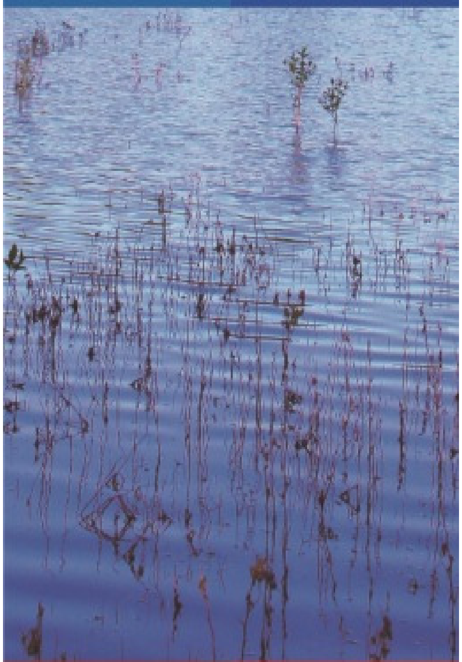

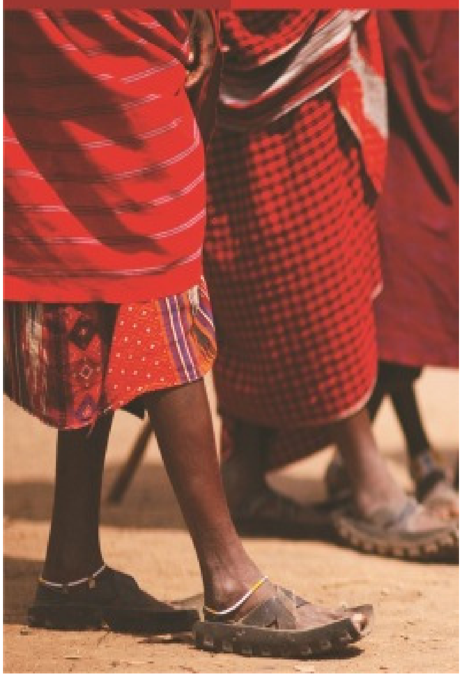

DIGBY WELLS
ENVIRONMENTAL

Environmental Impact Assessment for BHP Billiton Weltevreden Expansion Project

Groundwater Report

Project Number:

BHP2690

Prepared for:

BHP Billiton Energy Coal South Africa Pty (Ltd) Energy Coal South Africa Pty (LTD)

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EXECUTIVE SUMMARY

BECSA requested Digby Wells Environmental to undertake an integrated regulatory process to enable BECSA to commence mining in the proposed KPSX: Weltevreden project area. A groundwater investigation was undertaken to provide baseline information into the Identification Phase Study (IPS) EIA and associated environmental authorisation documents.

The groundwater investigation included a review of available documentation, field work programmes, numerical modelling and a final written report. Field work programmes comprised of a hydrocensus, geophysics, drilling and aquifer testing programme, as well as geochemical and hydrochemical sampling and analyses.

Field Work Outcomes

The hydrocensus identified a total of 55 groundwater sites, of which 53 were boreholes and 2 were groundwater springs. Groundwater use associated with the boreholes was related predominantly to domestic use (30 boreholes) including use as a potable water supply. Groundwater monitoring (3 boreholes) was the other confirmed use, if boreholes were used at all (9 boreholes unused). 11 boreholes were identified with an unknown purpose.

9 geophysical traverses were walked across the project area using electromagnetic and magnetic ground surveying methods. 9 potential drilling targets were identified for further investigation by percussion drilling. Of the 9 potential targets 6 were identified as high priority and 3 as low priority sites.

The geophysical programme was followed by the percussion drilling programme where 5 target locations were drilled and constructed to a final depth of 60 m. Boreholes intersected the coal bearing Ecca Sediments and associated intrusive rocks (dykes and sills). The drilled depths did not extend into the Dwyka tillite or Pre-Karoo basement rocks.

The intersected weathered profile extends to a depth of between 3 and 14 m bgl, which would correspond to the upper weathered aquifer. No seepage was identified with this aquifer zone. From the end of the weathered profile till a depth of 60 m the fractured Karoo aquifer was intersected comprising of dolerite, sandstone, mudstone, shale, carbonaceous shale and coal rock types. The fractured Karoo aquifer resulted in minor seepage and 1 low yielding fracture with an estimated yield of 0.14 L/s.

