts that result in the groundwater quality deterioration, is less with scenarios “A” and “FG”. The initial base line environment impacts risk is higher with the scenario A than the scenario “FG”, resulting in higher cumulative impacts risk with the scenario A than the scenario “FG”. In either cases, with a strict application of the proposed mitigation measure, the overall residual impacts risk can be reduced to “very low” level.

By considering the construction phase, the Alternative A appears to be the preferred in terms of protection of the groundwater resource. The following factors have contributed to the reduction of such impacts risks:

- The recharge potential is low,
- No diversion or destruction of fuel pipe line will take place,
- Only two (2) dam construction will be required,
- Only four (4) water bodies will be crossed by overland conveyor,
- The seepage permeability is low to moderate,

Rated By:	Pacome D. AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		NO-GO						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Increasing of infiltration rates due to footprint clearance	1	No Impact	Unsure	0	0	0	0	
					NO	#N/A	#N/A	#N/A	
Impact 2	Decreasing of the soils buffering capacity to absorb contaminants from surface activities	2	No Impact	Unsure	0	0	0	0	
					NO	#N/A	#N/A	#N/A	
Impact 3	Deterioration of groundwater quality due to construction wastes	5	No Impact	Unsure	0	0	0	0	
					NO	#N/A	#N/A	#N/A	
Impact 4	Deterioration of groundwater quality due to hydrocarbone spills from storage, and diversion of fuel pipes	4	No Impact	Unsure	0	0	0	0	
					NO	#N/A	#N/A	#N/A	
Impact 5	Alteration of the groundwater flow system (including perched aquifer) due to stream diversion and groundwater use and aquifer dewatering	2	No Impact	Unsure	0	0	0	0	
					NO	#N/A	#N/A	#N/A	
COMBINED WEIGHTED RATING	**BEFORE MITIGATION**	**4**	Positive	Unsure	0	0	0	0	**0**
									NO
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	No mitigation is available for the increase in infiltration rate and decreanse of soil buffering during construction								
	The construcion phase should be carried out under the supervision of a accreditated or recognised professional civil engineer,								
	Storage area for hydrocarbones or any toxic construction material should be bunded according to Departemental minimum requirement								
	Waste and spills need to be cleaned up immediately according to the Departemental minimum requiremen								
	DWA need to be notified in the event of a spill								
PROJECT IMPACT	**AFTER MITIGATION**		No Impact	Unsure	0	0	0	0	**0**
					NO	#N/A	#N/A	#N/A	**NO**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	3	3	3	5	**-3.3**
					MODL	ADJ	MED	OCCUR	**MODH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		No Impact	Unsure	0	0	0	0	**0**
					NO	#N/A	#N/A	#N/A	**NO**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		No Impact	Unsure	0	0	0	0	**0**
					NO	#N/A	#N/A	#N/A	**NO**

Figure 26: No Go Scenario construction phase impacts assessment

Rated By:	Pacome D. AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		Site A						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Increasing of infiltration rates due to footprint clearance	1	Positive	Possible	3 MODL	1 ISO	2 SHORT	2 UNLIKE	**-0.9** **VLOW**
Impact 2	Decreasing of the soils buffering capacity to absorb contaminants from surface activities	2	Negative	Definite	2 LOW	1 ISO	2 SHORT	3 LIKE	**-1.1** **LOW**
Impact 3	Deterioration of groundwater quality due to construction wastes	5	Negative	Probable	4 MODH	4 LOC	3 MED	3 LIKE	**-2.4** **MODL**
Impact 4	Deterioration of groundwater quality due to hydrocarbone spills from storage, and diversion of fuel pipes	4	Negative	Probable	2 LOW	4 LOC	3 MED	2 UNLIKE	**-1.3** **LOW**
Impact 5	Alteration of the groundwater flow system (including perched aquifer) due to stream diversion and groundwater use and aquifer dewatering	2	Negative	Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	**-1** **VLOW**
COMBINED WEIGHTED RATING	**BEFORE MITIGATION**	**4**	Negative	Probable	-1.6 LOW	-1.8 DEV	-1.5 SHORT	1.4 UNLIKE	**-0.5** **VLOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	No mitigation is available for the increase in infiltration rate and decreanse of soil buffering during construction								
	The construcion phase should be carried out under the supervision of a accreditated or recognised professional civil engineer,								
	Storage area for hydrocarbones or any toxic construction material should be bunded according to Departemental minimum requirement								
	Waste and spills need to be cleaned up immediately according to the Departemental minimum requiremen								
	DWA need to be notified in the event of a spill								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	1 VLOW	1 ISO	1 INCID	2 UNLIKE	**-0.4** **VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	4 MODH	4 LOC	3 MED	5 OCCUR	**-4.1** **HIGH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Probable	4 MODH	4 LOC	3 MED	4 VLIKE	**-3.2** **MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Probable	2 LOW	3 ADJ	2 SHORT	3 LIKE	**-1.5** **LOW**

Figure 27: Alternative A construction phase impacts assessment.

Rated By:	Pacome D. AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		SITE B						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	Impact Risk
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Increasing of infiltration rates due to footprint clearance	1	Positive	Possible	1	2	2	3	**-1.1**
					VLOW	DEV	SHORT	LIKE	**LOW**
Impact 2	Decreasing of the soils buffering capacity to absorb contaminants from surface activities	2	Negative	Definite	2	1	2	2	**-0.7**
					LOW	ISO	SHORT	UNLIKE	**VLOW**
Impact 3	Deterioration of groundwater quality due to construction wastes	5	Negative	Probable	6	4	3	4	**-3.8**
					VHIGH	LOC	MED	VLIKE	**MODH**
Impact 4	Deterioration of groundwater quality due to hydrocarbone spills from storage, and diversion of fuel pipes	4	Negative	Probable	6	4	3	4	**-3.8**
					VHIGH	LOC	MED	VLIKE	**MODH**
Impact 5	Alteration of the groundwater flow system (including perched aquifer) due to stream diversion and groundwater use and aquifer dewatering	2	Negative	Unsure	4	2	2	2	**-1.2**
					MODH	DEV	SHORT	UNLIKE	**LOW**
COMBINED WEIGHTED RATING	**BEFORE MITIGATION**	**4**	Negative	Probable	-2.7	-1.8	-1.5	1.9	**-0.8**
					MODL	DEV	SHORT	UNLIKE	**VLOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	No mitigation is available for the increase in infiltration rate and decrease of soil buffering during construction								
	The construcion phase should be carried out under the supervision of a accreditated or recognised professional civil engineer,								
	Storage area for hydrocarbones or any toxic construction material should be bunded according to Departemental minimum requirement								
	Waste and spills need to be cleaned up immediately according to the Departemental minimum requiremen		Care should be taken for the 2740 m of demolition or divertion of fuel pipe line						
	DWA need to be notified in the event of a spill								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	1	1	1	2	**-0.4**
					VLOW	ISO	INCID	UNLIKE	**VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	2	4	3	5	**-3.3**
					LOW	LOC	MED	OCCUR	**MODH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Probable	2	4	3	4	**-2.7**
					LOW	LOC	MED	VLIKE	**MODL**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Probable	2	2	1	2	**-0.7**
					LOW	DEV	INCID	UNLIKE	**VLOW**

Figure 28: Alternative B construction impacts assessment.

Rated By:	Pacome D. AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		SITE C						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Increasing of infiltration rates due to footprint clearance	1	Positive	Possible	2 / LOW	1 / ISO	2 / SHORT	4 / VLIKE	**-1.5** / **LOW**
Impact 2	Decreasing of the soils buffering capacity to absorb contaminants from surface activities	2	Negative	Definite	2 / LOW	1 / ISO	2 / SHORT	3 / LIKE	**-1.1** / **LOW**
Impact 3	Deterioration of groundwater quality due to construction wastes	5	Negative	Probable	2 / LOW	3 / ADJ	3 / MED	4 / VLIKE	**-2.4** / **MODL**
Impact 4	Deterioration of groundwater quality due to hydrocarbone spills from storage, and diversion of fuel pipes	4	Negative	Probable	5 / HIGH	3 / ADJ	3 / MED	4 / VLIKE	**-3.2** / **MODH**
Impact 5	Alteration of the groundwater flow system (including perched aquifer) due to stream diversion and groundwater use and aquifer dewatering	2	Negative	Unsure	2 / LOW	1 / ISO	2 / SHORT	2 / UNLIKE	**-0.7** / **VLOW**
COMBINED WEIGHTED RATING	**BEFORE MITIGATION**	**4**	Negative	Probable	-1.6 / LOW	-1.3 / DEV	-1.5 / SHORT	2 / UNLIKE	**-0.6** / **VLOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	No mitigation is available for the increase in infiltration rate and decrease of soil buffering during construction								
	The construcion phase should be carried out under the supervision of a accreditated or recognised professional civil engineer,								
	Storage area for hydrocarbones or any toxic construction material should be bunded according to Departemental minimum requirement								
	Waste and spills need to be cleaned up immediately according to the Departemental minimum requiremen		Care should be taken for the 4943 m of demolition or divertion of fuel pipe line						
	DWA need to be notified in the event of a spill								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	1 / VLOW	1 / ISO	1 / INCID	2 / UNLIKE	**-0.4** / **VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	3 / MODL	3 / ADJ	3 / MED	5 / OCCUR	**-3.3** / **MODH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Probable	3 / MODL	3 / ADJ	3 / MED	4 / VLIKE	**-2.7** / **MODL**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Probable	2 / LOW	1 / ISO	1 / INCID	2 / UNLIKE	**-0.6** / **VLOW**

Figure 29: Alternative C construction impacts assessment.

Rated By: Pacome D. AHOKPOSSI Reviewed By: Albertus Lombaard			ALTERNATIVES:						
			SITE A+F						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	Impact Risk
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Increasing of infiltration rates due to footprint clearance	1	Positive	Possible	3	1	2	2	-0.9
					MODL	ISO	SHORT	UNLIKE	VLOW
Impact 2	Decreasing of the soils buffering capacity to absorb contaminants from surface activities	2	Negative	Definite	2	1	4	3	-1.5
					LOW	ISO	LONG	LIKE	LOW
Impact 3	Deterioration of groundwater quality due to construction wastes	5	Negative	Probable	5	4	3	2	-1.8
					HIGH	LOC	MED	UNLIKE	LOW
Impact 4	Deterioration of groundwater quality due to hydrocarbone spills from storage, and diversion of fuel pipes	4	Negative	Probable	2	4	3	3	-2
					LOW	LOC	MED	LIKE	LOW
Impact 5	Alteration of the groundwater flow system (including perched aquifer) due to stream diversion and groundwater use and aquifer dewatering	2	Negative	Unsure	2	3	2	2	-1
					LOW	ADJ	SHORT	UNLIKE	VLOW
COMBINED WEIGHTED RATING	**BEFORE MITIGATION**	**4**	Negative	Probable	-1.8	-1.8	-1.6	1.4	-0.5
					LOW	DEV	SHORT	UNLIKE	VLOW
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	No mitigation is available for the increase in infiltration rate and decrease of soil buffering during construction								
	The construcion phase should be carried out under the supervision of a accreditated or recognised professional civil engineer,								
	Storage area for hydrocarbones or any toxic construction material should be bunded according to Departemental minimum requirement								
	Waste and spills need to be cleaned up immediately according to the Departemental minimum requiremen								
	DWA need to be notified in the event of a spill								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	1	1	1	2	-0.4
					VLOW	ISO	INCID	UNLIKE	VLOW
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	4	4	3	5	-4.1
					MODH	LOC	MED	OCCUR	HIGH
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Probable	4	4	3	4	-3.2
					MODH	LOC	MED	VLIKE	MODH
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Probable	2	1	1	2	-0.6
					LOW	ISO	INCID	UNLIKE	VLOW

Figure 30: Alternative AF construction impacts assessment.

Rated By:	Pacome D. AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		SITEA+G						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Increasing of infiltration rates due to footprint clearance	1	Positive	Possible	3 MODL	1 ISO	2 SHORT	2 UNLIKE	**-0.9** **VLOW**
Impact 2	Decreasing of the soils buffering capacity to absorb contaminants from surface activities	2	Negative	Definite	2 LOW	1 ISO	2 SHORT	2 UNLIKE	**-0.7** **VLOW**
Impact 3	Deterioration of groundwater quality due to construction wastes	5	Negative	Probable	3 MODL	4 LOC	3 MED	3 LIKE	**-2.2** **MODL**
Impact 4	Deterioration of groundwater quality due to hydrocarbone spills from storage, and diversion of fuel pipes	4	Negative	Probable	4 MODH	4 LOC	3 MED	4 VLIKE	**-3.2** **MODH**
Impact 5	Alteration of the groundwater flow system (including perched aquifer) due to stream diversion and groundwater use and aquifer dewatering	2	Negative	Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	-1 **VLOW**
COMBINED WEIGHTED RATING	**BEFORE MITIGATION**	**4**	Negative	Probable	-1.7 LOW	-1.8 DEV	-1.5 SHORT	1.6 UNLIKE	**-0.6** **VLOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	No mitigation is available for the increase in infiltration rate and decrease of soil buffering during construction								
	The construcion phase should be carried out under the supervision of a accreditated or recognised professional civil engineer,								
	Storage area for hydrocarbones or any toxic construction material should be bunded according to Departemental minimum requirement								
	Waste and spills need to be cleaned up immediately according to the Departemental minimum requiremen		Care should be taken for the 12690 m of demolition or divertion of fuel pipe line						
	DWA need to be notified in the event of a spill								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	1 VLOW	1 ISO	1 INCID	2 UNLIKE	**-0.4** **VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	4 MODH	4 LOC	3 MED	5 OCCUR	**-4.1** **HIGH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	4 MODH	4 LOC	3 MED	4 VLIKE	**-3.2** **MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Probable	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6** **VLOW**

Figure 31: Alternative AG construction impacts assessment.

Rated By: Pacome D. AHOKPOSSI Reviewed By: Albertus Lombaard			ALTERNATIVES: SITE F+G						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Increasing of infiltration rates due to footprint clearance	1	Positive	Possible	2 LOW	2 DEV	2 SHORT	2 UNLIKE	**-0.9** **VLOW**
Impact 2	Decreasing of the soils buffering capacity to absorb contaminants from surface activities	2	Negative	Definite	2 LOW	1 ISO	2 SHORT	2 UNLIKE	**-0.7** **VLOW**
Impact 3	Deterioration of groundwater quality due to construction wastes	5	Negative	Probable	2 LOW	3 ADJ	3 MED	3 LIKE	**-1.8** **LOW**
Impact 4	Deterioration of groundwater quality due to hydrocarbone spills from storage, and diversion of fuel pipes	4	Negative	Probable	4 MODH	3 ADJ	3 MED	4 VLIKE	**-2.9** **MODL**
Impact 5	Alteration of the groundwater flow system (including perched aquifer) due to stream diversion and groundwater use and aquifer dewatering	2	Negative	Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	**-1** **VLOW**
COMBINED WEIGHTED RATING	**BEFORE MITIGATION**	**4**	Negative	Probable	-1.4 LOW	-1.5 DEV	-1.5 SHORT	1.6 UNLIKE	**-0.5** **VLOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	No mitigation is available for the increase in infiltration rate and decrease of soil buffering during construction								
	The construcion phase should be carried out under the supervision of a accreditated or recognised professional civil engineer,								
	Storage area for hydrocarbones or any toxic construction material should be bunded according to Departemental minimum requirement								
	Waste and spills need to be cleaned up immediately according to the Departemental minimum requiremen		Care should be taken for the 12690 m of demolition or divertion of fuel pipe line						
	DWA need to be notified in the event of a spill								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	1 VLOW	1 ISO	1 INCID	2 UNLIKE	**-0.4** **VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	2 LOW	3 ADJ	2 SHORT	4 VLIKE	**-2.1** **MODL**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Possible	2 LOW	3 ADJ	2 SHORT	4 VLIKE	**-2.1** **MODL**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6** **VLOW**

Figure 32: Alternative FG construction impacts assessment.

5.2.2 Operation phase

Prior to mitigation, the overall (combined impacts) impacts risks that the operation of the coal Ash Disposal Facility would have on the groundwater systems present below the respective site (s) of the six (6) alternatives rate from negative Moderately low impacts risk to negative High impacts risk. The risk impacts that result in the groundwater quality deterioration, is less with Alternative "A" and "C". The initial base line environment impacts risk are higher with the Alternative A than the Alternative "C", resulting in higher cumulative impacts risk with the Alternative A than Alternative "C". In either the cases, the resulting cumulative impacts risks are Moderately high, and with a strict application of the proposed mitigation measure, the overall residual impacts risk will be reduced to a "very low" level.

By considering the operation phase, Alternative A appears to be the preferred in term of protection of the groundwater resource. The following factors have contributed to the reduction of such impacts risks:

- The recharge potential is low,
- Only two (2) dams will be operating,
- Ash will be conveyed across a short distance.

Rated By: *D. Pacome AHOKPOSSI*
Reviewed By: *Albertus Lombaard*

	IMPACT DESCRIPTION	Weighting	NO-GO Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	6	No Impact	Unsure	0 NO	0 #N/A	0 #N/A	0 #N/A	**0** **NO**
Impact 2	Alteration of the groundwater flow system due to groundwater pumping (different uses)	4	No Impact	Unsure	0 NO	0 #N/A	0 #N/A	0 #N/A	**0** **NO**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Positive	Unsure	0	0	0	0	**0** **NO**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Ash Dam and all pollution control facilities (dams , trenches) must lined according to the Departemental minimum requirements (1998/2012) with a cuspate leak detection layer in-between.								
	Avoid as possible longer lag time bettween liner installation and ash disposal or trenches construction.								
	Ash Dams and all pollution control facilities (dams , trenches) must be operated and to have a mimimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.								
	Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .								
	Pump treatment and re-use contaminated water								
	Disposal of coal ash and operation of the ash dam must be done in a maaner to prevent water pollution								
PROJECT IMPACT	**AFTER MITIGATION**		No Impact	Unsure	0 NO	0 #N/A	0 #N/A	0 #N/A	**0** **NO**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		No Impact	Unsure	3 MODL	4 LOC	3 MED	5 OCCUR	**3.7** **MODH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		No Impact	Unsure	0 NO	0 #N/A	0 #N/A	0 #N/A	**0** **NO**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		No Impact	Unsure	0 NO	0 #N/A	0 #N/A	0 #N/A	**0** **NO**

Figure 33: No Go Alternative Operation impacts assessment

Rated By:	D. Pacome AHOKPOSSI		**ALTERNATIVES:**						
Reviewed By:	Albertus Lombaard		**Site A**						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	6	Negative	Probable	5 HIGH	4 LOC	4 LONG	3 LIKE	**-2.9** **MODL**
Impact 2	Alteration of the groundwater flow system due to groundwater pumping (different uses)	4	Negative	Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	**-1** **VLOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-3.8 MODH	-3.6 LOC	-3.2 LONG	2.6 COULD	**-2** **LOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Ash Dam and all pollution control facilities (dams , trenches) must lined according to the Departemental minimum requirements (1998/2012) with a cuspate leak detection layer in-between.								
	Avoid as possible longer lag time bettween liner installation and ash disposal or trenches construction.								
	Ash Dams and all pollution control facilities (dams , trenches) must be operated and to have a mimimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.								
	Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .		Monitoring need to take place beween the ash dam facility and the New Largo to detec any croos contamination						
	Pump treatment and re-use contaminated water								
	Disposal of coal ash and operation of the ash dam must be done in a maaner to prevent water pollution								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	3 ADJ	1 INCID	2 UNLIKE	**-0.9** **VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	4 MODH	4 LOC	3 MED	5 OCCUR	**-4.1** **HIGH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	5 HIGH	4 LOC	4 LONG	4 VLIKE	**-3.8** **MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	3 ADJ	1 INCID	2 UNLIKE	**-0.9** **VLOW**

Figure 34: Alternative A Operation impacts assessment

Rated By: D. Pacome AHOKPOSSI Reviewed By: Albertus Lombaard			ALTERNATIVES:						
			SITE B						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	6	Negative	Possible	6 VHIGH	4 LOC	4 LONG	4 VLIKE	**-4.1** **HIGH**
Impact 2	Alteration of the groundwater flow system due to groundwater pumping (different uses)	4	Negative	Unsure	5 HIGH	2 DEV	2 SHORT	2 UNLIKE	**-1.3** **LOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-5.6 VHIGH	-3.2 LOC	-3.2 LONG	3.2 VLIKE	**-2.8** **MODL**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Ash Dam and all pollution control facilities (dams , trenches) must lined according to the Departemental minimum requirements (1998/2012) with a cuspate leak detection layer in-between.								
	Avoid as possible longer lag time bettween liner installation and ash disposal or trenches construction.								
	Ash Dams and all pollution control facilities (dams , trenches) must be operated and to have a mimimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.								
	Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .		Monitoring need to take place down gradient on the two concerned catchments						
	Pump treatment and re-use contaminated water								
	Disposal of coal ash and operation of the ash dam must be done in a maaner to prevent water pollution								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	2 DEV	1 INCID	2 UNLIKE	**-0.7** **VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	2 LOW	4 LOC	3 MED	5 OCCUR	**-3.3** **MODH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	6 VHIGH	4 LOC	4 LONG	4 VLIKE	**-4.1** **HIGH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	2 DEV	1 INCID	2 UNLIKE	**-0.7** **VLOW**

Figure 35: Alternative B Operation impacts assessment

Rated By: *D. Pacome AHOKPOSSI* Reviewed By: *Albertus Lombaard*			**ALTERNATIVES:**						
			SITE C						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	6	Negative	Probable	6 VHIGH	3 ADJ	4 LONG	3 LIKE	**-2.9** **MODL**
Impact 2	Alteration of the groundwater flow system due to groundwater pumping (different uses)	4	Negative	Unsure	3 MODL	1 ISO	2 SHORT	2 UNLIKE	**-0.9** **VLOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-4.8 HIGH	-2.2 ADJ	-3.2 LONG	2.6 COULD	**-2** **LOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Ash Dam and all pollution control facilities (dams , trenches) must lined according to the Departemental minimum requirements (1998/2012) with a cuspate leak detection layer in-between.								
	Avoid as possible longer lag time between liner installation and ash disposal or trenches construction.								
	Ash Dams and all pollution control facilities (dams , trenches) must be operated and to have a mimimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.								
	Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .								
	Pump treatment and re-use contaminated water								
	Disposal of coal ash and operation of the ash dam must be done in a maaner to prevent water pollution								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	2 DEV	1 INCID	2 UNLIKE	**-0.7** **VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	3 MODL	3 ADJ	3 MED	5 OCCUR	**-3.3** **MODH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	6 VHIGH	3 ADJ	4 LONG	4 VLIKE	**-3.8** **MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	2 DEV	1 INCID	2 UNLIKE	**-0.7** **VLOW**

Figure 36: Alternative C Operation Impacts assessment

Rated By: D. Pacome AHOKPOSSI Reviewed By: Albertus Lombaard			**ALTERNATIVES:**						
			SITE A+F						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	6	Negative	Probable	5 HIGH	4 LOC	4 LONG	4 VLIKE	**-3.8** **MODH**
Impact 2	Alteration of the groundwater flow system due to groundwater pumping (different uses)	4	Negative	Unsure	3 MODL	3 ADJ	2 SHORT	2 UNLIKE	**-1.2** **LOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-4.2 HIGH	-3.6 LOC	-3.2 LONG	3.2 VLIKE	**-2.6** **MODL**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Ash Dam and all pollution control facilities (dams , trenches) must lined according to the Departemental minimum requirements (1998/2012) with a cuspate leak detection layer in-between.								
	Avoid as possible longer lag time betweeen liner installation and ash disposal or trenches construction.								
	Ash Dams and all pollution control facilities (dams , trenches) must be operated and to have a mimimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.								
	Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .								
	Pump treatment and re-use contaminated water								
	Disposal of coal ash and operation of the ash dam must be done in a maaner to prevent water pollution								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	3 ADJ	1 INCID	2 UNLIKE	**-0.9** **VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	4 MODH	4 LOC	3 MED	5 OCCUR	**-4.1** **HIGH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	5 HIGH	4 LOC	4 LONG	4 VLIKE	**-3.8** **MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	3 ADJ	1 INCID	2 UNLIKE	**-0.9** **VLOW**

Figure 37: Alternative AF Operation impacts assessment

Rated By: D. Pacome AHOKPOSSI Reviewed By: Albertus Lombaard			**ALTERNATIVES:**						
			SITEA+G						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	6	Negative	Probable	5 HIGH	4 LOC	4 LONG	4 VLIKE	**-3.8** **MODH**
Impact 2	Alteration of the groundwater flow system due to groundwater pumping (different uses)	4	Negative	Unsure	4 MODH	3 ADJ	2 SHORT	2 UNLIKE	**-1.3** **LOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-4.6 HIGH	-3.6 LOC	-3.2 LONG	3.2 VLIKE	**-2.7** **MODL**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Ash Dam and all pollution control facilities (dams , trenches) must lined according to the Departemental minimum requirements (1998/2012) with a cuspate leak detection layer in-between.								
	Avoid as possible longer lag time betwteen liner installation and ash disposal or trenches construction.								
	Ash Dams and all pollution control facilities (dams , trenches) must be operated and to have a mimimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.								
	Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .								
	Pump treatment and re-use contaminated water								
	Disposal of coal ash and operation of the ash dam must be done in a maaner to prevent water pollution								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	3 ADJ	1 INCID	2 UNLIKE	**-0.9** **VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	4 MODH	4 LOC	3 MED	5 OCCUR	**-4.1** **HIGH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	5 HIGH	4 LOC	4 LONG	4 VLIKE	**-3.8** **MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	3 ADJ	1 INCID	2 UNLIKE	**-0.9** **VLOW**

Figure 38: Alternative AG Operation impacts assessment

Rated By: D. Pacome AHOKPOSSI Reviewed By: Albertus Lombaard			ALTERNATIVES:						
			SITE F+G						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	6	Negative	Probable	6	3	4	4	**-3.8**
					VHIGH	ADJ	LONG	VLIKE	**MODH**
Impact 2	Alteration of the groundwater flow system due to groundwater pumping (different uses)	4	Negative	Unsure	4	3	2	2	**-1.3**
					MODH	ADJ	SHORT	UNLIKE	**LOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-5.2	-3	-3.2	3.2	**-2.7**
					VHIGH	ADJ	LONG	VLIKE	**MODL**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Ash Dam and all pollution control facilities (dams , trenches) must lined according to the Departemental minimum requirements (1998/2012) with a cuspate leak detection layer in-between.								
	Avoid as possible longer lag time betwteen liner installation and ash disposal or trenches construction.								
	Ash Dams and all pollution control facilities (dams , trenches) must be operated and to have a mimimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.								
	Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .								
	Pump treatment and re-use contaminated water								
	Disposal of coal ash and operation of the ash dam must be done in a maaner to prevent water pollution								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2	2	1	2	**-0.7**
					LOW	DEV	INCID	UNLIKE	**VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	2	3	2	5	**-2.6**
					LOW	ADJ	SHORT	OCCUR	**MODL**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	6	3	4	4	**-3.8**
					VHIGH	ADJ	LONG	VLIKE	**MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2	2	1	2	**-0.7**
					LOW	DEV	INCID	UNLIKE	**VLOW**

Figure 39: Alternative FG Operation impacts assessment

5.2.3 Closure

Before mitigation there is no major difference in the combined impact risks for the various alternative sites. All the risks have been rated as negative, low impact risks.

The impact risks that result in groundwater quality deterioration, is less with scenarios "A" and "AF". The main advantages that scenario A has over the scenario "AF", are:

- The implementation of remediation actions will be easier on one (1) site than on two (2) sites at same the time;
- The risk for liner leaks in two (2) dams is considerably less thanfor seven (7) dams as in the case of Alternative "AF".