The 5 drilled boreholes were aquifer tested using the slug test method as a result of the intersected yields being too low to sustain either step tests or constant discharge tests. Static water levels prior to slug testing ranged from 20.03 to 27.78 m bgl. BHPW05 was still recovering to the static level at the time of aquifer testing, thereby limiting the results that could be obtained from this borehole. Interpreted hydraulic conductivities for the remaining 4 boreholes ranged from 0.053 to 0.348 m/d. The fracture hydraulic conductivity ranged from 0.003 to 0.045 m/d, indicating that seepage is the main contributor for groundwater supply to the boreholes. It must be noted that fractures are the main pathways for groundwater supply and contamination migration and even though no significant fractures were intersected

during this investigation their presence in the project area should not be ruled out or be considered as negligible. The hydraulic conductivity results confirm that the aquifer is low yielding which will restrict the migration of contamination from the sources or limit the cone of dewatering to the vicinity of the pit, unless a fracture of significance is identified in these areas.

Laboratory Outcomes

Hydro-chemical Results

Ten water quality samples were selected from the 55 hydrocensus results for analyses. 6 of the samples (WELWEL5, WELBH01, WELBH05, WELBH15, WELBH24 and WELBH42) returned results which do not exceed the SANS 241-1: 2011 guidelines for aesthetic, operational, acute health and chronic health limits. These samples represent ideal water quality and no health risks are expected from these boreholes.

Water sample from WELBH43 returned a sulphate value of 480 mg/L which exceeds the aesthetic limit (250 mg/L) but is still below the acute health limit (500 mg/L).

Samples from WELBH09 and WELBH26 both exceed the chronic health limit (2 mg/L) for iron with concentrations of 2.09 and 4.24 mg/L respectively.

The water sample from WELBH28 exceeds the chronic health limit of 1.5 mg/L for fluoride, with a concentration of 1.65 mg/L.

The groundwater type identified from the Piper Diagram suggests a Ca-Na- HCO_3-Cl type with sulphate having a minor influence on samples from WELBH09, WELBH15, WELBH24, WELBH26 and WELBH42. Sulphate is the dominant anion for WELBH43. The Schoeller Plot however indicates that there is very little variability between the 10 sulphate samples (with the exception of WELBH43) suggesting that it is the ratio between the remaining anions and cation distribution which is causing the sulphate influence in the Piper Diagram.

Geochemical Results

Eleven geochemical samples were submitted for basic ABA and NAG analyses. Results indicate that the coal seams are typically acid generating with the overburden, interburden and underburden varying between acid generating to neutralising with no particular preference for sampled groups. The samples indicate that there is the potential for acid generating environment to develop with some potential to buffer the system provided from the overburden, interburden and underburden units, however kinetic testing is required to determine the long term buffering capacity for the project.

Numerical Model Outcomes

- The calibrated steady state model achieved an RMSE of 5.67%. The threshold to identify a well calibrated model is less than 10%;
- The calibrated steady state model was used to populate the transient model simulations, of which three scenarios were investigated:
  - Simulation 1: Mine Dewatering;

  - Simulation 2: Contaminant transport; and
  - Simulation 3: Post operational decant and contaminant transport.

- Dewatering was simulated for the LoM (22 years) for the proposed pit. The simulated radius of influence (ROI) at the end of LoM indicates approximately 100 m of drawdown is expected at the proposed pit reducing to 0 at the extent of the ROI at a maximum distance of 1.2 km from the pit (based on the current model setup and available data):
  - Expected inflows into the mining operation are expected to peak at approximately 6,000 m^3/d after 12 years of mining; and
  - No boreholes were identified during the hydrocensus are located the drawdown cone.

- The contamination plume was simulated using SO_4 as the potential leachate indicator:
  - The extent of the contamination plume at the LoM (22 years) reaches a maximum distance of 1.1 km from the stockpiles;
  - The change in hydraulic head created by dewatering the proposed pit will draw water from the surrounding aquifer towards the pits during operations. This will assist with containing a portion of the contamination plume;
  - Natural advection, dispersion and diffusion groundwater flow methods will still occur which causes the plume to move towards the nearby drainages, away from the proposed pit;
  - Post closure (simulation at 100 years), the simulated contamination plume from the backfilled pit and waste stockpiles extends to a maximum of 2 km. Natural groundwater flows will return to pre-mining flow paths causing the plume to extend towards the drainage systems to the north and west of the proposed pit;
  - Private borehole WELBH08 (borehole) and WELWEL03 (spring) are located in the simulated contamination plume for 22 years and 100 years respectively. Monitoring needs to be conducted at these sites to establish baseline conditions prior to operations commencing. Owners using groundwater from these locations will need to be notified and compensated accordingly;
  - Establishing a monitoring network between the Phola Township and drainage systems is required an early warning indicator so that corrective and/ or treatment options can be investigated prior to impacts on the Phola Township and drainage streams are realised during mine operations and post closure; and
  - Active private boreholes in the vicinity of the mine and projected contamination plume, could draw the plume towards the borehole through the development of its own cone of drawdown;

- One decant point was identified at the topographical low in the north-eastern corner of the proposed pit;
  - Using a recharge rate of 12% of mean annual precipitation (MAP) the proposed pit BD is expected to decant 63 years post closure with a volume of 3,576 m^3/d;
  - Using a recharge rate of 15% of MAP, the proposed pit BD is expected to decant in 54 years post closure with a volume of 4,470 m^3/d; and
- This numerical model should be updated as more monitoring and hydrogeological information becomes available with the development of mining operations.

Recommendations

- It is recommended that all identified hydrocensus boreholes, used for domestic and agricultural purposes be sampled to update the baseline assessment. The 10 analysed samples are scattered across the project site and indicate groundwater typical of the Karoo aquifers. The results of sample WELBH43 indicate a strong influence of contamination by mining activities with no clear indication of what could be the cause.
- Eight boreholes are located within the proposed pit BD boundary, identified as WELBH02, WELBH03, WELBH04, WELBH05, WELBH06, WELBH07, WELBH27 and WELBH28. It is recommended that they be sampled for water quality and borehole depth prior to the commencement of mining to establish if they are connected to the underlying pre-Karoo aquifers potentially forming a link for contamination to migrate.
- No boreholes, identified during the hydrocensus were located in the simulated cone of depression, however WELBH08 (borehole) and WELWEL03 (spring) are within the 22 year and 100 year simulated contamination plume. Monitoring of groundwater levels and qualities of these sites are required and should begin one year prior to the commencement of mining operations to establish a strong baseline reference for future comparisons
- Additional geochemical samples should be collected from the proposed pit areas, to get a better understanding of the actual waste discard acid or neutralising potential. The geochemical evaluation undertaken in this report provides an initial indication of the acid generating and neutralising conditions, however significantly more samples are reqired from the proposed pit locations to full understand and assess the implications of backfilling;
- Long term (20 week) geochemical kinetic tests are required to understand the long term buffering or acid generating potential of the project;
- Monitoring should commence at least one year prior to the commencement of mining to establish seasonal variations in the baseline water quality and level results;

- Nine monitoring locations were identified from the hydrocensus and newly drilled borehole lists, however there are locations around the pits were no boreholes were identified. These zones must be investigated further for potential fractures which could bring groundwater into the pit or allow the migration of contamination away from the sources:
  - The numerical model proposes six new monitoring locations around the waste stockpile and proposed pits to supplement the gaps in the monitoring network;
- Should private groundwater users become affected by the mining operations, either by unacceptable water quality as a result of the contamination plume or insufficient groundwater supply as a result of dewatering, the mine will need to supply them with equal or better quality water:
  - Groundwater users must be notified of changes to the water quality or levels at the earliest indication;
- The numerical model must be updated yearly for the first five years of mining operations to accommodate the changes identified by the newly collected information. Thereafter the model can be updated over a period of five years;
- Hazardous substances must be handled and stored according to best practise, with bunding to prevent spillage:
  - Standard operating procedure must be developed for the clean-up of hazardous substances should bunding fail or accidental spillage occur outside of the bunded areas;
- PCD and coal discard stockpile locations must be lined to prevent seepage of contaminated water to the groundwater environment:
  - PCD's must be designed for sufficient storage volume required for the project dirty water requirements;
  - PCD's must be designed to catch potential overflow; and
  - Provision must be made for the treatment of decanting water, to a quality that is acceptable for release into the environment.