Rated By:	*D. Pacome AHOKPOSSI*		**ALTERNATIVES:**						
Reviewed By:	*Albertus Lombaard*		NO-GO						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Deterioration of groundwater quality due to waste, and spills related to closure activities	4	No Impact	Unsure	0	0	0	0	**0**
					NO	#N/A	#N/A	#N/A	**NO**
Impact 2	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	5	No Impact	Unsure	0	0	0	0	**0**
					NO	#N/A	#N/A	#N/A	**NO**
Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses)	3	No Impact	Unsure	0	0	0	0	**0**
					NO	#N/A	#N/A	#N/A	**NO**
COMBINED WEIGHTED	**BEFORE MITIGATION**		No Impact	Unsure	0	0	0	0	**0**
									NO
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Waste and spills need to be cleaned up immediately according to the Departemental minimum requirements (WULA).								
	DWA need to be notified in the event of a spill or leachate								
	Proper construction of liner								
	Avoid as possible longer lag time betwwen liner installation and ash disposal or trenches								
	Ash Dams and all pollution control facilities (dams , trenches) must be operated and to have a mimimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.								
	Extension of Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .								
	Ash Dam and all pollution control facilities (dams , trenches) must lined according to the Departemental minimum requirements (1998/2012) with a cuspate leak detection layer in-between.								
	Pump treatment and re-use contaminated water								
PROJECT IMPACT	**AFTER MITIGATION**		No Impact	Unsure	0	0	0	0	**0**
					NO	#N/A	#N/A	#N/A	**NO**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		No Impact	Unsure	3	4	3	5	**3.7**
					MODL	LOC	MED	OCCUR	**MODH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		No Impact	Unsure	0	0	0	0	**0**
					NO	#N/A	#N/A	#N/A	**NO**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		No Impact	Unsure	0	0	0	0	**0**
					NO	#N/A	#N/A	#N/A	**NO**

Figure 40: No Go Alternative Closure impacts assessment

Rated By:	D. Pacome AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		Site A						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Deterioration of groundwater quality due to waste, and spills related to closure activities	4	Negative	Probable	4	4	3	3	**-2.4**
					MODH	LOC	MED	LIKE	**MODL**
Impact 2	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	5	Negative	Probable	3	4	3	2	**-1.5**
					MODL	LOC	MED	UNLIKE	**LOW**
Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses)	3	Negative	Unsure	2	3	2	2	**-1**
					LOW	ADJ	SHORT	UNLIKE	**VLOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-2.5	-3	-2.2	1.9	**-1.1**
					MODL	ADJ	MED	UNLIKE	**LOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Waste and spills need to be cleaned up immediately according to the Departemental minimum requirements (WULA).								
	DWA need to be notified in the event of a spill or leachate								
	Proper construction of liner								
	Avoid as possible longer lag time between liner installation and ash disposal or trenches								
	Ash Dams and all pollution control facilities (dams , trenches) must be operated and to have a mimimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.								
	Extension of Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .		Extension of Monitoring need to take place beween the ash dam facility and the New Largo to detec any croos contamination						
	Ash Dam and all pollution control facilities (dams , trenches) must lined according to the Departemental minimum requirements (1998/2012) with a cuspate leak detection layer in-between.								
	Pump treatment and re-use contaminated water								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2	3	1	2	**-0.9**
					LOW	ADJ	INCID	UNLIKE	**VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	4	4	3	5	**-4.1**
					MODH	LOC	MED	OCCUR	**HIGH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Probable	4	4	3	4	**-3.2**
					MODH	LOC	MED	VLIKE	**MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2	3	1	2	**-0.9**
					LOW	ADJ	INCID	UNLIKE	**VLOW**

Figure 41: Alternative A Closure impacts assessment

Rated By:	D. Pacome AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		SITE B						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Deterioration of groundwater quality due to waste, and spills related to closure activities	4	Negative	Probable	6	4	3	4	**-3.8**
					VHIGH	LOC	MED	VLIKE	**MODH**
Impact 2	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	5	Negative	Probable	6	4	3	4	**-3.8**
					VHIGH	LOC	MED	VLIKE	**MODH**
Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses)	3	Negative	Unsure	4	2	2	2	**-1.2**
					MODH	DEV	SHORT	UNLIKE	**LOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-4.4	-2.8	-2.2	2.8	**-1.9**
					HIGH	ADJ	MED	COULD	**LOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Waste and spills need to be cleaned up immediately according to the Departemental minimum requirements (WULA).								
	DWA need to be notified in the event of a spill or leachate								
	Proper construction of liner								
	Avoid as possible longer lag time bettween liner installation and ash disposal or trenches								
	Ash Dams and all pollution control facilities (dams , trenches) must be operated and to have a mimimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.								
	Extension of Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .		Extension of Monitoring need to take place down gradient on the two concerned catchments						
	Ash Dam and all pollution control facilities (dams , trenches) must lined according to the Departemental minimum requirements (1998/2012) with a cuspate leak detection layer in-between.								
	Pump treatment and re-use contaminated water								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2	2	1	2	**-0.7**
					LOW	DEV	INCID	UNLIKE	**VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	2	4	3	5	**-3.3**
					LOW	LOC	MED	OCCUR	**MODH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Probable	5	4	4	4	**-3.8**
					HIGH	LOC	LONG	VLIKE	**MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2	2	1	2	**-0.7**
					LOW	DEV	INCID	UNLIKE	**VLOW**

Figure 42: Alternative B Closure impacts assessment

Rated By:	D. Pacome AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		SITE C						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	Impact Risk
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Deterioration of groundwater quality due to waste, and spills related to closure activities	4	Negative		5	3	3	4	**-3.2**
					HIGH	ADJ	MED	VLIKE	**MODH**
Impact 2	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	5		Probable	5	3	3	4	**-3.2**
					HIGH	ADJ	MED	VLIKE	**MODH**
Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses)	3	Negative		2	1	2	2	**-0.7**
					LOW	ISO	SHORT	UNLIKE	**VLOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-3.4	-2	-2.2	2.8	**-1.6**
					MODH	DEV	MED	COULD	**LOW**
MITIGATION MEASURES	*GENERAL:*								
	Waste and spills need to be cleaned up immediately according to the Departemental minimum requirements (WULA).								
	DWA need to be notified in the event of a spill or leachate								
	Proper construction of liner								
	Avoid as possible longer lag time betwteen liner installation and ash disposal or trenches								
	Ash Dams and all pollution control facilities (dams , trenches) must be operated and to have a mimimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.								
	Extension of Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .								
	Ash Dam and all pollution control facilities (dams , trenches) must lined according to the Departemental minimum requirements (1998/2012) with a cuspate leak detection layer in-between.								
	Pump treatment and re-use contaminated water								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2	2	1	2	**-0.7**
					LOW	DEV	INCID	UNLIKE	**VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT				3	3	3	5	**-3.3**
					MODL	ADJ	MED	OCCUR	**MODH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**				4	3	3	4	**-2.9**
					MODH	ADJ	MED	VLIKE	**MODL**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**				2	2	1	2	**-0.7**
					LOW	DEV	INCID	UNLIKE	**VLOW**

Figure 43: Alternative C Closure impacts assessment

Rated By:	D. Pacome AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		SITE A+F						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Deterioration of groundwater quality due to waste, and spills related to closure activities	4		Probable	4 MODH	4 LOC	3 MED	3 LIKE	**-2.4** **MODL**
Impact 2	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	5	Negative	Probable	2 LOW	4 LOC	3 MED	3 LIKE	**-2** **LOW**
Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses)	3		Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	**-1** **VLOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-2.1 MODL	-3 ADJ	-2.2 MED	2.2 COULD	**-1.2** **LOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Waste and spills need to be cleaned up immediately according to the Departemental minimum requirements (WULA).								
	DWA need to be notified in the event of a spill or leachate								
	Proper construction of liner								
	Avoid as possible longer lag time between liner installation and ash disposal or trenches								
	Ash Dams and all pollution control facilities (dams , trenches) must be operated and to have a mimimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.								
	Extension of Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .								
	Ash Dam and all pollution control facilities (dams , trenches) must lined according to the Departemental minimum requirements (1998/2012) with a cuspate leak detection layer in-between.								
	Pump treatment and re-use contaminated water								
PROJECT IMPACT	**AFTER MITIGATION**				2 LOW	3 ADJ	1 INCID	2 UNLIKE	**-0.9** **VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	4 MODH	4 LOC	3 MED	5 OCCUR	**-4.1** **HIGH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	4 MODH	4 LOC	3 MED	4 VLIKE	**-3.2** **MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	3 ADJ	1 INCID	2 UNLIKE	**-0.9** **VLOW**

Figure 44: Alternative AF Closure impacts assessment

Rated By:	D. Pacome AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		SITEA+G						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Deterioration of groundwater quality due to waste, and spills related to closure activities	4	Negative	Probable	4 MODH	4 LOC	3 MED	3 LIKE	**-2.4 MODL**
Impact 2	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	5	Negative	Probable	4 MODH	4 LOC	3 MED	4 VLIKE	**-3.2 MODH**
Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses)	3	Negative	Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	**-1 VLOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-2.8 MODL	-3 ADJ	-2.2 MED	2.5 COULD	**-1.5 LOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Waste and spills need to be cleaned up immediately according to the Departemental minimum requirements (WULA).								
	DWA need to be notified in the event of a spill or leachate								
	Proper construction of liner								
	Avoid as possible longer lag time betwween liner installation and ash disposal or trenches								
	Ash Dams and all pollution control facilities (dams , trenches) must be operated and to have a mimimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.								
	Extension of Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .								
	Ash Dam and all pollution control facilities (dams , trenches) must lined according to the Departemental minimum requirements (1998/2012) with a cuspate leak detection layer in-between.								
	Pump treatment and re-use contaminated water								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	3 ADJ	1 INCID	2 UNLIKE	**-0.9 VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	4 MODH	4 LOC	3 MED	5 OCCUR	**-4.1 HIGH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	4 MODH	4 LOC	3 MED	4 VLIKE	**-3.2 MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	3 ADJ	1 INCID	2 UNLIKE	**-0.9 VLOW**

Figure 45: Alternative AG Closure impacts assessment

Rated By:	D. Pacome AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		SITE F+G						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Deterioration of groundwater quality due to waste, and spills related to closure activities	4	Negative	Probable	4 MODH	3 ADJ	3 MED	3 LIKE	**-2.2** **MODL**
Impact 2	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	5	Negative	Probable	4 MODH	3 ADJ	3 MED	4 VLIKE	**-2.9** **MODL**
Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses)	3	Negative	Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	**-1** **VLOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-2.8 MODL	-2.4 ADJ	-2.2 MED	2.5 COULD	**-1.4** **LOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Waste and spills need to be cleaned up immediately according to the Departemental minimum requirements (WULA).								
	DWA need to be notified in the event of a spill or leachate								
	Proper construction of liner								
	Avoid as possible longer lag time betwween liner installation and ash disposal or trenches								
	Ash Dams and all pollution control facilities (dams , trenches) must be operated and to have a mimimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.								
	Extension of Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .								
	Ash Dam and all pollution control facilities (dams , trenches) must lined according to the Departemental minimum requirements (1998/2012) with a cuspate leak detection layer in-between.								
	Pump treatment and re-use contaminated water								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	2 DEV	1 INCID	2 UNLIKE	**-0.7** **VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	2 LOW	3 ADJ	2 SHORT	5 OCCUR	**-2.6** **MODL**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	3 MODL	3 ADJ	3 MED	4 VLIKE	**-2.7** **MODL**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	2 DEV	1 INCID	2 UNLIKE	**-0.7** **VLOW**

Figure 46: Alternative FG Closure impacts assessment

5.2.4 Post Closure

Prior to mitigation, the overall (combined impacts) impacts risks that the operation of the coal Ash Disposal Facility would have on the groundwater systems present below the respective site (s) of the six (06) altrnatives rate from negative Low impacts risk to negative Moderately low impacts risk. The risk impacts that result in the groundwater quality deterioration, is higher with Alternatives “B” and “C”. The main advantages that Alternative A has over the others remaining Alternatives (AF, AG, FG), are:

- The implementation of remediation actions will be easier on one (1) site than on two (2) sites at the same time;
- The risk for liner leaks in two (2) dams is considerably less than for seven (7) dams in the case of the others scenarios.

Rated By:	*D. Pacome AHOKPOSSI*		**ALTERNATIVES:**						
Reviewed By:	*Albertus Lombaard*		**NO-GO**						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Groundwater pollution due leachate (leak) from the Ash dam, Contaminated water trenches and other contaminated water storage facilities.	5	No Impact	Unsure	0 NO	0 #N/A	0 #N/A	0 #N/A	**0** **NO**
Impact 2	Reduction of infiltration rates.	6	No Impact	Unsure	0 NO	0 #N/A	0 #N/A	0 #N/A	**0** **NO**
Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses).	3	No Impact	Unsure	0 NO	0 #N/A	0 #N/A	0 #N/A	**0** **NO**
COMBINED WEIGHTED	**BEFORE MITIGATION**		No Impact	Unsure	0	0	0	0	**0** **NO**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Ensure the long term integrity of the contaminated water trenches and dams (during design time).								
	Repair trenches and dams as may be required, and according the DWA minimum requirements.								
	Enhance monitoring network with abstraction boreholes around the ash dam facilities.								
	Pump treatment and re-use contaminated water; Report any								
	Avoid rain water entering into the ash dam by protecting it with adequate geomembrane prior to rehabilitation (top soil).								
	Direct precipitation falling ADF by the stormwater management system to areas where infiltration could occur.								
PROJECT IMPACT	**AFTER MITIGATION**		No Impact	Unsure	0 NO	0 #N/A	0 #N/A	0 #N/A	**0** **NO**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		No Impact	Unsure	3 MODL	3 ADJ	3 MED	5 OCCUR	**3.3** **MODH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		No Impact	Unsure	0 NO	0 #N/A	0 #N/A	0 #N/A	**0** **NO**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		No Impact	Unsure	0 NO	0 #N/A	0 #N/A	0 #N/A	**0** **NO**

Figure 47: No Go Alternative Post-closure impacts assessment

Rated By:	D. Pacome AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		Site A						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Groundwater pollution due leachate (leak) from the Ash dam, Contaminated water trenches and other contaminated water storage facilities.	5	Negative	Probable	4 MODH	3 ADJ	4 LONG	3 LIKE	**-2.4 MODL**
Impact 2	Reduction of infiltration rates.	6	Negative	Probable	4 MODH	3 ADJ	2 SHORT	3 LIKE	**-2 LOW**
Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses).	3	Negative	Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	**-1 VLOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-3.3 MODH	-2.8 ADJ	-2.5 MED	2.6 COULD	**-1.6 LOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Ensure the long term integrity of the contaminated water trenches and dams (during design time).								
	Repair trenches and dams as may be required, and according the DWA minimum requirements.								
	Enhance monitoring network with abstraction boreholes around the ash dam facilities.		Monitoring and abstraction boreholes should also be placed to constitute barrier between New Largo and the Ash dam Facility.						
	Pump treatment and re-use contaminated water; Report any								
	Avoid rain water entering into the ash dam by protecting it with adequate geomembrane prior to rehabilitation (top soil).								
	Direct precipitation falling ADF by the stormwater management system to areas where infiltration could occur.								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6 VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	3 MODL	3 ADJ	4 LONG	5 OCCUR	**-3.7 MODH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	4 MODH	3 ADJ	4 LONG	4 VLIKE	**-3.2 MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6 VLOW**

Figure 48:Alternative A Post-closure impacts assessment

Rated By:	D. Pacome AHOKPOSSI		**ALTERNATIVES:**						
Reviewed By:	Albertus Lombaard		**SITE B**						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Groundwater pollution due leachate (leak) from the Ash dam, Contaminated water trenches and other contaminated water storage facilities.	5	Negative	Probable	6 VHIGH	3 ADJ	4 LONG	4 VLIKE	**-3.8 MODH**
Impact 2	Reduction of infiltration rates.	6	Negative	Probable	6 VHIGH	3 ADJ	2 SHORT	4 VLIKE	**-3.2 MODH**
Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses).	3	Negative	Unsure	4 MODH	2 DEV	2 SHORT	2 UNLIKE	**-1.2 LOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-5.2 VHIGH	-2.6 ADJ	-2.5 MED	3.3 VLIKE	**-2.5 MODL**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Ensure the long term integrity of the contaminated water trenches and dams (during design time).								
	Repair trenches and dams as may be required, and according the DWA minimum requirements.								
	Enhance monitoring network with abstraction boreholes around the ash dam facilities.		Monitoring network with abstraction boreholes around the ash dam facilities in the two concerned catchments.						
	Pump treatment and re-use contaminated water; Report any								
	Avoid rain water entering into the ash dam by protecting it with adequate geomembrane prior to rehabilitation (top soil).								
	Direct precipitation falling ADF by the stormwater management system to areas where infiltration could occur.								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6 VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	2 LOW	3 ADJ	3 MED	5 OCCUR	**-2.9 MODL**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	4 MODH	3 ADJ	4 LONG	4 VLIKE	**-3.2 MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6 VLOW**

Figure 49: Alternative B Post-closure impacts assessment

Rated By:	D. Pacome AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		SITE C						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Groundwater pollution due leachate (leak) from the Ash dam, Contaminated water trenches and other contaminated water storage facilities.	5	Negative	Probable	5 HIGH	3 ADJ	4 LONG	3 LIKE	**-2.7** **MODL**
Impact 2	Reduction of infiltration rates.	6	Negative	Probable	6 VHIGH	3 ADJ	2 SHORT	4 VLIKE	**-3.2** **MODH**
Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses).	3	Negative	Unsure	2 LOW	1 ISO	2 SHORT	2 UNLIKE	**-0.7** **VLOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-4.5 HIGH	-2.4 ADJ	-2.5 MED	3 COULD	**-2.1** **MODL**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Ensure the long term integrity of the contaminated water trenches and dams (during design time).								
	Repair trenches and dams as may be required, and according the DWA minimum requirements.								
	Enhance monitoring network with abstraction boreholes around the ash dam facilities.		Monitoring and abstraction boreholes should also be placed to constitute barrier between Wilge Riverf and the Ash dam Facility.						
	Pump treatment and re-use contaminated water; Report any								
	Avoid rain water entering into the ash dam by protecting it with adequate geomembrane prior to rehabilitation (top soil).								
	Direct precipitation falling ADF by the stormwater management system to areas where infiltration could occur.								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6** **VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	3 MODL	3 ADJ	3 MED	5 OCCUR	**-3.3** **MODH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	4 MODH	3 ADJ	4 LONG	4 VLIKE	**-3.2** **MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6** **VLOW**

Figure 50: Alternative C Post-closure impacts assessment

Rated By: D. Pacome AHOKPOSSI Reviewed By: Albertus Lombaard			ALTERNATIVES: SITE A+F						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	Impact Risk
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Groundwater pollution due leachate (leak) from the Ash dam, Contaminated water trenches and other contaminated water storage facilities.	5	Negative	Probable	4 MODH	3 ADJ	4 LONG	4 VLIKE	-3.2 MODH
Impact 2	Reduction of infiltration rates.	6	Negative	Probable	5 HIGH	3 ADJ	2 SHORT	3 LIKE	-2.2 MODL
Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses).	3	Negative	Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	-1 VLOW
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-3.7 MODH	-2.8 ADJ	-2.5 MED	2.9 COULD	-1.9 LOW
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Ensure the long term integrity of the contaminated water trenches and dams (during design time).								
	Repair trenches and dams as may be required, and according the DWA minimum requirements.								
	Enhance monitoring network with abstraction boreholes around the ash dam facilities.								
	Pump treatment and re-use contaminated water; Report any								
	Avoid rain water entering into the ash dam by protecting it with adequate geomembrane prior to rehabilitation (top soil).								
	Direct precipitation falling ADF by the stormwater management system to areas where infiltration could occur.								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	-0.6 VLOW
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	4 MODH	3 ADJ	3 MED	5 OCCUR	-3.7 MODH
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	4 MODH	3 ADJ	4 LONG	4 VLIKE	-3.2 MODH
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	-0.6 VLOW

Figure 51: Alternative AF Post-closure impacts assessment

Rated By:	D. Pacome AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		SITEA+G						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Groundwater pollution due leachate (leak) from the Ash dam, Contaminated water trenches and other contaminated water storage facilities.	5	Negative	Probable	4 MODH	3 ADJ	4 LONG	4 VLIKE	**-3.2 MODH**
Impact 2	Reduction of infiltration rates.	6	Negative	Probable	4 MODH	3 ADJ	2 SHORT	2 UNLIKE	**-1.3 LOW**
Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses).	3	Negative	Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	**-1 VLOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-3.3 MODH	-2.8 ADJ	-2.5 MED	2.5 COULD	**-1.6 LOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Ensure the long term integrity of the contaminated water trenches and dams (during design time).								
	Repair trenches and dams as may be required, and according the DWA minimum requirements.								
	Enhance monitoring network with abstraction boreholes around the ash dam facilities.								
	Pump treatment and re-use contaminated water; Report any								
	Avoid rain water entering into the ash dam by protecting it with adequate geomembrane prior to rehabilitation (top soil).								
	Direct precipitation falling ADF by the stormwater management system to areas where infiltration could occur.								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6 VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	4 MODH	3 ADJ	3 MED	5 OCCUR	**-3.7 MODH**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	4 MODH	3 ADJ	4 LONG	4 VLIKE	**-3.2 MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6 VLOW**

Figure 52: Alternative AG Post-closure impacts assessment

Rated By:	D. Pacome AHOKPOSSI		ALTERNATIVES:						
Reviewed By:	Albertus Lombaard		SITE F+G						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*								
	CONSTRUCTION	5							
Impact 1	Groundwater pollution due leachate (leak) from the Ash dam, Contaminated water trenches and other contaminated water storage facilities.	5	Negative	Probable	4 MODH	3 ADJ	4 LONG	4 VLIKE	**-3.2** **MODH**
Impact 2	Reduction of infiltration rates.	6	Negative	Probable	4 MODH	3 ADJ	2 SHORT	2 UNLIKE	**-1.3** **LOW**
Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses).	3	Negative	Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	**-1** **VLOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-3.3 MODH	-2.8 ADJ	-2.5 MED	2.5 COULD	**-1.6** **LOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*						
	Ensure the long term integrity of the contaminated water trenches and dams (during design time).								
	Repair trenches and dams as may be required, and according the DWA minimum requirements.								
	Enhance monitoring network with abstraction boreholes around the ash dam facilities.								
	Pump treatment and re-use contaminated water; Report any								
	Avoid rain water entering into the ash dam by protecting it with adequate geomembrane prior to rehabilitation (top soil).								
	Direct precipitation falling ADF by the stormwater management system to areas where infiltration could occur.								
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6** **VLOW**
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	2 LOW	2 DEV	2 SHORT	5 OCCUR	**-2.2** **MODL**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	4 MODH	3 ADJ	4 LONG	4 VLIKE	**-3.2** **MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6** **VLOW**

Figure 53: Alternative FG Post-closure impacts assessment

Based on the geohydrological comparative impact assessments of the different alternative scenarios, scenario A appears to be the most preferred scenario.

Considering DWA specific requirements such (Strategic and catchment management goals and objectives), detailed impacts and mitigation for site A and B is provided, and (cumulative) impact scenarios on site A is considered with and without New Largo, to facilitate better decision-making.

6 Base line numerical model of the preferred sites (scenario A and Scenario B)

A groundwater model is an idealized representation of the natural system you are working in; hence the first step is the development of a conceptual model. Each model is therefore preceded by the conceptual model to provide a simplified but clear definition of the flow and transport problem in the natural system at hand.

The conceptual model is designed based on the nature of the problems to be solved by the model. A relatively simple initial conceptual model based on the existing background information and the geohydrological field investigations (position and extent of mining activities, climate, geology, hydrogeology, surface drainage) describes the first understanding of the aquifer system. Each preferred site conceptual model is first presented in the this section.

6.1 Conceptual geohydrological models

Based on our field investigation, the main host formations underlining the preferred site B are the shale and sandstone.

6.1.1 Site A conceptual model

The preferred Alternative A will be implemented on Site A. Site A is located on top of a semi-confined to unconfined shallow, secondary (weathered and fractured) aquifer. Our field investigations suggest that the groundwater bearing features are located at depth between 4 m and 24 mbgl, with an average of 15 mbgl. At such depths, the groundwater below Site A is predominantly flowing through weathered shale (upper), the contact between the upper shale and underlining sandstone, fractures and joints developed locally along the fresh shale bedding planes. However the groundwater flow may also be occurring through the shale brecciated joints, and in the contact zones between different lithologies (sandstone, shale, silstone and rhyolite).

The depths to the static groundwater levels range between 2 m to 14 mbgl, with an average of 6 mbgl. At Site "A", groundwater is expected to drain from the east of the catchment (B20F) boundary, towards the west at the Wilge River, and toward the north-west at the Klipfontein River. The upstream boundary of Site A coincides with the New Largo coal mining (underground and opencast) area where the underlying in aquifer is in contact with the artificial underground mining related aquifer. Groundwater elevations surrounding the site range from 1440 to 1540 mamsl. The saturated thickness of the aquifer varies spatially to an average of approximately 30 m. No preferential flow has been identified in the area during investigation.

The potential rainfall recharge in the area is calculated to average 31 % of the mean annual rainfall. This results in an annual rainfall recharge to the shallow aquifer, of 196.85 mm.

Vegter (1995) estimated the water recharge to groundwater to range between 32mm/a and 65mm/a, whereas the study conducted by JMA for the New Largo area, considered 37mm/a in their geohydrological calculations.

Measured blow yields during the present investigation together with reported blow yields (JMA for New Largo) show that blow yields range between 0.01 l/sec and 3.33 l/sec. Estimated transmissivity (T) in the area range from 0.01 m^2/day to 0.8 m^2/day (Cooper Jacob method) with an average of 0.7 m^2/day, whereas storativity range between 1.48 x 10^{-5} to 2.00 x 10^{-3} with an average of 8 x 10^{-4}. Previous studies at the New Largo mining area in 2012 (JMA) reported that the effective porosities (n_e) in the shallow aquifer vary between 0.01 and 0.07 with a probable bulk effective porosity of 0.05.

Groundwater in the area is generally unpolluted water qualities which generally falls into the SANS-2006 recommended operational limit for all the constituents measured.

Slightly alkaline water was measured at the South-East of the preferred site. This alkaline water could be associated to polluted groundwater. As result of pollution, fluoride and iron concentrations are above the SANS class 2 maximum allowable limit. The source of pollution may be related to the historical underground coal mine activities in the New Largo, but is not proved beyond with the current investigations.

6.1.2 Site B conceptual model

Site B (Alternative B) is located on top of a semi-confined to unconfined shallow, secondary (weathered and fractured) aquifer. The general geology associated with site B consist of tillite and shale, carbonaceous, hornfels, chert, shaly sandstone, sandstone, Diabase sills, Quartzite, Minor hornfels. The groundwater bearing features of the shallow aquifer are located at depth between 8 m and 24 mbgl. At such depths, the field investigations (drilling) suggest that the groundwater below Site B is predominantly flowing through the contact zone between the upper yellowish to red shale and the weathered sandstone, and the very fine grained brownish weathered sandstone. But taking into account the other geological formations which may be present at site, groundwater occurrence in the Site B area may also be associated with the upper weathered shale and tillite (upper), through fractures and joints developed locally along bedding planes, and in other contact zones between different lithologies (shale, shaly sandstone, sandstone conglomerate and coal).

The depths to the static groundwater levels averages at 6 mbgl. Site B is located on a water divide and groundwater is expected to drain in North East and East directions away from the site in B20F, and in North East and North West directions in B20D. In B20F groundwater drains into Wilge River (minimum distance of 3.53 km), and in B20D it drains to Bronkhorstspruit River (minimum distance of 6.23 km. Groundwater elevations surrounding the site range from 1391 to 1517 mamsl with a mean of 1453 mamsl. The saturated thickness of the aquifer varies spatially with an average of approximately 30 m. No preferential flow has been identified in the area during investigation.

Site B may be relatively more sensitive to recharge when compare to the others alternatives (Sites: A, F, G). The potential rainfall recharge in the area is calculated to average 42 % of the mean annual rainfall. This results in an annual rainfall recharge to the shallow aquifer, of 248 mm. Generally the calculated highest recharge values are associated with boreholes located in the riparian zone. This values seems overestimated when compare to the Vegter (1995) estimation for the area.