TABLE OF CONTENTS

1 Introduction 1
1.1 Project Location 1
1.2 Study Objectives 1
2 Project Area Description 2
2.1 Topography and Drainage 2
2.2 Climate 3
2.2.1 Temperature 3
2.2.2 Humidity 4
2.2.3 Precipitation 4
2.2.4 Evaporation 5
2.3 Groundwater Recharge 6
2.4 Mine Plan 6
2.5 Geology 7
2.5.1 Regional Geology 7
2.5.2 Site Specific Geology 8
2.5.3 Structural Geology 8
2.6 Hydrogeological Environment 9
2.6.1 Aquifer types 9
2.6.1.1 Aquifer Classification 9
3 Methodology 10
3.1 Desktop Study 10
3.2 Field Investigations 10
3.2.1 Hydrocensus 10
3.2.1.1 Groundwater sampling 11
3.2.1.1.1 Piper Diagram 12
3.2.1.1.2 Schoeller Diagram 12
3.2.1.2 Groundwater Level Measurements 13
3.2.1.3 Geosite Co-Ordinates and Elevations 13

3.2.2 Geophysical Surveys ... 13
3.2.2.1 Magnetic Method ... 13
3.2.2.2 Electromagnetic (EM) Method ... 14
3.2.3 Percussion Drilling Programme ... 14
3.2.4 Aquifer Testing Programme ... 15
3.2.5 Geochemical Evaluations ... 15
3.2.6 Conceptual Model ... 16
3.2.7 Numerical Model ... 16
4 Investigation Results ... 17
4.1 Hydrocensus ... 17
4.1.1 Groundwater Quality ... 21
4.2 Geophysical Surveys ... 26
4.3 Drilling Programme ... 33
4.4 Aquifer Testing Programme ... 33
4.5 Geochemical Assessment ... 35
4.5.1 ABA and NAG Results ... 35
4.5.2 Waste Classification ... 38
5 Conceptual Groundwater Model ... 42
5.1 Groundwater Sources ... 42
5.1.1 Sources of recharge ... 42
5.1.1.1 Natural Contributions ... 42
5.1.1.2 Artificial Contributions ... 43
5.1.2 Sources of Contamination ... 43
5.1.2.1 Artificial Contributions ... 43
5.2 Aquifer (Pathway) Characterisation ... 43
5.3 Groundwater Receptors ... 44
5.3.1 River Systems ... 44
5.3.2 Private Boreholes ... 44
5.3.3 Proposed Pit ... 46
6 Numerical Groundwater Model ... 46

6.1 Model Limitations 46
6.2 Model Design and Steady State Modelling Parameters 47
6.2.1 Model Boundaries 47
6.2.2 Recharge 48
6.2.3 Hydraulic Conductivities 48
6.2.4 Storativity / Storage Coefficient 48
6.2.5 Drainage systems 48
6.3 Calibration 49
6.4 Predictive Simulations 50
6.4.1 Simulation 1: Mine Dewatering 51
6.4.2 Simulation 2: Contaminant Transport 53
6.4.3 Simulation 3: Post Operational Decant and Contaminant Transport 54
6.4.3.1 Contamination Transport 54
6.4.3.2 Decant 55
6.4.3.2.1 Storage and Decant Point 56
6.4.3.2.2 Decant Rate and Time to Decant 57
6.5 Numerical Model Outcome 65
7 Environmental Impact Assessment 66
7.1 Summary of Infrastructure Requirements 66
7.2 Project Activities 67
7.3 Description of Environmental Issues and Potential Impacts 69
7.3.1 Construction Phase 69
7.3.2 Operational Phase 72
7.3.3 Decommissioning Phase 76
7.3.4 Post Closure Phase 78
8 Cumulative Impacts 79
8.1 Dewatering 79
8.2 Acid Mine Drainage 79
9 Groundwater Monitoring Programme 80
9.1.1 Sampling Protocols and Quality Control 81

9.1.2 Water Level Measurement ... 82
9.1.3 General Sampling and Decontamination Procedures ... 82
9.1.4 Constituents to be analysed ... 83
10 Gap Analysis ... 83
11 Conclusions ... 84
11.1 Field Work Outcomes ... 84
11.2 Laboratory Outcomes ... 85
11.2.1 Hydro-chemical Results ... 85
11.2.2 Geochemical Results ... 85
11.3 Numerical Model Outcome ... 86
12 Recommendations ... 88
13 References ... 90

LIST OF FIGURES

Figure 2-1: Monthly average temperature for KPSX: Weltevreden, (DWE, 2014) ... 4
Figure 2-2: Maximum monthly precipitation for KPSX: Weltevreden (2011-2013) – (DWE, 2014) ... 5
Figure 2-3: Box and whisker graph indicating the maximum, minimum and average ranges of evaporation data from the Bethal Weather Station, S-pan Evaporation (1963-1987) ... 6
Figure 4-1: Piper Diagram for hydrocensus results ... 24
Figure 4-2: Schoeller Diagram for hydrocensus results ... 25
Figure 4-3: KPSX: Weltevreden traverse one ... 28
Figure 4-4: KPSX: Weltevreden traverse two ... 29
Figure 4-5: KPSX: Weltevreden traverse three ... 29
Figure 4-6: KPSX: Weltevreden traverse four ... 30
Figure 4-7: KPSX: Weltevreden traverse five ... 30
Figure 4-8: KPSX: Weltevreden traverse six ... 31
Figure 4-9: KPSX: Weltevreden traverse seven ... 31
Figure 4-10: KPSX: Weltevreden traverse eight ... 32
Figure 4-11: KPSX: Weltevreden traverse nine ... 32

Figure 4-12: Class C landfill site liner requirements 39
Figure 4-13: Class D landfill site liner requirements 40
Figure 6-1: Graph indicating measured and simulated head for calibration checks 50
Figure 6-2: Simulated inflows for KPSX: Weltevreden 53
Figure 6-3: Stage curve for water holding capacity in pit BD 57

LIST OF TABLES

Table 2-1: Summary of temperatures for KPSX: Weltevreden (2011-2013) – (DWE, 2013) .. 3
Table 2-2: Average monthly precipitation for the period 2009 – 2011 for KPSX: Weltevreden (DWE, 2014) 4
Table 2-3: Summary of the monthly evaporation rates as compiled from the Bethal Weather Station, S-Pan Evaporation (1963-1987) 5
Table 4-1: Summary of hydrocensus information 18
Table 4-2: Water quality results from the hydrocensus (concentrations in mg/L) 23
Table 4-3: Summary of identified target boreholes 27
Table 4-4: Structure of slug tests 34
Table 4-5: Results of slug test interpretation 34
Table 4-6: Geochemical Samples 35
Table 4-7: Classification guidelines 36
Table 4-8: Geochemical characterisation for KPSX: Weltevreden 37
Table 4-9: Summary of Waste Classification Summary 39
Table 4-10: Total Concentration Thresholds and Classification 41
Table 4-11: Leachable Concentration Thresholds and Classification 41
Table 6-1: Affected properties from the dewatering simulation 51
Table 6-2: Expected inflow volumes into the proposed pit 51
Table 6-3: Time to decant with recharge at 12% of Map 59
Table 6-4: Time to decant with recharge at 15% of MAP 62
Table 7-1: Activity list for KPSX: Weltevreden 67
Table 9-1: Recommended monitoring boreholes (existing) 81
Table 9-2: Proposed new monitoring locations from the numerical model 81

LIST OF APPENDICES

Appendix A: Plans

Appendix B: Hydrochemical Data

Appendix C: Geophysical Data

Appendix D: Borehole Logs

Appendix E: Geochemical Data

LIST OF PLANS

Plan 1: Regional Setting

Plan 2: Local Setting

Plan 3: Topography

Plan 4: Infrastructure

Plan 5: Regional Geology

Plan 6: Hydrocensus

Plan 7: Geophysics Traverses and Identified Targets

Plan 8: Drilled Boreholes

Plan 9: Life of Mine

Plan 10: Model Boundary and Calibration Boreholes

Plan 11: Calibrated Initial Hydraulic Head

Plan 12: Dewatering - Radius of Influence after 7 Years

Plan 13: Dewatering - Radius of Influence after 14 Years

Plan 14: Dewatering - Radius of Influence after 22 Years (LoM)

Plan 15: Contaminant Transport Plumes after 22 Years (LoM)

Plan 16: Contaminant Transport Plumes after 100 Years

Plan 17: Coal Seam 1 Floor Contours

Plan 18: Decant Location

Plan 19: Recommended Monitoring Locations for the KPSX: Weltevreden Project

TABLE OF ACRONYMS

Abbreviation	Description
ABA	Acid Base Accounting
AG	Acid Generating
AMD	Acid Mine Drainage
ARD	Acid Rock Drainage
BH	Borehole
Coeff. Var.	Coefficient of Variance
DEA	Department of Environmental Affairs
DMR	Department of Mineral Resources
DWA	Department of Water Affairs
EAP	Environmental Assessment Practitioner
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EMPR	Environmental Management Programme Report
GPS	Global Positioning System
ICP	Inductively Coupled Plasma
IWULA	Integrated Water Use License Application
k	Hydraulic conductivity
L/s	Litre per second
L/h	Litre per hour
MAE	Mean Annual Evaporation
m amsl	Meters above mean sea level
MAP	Mean Annual Precipitation
m bgl	Meters below ground level
mg/ℓ	Milligrams per litre
mm	Millimeter
mm/a	Millimeter per annum
ms	Milli-seconds
mS/m	Milli Siemens per meter