Measured blow yield during the present investigation at the site indicate a blow yield value of 1.9 l/sec. Estimated transmissivity (T) in the area varies between 0.20 m^2/day to 4 m^2/day (Cooper Jacob method), whereas the storativity range between 2.54 x 10^{-5} to 3.97 x 10^{-5}. When considering that Lowman (1972) found that, in unconfined aquifers system, the storativity generally range from 0.1 to 0.3, and some reported calculated storativities in B20F, the estimated storativity values surrounding site B may underestimate the real shallow aquifer storage capacity.

Groundwater in the area is generally unpolluted water qualities (calcium/magnesium bicarbonate) which generally falls into the SANS-2006 recommended operational limit for all the constituents measured. A sodium bicarbonate/ chloride water quality was depicted at the South-West of the preferred site and may be associated with surface water pan nearby the samples point. At the Northwestern and Northeastern corners of the site a calcium/sodium, sulphate water quality is evident, suggesting a mining related contamination.

6.2 Aquifer classification

The water supply potential (yield), quality, and local importance of the aquifer system involved with scenario A, have been considered for the aquifer classification. The Parson's classification scheme (1995) and the revised one (1998) are used for the classification. Based on these South African classification schemes, the aquifer systems associated with both the Preferred Alternative A and Alternative B are considered to be "minor aquifer systems" (Management classification point 2), and the its vulnerability is classified as medium (Vulnerability classification point 2). These classifications result in a Groundwater Quality Management (GQM) Index of "6", indicating that Medium level of groundwater protection is required for the aquifers present on site A and site B.

6.3 Numerical flow model

A modular three-dimensional finite difference groundwater flow model MODFLOW, developed by U.S. Geological Survey is used during the present modelling project. This modelling package, calculates the solution of the groundwater flow equation using the finite difference approach.

A steady state groundwater flow model is constructed to simulate undisturbed groundwater heads distribution, based on the generalised steady state conditions, groundwater flow Equation (1) is as follows:

$$\frac{\partial}{\partial x}(K_x \frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(K_y \frac{\partial h}{\partial y}) + \frac{\partial}{\partial z}(K_z \frac{\partial h}{\partial z}) \pm W = 0 \qquad (1)$$

Where:

h = hydraulic head [L]
Kx,Ky,Kz = Hydraulic Conductivity [L/T]
t = time [T]
W = source (recharge) or sink (pumping) per unit area [L/T]
x,y,z = spatial co-ordinates [L]

These conditions serve as initial heads for the transient simulations of groundwater flow, in which changes with time are simulated, using the three-dimensional groundwater flow model equation:

$$\frac{\partial}{\partial x}(K_x \frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(K_y \frac{\partial h}{\partial y}) + \frac{\partial}{\partial z}(K_z \frac{\partial h}{\partial z}) \pm W = S \frac{\partial h}{\partial t} \qquad (2)$$

Where: S = storage coefficient.

6.3.1 Models domain and boundaries conditions

One of the first and most demanding tasks in groundwater modelling is the identification of the appropriate model boundaries. Consequently, a model boundary is the interface between the model area and the surrounding environment. Conditions on the boundaries, however, have to be specified. Boundaries occur at the edges of the model area and at locations in the model area where external influences are represented, such as rivers, wells, and leaky impoundments. Criteria for selecting hydraulic boundary conditions are primarily topography, hydrology and geology. The topography, hydrology, and groundwater drainage have been used mainly in the definition of the lateral boundary, where as the geology and the hydrogeology have been used mainly for the aquifer layer thickness.

The domain of the aquifer model is represented by a finite difference mesh. The model domain together with the mesh description, and the boundaries conditions used for the each of the model developed for the respective Site A and B, are given below.

6.3.1.1 Site A model boundary

The mesh constructed for the model consisted of 457 rows and 454 columns. The sizes of the cells vary from 100 m x 100 m outside the domain of concern, to 25 m x 25 m within the domain of the target site. The coordinates for the modelled area are from 683955.8, 7137278 (Min x, Max y) to 703955.8 E, 7117278 (Max x, Min y).

The four external lateral boundaries of the modelled area have been set as Dirichlet boundary (constant head).

6.3.1.2 Site B model boundary

The domain of the aquifer model is represented by a finite difference mesh. The mesh constructed for the model consisted of 245 rows and 200 columns. The coordinates for the modelled area are from 669587, 7147438 (Min x, Max y) to 689623, 7122950, (Max x, Min y).

The eastern, the northern, and the northwestern boundaries of the model area have been set as Dirichlet boundary (constant head), whereas the southern and south-western boundaries have been set as Zero specified flux Neuman (“no-flow”) boundary condition.

6.3.2 Initial conditions

Initial conditions are vital for modelling flow problems. Initial conditions have been specified for the entire area. The water elevations distributions shown in Figure 13 were used as initial conditions for the models’ steady state calibration.

After steady state calibration, the resultant groundwater elevations (drainage) distributions have become the new set of initial heads for scenarios simulation.

6.3.3 Sources and sinks

An estimated recharge was used as the starting point for the numerical calculation. The list of 19 boreholes that have been used in the models as observation boreholes are provided in Table 25 and Table 26 respectively for Alternative A and Alternative B.

Table 25 : List of the observations boreholes used in the steady state calibration of site A Model

Name of the Borehole	Geographic coordinate WGS84	
	Latitude	Longitude
KABH92	-25.9639	28.8627
KABH18	-25.8784	28.9654
CBH84	-25.9978	28.9294
CBH79	-26.0442	28.9313
CBH86	-25.9957	28.9367
CBH82	-25.9607	28.9381
CBH78	-26.0444	28.9441
CBH83	-25.9617	28.9429
CBH77	-26.0450	28.9542
KABH35	-25.9813	28.9545
CBH85	-26.0166	28.9591
KABH34	-25.9411	28.9583
KABH31	-25.9314	28.9611
CBH73	-26.0110	28.9657
CBH72	-26.0111	28.9657
CBH57	-25.9065	28.9742
LGW-B15	-25.9504	29.0243
BH30	-25.9332	28.9432
KPS05	-25.9196	28.9321

Table 26 : List of the observations boreholes used in the steady state calibration of site B Model

Name of the Borehole	Geographic coordinate WGS84	
	Latitude	Longitude
CBH51	-25.8778	28.7807
CBH52	-25.8771	28.7796
CBH53	-25.8781	28.7810
KABH40	-25.87	28.7714
KABH42	-25.8729	28.7776
KABH45	-25.8866	28.7723
CBH21	-25.8373	28.853
KABH74	-25.8578	28.8048
KABH75	-25.8529	28.8202
CBH32	-25.8625	28.8631
CBH27	-25.8559	28.8648
CBH29	-25.8652	28.8560
CBH30	-25.8719	28.8545
KABH62	-25.8719	28.8545
KABH60	-25.8864	28.8504
CBH31	-25.8969	28.8391
KABH63	-25.8968	28.8392
KABH48	-25.9212	28.8191

KABH49	-25.9221	28.8184

6.3.4 General assumptions and model limitations

A numerical model solves both complex and simple problems, and serves as basis for the simulation of various scenarios. However, it should be reiterated that, a numerical groundwater model is a simplified representation (approximation) of the real system, and the level of accuracy is sensitive to the quality of the data that is available. The available data constituted of:

- all the groundwater monitoring data gathered by Zitholele on the Kusile Power station (from May2013 up to April 2013);
- the data reported by JMA (2012) in the geohydrological study of the New Largo;
- The data collected by AEC through the different field investigations.

Errors due to uncertainty in the data and the capability of numerical methods to describe natural physical processes are always associated with groundwater numerical models. The building of a numerical model requires some assumptions to make an easier representation of the real aquifer systems. Such assumptions involve mainly:

- Geological and hydrogeological features;
- Boundary conditions of the study area (based on the geology and hydrogeology);
- Initial water levels of the study area;
- The processes governing groundwater flow; and
- The selection of the most appropriate numerical code.

Based on the available field data, the following assumptions have been made:

- The top of the aquifer is represented by the generated groundwater heads;
- Averages of the distribution of the determined parameters have been used as input of the model, and a homogenous and continuous aquifer system has been assumed;
- Where specific aquifer parameters have not been determined for some reason, text book values have been used where applicable, with reasonable estimates of similar geohydrological environments;The system is initially in equilibrium and therefore in steady state, even though natural conditions have been disturbed.
- No abstraction boreholes were included in the initial model.
- The boundary conditions assigned to the model are considered correct.
- The impacts of other activities (agriculture, etc...) have not been taken into account.

Such generalisations, interpretations, and assumptions made in attempting to simulate the natural environment, limit the present baseline to a simple tool for determining the order of magnitude of dewatering and contamination motion. The complexities of fractures rocks aquifer have not been taken into account. Any interpretation of the model results should be based on these assumptions.

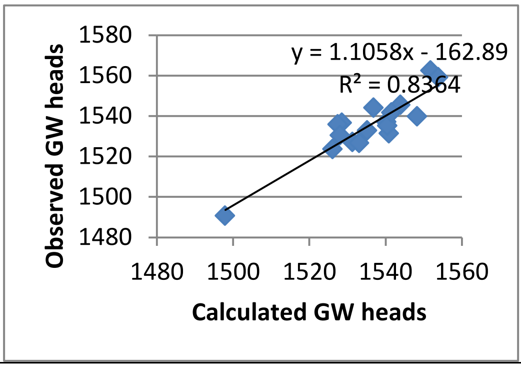
6.3.5 Steady state flow models calibration and numerical model sensitivity

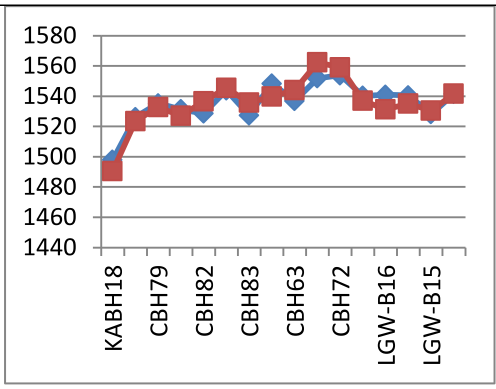
The steady state calibration is done by finding a set of boundary conditions, and hydrological parameters (recharge and conductivity/transmissivity), which generate the result that most strongly matches field measurements of hydraulics heads (or flow). An advantage of a steady state model is that there are less unknown parameters to determine. The parameter for storativity is not required to solve the groundwater flow equation.

In the present case, the “Preconditioned Conjugated-Gradient 2” solving package has been used. The initial boundary conditions have been maintained, and only the recharge and the conductivity/transmissivity have been changed to generate the highest matching between observed and calculated heads distributions. Observations boreholes (Table 25 and Table 26) have been chosen to verify the conditions at the models boundaries, and surrounding the ash dam site. Steady state calibration has been conducted by assuming that the transmissivity may vary, as the saturated thickness varies during different steps of the period of simulation.

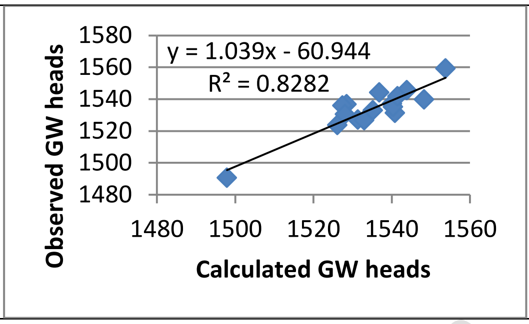
Considering varying transmissivity, the set of hydraulics parameters required for acceptable correlations between observed and calculated heads, are presented together with their respective results Table 27 for Alternative A and in Table 28 for Alternative B.

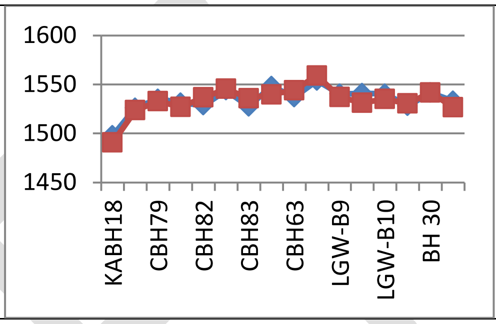
Table 27 : Steady state calibration results Site A Model



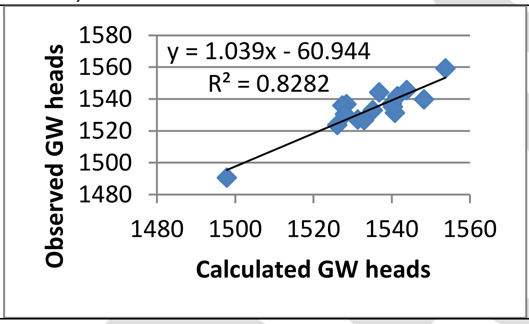


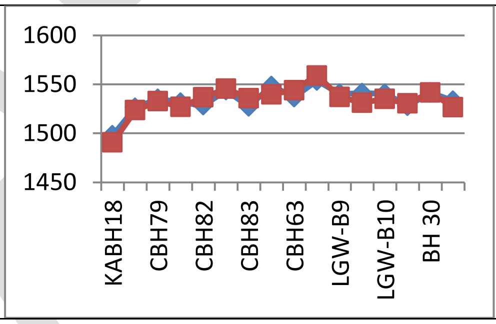
T = 16 , R = 0.0000547



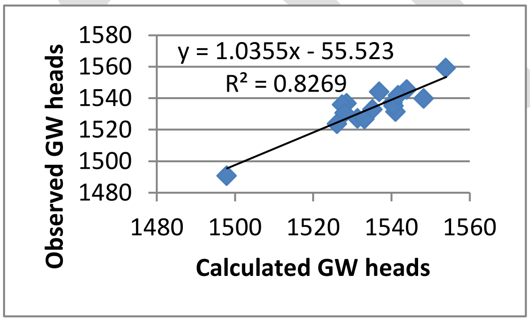


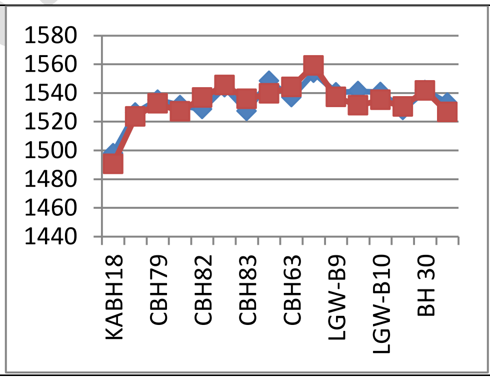
T = 3 , R = 0.0000103



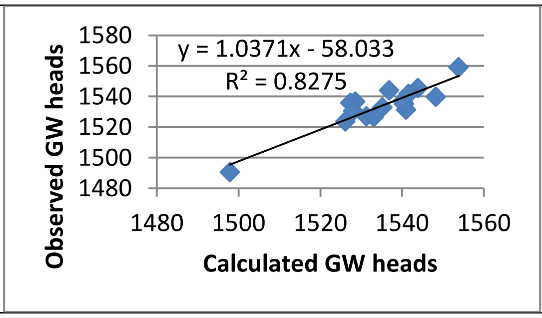


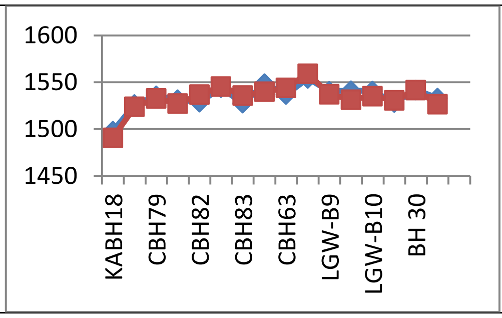
T = 30 , R = 0.000103





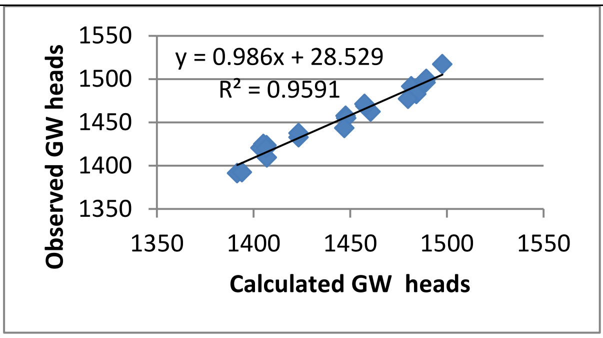
T = 44 , R = 0.000153

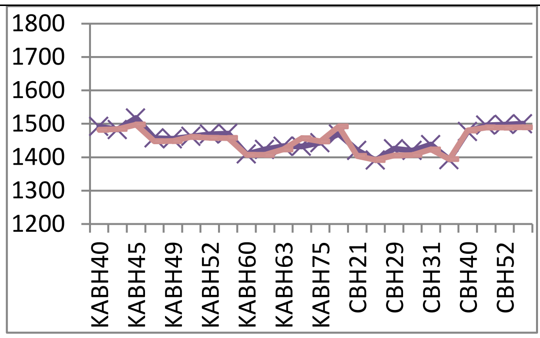




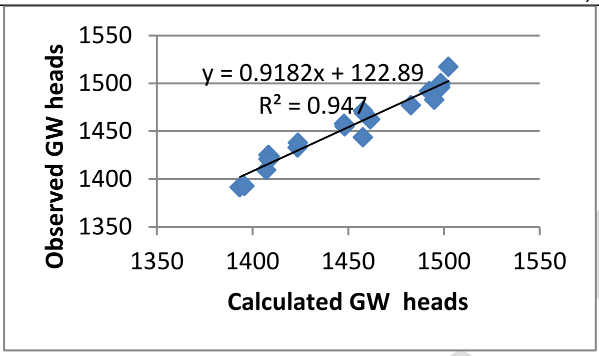
T = 20 , R = 0.0000697

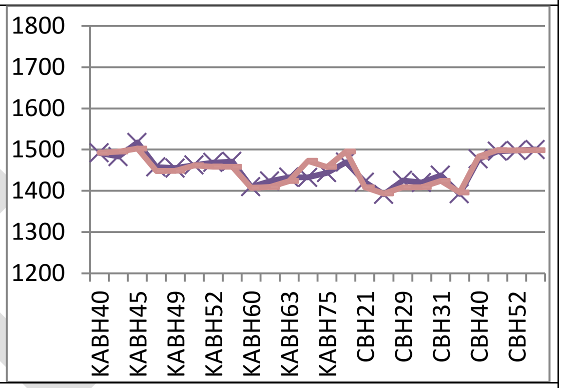
Table 28 : Steady state calibration results Site B Model



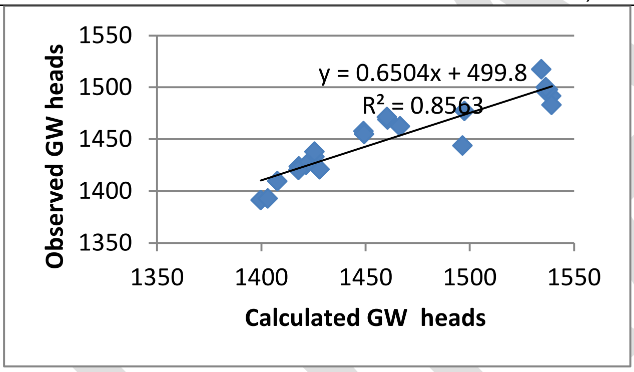


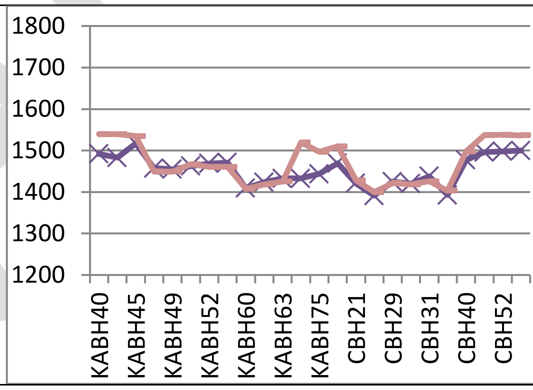
K = 100 , R = 0.013



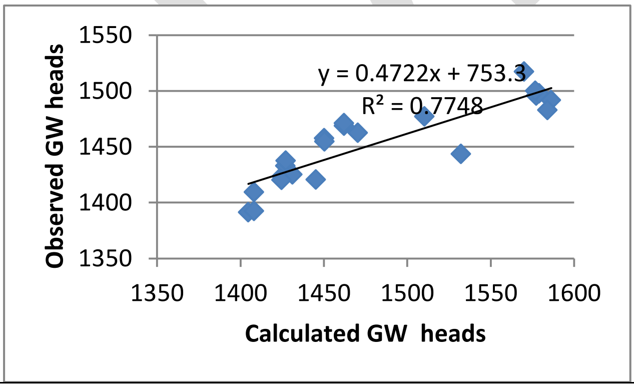


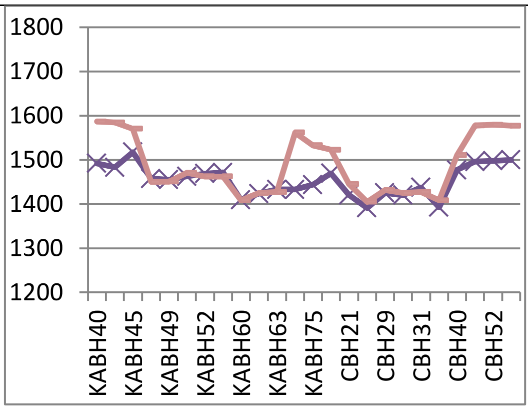
K = 100 , R = 0.015



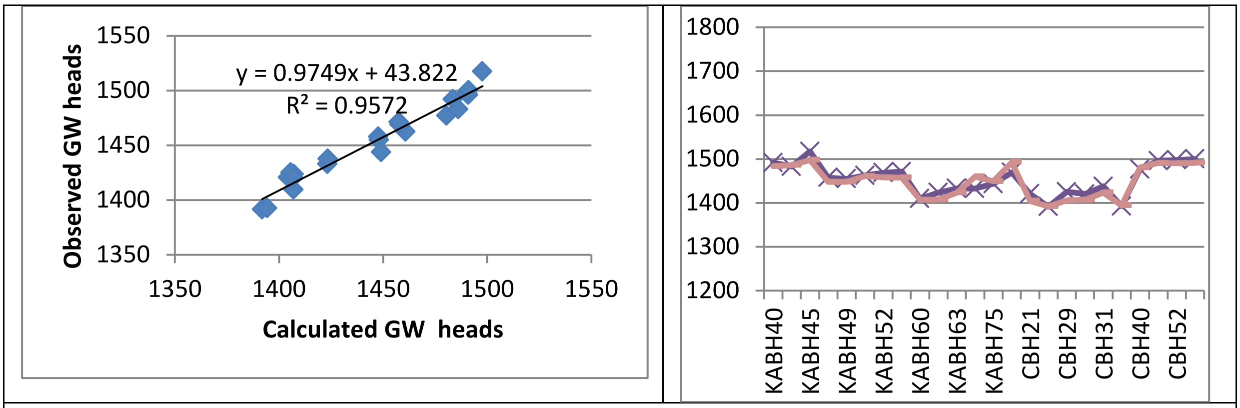


K = 100 , R = 0.030

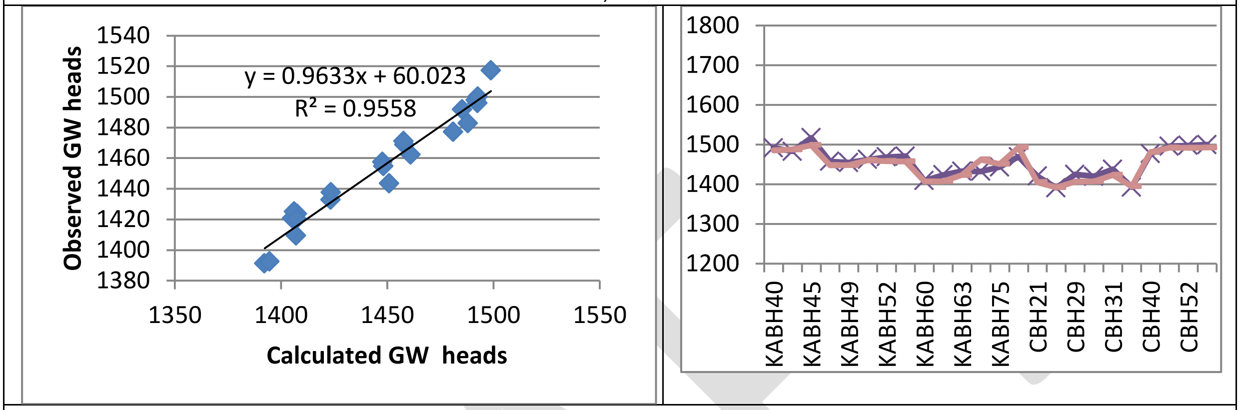




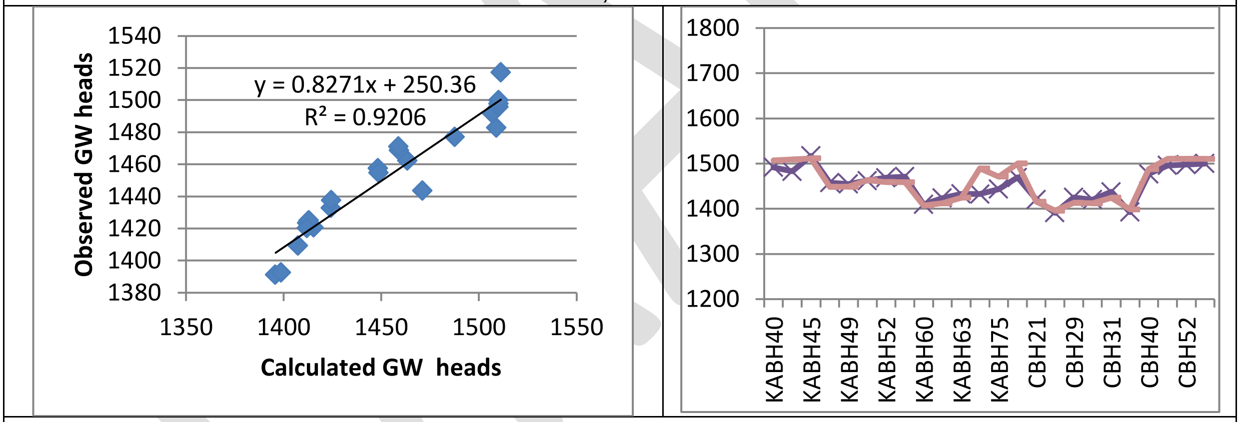
K = 100 , R = 0.01



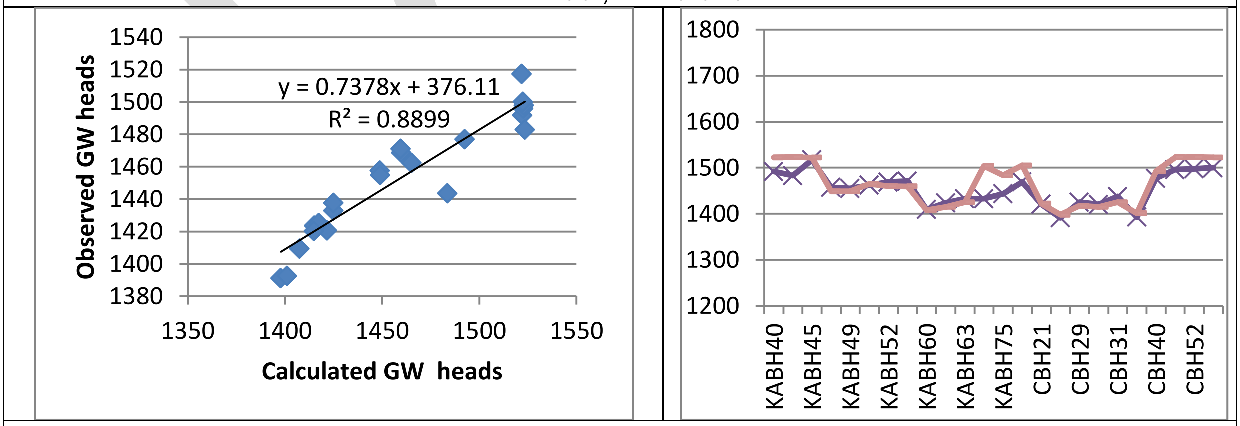
K = 80 , R = 0.01



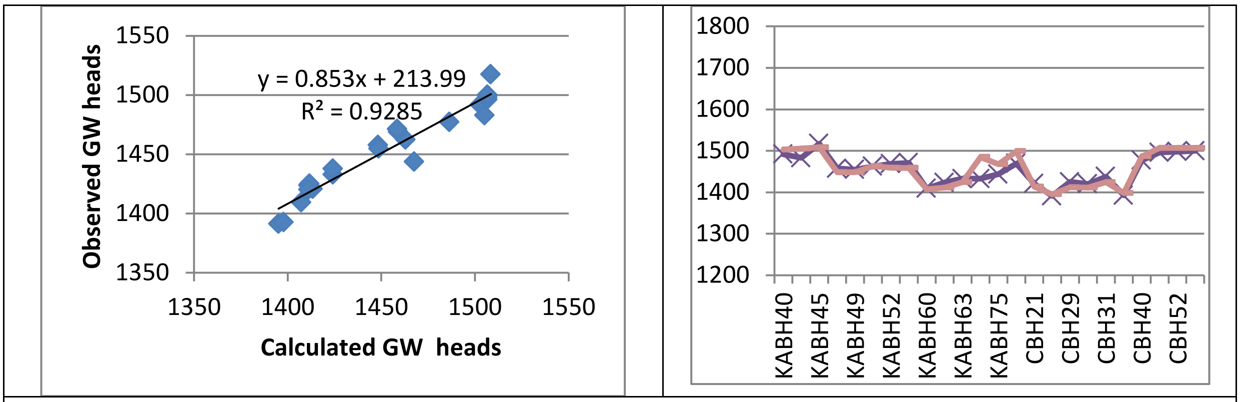
K = 100 , R = 0.013



K = 100 , R = 0.020



K = 100 , R = 0.025



K = 70 , R = 0.013

6.3.6 Transient state flow model calibration

The transient state flow calibration is highly recommended in groundwater numerical modelling for the following reasons:

- Groundwater flow is dependent on natural processes (geology, climate, ect…) and man-made changes, which may cause changes with time;
- Predictions are time related;
- The storage properties can only be assessed in transient state.