Abbreviation	Description
Mtpa	Million ton per annum
m^3	Cubic meters
Mm^3/a	Million cubic meters per annum
NAG	Net Acid Generating
NEMA	National Environmental Management Act
NEMWA	National Environmental Management: Waste Act
NNP	Net Neutralising Potential
NPR	Net Potential Ratio
nT	nanoTesla
NTU	Nephelometric Turbidity Units
PAG	Potential Acid Generating
PCD	Pollution Control Dam
S	Storativity
SANAS	South African National Accreditation System
SPLP	Synthetic Precipitation Leaching Procedure
St. Dev.	Standard Deviation
S_y	Specific yield
TDS	Total Dissolved Solids
T	Transmissivity

1 Introduction

Digby Wells Environmental (Digby Wells) has been appointed by BHP Billiton Energy Coal South Africa (Pty) Limited (BECSA) to undertake an integrated regulatory process to enable BECSA to commence mining the proposed KPSX: Weltevreden project area.

BECSA has identified coal reserves adjacent to its current Klipspruit Colliery at the proposed Klipspruit Extension Project area, situated approximately 40 kilometres (km) west of eMalahleni. It is understood that BECSA currently holds three prospecting rights for the project area and is undertaking an Identification Phase Study (IPS) (also known as Conceptual Phase Study). The aim of the IPS is to identify a value-creating investment and determine potential strategic alternatives to be assessed further during a Selection Phase Study (SPS) (equivalent to Pre-feasibility).

This report serves as the groundwater specialist report to the IPS study.

1.1 Project Location

The proposed KPSX: Weltevreden project area is located in the Mpumalanga Province of South Africa, approximately 5 km northwest of the town Ogies. The N12 crosses the southern portion of the project area, connecting Johannesburg (approximately 150 km to the southwest) to eMalahleni (approximately 40 km to the east). The regional and local setting for KPSX: Weltevreden are represented as Plan 1 and Plan 2 (Appendix A), respectively.

1.2 Study Objectives

The deliverables for the groundwater assessment for the proposed KPSX: Weltevreden project include:

- A clear outline of the baseline (existing) groundwater quality, level, gradient and flow direction;
- Environmental significance rating of the baseline water quality by comparing the water chemistry with the South African water quality guidelines;
- All borehole construction details, hydrogeological logging and aquifer testing results;
- A mine water balance (dynamic water balance for KPSX: Weltevreden will be completed by Aurecon);
- Post-closure decant assessment using the numerical model;
- Geochemical assessment for acid base generation and/or neutralisation potential of the mine site with comments on the long term implications;
- Contamination plumes originating from the mine area during operation and after mine closure;
- An estimate of the groundwater inflow rates into the proposed mine at various stages of the life of mine;

- The radius of influence of the cone of depression that will be created by the mine dewatering;
- List of boreholes and farms that will be affected by the mine dewatering;
- Environmental significance rating of each of the activities that could potentially impact on the groundwater environment;
- Migration patterns and flow pathways of the contamination plume and the connectivity between the contamination sources and the groundwater receptors;
- Co-ordinates of preferred monitoring boreholes that are located up-gradient, as well as down gradient of the mine sites and associated infrastructure. This will ensure the accurate quantification of any contaminants released from the mine by comparing the inflow quality with the outflow quality;
- Electronic copies of the numerical model files of the mine site;
- Comments on the design of the mine activities so as to prevent and abate groundwater contamination; and
- A final report conforming to EIA and EMP standards. The report will include all data, information and findings and recommendations and a full risk assessment derived from the transient simulations for the life of the project and post closure as well as groundwater monitoring protocol.

2 Project Area Description

2.1 Topography and Drainage

The proposed KPSX: Weltevreden project occurs predominantly within the B20G quaternary catchment, with minor portions within the B11F and B11G quaternary catchments (Plan 3 Appendix A).

The topography of these catchments comprises of gently undulating hills and valleys with an average gradient of 0.009m.

The main streams draining the catchments are as follows (GRDM software):

- B20G:
  - Saalklapspruit – first order perennial stream flowing towards the north; and
  - Grootspruit – first order perennial stream flowing towards the north.
- B11F:
  - Tweefonteinspruit – first order perennial stream flowing towards the east;
  - Saaiwaterspruit – first order perennial stream flowing towards the southeast; and
  - Olifants River – fourth order perennial stream flowing towards the north.

- B11G:
  - Olifants River – fourth order perennial stream flowing towards the north, continuation from the B11F catchment.

Land use within the vicinity of the proposed KPSX: Weltevreden project area is dominated by cultivated farms, mining operations, power generation plants, natural grasslands, wetland exposures and scattered urban settlements. Opencast strip mining methods are the dominant mining practices within the catchment, for the exploitation of coal resources.

2.2 Climate

The climate data used within the descriptions below was taken from the air quality impact assessment report completed for the proposed Weltevreden project (DWE, 2014). Data used to compile the report was obtained from a location within the KPSX: Weltevreden project site, with the monitoring period covering three full calendar years from January 2011 until December 2013. The exception is the evaporation data which was supplied by the South African Weather Service for the Bethal weather station.

2.2.1 Temperature

Modelled monthly temperatures vary between a minimum of 7.4 °C in July and a maximum of 21.0 °C in February during the monitoring period (DWE, 2014). Actual temperatures have been recorded above and below the maximum and minimum range.

Table 2-1 indicates the maximum, minimum and average temperatures calculated per month for the monitoring period (2011 to 2013), with Figure 2-1 indicating the average monthly temperature for the same monitoring period. The coldest months are June and July and the warmest months occur between November and March.

Table 2-1: Summary of temperatures for KPSX: Weltevreden (2011-2013) – (DWE, 2013)

Temp (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Max.	20.4	21.0	19.7	14.6	12.2	9.8	9.2	11.9	14.4	17.7	19.6	20.1	15.9
Min.	20.0	19.1	18.7	14.2	11.9	8.1	7.4	10.4	14.0	17.2	19.3	19.9	15.0
Ave.	20.2	20.0	18.9	14.4	12.1	8.7	8.3	11.2	14.2	17.4	19.5	20.0	15.4

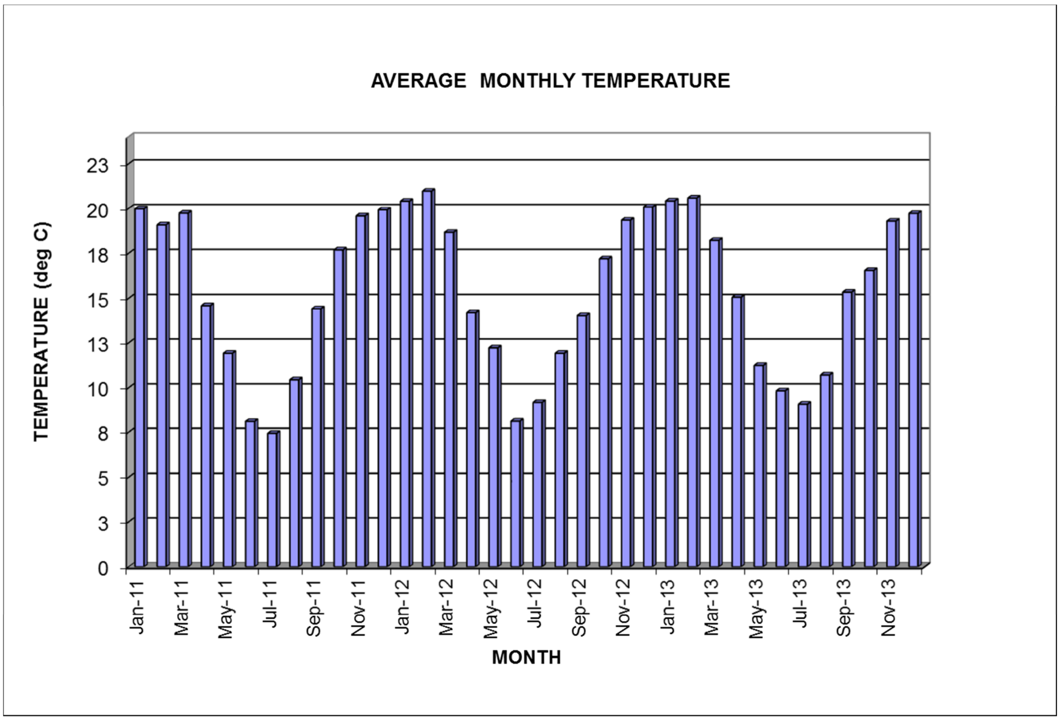

Figure 2-1: Monthly average temperature for KPSX: Weltevreden, (DWE, 2014)

2.2.2 Humidity

The humidity values for the proposed KPSX: Weltevreden project area remains relatively constant throughout the year ranging between 64 and 77%, with an average of 70% (DWE, 2014).