Ideally, transient state flow calibration should involve:

- Monthly hydraulic heads;
- Average monthly groundwater withdrawal;
- Average monthly evapotranspiration in case of shallow water levels (like in riparian zone)
- Monthly precipitation;
- Average monthly river stage;

The only time-series available data on the groundwater is from the monthly monitoring activities conducted by Zitholele since May 2009, and cover the area immediate north of the Site A. Transient calibration has then been conducted only for the site A model. The site A model has been calibrated based on a simulation period of 3 steps (01-2011, 01-2012, 01-2013) of 1 year each. BH30 and KP05 were chosen as observations boreholes. The analyses of the variations in water levels shows that they are less affected by artificial changes (stresses). Specific yield and specific storage have been changed until the hydraulic residual at each step is less than 5 m, and the residual drawdown at each step is less than 2 m.

6.4 Numerical mass transport model

Mass transport modelling consists of the simulation of water contamination or pollution due to deteriorating water quality in response to man's disturbance of the natural system. The most important processes that involved in the transport through a medium are Advection, and the Hydrodynamic dispersion (Mechanical dispersion and Molecular diffusion). Other phenomena (sorption, adsorption, deposition, ion exchange, etc...) may affect the concentrations distribution of a contaminant as it moves through a medium. The effective porosity is required to calculate the average linear velocity of groundwater flow, which in turn is needed to track water particles and to calculate contaminant concentrations in the groundwater.

The MT3DS software was used to provide numerical solutions for the concentration values in the aquifer in time and space. Flow model input parameters (Boundaries conditions, hydraulic conductivity, Recharge, Specific Storage, and Specific Yield) values that serve in steady state flow and transient flow calibrations were specified for the aquifer. Among the biggest uncertain parameters used during transport modelling of pollutants are the kinematic porosity of the aquifer and the longitudinal dispersivity. Bear and Verruijt (1992) estimated the average transversal dispersivity to be 10 to 20 times smaller than the average longitudinal dispersivity. The transport model input parameters are summarized in

Table 29.

Table 29 Summary on the input for transport simulation

	Effective Porosity	Longitudinal Dispersivity	Transversal Dispersivity
Units	--	(m)	(m)
Values	0.02	50	5

6.5 Model Predictive scenarios

It is good practise that potential groundwater environmental impacts (contaminant transport, dewatering) related to the ash disposal facility project be addressed through modelling simulation. An overview of overall impact risks from the project, allow the distinguishing of two main groups of potential impacts that deserve a special attention:

- Groundwater contamination at the ash disposal facilities site and contaminants transport to downstream, and any surrounding open pits (New Largo);
- Groundwater drainage alteration due to diverse probable groundwater pumping (dewatering, pumping of contaminated groundwater);

One of the main contaminants associated with leachate from a coal ADF, and that has retain attention in the kusile ash classification (geotechnical investigation) is the Chromium VI. Occupational exposure to chromium (VI) is associated with the occurrence of nasal septum and skin ulcers, as well as with the occurrence of lung cancer. Chromium(VI) when ingested is associated with taste effects and nausea when the concentration exceeds 1 mg/R. Definitive evidence of carcinogenesis via the oral route is equivocal, and chromium(VI) has also been implicated in the cause of gastrointestinal cancer. Chromium (II) and chromium (III) have much lower toxicities than chromium (VI). Others major elements are: Sulphate, Silicon (Si), Aluminium (Al), Iron (Fe), Calcium (Ca), Magnesium (Mg), Zink (Zn), and Copper (Cu).

The coal ADF has been considered as the main source of the contamination. A worse case initial concentration value of 1600 mg/L has been considered as initial concentration of salt load.

Numerical simulations results are presented and discussed in detail together with groundwater impacts assessment in the next chapter.

7 Groundwater impact assessment of the ash disposal on Sites A and B

This section describes in detail the potential impacts that the 60 years Ash Disposal Facility project phases could have on the weathered shallow aquifer systems underlying Sites A and B. Proposed mitigation actions are also described. This detailed preferred sites impact assessment is based on the initial geohydrological numerical model predictions to assess the likely hydrogeological impacts that the proposed ADF might have on the receiving environment.

Potential groundwater environmental impacts (contaminant transport, dewatering) from the facilities is addressed in the modelling exercise.

Based on the existing information, it is envisaged that ash might be deposited while opencast mining at the New Largo is operating. Since pit dewatering and groundwater contamination may be associated with the mining activities at the New Largo, the risk of such impacts is numerically assessed.

The risk impacts that a residual coal ADF, may have on the groundwater system associated with the Site A, are of particular importance.

The same potential impacts stated in Chapter 6 of the present document, are valid for the Alternatives A and B. Emphasis have been put on the following:

- Impact on downstream water users;
- Groundwater quality impacts;
- Impacts on any open-cast or underground workings.

7.1 Status quo

If no ash is disposed on Site A, the different man-made activities and natural processes that lead to the established baseline groundwater conditions will prevail.

In the case of Site A, contaminant transport from New Largo as depicted at KAM7 and KAM8 would probably continue downstream if no remediation action is taken. The water elevations would also probably continue to decrease. The analysis of the monitoring data (water levels) at Kusile power station shows an average annual decrease of 0.77m. The model simulation results in a maximum drawdown of 2.5m over 3 years, and the probable associated groundwater drainage is presented in Figure 54. The initial baseline environmental impact risks have been rated as High (-4.1).

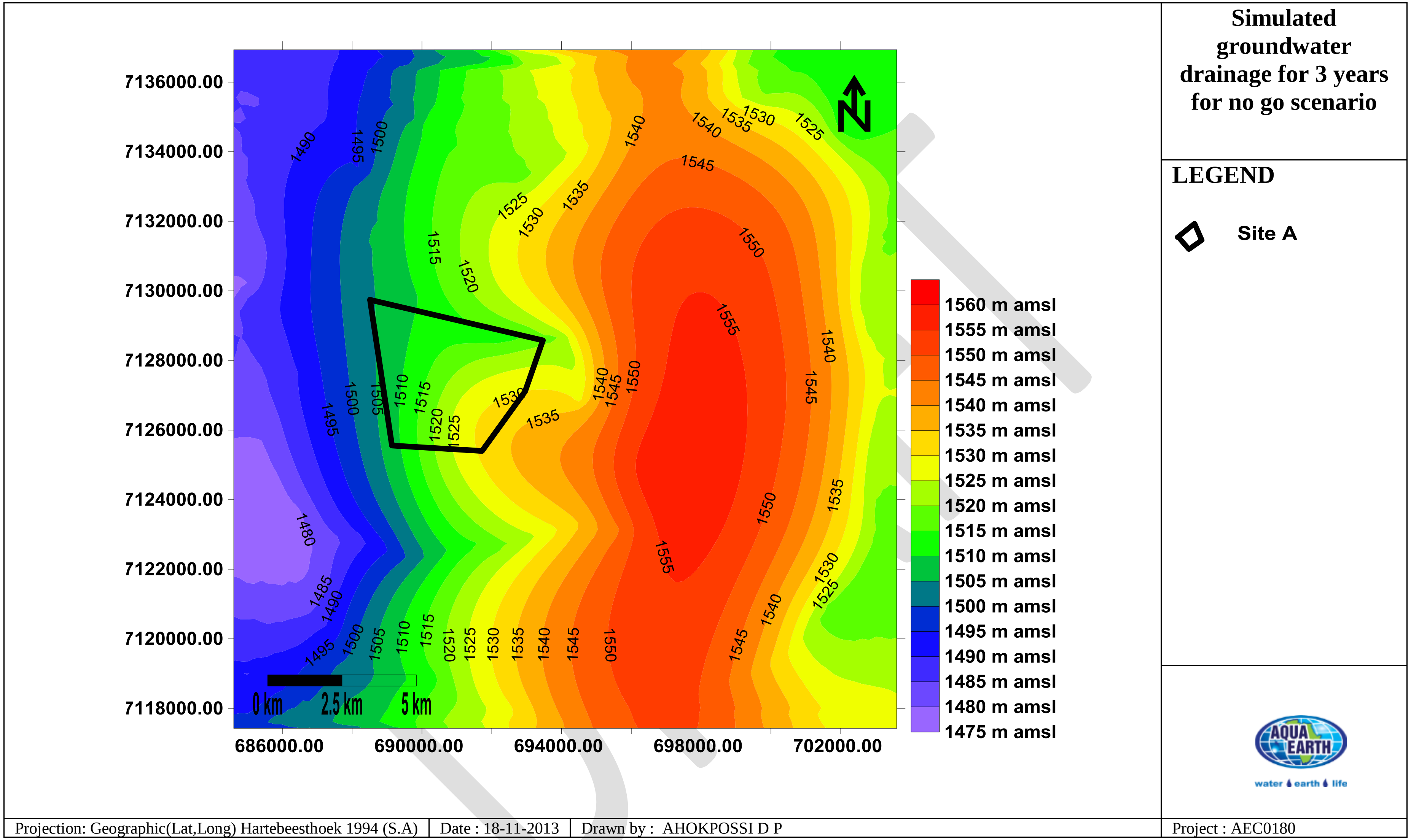


Figure 54: Simulated groundwater drainage for 3 years considering No Go Alternative

*

The open cast coal mine depicted in the north-western (KABH42) and north-eastern (KABH62) corners of Site B, would probably represent the biggest groundwater issues in the area. Both points, located downstream of the site B, would probably not be contaminated from the site B. The sources of such calcium/sodium sulphate water quality are not clearly identified. In the case of continuous sources, these sources may affect downstream groundwater if no remediation action is taken.

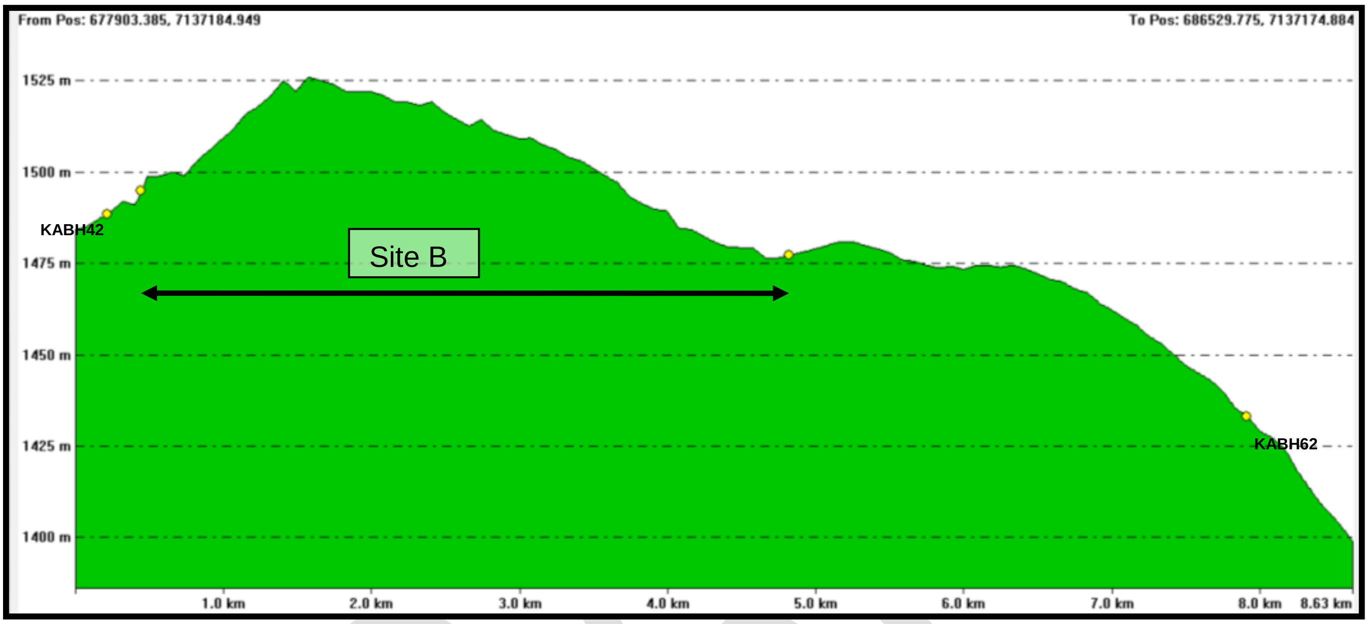


Figure 55: West-East (KABH42-KABH62) cross section over the preferred site B

The model simulation results indicate an average fall of the static water level of 0.68 m per year, which results in a general head fall of 6.8 m over 10 years. The probable groundwater elevations and drainage is presented in Figure 55. The initial baseline environmental impact risks have been rated as Moderately High (-3.3).

7.2 Project impacts: Construction phase

The following impacts have been considered and quantified during the construction phase on site A:

- Increasing of infiltration rates;
- Decreasing of the soils buffering capacity;
- Deterioration of groundwater quality due to construction waste (toxic construction material);
- Deterioration of groundwater quality due to hydrocarbon spills from storage (organic contaminants);
- Altered Flow systems that may be associated with probable groundwater dewatering and stream diversion;

The total estimated maximum depth of excavation for the construction of the ADF and associated facilities is approximately 5 mbgl. Considering such depth of excavation, it is probable that excavations intersect groundwater seepage at 1.9 mbgl and 2.0 mbgl respectively at Site A and Site B. This implies that limited groundwater dewatering will take place during construction. However, the impacts related construction waste constitutes a higher risk (Moderately Low) during construction phase.

Although the overall (combined impacts) impact risks that the construction of the coal Ash Disposal Facility would have on either underlying groundwater systems have been rated to be a Very Low impact risk, if no mitigation take place, Site B impact risks (-0.8) are relatively higher than impacts associated with Site A (-0.5).

7.3 Project impacts: Operational phase

The following impacts have been considered and quantified during the operational phase:

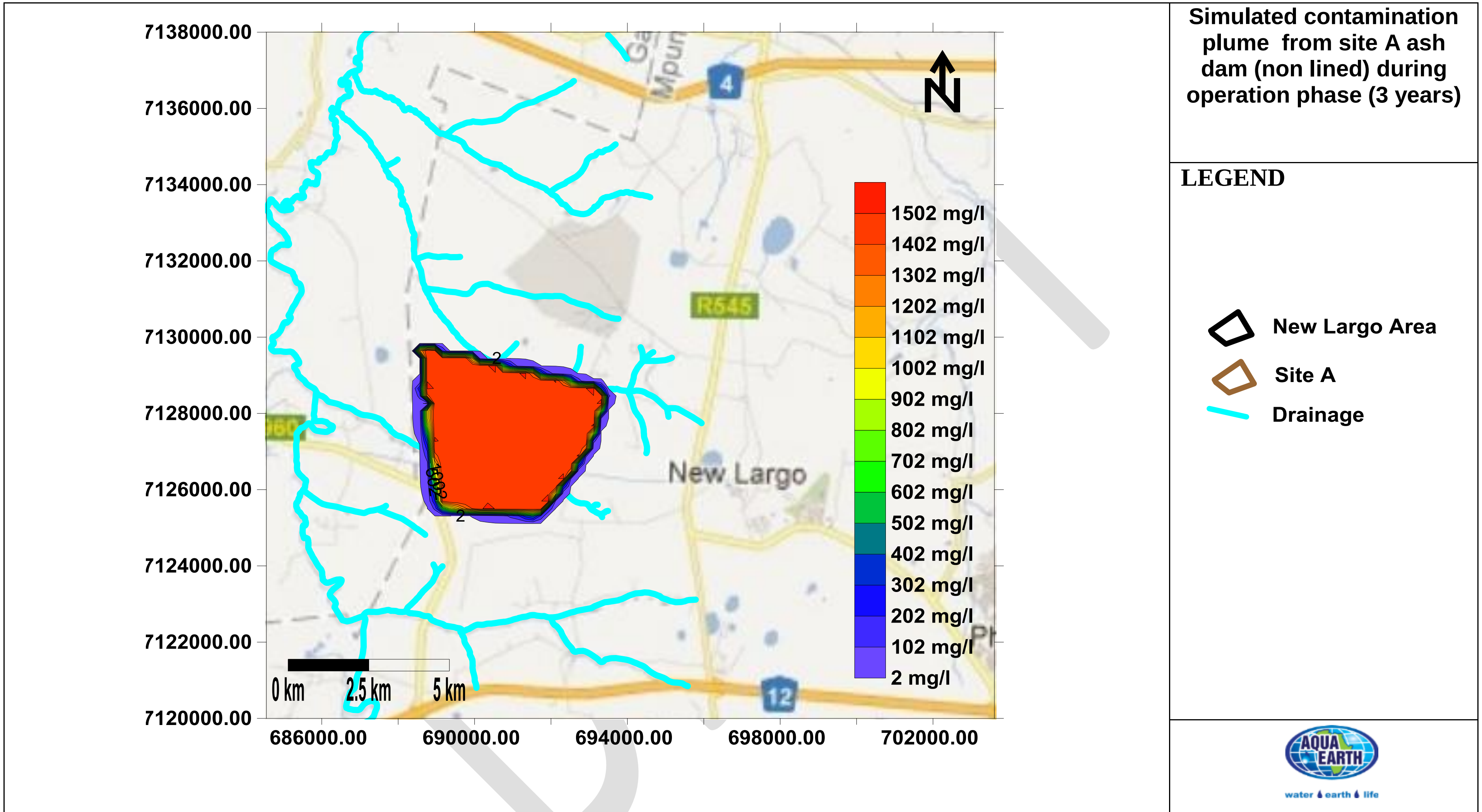
- Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ADF, contaminated water trenches and pollution control dams;
- Alteration of the groundwater flow system due to groundwater pumping (different uses).

Prior to mitigation (with lining systems), the overall (combined impacts) impacts risk that the operation of the coal Ash Disposal Facility would have on the underlying groundwater systems, vary from Low (-2.0) in Alternative A to Moderately Low (-2.8) in Alternative B. This is related to the fact that the impact risks related to seepage, leachate infiltration (leak of liner) from ADF, contaminated water trenches and pollution control dams are moderately low in Alternative A (-2.9), and high in Alternative B (-4.1).

The probable contamination plumes migration from the main potential source (Ash Disposal Facility) associated with each scenario have been simulated with no lining system in place. The simulated pollution for different horizons (3 years, 5 years, 20 years, and 60 years) of the operation are illustrated from Figure 56 to Figure 59 for Alternative A, and from Figure 62 to Figure 63 for Alternative B. Without any mitigation measures (no lining system in place), and stresses, the pollution plume motion will be dominated by advection and is directed downstream of each proposed preferred site. Figure 59 and Figure 63 show pollution plumes simulation in the case lining system to be put in place leaks on 3 % of the ADF area, for alternatives A and B respectively. The considered leaking points (center of ADF, and dams) are assumed to be the more sensitive point to leaks.

Site A is located close to the water divided, and in Altrnative A the plume migration would be in one direction (East-West) toward the Wilge River. Up to 5 years of operation, the pollution plume would be localised at the immediate vicinity (less 50 m) of the ADF. Within 20 years, the pollution plume would move approximately 1.2 km downstream of the ADF and would cover an area of 7.2 km^2. Within 60 years (end of operation), the pollution plume would move approximately 3.2 km downstream of the ADF and would probably reach the Wilge river. The pollution plumes at 60 years would cover an area of 19.2 km^2.

The position of the Alternative B water divided would cause contaminants plumes migration in multiples downstream directions as shown in Figure 62. Plume migration would be mainly toward the Wilge River in B20F and toward the Bronkhorstspruit River in B20D. Within 60 years (end of operation), the pollution plume would migrate approximately to maximum distances of 3.1 km and 2.7 km downstream of the ADF, respectively in B20D and B20F.



Projection: Geographic(Lat,Long) Hartebeesthoek 1994 (S.A) | Date : 18-11-2013 | Drawn by : AHOKPOSSI D P | Project : AEC0180

Figure 56: Simulated contamination plume from Alternative A ADF (non lined) during operation phase (3 years)

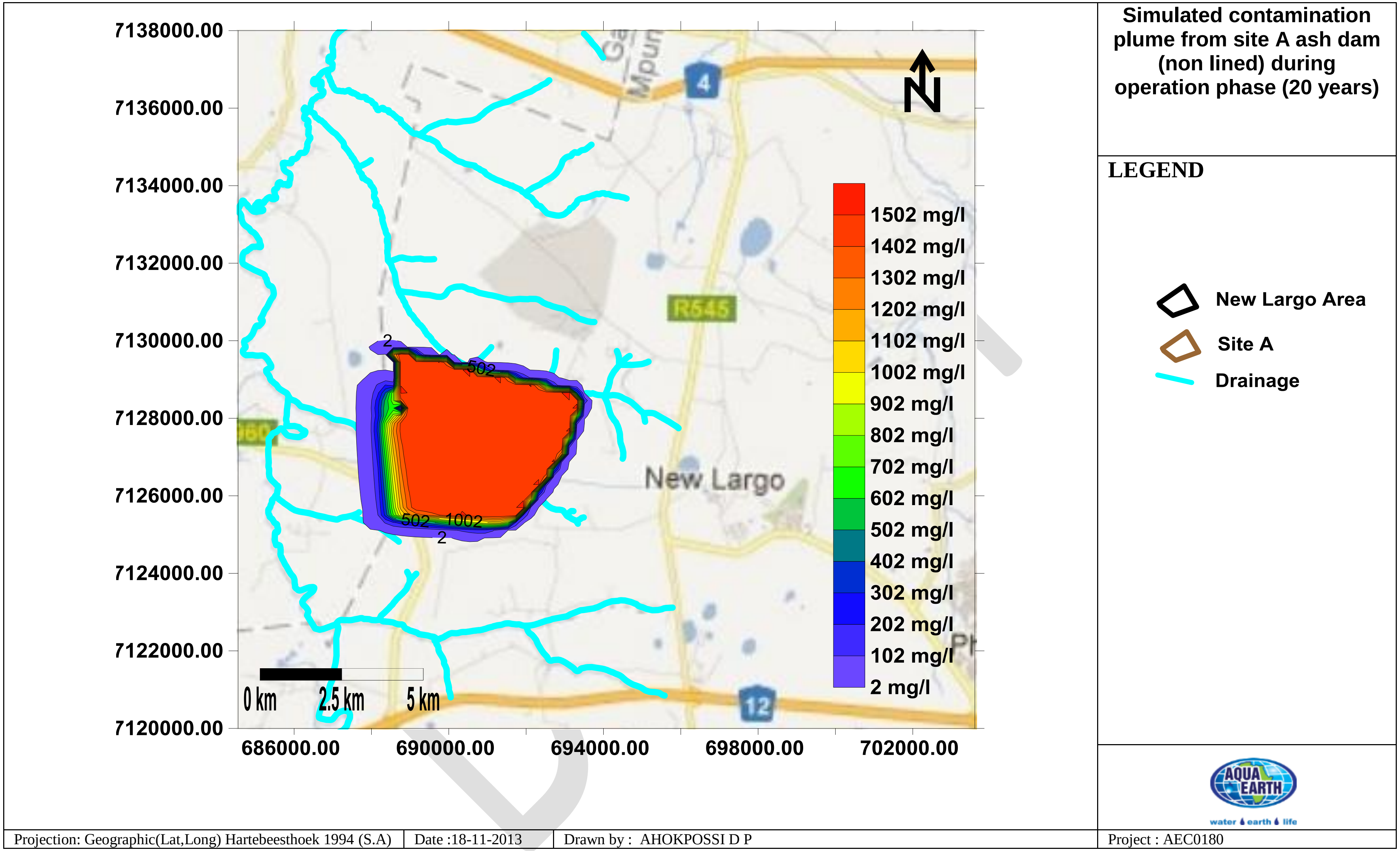


Figure 57:Contamination plume from Alternative A ADF (non lined) during operation-construction phase (20 years)

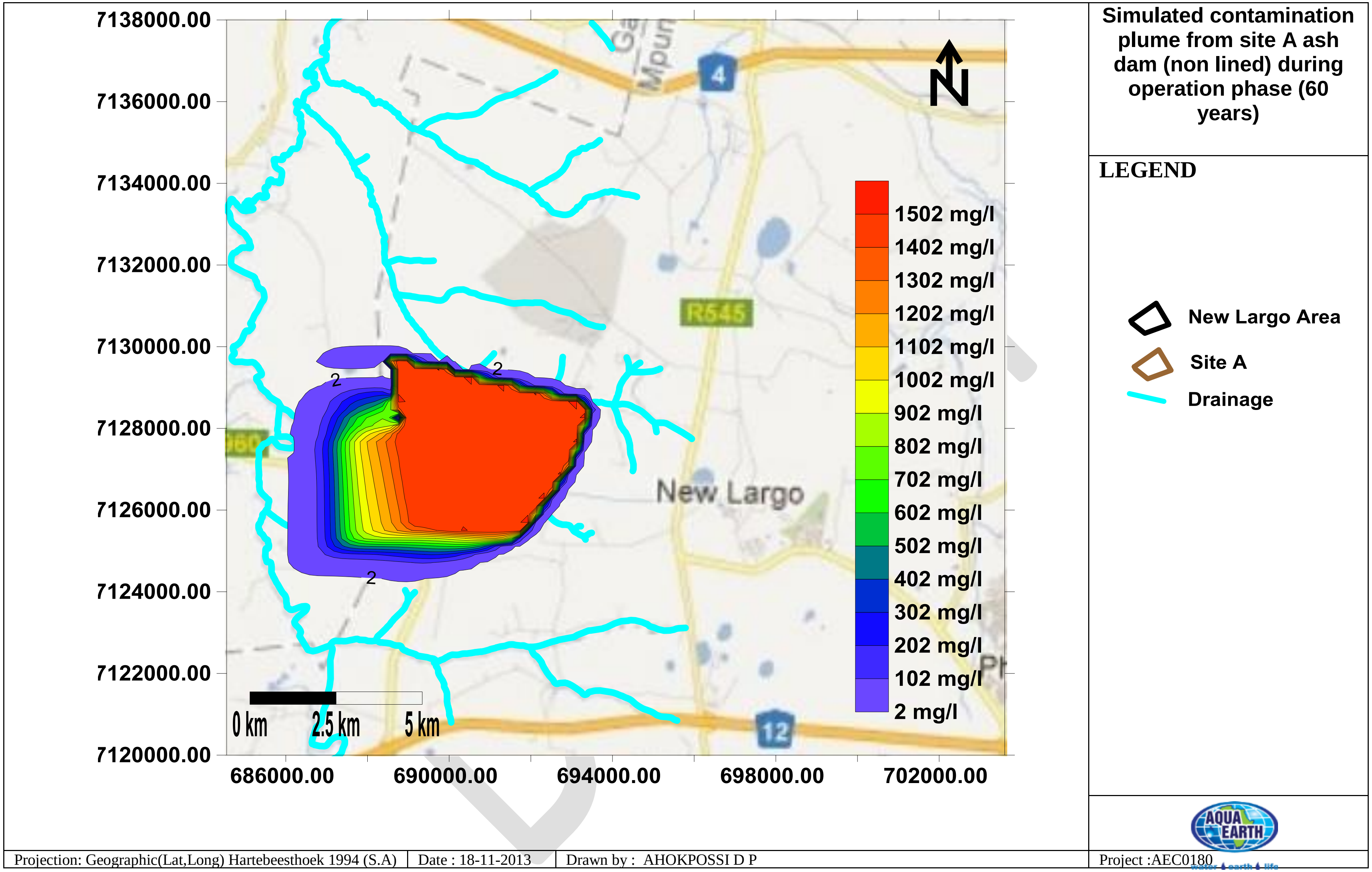
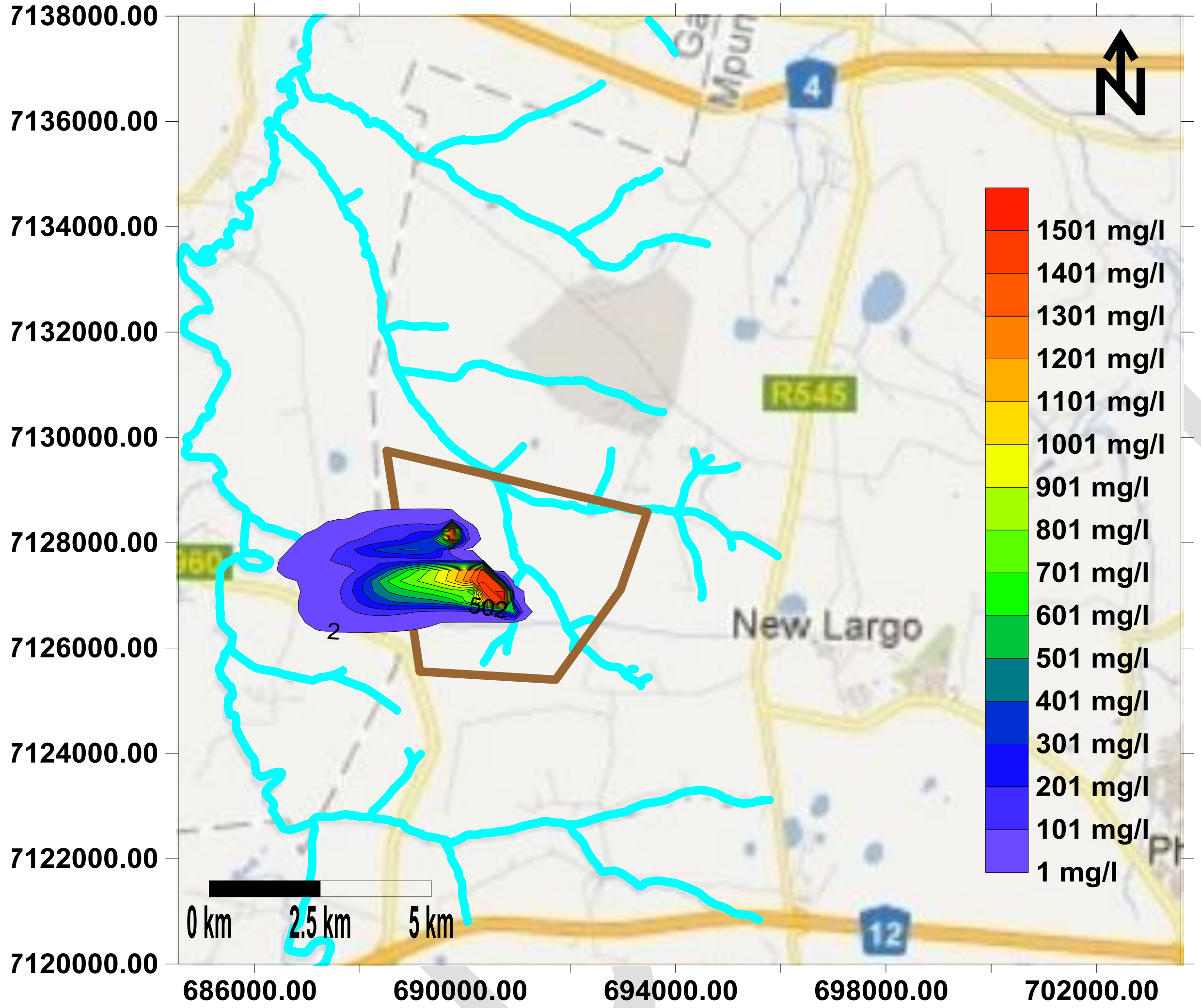


Figure 58: Contamination plume from Alternative A ADF (non lined) during operation-construction phase (60 years)



Simulated contamination plume from site A ash dam during operation phase (60 years)

LEGEND

- New Largo Area
- Site A
- Drainage

Projection: Geographic(Lat,Long) Hartebeesthoek 1994 (S.A) | Date : 03-2014 | Drawn by : AHOKPOSSI D P | Project :AEC0180

Figure 59: Contamination plume from Alternative A ADF (2% leakage of lining system) during operation-construction phase (60 years)

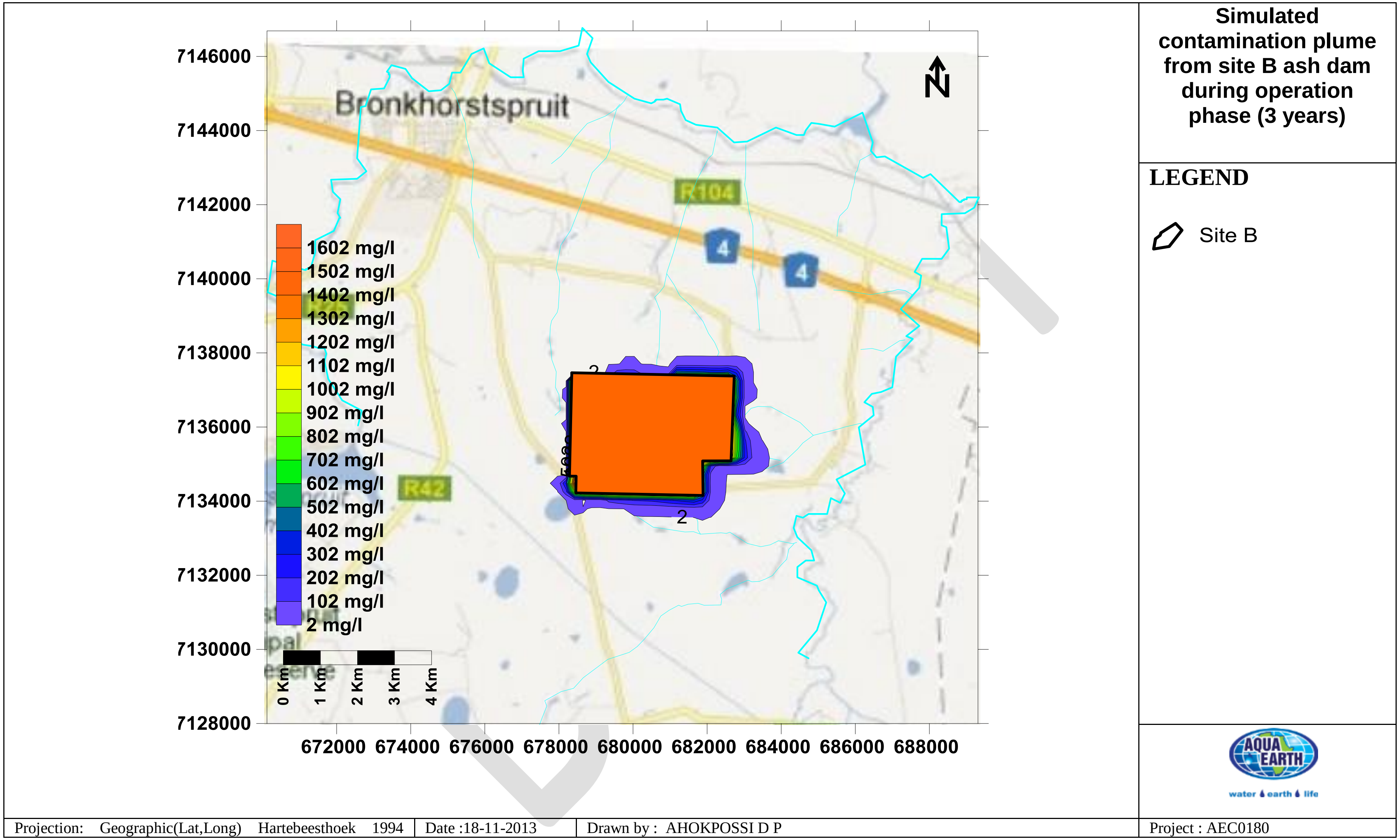
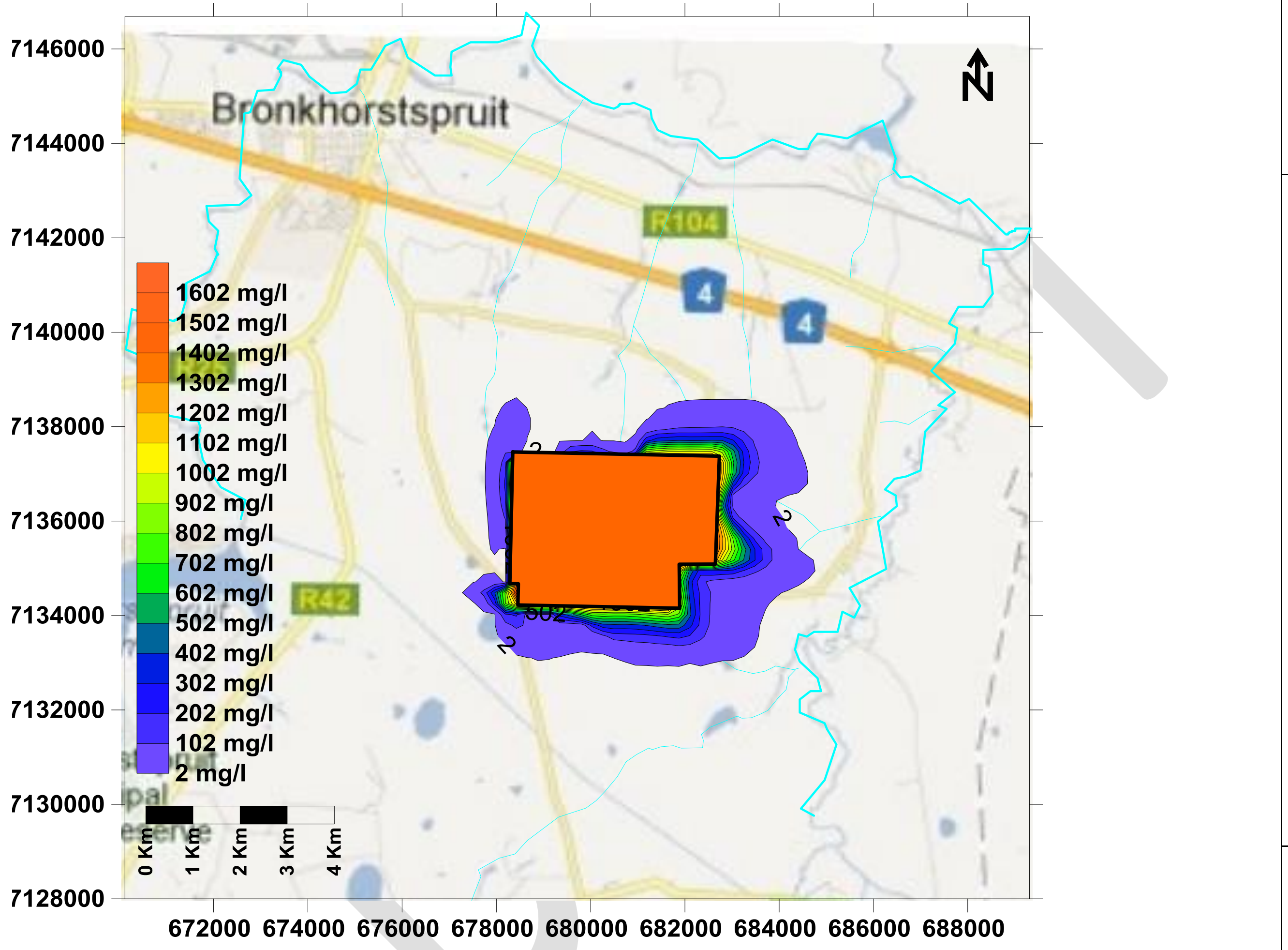


Figure 60: Simulated contamination plume from Alternative B ADF during operation phase (03 years)



Simulated contamination plume from site B ash dam during operation phase (20 years)

LEGEND

Site B

Projection: Geographic(Lat,Long) Hartebeesthoek 1994	Date :18-11-2013	Drawn by : AHOKPOSSI D P	Project : AEC0180

Figure 61: Simulated contamination plume from Alternative B ADF during operation phase (20 years)

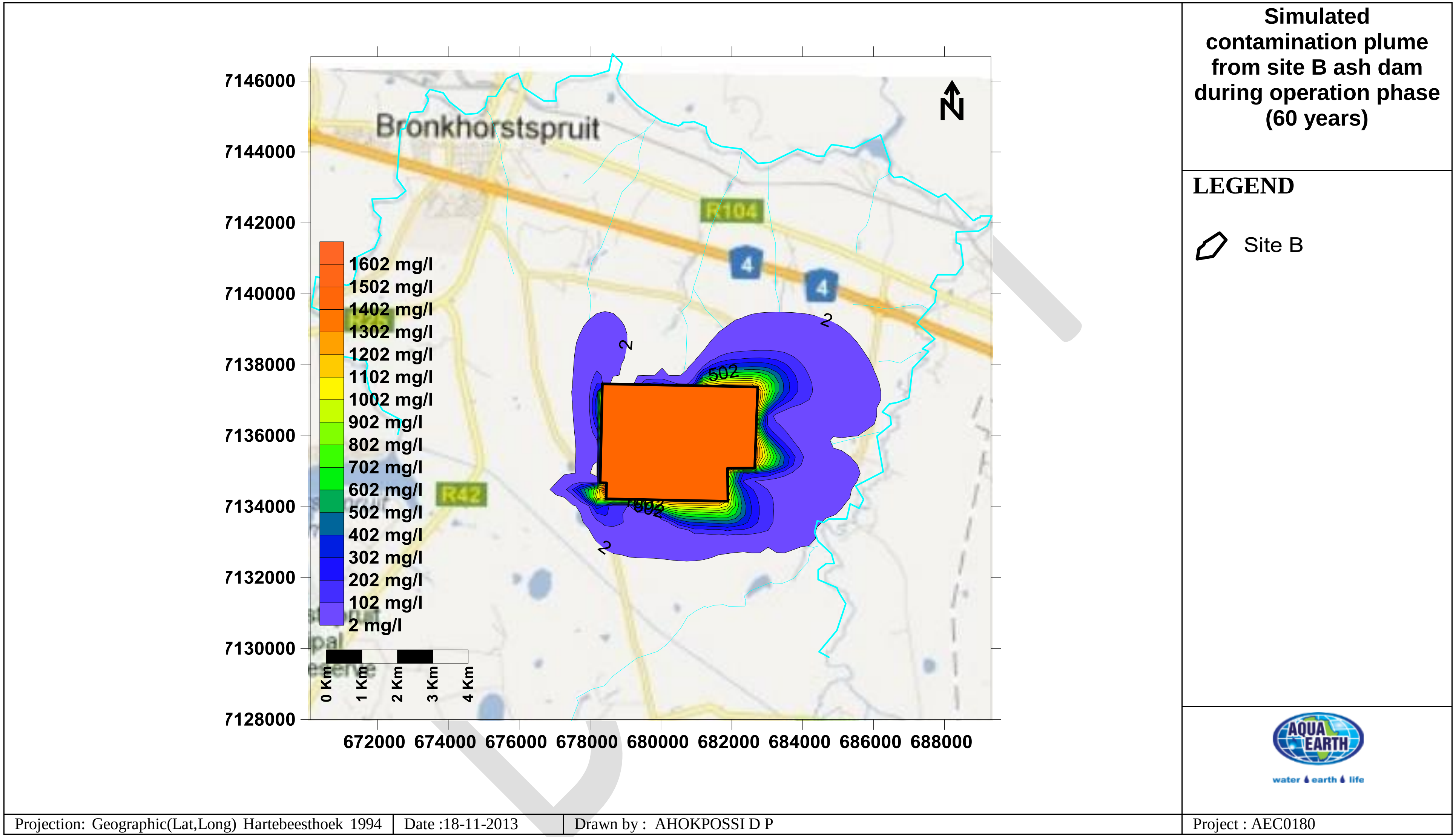


Figure 62: Simulated contamination plume from Alternative B ADF during operation phase (60 years)

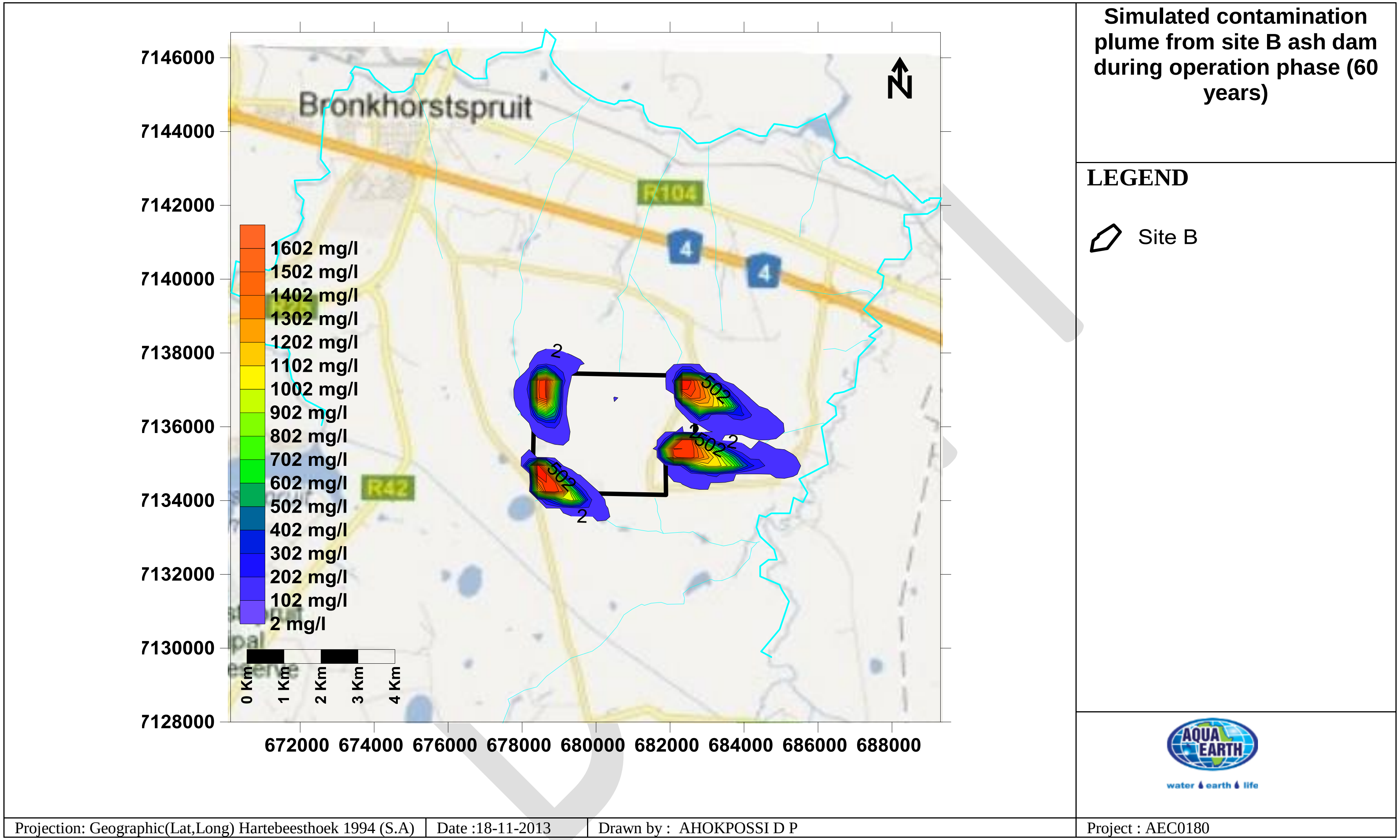


Figure 63: Contamination plume from Alternative B ADF (2% leakage of lining system) during operation phase (60 years)

7.3.1 Project impacts: Closure (Decommissioning) phase

The following impacts have been considered and quantified during the closure phase:

- Deterioration of groundwater quality due to waste, and spills related to closure activities;
- Groundwater pollution due to seepage, leachate infiltration (leak of liner) from a ADF, contaminated water trenches and pollution control dams;
- Alteration of the groundwater flow system due to groundwater pumping (different users).

Although the overall (combined) impact risks at the closure of the coal Ash Disposal Facility would have on either underlying groundwater systems (Site A and Site B) have been rated to be a Low impact risk, if no mitigation take place, Site B impact risks (-1.9) are relatively higher that Site A ones (-1.1). The impacts risk (Moderately Low) associated with deterioration of groundwater quality due to waste, and spills related to closure activities are of most concern. Such impact risk have been rated Low (-1.5) for Alternative A and Moderately High (-3.8) for Alternative B.

The installation of a linear low-density polyethylene (LLDPE) geomembrane at the top soil layers will reduce possible groundwater pollution due to seepage, from the ash dam.

7.4 Project impacts: Post closure phase

The following aspects may impact the groundwater conditions (quality and quantity) and have been quantified for post-closure phase:

- Groundwater pollution due to leachate (leak) from the ADF, contaminated water trenches and other contaminated water storage facilities;
- Reduction of infiltration rates;
- Alteration of the groundwater flow system due to groundwater pumping (different uses)

Before any mitigation, the overall combined impact risks at the post closure of the ADF are negative Low (-1.6) for Site A, but Moderately High (-2.5) for Site B. The risk impacts that result in the groundwater quality deterioration need to be addressed in a conscientious manner especially at the closure phase. Such risk have been rated Moderately Low (-2.4) in Alternative A and Moderately High (-3.4) in Alternative B.

7.5 Cumulative impacts

The main cumulative impacts of concern in Alternative A are the impacts from New Largo. Necessary groundwater dewatering would probably be implemented, which might create a cone of groundwater depression around the open pit at New Largo. The groundwater flow regime would therefore be altered, and flow between Site A and New Largo would probably be reversed toward the New Largo. This would help in containing any pollution associated with open cast mining, at New Largo, but will result in the spreading of the pollution from the 60 years ash dam towards the south of Site A. At the 60 years horizon, New Largo dewatering will result in a plume expansion of an extra 800 m (further than without dewatering) at the south of ash dam site A. This would involve an extra 2.4 km^2 polluted area at the south of site A. The overall cumulative impacts risk associated with Site A would be Moderately High (-3.2 during construction, closure and post closure, and -3.8 during operation) including impacts from operation of New Largo.

In the case where operation of New Largo is not considered, the historical underground mining impacts (acidic water) would still prevail since it's included in the site background groundwater quality and such impacts cannot be neglected. But the spreading (due to New Largo) dewatering of the pollution plume from the 60 years ADF towards the south of site A, would be avoided.

In the Alternative B, the impacts risk associated with operation phase activities is High (-4.1), and would be Moderately Low during construction phase (-2.7). The overall impacts risks calculated for the closure and the post closure are Moderately High (-3.8 and -3.2 respectively).

Considering the locations (downstream of the Site B) of areas with calcium/sodium sulphate water quality, the potential for accumulation of impacts from the Ash Disposal Facility in Alternative B is High. Although the diagnostic plots indicate some open cast coal mine related water, the real sources of such polluted background water quality could not be associated directly to any tangible physical sources at the surface during hydrocensus. This make difficult to appreciate the real extend of the cumulative impacts risks. In the case of continuous sources for instance, these unidentified sources may accentuate any impact from the ash dam to the downstream groundwater if no remediation action is taken.

For both Sites A and B the most important overall impacts risk appear to be associated with Ash Disposal Facility operation phase. But the operation phase impacts would surely be more severe in the Alternative B than in Alternative A.

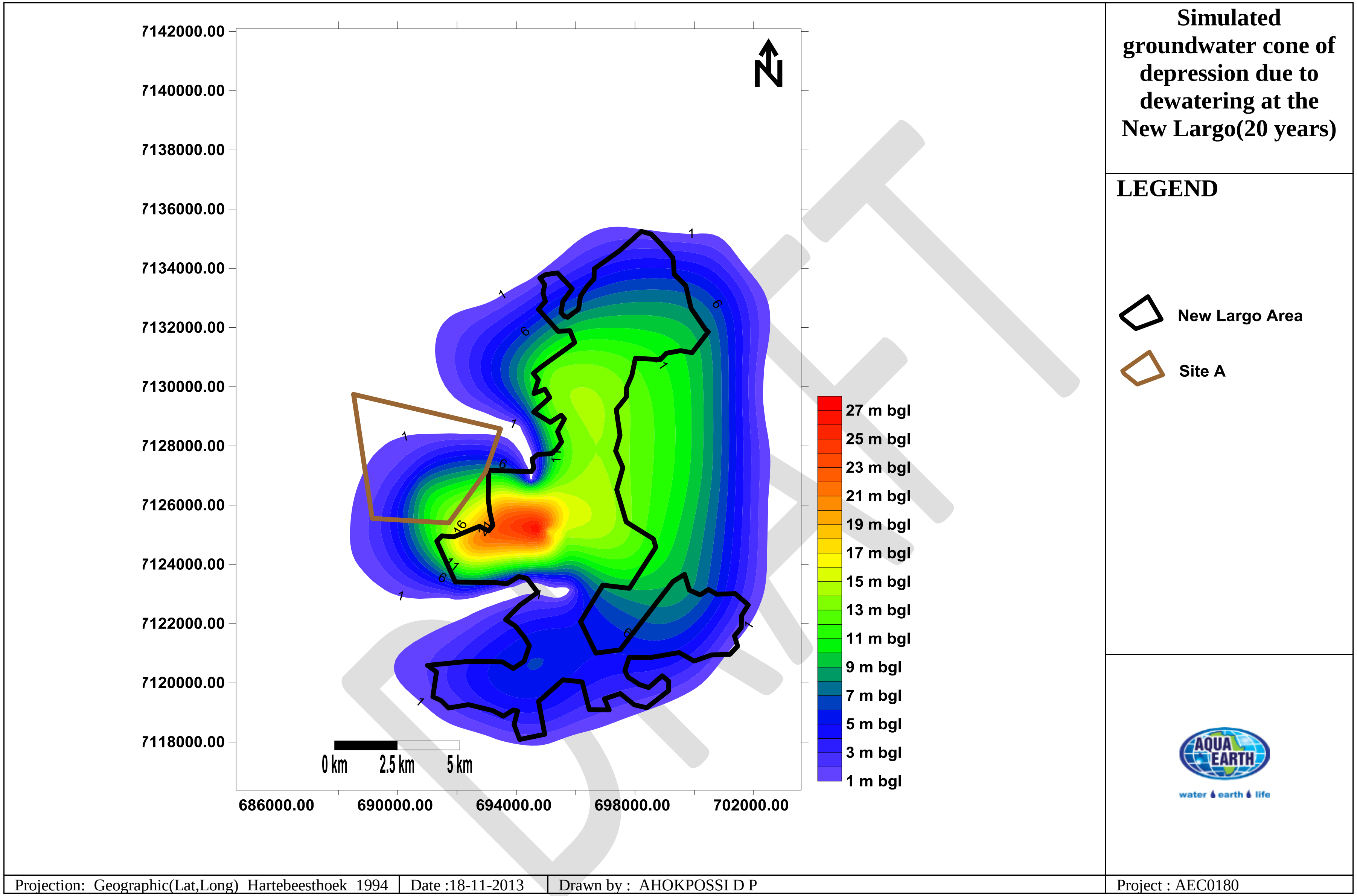


Figure 64: Simulated groundwater cone of depression due to dewatering at the New Largo (20 years)

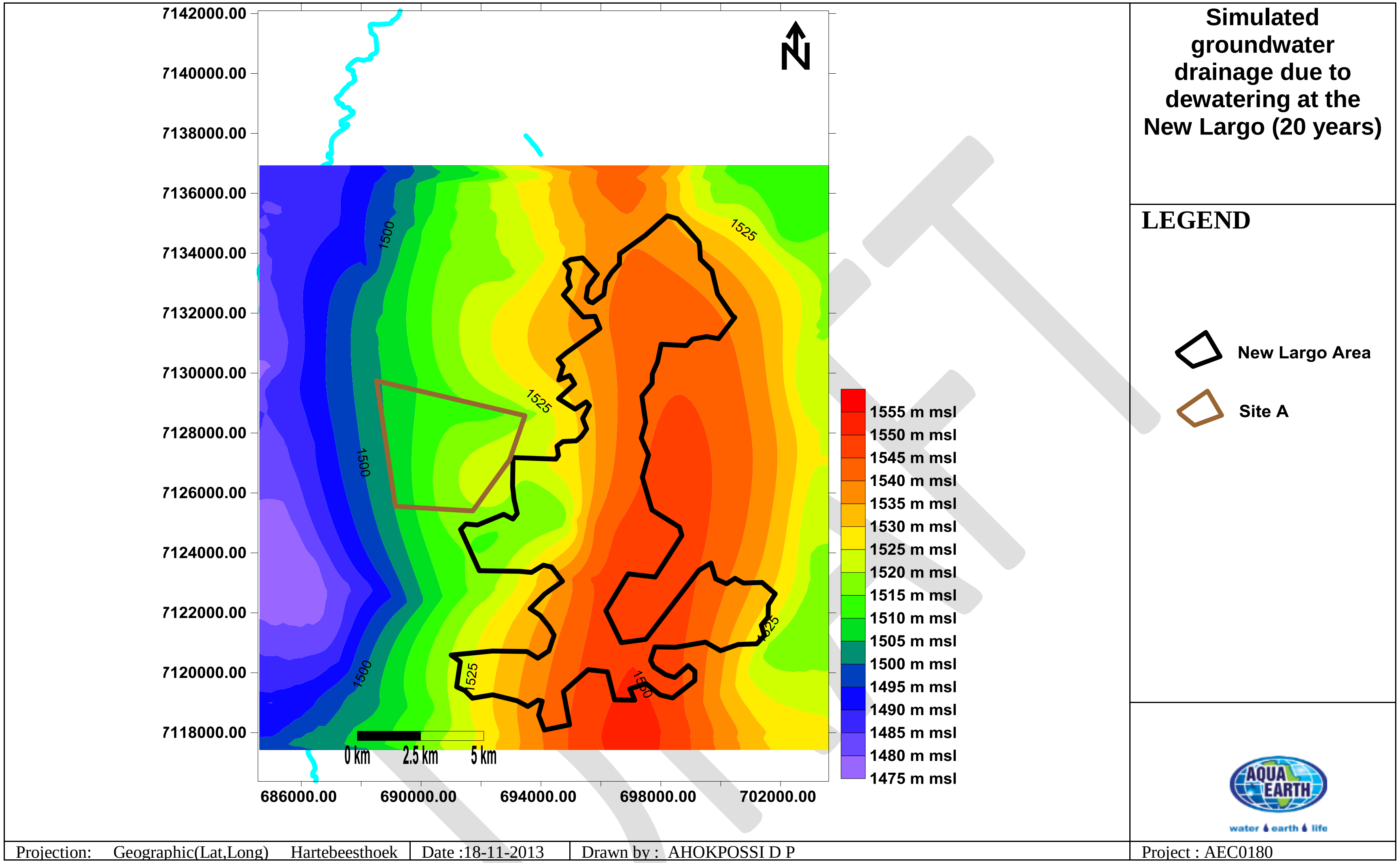
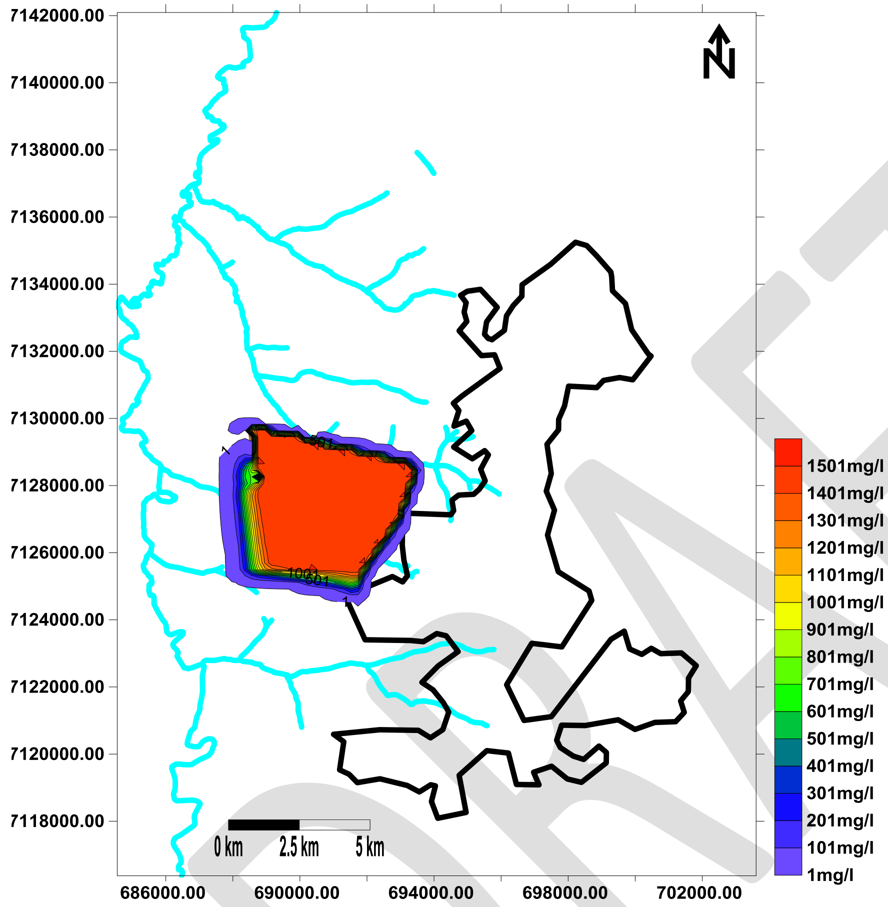


Figure 65: Simulated groundwater drainage due to dewatering at the New Largo (20 years)



Simulated pollution plume affected by dewatering at the New Largo (20 years)

LEGEND

New Largo Area

Site A

water earth life

Projection: Geographic(Lat,Long) Hartebeesthoek	Date :18-11-2013	Drawn by : AHOKPOSSI D P	Project : AEC0180

Figure 66: Simulated pollution plume affected by dewatering at the New Largo (20 years)

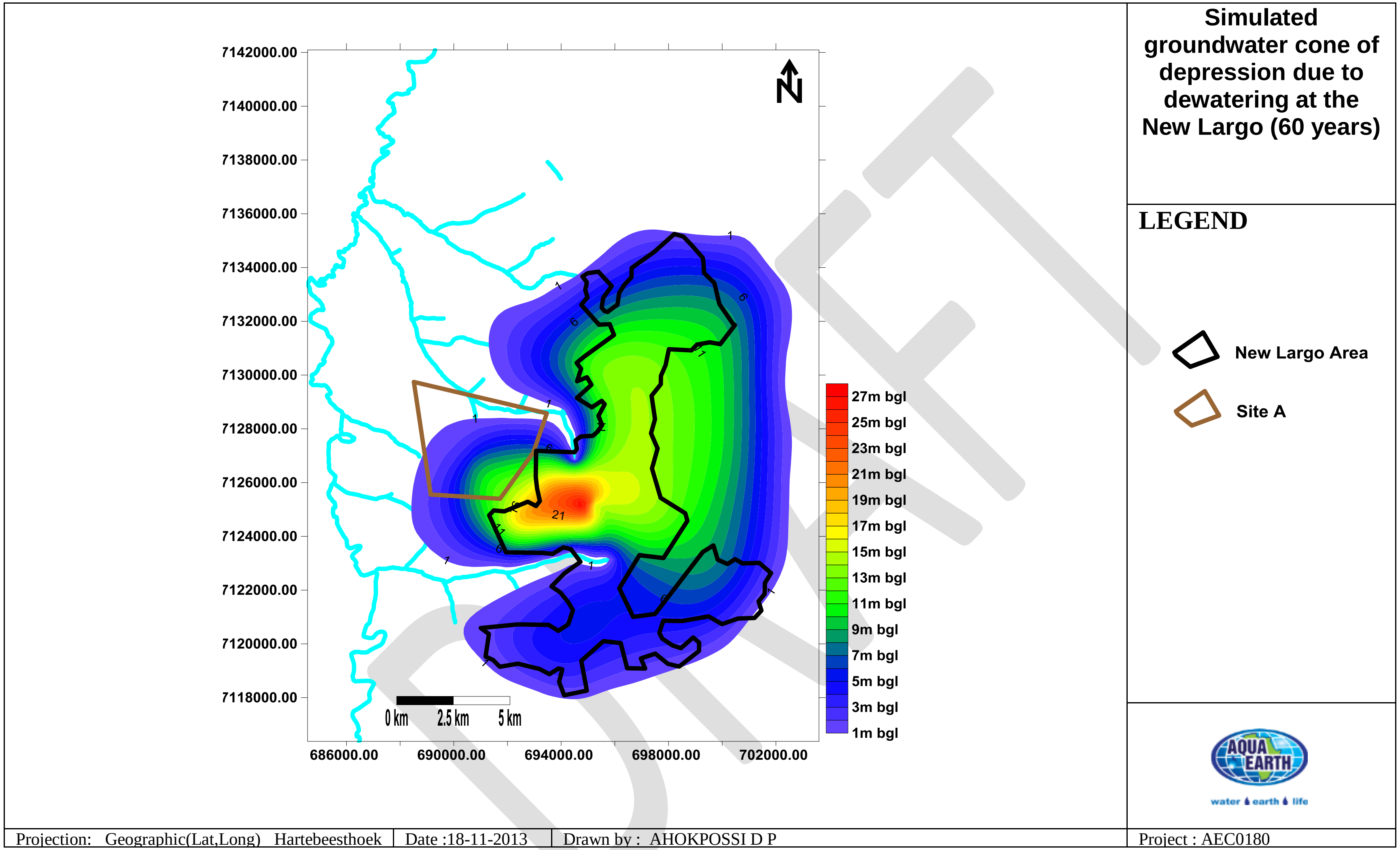


Figure 67: Simulated groundwater cone of depression due to dewatering at the New Largo (60 years)

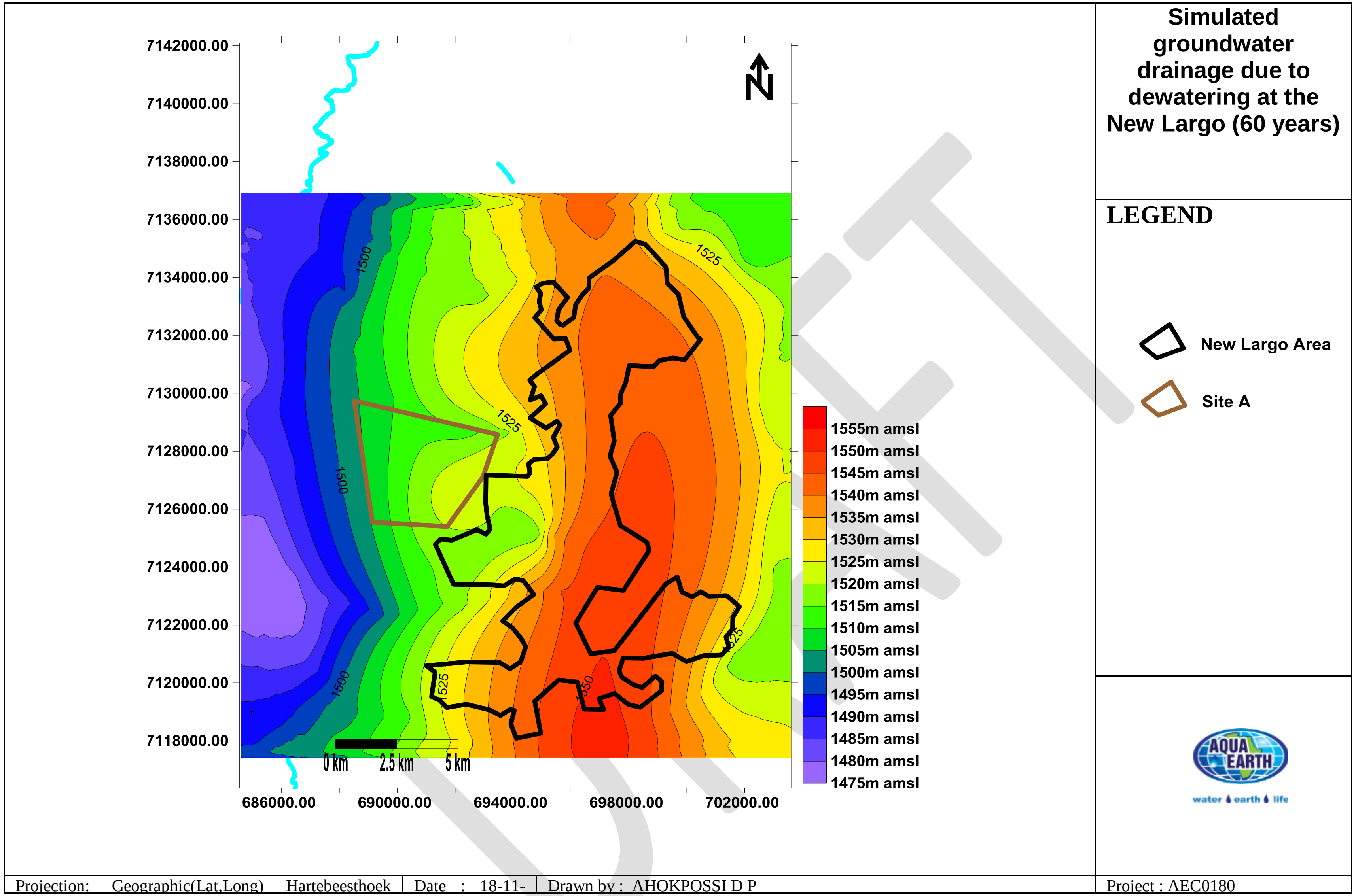


Figure 68: Simulated groundwater drainage due to dewatering at the New Largo (60 years)

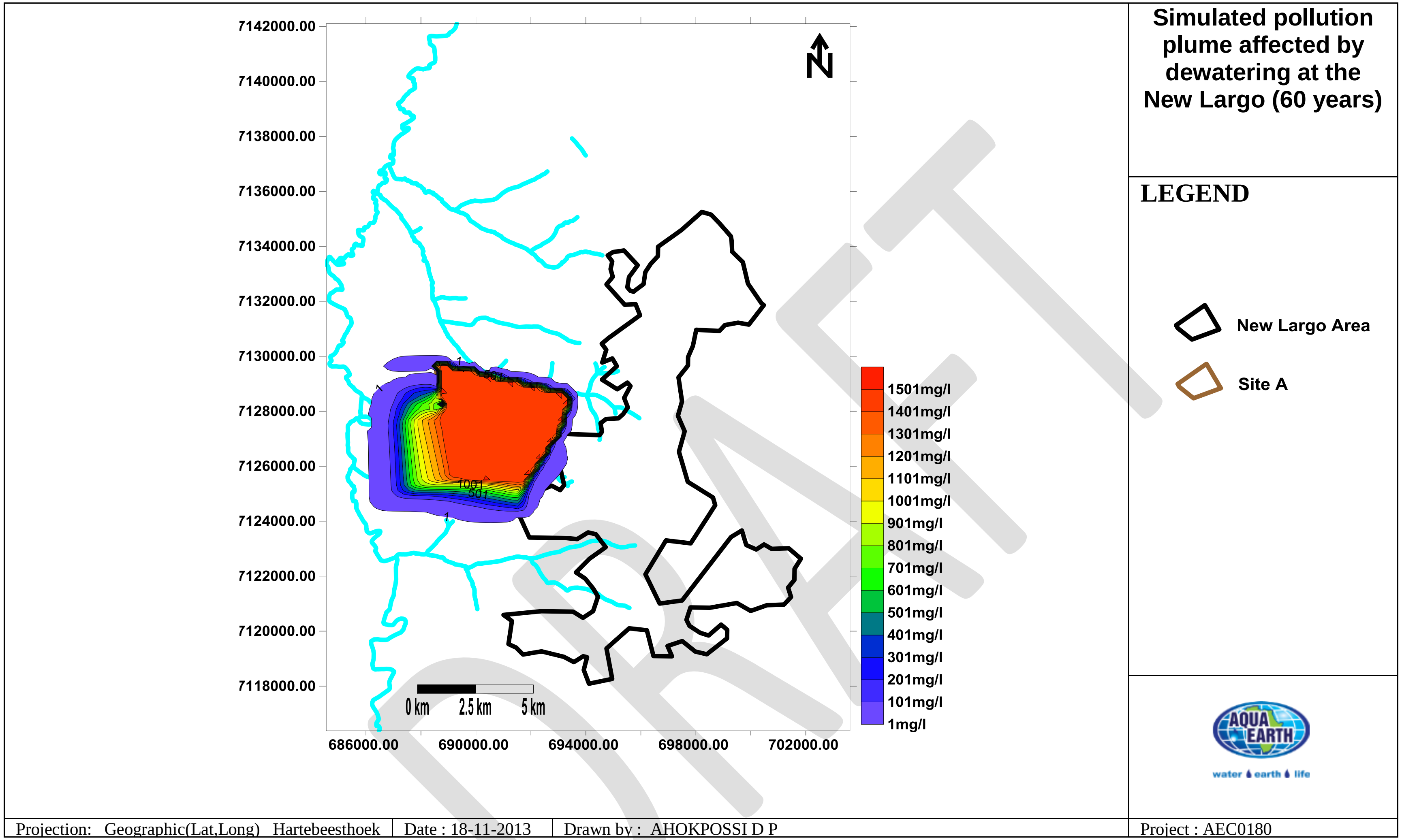


Figure 69: Simulated pollution plume affected by dewatering at the New Largo (60 years)

7.6 Mitigation measures

The ash disposal site pose a groundwater contaminant risks as assessed at site A. The proper design, construction and maintenance of the liner system below the ADF, and the rehabilitation of the ADF are part of the key focus areas to mitigate groundwater impacts. The rehabilitation of the ADF will be aimed at minimising infiltration of oxygen rich water and direct oxygen exposure of the ADF.

The following precautions have to be taken into consideration to reduce possible groundwater risks posed by the ash disposal site:

- Any waste and spills (specially during construction and closure) need to be cleaned up immediately according to the departmental minimum requirements;
- Groundwater monitoring network should be installed before the starting of any construction activities on site;
- The monitoring network should be updated per project phase according to the DWA minimum requirements;
- Authorities need to be notified in the event of a spill or leachate during construction and closure;
- In the case of any groundwater dewatering, or pumping of contaminated groundwater, pumped water should be re-injected into the aquifer system at downstream of the site. If the groundwater is contaminated, treatment needs to take place to ensure that the quality of the re-injected water complies with the groundwater quality reserve as required by DWA;

Prior to construction

- During design phase, the ADF and all pollution control facilities (dams, trenches) must be designed with the appropriate liner system and comply with the departmental minimum requirements (1998/2012) with cuspate leak detection;
- The design of the contaminated water trenches and dams should ensure their long term integrity;
- The ADF and all pollution control facilities (dams, trenches) must be designed to have a minimum freeboard above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level.

During construction

- A proper construction phase should be carried out under the supervision of an accredited or recognised professional civil engineer, as approved by the designer;

- Storage area for hydrocarbons or any toxic construction material should be bonded according to departmental minimum requirement;
- Special care should be given to the diversion and demolition of 2740 m of fuel pipes associated with site B.

During operation

- Avoid possible longer lag time between liner installation and ash disposal or trench construction;
- Proper operation and maintenance of contaminated water trenches and dams;
- All pollution control facilities (dams, trenches) must be operated to have a minimum freeboard above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level;

At the closure

- Rehabilitation of the ADF should start immediately after the deposition of the last coal ash;

At the post closure

- Repair trenches and dams as may be required, and according the DWA minimum requirements;
- Avoid rain water entering into the ADF by protecting it with adequate geomembrane prior to rehabilitation (top soil);
- Direct precipitation falling onto the ADF should be drained by the storm water management system to areas where infiltration could occur.

The way these mitigation measures would be implemented is detailed in the groundwater management plan. With a strict application of the proposed mitigation measures, the overall project impacts risk will be reduced to:

- very low level (-0.4) at the construction phase for both preferred alternatives;
- very low level (-0.9; -0.7) and at the operation phase for respectively Site A and Site B;
- very low level (-0.9; -0.7) at the closure phase for respectively Site A and Site B;
- Very low level (-0.6) at the post closure phase for both alternatives.

The remediation options that might be applicable in the case of groundwater contamination are briefly discussed below:

- Natural flushing (attenuation): Unlike the other remediation technologies, natural flushing or attenuation does not necessitate other actions than the intensive monitoring of groundwater quality (contaminants concentration) and institutional control through the lifetime of the process. It should be the first remedial alternative to consider, since under certain conditions, a combination of naturally occurring processes (physical, chemical or biological) may act without human intervention to reduce the risks (concentration, volume, mobility or toxicity) posed by contamination in groundwater, and so constitutes the most cost effective and complete remediation technology. It is a no-go option to be considered but it is definitively not a "do nothing" remedial option.
- In situ bioremediation (ISB): Bioremediation (biodegradation and biotransformation) is the change (breakdown or transformation) of water chemical by living organisms eventually resulting in the formation of gas (carbon dioxide or methane) and water. The living organisms may be naturally present in the groundwater or injected in groundwater. In the case of inorganic compounds, the contaminants are bio transformed.
- In-situ Chemical Oxidation Reduction (ISCOR): The chemical oxidation reduction reactions involve the transfer of electrons between species. When considered separately both reactions are each called “half-reaction“, but can only occur simultaneously. The in situ chemical oxidation reduction involves the injection of chemical into both dissolved plumes and source, to change by chemical reactions (oxidation and reduction), the chemistry, pH, or redox potential of water.
- Electrokinetic barriers: The process generally induces the migration of ionic species by passing a low direct current through the contaminated region between a series (barrier) of positive and negative electrodes. When implemented within the contaminants plume as the current passes through the barriers of electrodes, cationic contaminants tend to accumulate near the negative electrodes where they can be either removed in situ (adsorption, sorption precipitation, ion exchange (resin)) or pumped out for treatment. The bulk water tends to migrate toward the cathode. The amount of electricity required to maintain the process increases with the flow rates. The density of the electrodes to be installed depends on the size of the extent of the contaminants plume.
- Permeable Reactive Barriers (PRB): A PRB is a wall built below the surface to clean up groundwater. The wall allows groundwater to flow through while reactive material in the wall traps and changes harmful chemicals to harmless chemicals. PRB may be either constructed by excavation and installation of the barriers in trenches

(excavation), or constructed by jetting reactive materials into the ground, or by generating fractures within an aquifer and filling the fractures with reactive materials (Richardson & Nicklow 2002). A well known variation of PRB concept is the funnel and gate system in which, impermeable barriers are used to divert or channel contaminated groundwater towards a permeable reactive section of the barrier, and by doing so concentrating local groundwater flow the treatment process in a defined region. This allows the funnel gate system to be installed either in front of plumes to prevent further plume growth, or immediately down gradient of contaminant source areas to prevent contaminants from creating plumes.

- Pump and Treat and reuse: The system, consisting of appropriate access boreholes for groundwater extraction, removes contaminants that are dissolved in the water for treatment at the surface. The technique is used for cleanup of organics and inorganics (metals, anions, and radionuclides) in groundwater. This technology is simple to design and operate, uses standard equipment available from many sources, and treats all types of dissolved contamination. Given suitable regulatory approval, treated groundwater may then be either re-infiltrated into the aquifer or surface water, or disposed of to foul sewer, or be reused in industrial or mining processing.

The technical feasibility assessment of each of these options requires certain details of site characterisations specific to each site and level of potential? contamination. The selection of most favourable options depends not only on the technical and costs criteria, but also on the regulatory authority and legislation requirements, the ESKOM SHE politics and principles, and the opinion of all the affected parties.

Based on available information the pumping (hydraulic control) of any contaminated groundwater from the ADF has been numerically simulated and the results for site A show that such action:

- Would alter the groundwater drainage and create a sort of barrier for contaminant motion to downstream aquifer system(Figure 71);
- Would induce a groundwater cone of depression that expands to the New Largo area where it would surely help in the dewatering for coal open pit mining (Figure 72).

It is worthy to mention that such remediation action (pump and treat) would only be necessary in the case of failure of the preventives actions (liner systems, and others).

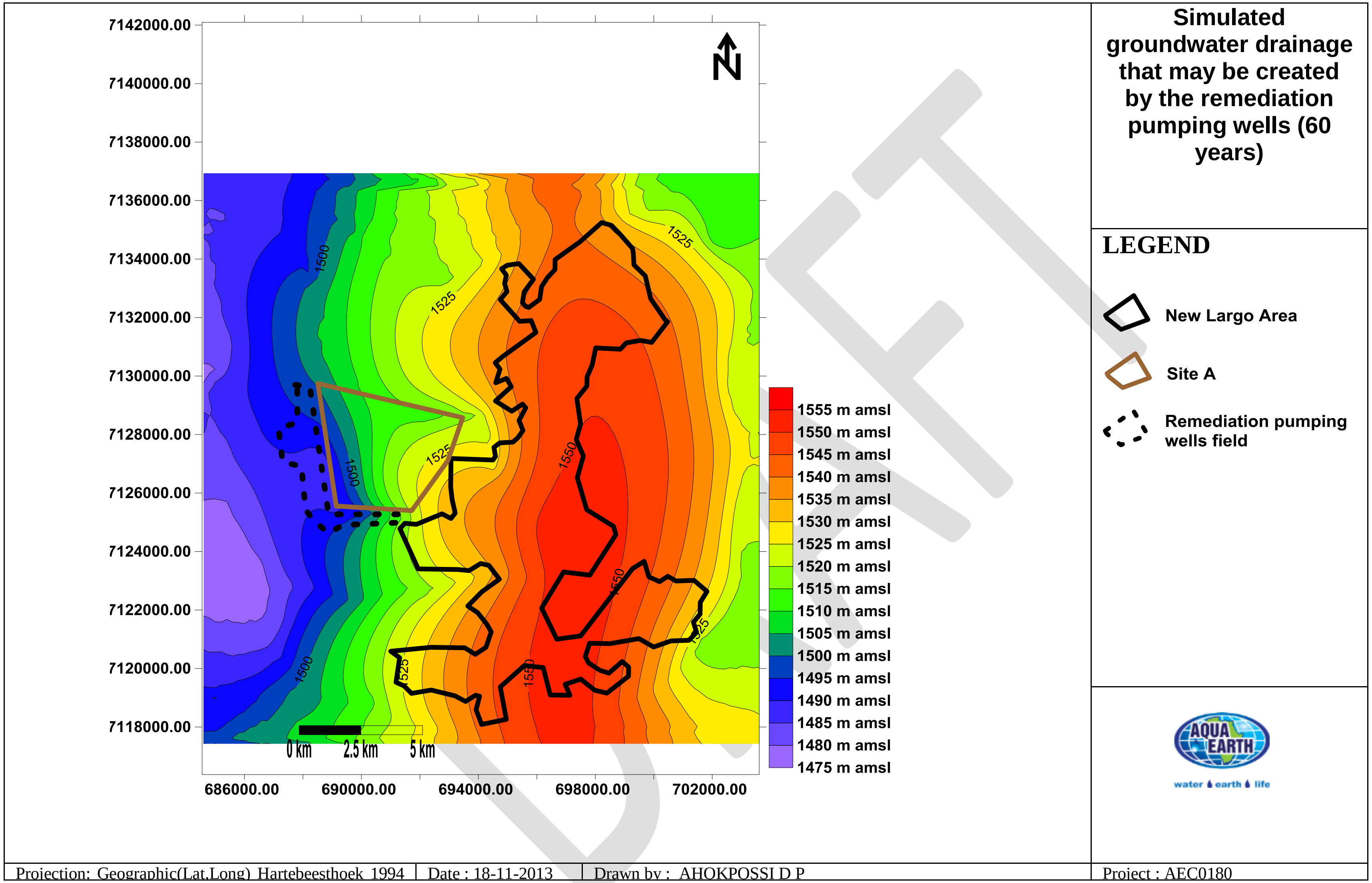


Figure 70: Simulated groundwater drainage that may be created by the remediation pumping wells field (60 years)

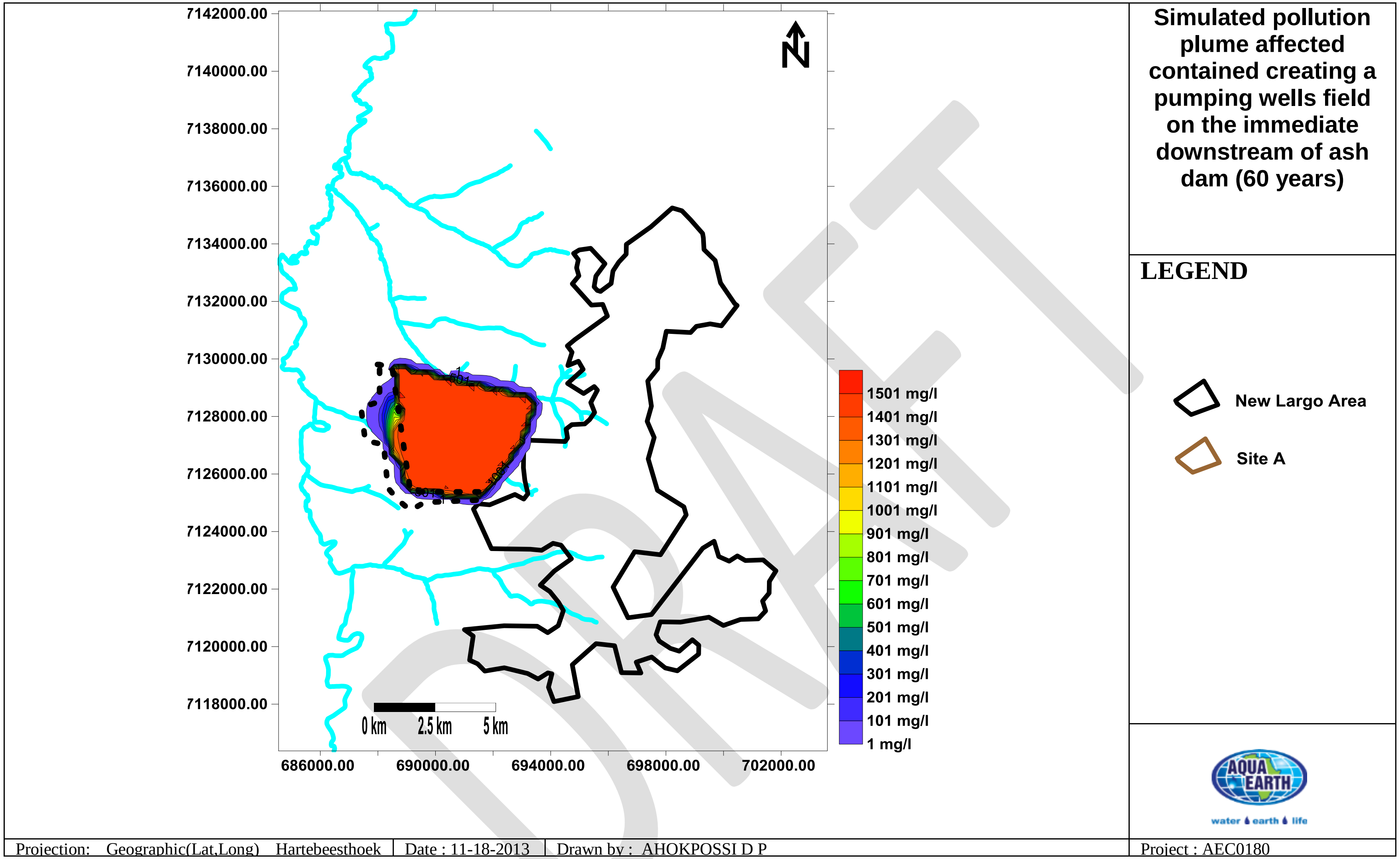


Figure 71: Simulated pollution plume contained by a pumping wells field on the immediate downstream of ADF (60 years

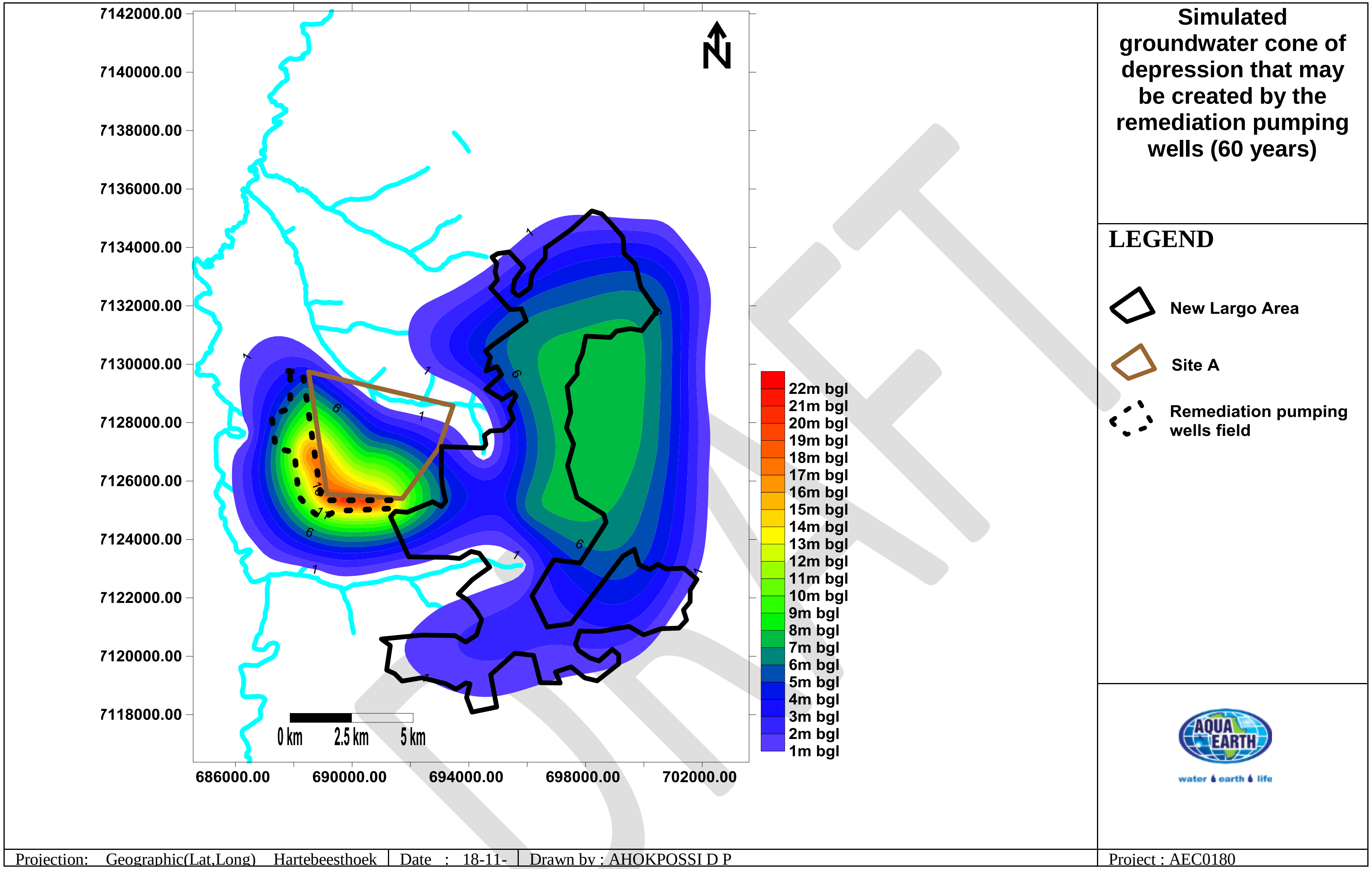


Figure 72: Simulated groundwater cone of depression that may be created by the remediation pumping wells (60 years)

7.7 Residual impacts

After the application of the mitigation measures, the groundwater risk impacts would be reduced as described in the mitigation section. The reduced impact risks together with the base line (status quo) impacts risk will constitute the residual risk impacts. The residual risk impacts have been quantified as:

- low level (-1.5) and very low level (-0.7) for the construction phase for respectively Site A and Site B;
- very low level (-0.9; -0.7) for the operation phase for respectively Site A and Site B;
- very low level (-0.9; -0.7) for the closure phase for respectively Site A and Site B;
- very low level (-0.6) for the post closure phase for both preferred alternatives ;

7.8 Impacts Matrix

The impacts identified and discussed above have been rated according to the impact assessment methodology described in appendix 6. These ratings are provided in form of the matrix and per project phase from Figure 73 to Figure 76.

Rated By:	Pacome D. AHOKPOSSI		ALTERNATIVES:													
Reviewed By:	Albertus Lombaard		Site A							SITE B						
IMPACT DESCRIPTION		Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	Impact Risk	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	Impact Risk
Code	Phase															
	CONSTRUCTION	5														
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	4 MODH	4 LOC	3 MED	5 OCCUR	-4.1 HIGH	Negative	Definite	2 LOW	4 LOC	3 MED	5 OCCUR	-3.3 MODH
Project Impact 1	Increasing of infiltration rates;	1	Positive	Possible	3 MODL	1 ISO	2 SHORT	2 UNLIKE	-0.9 VLOW	Positive	Possible	1 VLOW	2 DEV	2 SHORT	3 LIKE	-1.1 LOW
Project Impact 2	Decreasing of the soils buffering capacity to absorb contaminants from surface activities	2	Negative	Definite	2 LOW	1 ISO	2 SHORT	3 LIKE	-1.1 LOW	Negative	Definite	2 LOW	1 ISO	2 SHORT	2 UNLIKE	-0.7 VLOW
Project Impact 3	Deterioration of groundwater quality due to construction waste (toxic construction material);	5	Negative	Probable	4 MODH	4 LOC	3 MED	3 LIKE	-2.4 MODL	Negative	Probable	6 VHIGH	4 LOC	3 MED	4 VLIKE	-3.8 MODH
Project Impact 4	Deterioration of groundwater quality due to hydrocarbon spills from storage (organic contaminants);	4	Negative	Probable	2 LOW	4 LOC	3 MED	2 UNLIKE	-1.3 LOW	Negative	Probable	6 VHIGH	4 LOC	3 MED	4 VLIKE	-3.8 MODH
Project Impact 5	Altered Flow systems that may be associated with probable groundwater dewatering and stream diversion.	2	Negative	Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	-1 VLOW	Negative	Unsure	4 MODH	2 DEV	2 SHORT	2 UNLIKE	-1.2 LOW
COMBINED WEIGHTED RATING	BEFORE MITIGATION	4	Negative	Probable	-1.6 LOW	-1.8 DEV	-1.5 SHORT	1.4 UNLIKE	-0.5 VLOW	Negative	Probable	-2.7 MODL	-1.8 DEV	-1.5 SHORT	1.9 UNLIKE	-0.8 VLOW
MITIGATION MEASURES	GENERAL:		SITE SPECIFIC:							SITE SPECIFIC:						
	No mitigation is available for the increase in infiltration rate and decrease of soil buffering during construction															
	A proper construction phase should be carried out under the supervision of an accredited or recognised professional civil															
	Storage area for hydrocarbons or any toxic construction material should be bonded according to departmental minimum requirement															
	Any waste and spills (specially during construction and closure) need to be cleaned up immediately according to the									Care should be taken to the 2740 m of diversion and demolination of fuel pipeline						
	DWA need to be notified in the event of a spill															
PROJECT IMPACT	AFTER MITIGATION		Negative	Possible	1 VLOW	1 ISO	1 INCID	2 UNLIKE	-0.4 VLOW	Negative	Possible	1 VLOW	1 ISO	1 INCID	2 UNLIKE	-0.4 VLOW
CUMULATIVE IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION		Negative	Probable	4 MODH	4 LOC	3 MED	4 VLIKE	-3.2 MODH	Negative	Probable	2 LOW	4 LOC	3 MED	4 VLIKE	-2.7 MODL
RESIDUAL IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION		Negative	Probable	2 LOW	3 ADJ	2 SHORT	3 LIKE	-1.5 LOW	Negative	Probable	2 LOW	2 DEV	1 INCID	2 UNLIKE	-0.7 VLOW

Figure 73: Alternatives A and B construction impacts assessment

Rated By:	D. Pacome AHOKPOSSI		ALTERNATIVES:													
Reviewed By:	Albertus Lombaard		Site A							SITE B						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	Impact Risk	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	Impact Risk
Code	*Phase*															
	OPERATION	5														
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	4 MODH	4 LOC	3 MED	5 OCCUR	**-4.1 HIGH**	Negative	Definite	2 LOW	4 LOC	3 MED	5 OCCUR	**-3.3 MODH**
Project Impact 1	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	6	Negative	Probable	5 HIGH	4 LOC	4 LONG	3 LIKE	**-2.9 MODL**	Negative	Possible	6 VHIGH	4 LOC	4 LONG	4 VLIKE	**-4.1 HIGH**
Project Impact 2	Alteration of the groundwater flow system due to groundwater pumping (different uses)	4	Negative	Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	**-1 VLOW**	Negative	Unsure	5 HIGH	2 DEV	2 SHORT	2 UNLIKE	**-1.3 LOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-3.8 MODH	-3.6 LOC	-3.2 LONG	2.6 COULD	**-2 LOW**	Negative	Possible	-5.6 VHIGH	-3.2 LOC	-3.2 LONG	3.2 VLIKE	**-2.8 MODL**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*							*SITE SPECIFIC:*						
	Ash Dam and all pollution control facilities (dams, trenches) must lined according to the departmental minimum requirements (1998/2012) with cuspate leak detection															
	Avoid as possible longer lag time between liner installation and ash disposal or trenches construction															
	Ash Dams and all pollution control facilities (dams, trenches) must be operated to have a minimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level															
	Update Groundwaer monitoring system around facility to detect any leak and to pump out contaminated water if required .		Monitoring need to take place beween the ash dam facility and the New Largo to detec any croos contamination							Monitoring need to take place down gradient on the two concerned catchments						
	Pump treatment and re-use contaminated water															
	Disposal of coal ash and operation of the ash dam must be done in a manner to prevent water pollution															
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	3 ADJ	1 INCID	2 UNLIKE	**-0.9 VLOW**	Negative	Possible	2 LOW	2 DEV	1 INCID	2 UNLIKE	**-0.7 VLOW**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	5 HIGH	4 LOC	4 LONG	4 VLIKE	**-3.8 MODH**	Negative	Definite	6 VHIGH	4 LOC	4 LONG	4 VLIKE	**-4.1 HIGH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	3 ADJ	1 INCID	2 UNLIKE	**-0.9 VLOW**	Negative	Possible	2 LOW	2 DEV	1 INCID	2 UNLIKE	**-0.7 VLOW**

Figure 74: Alternatives A and B operation impacts assessment

Rated By:	D. Pacome AHOKPOSSI		ALTERNATIVES:													
Reviewed By:	Albertus Lombaard		Site A							SITE B						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	Impact Risk	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	Impact Risk
Code	*Phase*															
	CLOSURE	5														
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	4 MODH	4 LOC	3 MED	5 OCCUR	**-4.1 HIGH**	Negative	Definite	2 LOW	4 LOC	3 MED	5 OCCUR	**-3.3 MODH**
Project Impact 1	Deterioration of groundwater quality due to waste, and spills related to closure activities	4	Negative	Probable	4 MODH	4 LOC	3 MED	3 LIKE	**-2.4 MODL**	Negative	Probable	6 VHIGH	4 LOC	3 MED	4 VLIKE	**-3.8 MODH**
Project Impact 2	Groundwater pollution due to seepage, leachate infiltration (leak of liner) from ash dam, contaminated water trenches and pollution control dams	5	Negative	Probable	3 MODL	4 LOC	3 MED	2 UNLIKE	**-1.5 LOW**	Negative	Probable	6 VHIGH	4 LOC	3 MED	4 VLIKE	**-3.8 MODH**
Project Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses)	3	Negative	Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	**-1 VLOW**	Negative	Unsure	4 MODH	2 DEV	2 SHORT	2 UNLIKE	**-1.2 LOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-2.5 MODL	-3 ADJ	-2.2 MED	1.9 UNLIKE	**-1.1 LOW**	Negative	Possible	-4.4 HIGH	-2.8 ADJ	-2.2 MED	2.8 COULD	**-1.9 LOW**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*							*SITE SPECIFIC:*						
	Any waste and spills (specially during construction and closure) need to be cleaned up immediately according to the departmental minimum requirements															
	DWA need to be notified in the event of a spill or leachate															
	Proper construction of liner															
	Avoid as possible longer lag time between liner installation and ash disposal or trenches construction															
	Ash Dams and all pollution control facilities (dams, trenches) must be operated to have a minimum freeboard () above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level															
	Extension of Groundwaer monitoring network around facility to detect any leak and to pump out contaminated water if required		Extension of Monitoring need to take place beween the ash dam facility and the New Largo to detec any croos contamination							Extension of Monitoring need to take place down gradient on the two concerned catchments						
	Ash Dam and all pollution control facilities (dams, trenches) must lined according to the departmental minimum requirements (1998/2012) with cuspate leak detection															
	Pump treatment and re-use contaminated water															
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	3 ADJ	1 INCID	2 UNLIKE	**-0.9 VLOW**	Negative	Possible	2 LOW	2 DEV	1 INCID	2 UNLIKE	**-0.7 VLOW**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Probable	4 MODH	4 LOC	3 MED	4 VLIKE	**-3.2 MODH**	Negative	Probable	5 HIGH	4 LOC	4 LONG	4 VLIKE	**-3.8 MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	3 ADJ	1 INCID	2 UNLIKE	**-0.9 VLOW**	Negative	Possible	2 LOW	2 DEV	1 INCID	2 UNLIKE	**-0.7 VLOW**

Figure 75: Alternatives A and B closure impacts assessment

Rated By:	D. Pacome AHOKPOSSI		ALTERNATIVES:													
Reviewed By:	Albertus Lombaard		Site A							SITE B						
	IMPACT DESCRIPTION	Weighting	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	Impact Risk	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	Impact Risk
Code	*Phase*															
	POST CLOSURE	5														
STATUS QUO	INITIAL BASELINE IMPACTS TO ENVIRONMENT		Negative	Definite	3 MODL	3 ADJ	4 LONG	5 OCCUR	**-3.7 MODH**	Negative	Definite	2 LOW	3 ADJ	3 MED	5 OCCUR	**-2.9 MODL**
Project Impact 1	Groundwater pollution due leachate (leak) from the Ash dam, Contaminated water trenches and other contaminated water storage facilities	5	Negative	Probable	4 MODH	3 ADJ	4 LONG	3 LIKE	**-2.4 MODL**	Negative	Probable	6 VHIGH	3 ADJ	4 LONG	4 VLIKE	**-3.8 MODH**
Project Impact 2	Reduction of infiltration rates	6	Negative	Probable	4 MODH	3 ADJ	2 SHORT	3 LIKE	**-2 LOW**	Negative	Probable	6 VHIGH	3 ADJ	2 SHORT	4 VLIKE	**-3.2 MODH**
Project Impact 3	Alteration of the groundwater flow system due to groundwater pumping (different uses)	3	Negative	Unsure	2 LOW	3 ADJ	2 SHORT	2 UNLIKE	**-1 VLOW**	Negative	Unsure	4 MODH	2 DEV	2 SHORT	2 UNLIKE	**-1.2 LOW**
COMBINED WEIGHTED	**BEFORE MITIGATION**		Negative	Possible	-3.3 MODH	-2.8 ADJ	-2.5 MED	2.6 COULD	**-1.6 LOW**	Negative	Possible	-5.2 VHIGH	-2.6 ADJ	-2.5 MED	3.3 VLIKE	**-2.5 MODL**
MITIGATION MEASURES	*GENERAL:*		*SITE SPECIFIC:*							*SITE SPECIFIC:*						
	The design of the contaminated water trenches and dams should ensure their long term integrity															
	Repair trenches and dams as may be required, and according the DWA minimum requirements															
	Update monitoring network with abstraction boreholes around the ash dam facilities.		Monitoring and abstraction boreholes should also be placed to constitute barrier between New Largo and the Ash dam Facility.							Monitoring network with abstraction boreholes around the ash dam facilities in the two concerned catchments.						
	Pump treatment and re-use contaminated water															
	Avoid rain water entering into the ash dam by protecting it with adequate geomembrane prior to rehabilitation (top soil)															
	Direct precipitation falling ADF by the storm water management system to areas where infiltration could occur															
PROJECT IMPACT	**AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6 VLOW**	Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6 VLOW**
CUMULATIVE IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, BEFORE MITIGATION**		Negative	Definite	4 MODH	3 ADJ	4 LONG	4 VLIKE	**-3.2 MODH**	Negative	Definite	4 MODH	3 ADJ	4 LONG	4 VLIKE	**-3.2 MODH**
RESIDUAL IMPACT	**INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, AFTER MITIGATION**		Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6 VLOW**	Negative	Possible	2 LOW	1 ISO	1 INCID	2 UNLIKE	**-0.6 VLOW**

Figure 76: Alternatives A and B post closure impacts assessment

8 Groundwater management plan

The management plan describes implementable actions for the mitigation of the projects impacts previously assessed. Such action has to be implemented through the different phases of the project. The management plan is presented in table form (Table 30) and provides information on primary objectives, the implementation actions, the responsible of the action, and the period of monitoring or reporting.

Table 30 : Groundwater management plan

Management / Environmental Component:	**EMPR Reference Code:**		
Groundwater			
Primary Objective:			
Compliance of groundwater quality reserve			
Compliance of groundwater quantity reserve			
Implementation	**Responsibility**	**Resources**	**Monitoring / Reporting**
Detailed groundwater baseline characterisation and modelling has been conducted, however additional studies will still need to be conducted to understand the link between surface and groundwater, and for the design of the pumping well field for mitigation actions.	Groundwater specialist of the design team	Groundwater investigation equipment and qualified personnel	Immediate
The water removed from underground could be re-injected into the groundwater table downstream of ash dam activities. Appropriate monitoring of such water quality should be taken to ensure that the quality comply to groundwater quality reserve	Groundwater specialist of the design team	Pumping and re-injecting wells qualified personnel	Immediate
The drilling of any observation or pumping well shall ensure consistent, effective and safe performance of the well	Groundwater specialist of the design team	Well construction equipment qualified personnel	Immediate
Any pumping well needs to be equipped with flow metering devices to quantify water removed and recording should be continuous.	Groundwater specialist of the design team	Flow metering devices	Immediate

Calibration certificates of water flow metering devices needs to be established and be submitted to the appropriate authority after it has been installed and at regular intervals (2 years)	Groundwater specialist of the design team	calibration devices	upon request
During construction groundwater levels and quality shall be monitored	Groundwater specialist of the design team	Monitoring equipment	On every two months for the first six months, then quarterly until two years, and bi-annually thereafter.
All site workers should undergo an environmental awareness training	Groundwater specialist of the design team		NA
Analysis shall be carried out in accordance with the methods prescribed by the South African Bureau of Standards, in terms of the Standards Act 340 of 1982. The analysis methods shall not be changed without prior written approval	Groundwater specialist of the design team	Standards	NA
Monitoring points shall not be changed without prior written approval	Groundwater specialist consultant	NA	NA
Measurements shall be taken to prevent and provide for mechanical, electrical or operational failures of the pumping system	Groundwater specialist consultant		NA
During operation, groundwater levels and quality shall be monitored	Groundwater specialist consultant	Monitoring equipments	Monthly for the first six months, then quarterly until two years, and bi-annually thereafter.
During closure and post closure, groundwater levels and quality shall be monitored	Groundwater specialist consultant	Monitoring equipments	Bi-annually
Any leak, or failure of pollution control dams, and/or trenches should be reported to DWA and repaired according the DWA minimum requirements	ESKOM		Immediate
Internal and external groundwater and surface water use license auditing	ESKOM		Annual

Existing management plans / procedures:
Kusile Power station EMP
New Largo open pits mining EMP

9 Monitoring plan

9.1 Preamble

A long-term monitoring programme must be developed based on the guideline documented in *Best Practice Guideline G3. Water Monitoring Systems (2007)* available from DWA. These guidelines are summarised and implemented in the proposed monitoring plan.

A monitoring plan is necessary because (DWA, 2006):

- Accurate and reliable data forms a key component of many environmental management actions.
- Water monitoring is a legal requirement.
- The most common environmental management actions require data and thus the objectives of water monitoring include the following:
- Development of environmental and water management plans based on impact and incident monitoring (facilitate in decision-making, serve as early warning to indicate remedial measures or that actions are required in certain areas) for the mine and region.
- Generation of baseline/background data before project implementation.
- Identification of sources of pollution and extent of pollution (legal implications or liabilities associated with the risks of contamination moving off site).
- Monitoring of water usage by different users (control of cost and maximizing of water reuse).
- Calibration and verification of various prediction and assessment models (planning for decommissioning and closure).
- Evaluation and auditing of the success of implemented management actions (ISO 14000, compliance monitoring).
- Assessment of compliance with set standards and legislation (EMPs, water use licenses).
- Assessment of impact on receiving water environment.

9.2 General Principals of Monitoring

Monitoring on a mine consists of various components as illustrated by the overall monitoring process (Figure 77). It must be recognized and understood that the successful development and implementation of an appropriate, accurate and reliable monitoring programme requires that a defined structured procedure be followed. A monitoring programme must include the location of all monitoring points (indicated on a map), the type of data to be collected, as well as the data collection (protocol/procedure/methodology, frequency of monitoring and parameters determined, quality control and assurance), management (database and assessment) and reporting procedures. This programme must then be implemented. The results from the monitoring programme should be representative of the actual situation. To ensure that the monitoring programme functions properly, an operating and maintenance programme should be developed and implemented. A data management system is necessary to ensure that data is stored/used optimally and is accessible to all the relevant users. The monitoring programme must include quality control measures. It is important to note that this programme is dynamic and should change as the mine and water management needs change.

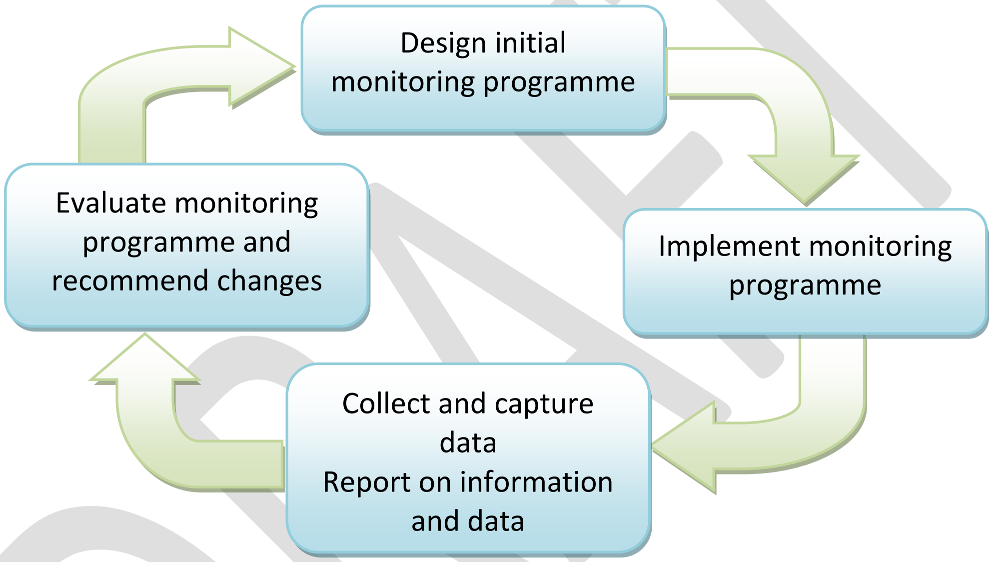


Figure 77: Monitoring process (DWA, 2007)

Effective groundwater monitoring systems on a mine consist of the following components:

- Surface water/groundwater quality monitoring system.
- Flow/water level monitoring system.
- Data and information management system.

When designing the monitoring system the following issues must also be taken into consideration:

- Potential or actual water use
- Aquifer or catchment vulnerability
- Toxicity of chemicals
- Potential for seepage or releases

- Quantities and frequency of release to the environment (point and non-point).
- Management measures in place to minimize risk.

- Identify all known potential point and diffuse sources of pollution
- Define key indicators of pollution for each source (e.g. sulphate, conductivity for residue deposits)
- Have a suitably qualified person evaluate groundwater qualities and quantities from existing boreholes in the vicinity of the potential pollution sources.
- Divide mine into sub-catchments on the basis of stream confluences, known pollution points, abstraction points and mine boundaries.
- Collect flow data, together with key water quality indicator data at the upstream and downstream points of key sub-catchments.
- Establish whether the calculated added or subtracted pollution load can be accounted for by known quantified sources or abstraction points.
- Establish whether there will be any long-term changes to the point and diffuse sources.

This table part of the heading "…designing the monitoring system the following issues must also be taken into consideration"?

9.3 Monitoring Plan for Ash disposal on Alernatives A and B

The present monitoring plan present what would be the monitoring requirements in each of the two alternatives, and aim to constitute a better decision tool for the regulatory authorities. The groundwater and surface monitoring is one of the actions to be implemented in the management of the receiving shallow aquifer system in either of the alternatives. The monitoring involves the understanding of:

- The changes in groundwater flow/levels within the mine and to monitor how this change with time.
- The development of a cone of depression and how this extends over time.
- The pollution on the mine and to monitor how the pollution changes with time.

The area influenced by groundwater dewatering, the groundwater discharge and abstraction points, the spring, and the sources of pollution with associated pathways will receive a particular focus in the monitoring plan.

Details surface and groundwater monitoring point's locations, which would be set for the initial monitoring network (first 5 years), are given in and are illustrated in

Figure 78 and Figure 79

Figure 80 for site A, and their respective geographic coordinates are presented in Table 31. In Table 32, and in Figure 80 and Figure 81 the correspondent required water monitored points that would be involved with Alternative B are also presented.

Table 31: Initial surface water and groundwater monitoring network for scenario A

Monitoring Point	WGS84 Co-ordinate	
	Long	**Lat**
Groundwater Monitoring		
KAM10	28.86341	-25.99264
KAM9-1	28.87815	-25.96275
KABH7	28.88928	-25.99245
KABH8	28.88854	-25.98607
KABH92	28.86266	-25.96389
KABH94	28.85871	-25.97859
KAMP1	28.87690484	-25.95438975
KAMP2	28.87907683	-25.97015389
CAMP3	28.88094666	-25.97786781
KAMP4	28.87523039	-25.94793659
KAMP5	28.87387792	-25.93974207
KAMP7	28.88764834	-25.97239182
KAMP8	28.88628327	-25.9652741
KAMP9	28.88441087	-25.9565096
KAMP10	28.88313002	-25.94860756
CAMP11	28.88196911	-25.94218325
KAMP12	28.88984651	-25.97741019
KAMP13	28.89977319	-25.97806334
KAMP14	28.90925907	-25.97824301
KAMP15	28.91594937	-25.97819807
KAMP16	28.91270327	-25.98285296
KAMP17	28.90355744	-25.98288659
KAMP18	28.89410744	-25.98196643
Surface Water monitoring		
KASW23	28.878772	-25.96068
KASW7	28.88816	-25.99342
KAMPS1	28.89856377	-25.94035237
KAMPS2	28.92227825	-25.97333923
KAMPS3	28.90451103	-26.00373719
KAMPS4	28.88146354	-25.98085352
KAMPS5	28.86981634	-26.00363721

KAMPS8	28.85154631	-25.94268983
KAMPS10	28.86057578	-25.95817269
KAMPS11	28.86345989	-25.99441029

Table 32: Initial surface water and groundwater monitoring network for scenario B

Monitoring Point	WGS84 Co-ordinate	
	Long	**Lat**
Groundwater Monitoring		
KAM1	28.78231	-25.9027
KAM2	28.82448	-25.8865
KABH42	28.77769	-25.8729
KABH79	28.81559	-25.8706
KABH83	28.8216	-25.8665
KAMP1	28.82458	-25.8939
KAMP2	28.81699	-25.8926
KAMP3	28.80062	-25.9026
KAMP4	28.81349	-25.9025
KAMP5	28.82458	-25.8817
KAMP6	28.82492	-25.8778
KAMP7	28.8254	-25.8742
KAMP8	28.8254	-25.8703
KAMP9	28.82504	-25.8904
KAMP10	28.80728	-25.9028
KAMP10	28.79363	-25.9029
KAMP11	28.78831	-25.9019
KAMP12	28.77952	-25.8687
KAMP13	28.77827	-25.8924
KAMP14	28.77813	-25.8816
KAMP15	28.79209	-25.8685
KAMP16	28.81071	-25.869
KAMP17	28.82752	-25.8716
KAMP18	28.82752	-25.8759
KAMP19	28.82728	-25.8795
KAMP20	28.82766	-25.8842
KAMP21	28.82745	-25.8882
KABH62	28.85451	-25.8719
KABH63	28.8392	-25.8968
KABH54	28.7935	-25.9094
KABH46	28.77368	-25.8853
KABH47	28.7731	-25.8792
KABH73	28.80731	-25.8589

Surface Water monitoring		
KAMPS1	28.84523	-25.8848
KMPS2	28.80518	-25.8459
KAMPS3	28.81521	-25.9092
KAMPS5	28.84118	-25.9109
KSMPS6	28.86032	-25.8926
KAMPS7	28.8637	-25.8641
KAMPS8	28.7939	-25.8027
KAMPS9	28.8285	-25.8118
KAMPS4	28.77578	-25.8702

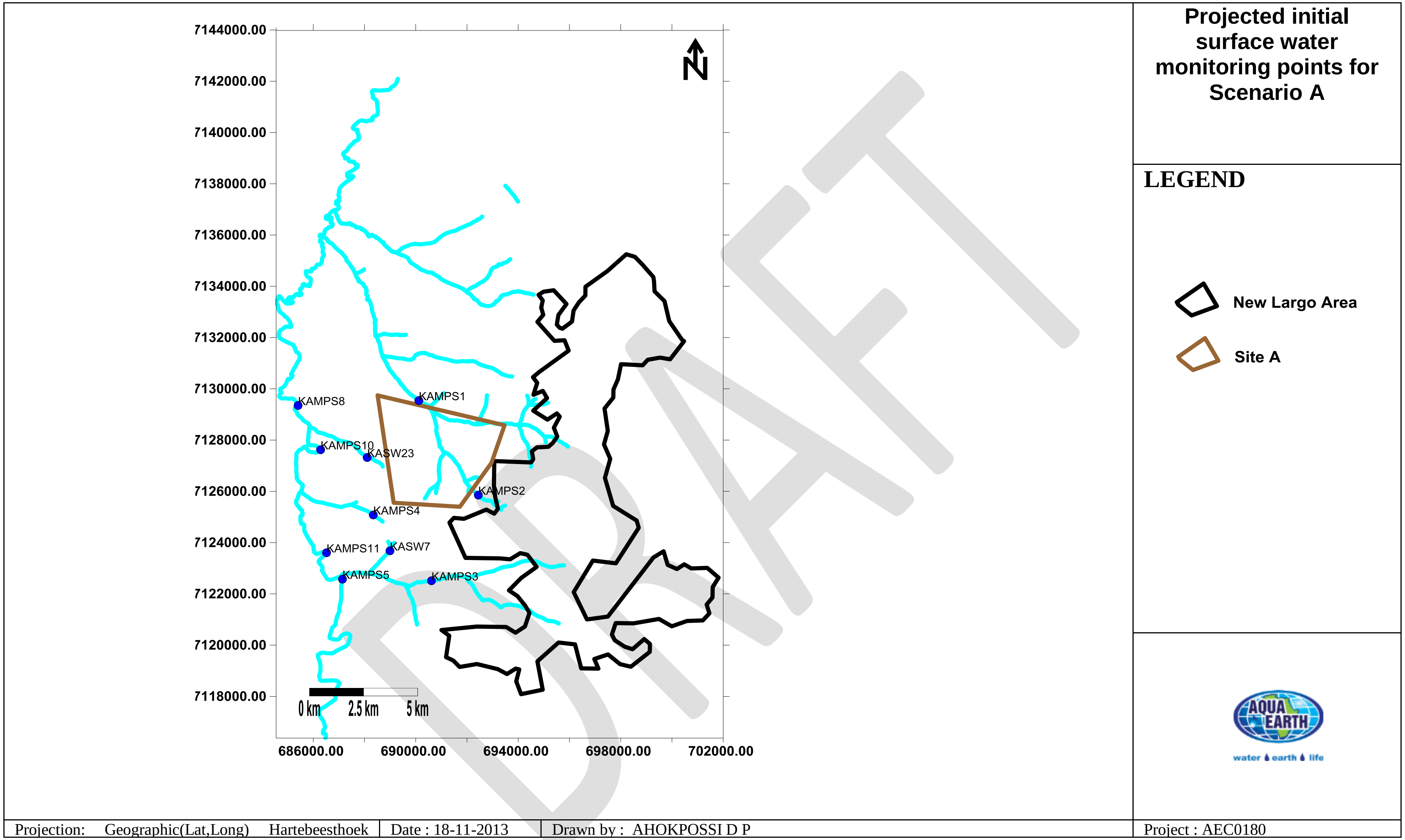


Figure 78: Projected initial surface water monitoring points for scenario A

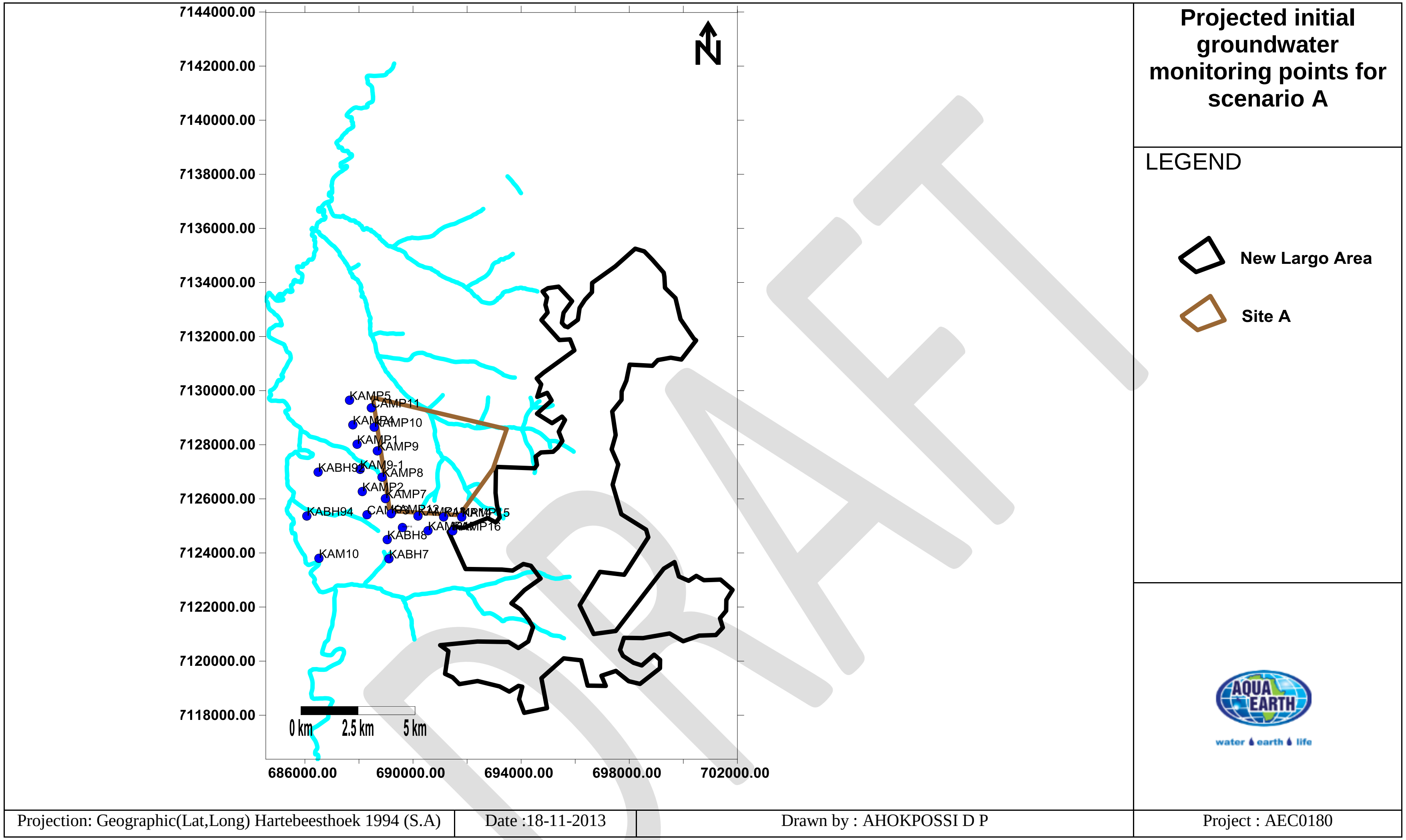
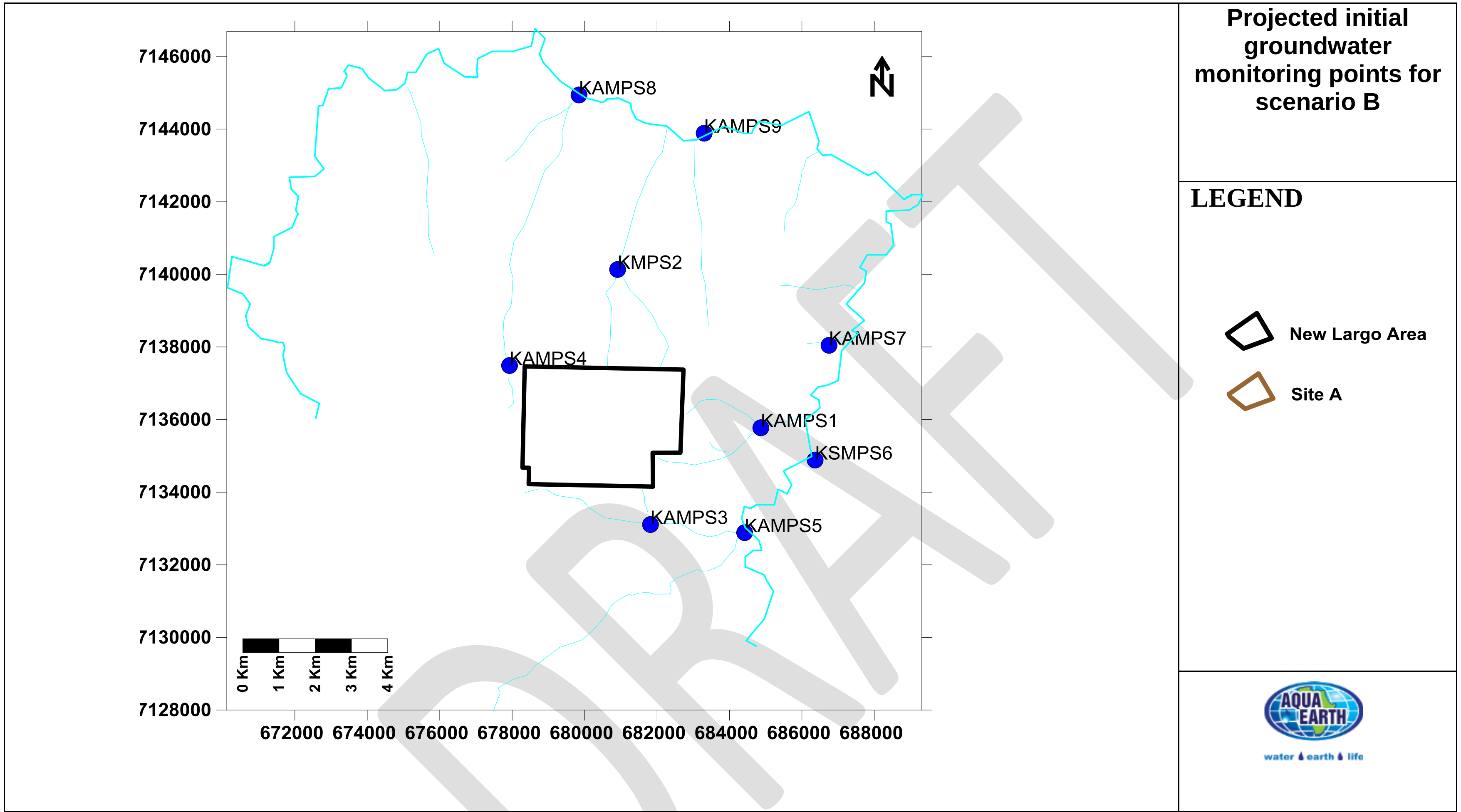


Figure 79: Projected initial groundwater monitoring points for Alternative A



Projection: Geographic(Lat,Long) Hartebeesthoek | Date : 18-11- | Drawn by : AHOKPOSSI D P | Project : AEC0180

Figure 80: Projected initial groundwater monitoring points for Alternative B.

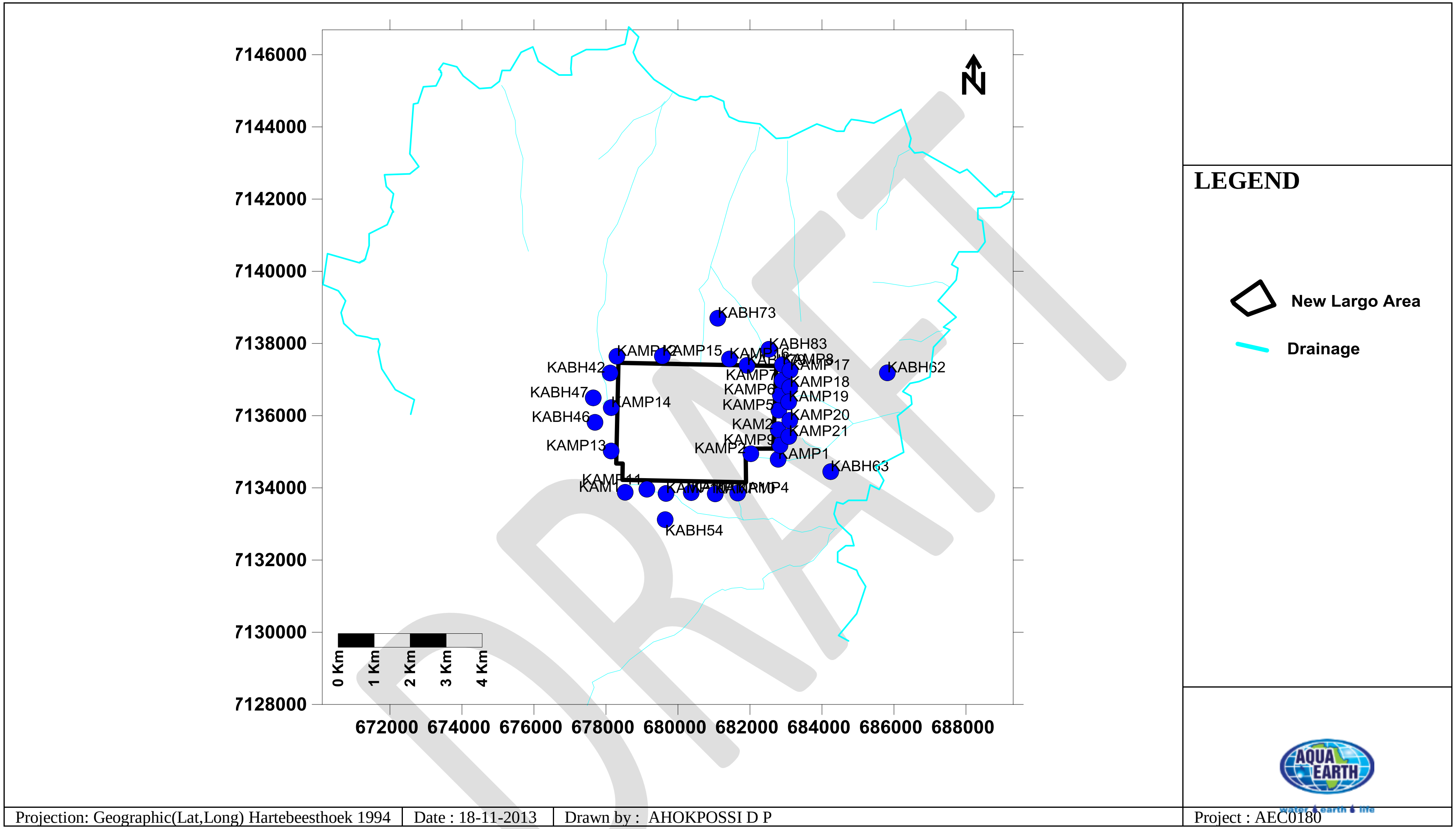


Figure 81: Projected initial groundwater monitoring points for Alternative B

10 Conclusion

Based on the scope of work and detailed assessments carried out under order from Zitholele, Aqua Earth has completed the study and assessments and the following conclusions are reached:

- Baseline regional and site specific hydrology and hydrogeology have been established based on findings from desktop studies, hydrocensus, water sample analyses, field geophysics, drilling and aquifer testing and analysis;
- The groundwater flow directions in the study areas have been established; the groundwater drainage is confirmed to follow the topography;
- Groundwater elevations, in general fluctuate between 1330 m and 1580 m above mean see level;
- The groundwater uses (withdrawal) in and surrounding the different alternative sites, does not dramatically impact on the natural groundwater drainage;
- A general reduction in groundwater storage is observed at the north of site A;
- Aquifers parameters (T,S) have been calculated;
- Baseline surface water and groundwater quality in the study areas have been established;
- In general all the water samples show water quality that falls within the recommended class 1 limits for all the constituents measured except for KASW20 and KABH96 which respectively indicates iron (Fe) and Manganese (Mn) concentrations that fall above the allowable class 2 concentrations;
- Samples from KABH10, KABH42 and KABH62 indicates altered concentrations, suggesting impacts from existing activities at their respective locations;
- Except the high concentration of iron (KAM8, KAM7, KAM3), and fluoride (KAM7) all the other groundwater samples from the newly drilled boreholes indicates water quality that falls within the recommended SANS limits;
- Samples from KAM7 and KAM1 indicate water of sodium bicarbonate/ chloride nature;
- The source of pollution in KAM7 may be related to the historical underground coal mining activities in the New Largo mining area;
- The 5 alternatives sites have been ranked based on sensitivity analyses;
- Based on the present geohydrological sensitivity ranking, Alternative A, appears to be the alternative that will be less sensitive in terms of groundwater;
- Comparative geohydrological impact risk assessments conducted throughout the different phases of the project confirms that Alternative A is a preferred scenario from a groundwater resource protection point of view;

- As specifically required by DWA for the strategic and catchment management goals and objectives, detailed impacts and mitigation for site A and B are provided, and (cumulative) impact scenarios on site A is considered with and without New Largo, to facilitate better decision-making
- The geohydrological conceptual model has been developed for each of the preferred sites and baseline numerical models have been build.
- Considering the worse cases, project and cumulative impacts have been numerically simulated to predict the magnitude of possible impacts on the receiving environment for Alternative A and B;
- Without any mitigation, pollution plume from the ADF (site A) would probably reach the Wilge river in 60 years;
- The dewatering of the New Largo, would mainly alter the groundwater drainage at the south of the site A and result in an extra spreading of the ADF pollution plume at the south of the site A;
- If operation form New Largo is neglected, the spreading (due to New Largo) dewatering of the pollution plume from the 60 years ADF towards the south of site A, would be avoided. But the historical underground mining impacts (acidic water) would still prevail since its included in the site background groundwater quality and such impacts cannot be neglected.
- In Scenario B, plume migration would be mainly toward the Wilge River in B20F and toward the Bronkhorstspruit River in B20D, and would migrate approximately to maximum distances of 3.1 km and 2.7 km downstream of the ADF, respectively in B20D and B20F, whithin 60 years (end of operation).
- The uncertainties related to sources of the background polluted water around site B makes difficult to appreciate the real extend of the cumulative impacts risks that may be associated with such scenario.
- For both sites A and B the most important overall impacts risk appear to be associated with Ash Disposal Facility operation phase. But the operation phase impacts are expected to be more severe in the Scenario B than in the Scenario A.
- A preliminary list of groundwater remediation options has been proposed; for regulatory authorities and ESKOM comments;
- Appropriate groundwater management plan that would reduce as low as possible the project impact risks has been proposed;
- An initial (first 5 years) groundwater monitoring plan have been proposed for Alternative A and B;

11 Recommendations

The following recommendations are put forward for consideration:

- The possible sources of pollution noticed in the area of Alternatives A and B needs to be clearly investigated and characterised;
- Detailed field and numerical studies need to be conducted to:
  - Better delineate the current extent of groundwater contaminations surrounding each of the preferred scenario sites;
  - Understand the link between surface and groundwater;
  - Understand the link between the considered shallow aquifer systems and the deeper aquifer systems;
  - Develop a scoping remediation sign the pumping well field for mitigation actions;
- The existing water monitoring network at the Kusile Power Station, need to be extended by considering the initial monitoring network as proposed in the present monitoring plan, according to the preferred alternative;
- The Initial Groundwater flow and transport model need to be updated based on groundwater monitoring data (water level and quality) in the local aquifer surrounding site A, and accounting for heterogeneity;
- All the prescriptions of the management plan need to be considered and special attention should be given to the pre-construction mitigation measures;
- The possible cumulative impacts from the New Largo mine need to be investigated using the groundwater model.

12 Appendix 1: Specialist Declaration

Details of specialist and declaration of interest in respect of an application for authorisation in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended and the Environmental Impact Assessment Regulations, 2010

PROJECT TITLE

Specialist:			
Nature of specialist study compiled:			
Contact person:			
Postal address:			
Postal code:		**Cell:**	
Telephone:		**Fax:**	
E-mail:			
Qualifications & relevant experience:			
Professional affiliation(s) (if any)			

13 Appendix 2: Laboratory measurements

14 Appendix 3: Geophysical data

15 Appendix 4: Drilling data

16 Appendix 5: Aquifer test data interpretation

17 Appendix 6: Impacts assessment methodology