2.2.3 Precipitation

Annual monthly precipitation ranges from a minimum of 2.7 mm to 210.1 mm, with a yearly average of 795.3 mm. Precipitation occurs predominantly during the summer months between October to March, totalling approximately 85% of the average annual precipitation.

Table 2-2 provides a summary of the maximum and average monthly precipitation values for the monitored period. Figure 2-2 displays the maximum monthly precipitation within the monitoring period.

Table 2-2: Average monthly precipitation for the period 2009 – 2011 for KPSX: Weltevreden (DWE, 2014)

Rainfall (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Max.	153.7	115.1	70.9	70.6	20.8	4.1	13.0	17.3	53.1	178.3	140.2	228.1	1065.2
Ave.	151.4	80.4	20.8	45.0	10.4	2.7	6.5	13.0	29.8	105.7	119.5	210.1	795.3

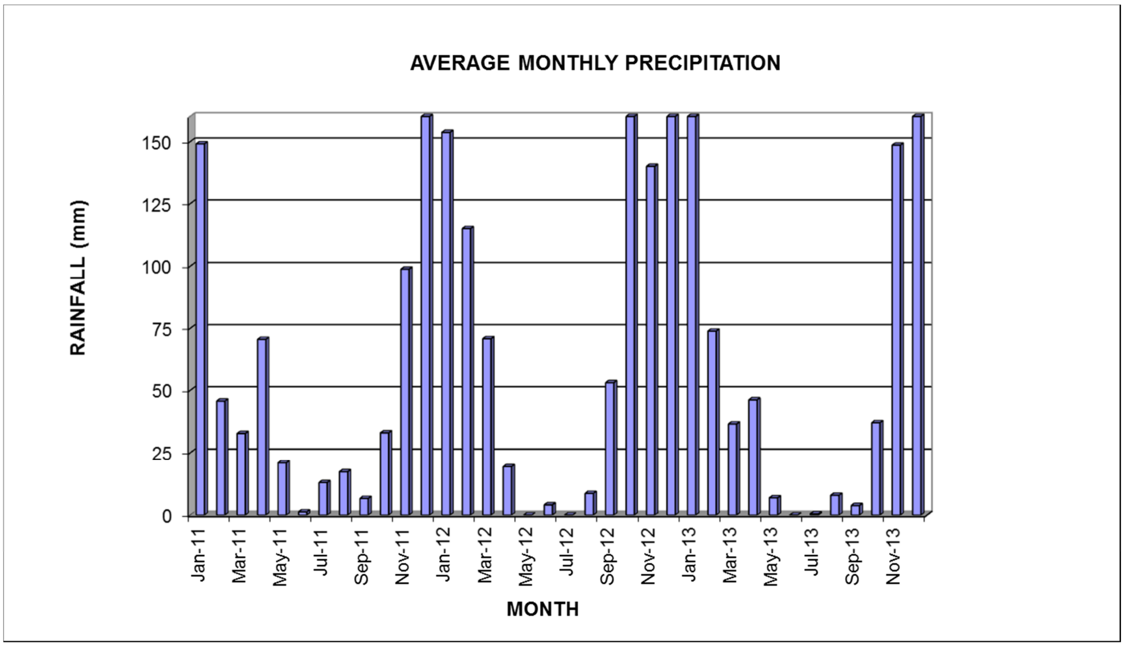

Figure 2-2: Maximum monthly precipitation for KPSX: Weltevreden (2011-2013) – (DWE, 2014)

2.2.4 Evaporation

Evaporation data was compiled from the nearest weather station (Bethal), with the data provided by the South African Weather Service. The monitoring period was taken from 1963 to 1987, with the data summarised in Figure 2-3 and Table 2-3. The average annual evaporation value is 1,721 mm, with lowest evaporation rates occurring in the winter months and highest during the summer months, corresponding to the precipitation distribution. On average the evaporation volume for the area exceeds the precipitation volume for the same month, with a possible exception during the month of December.

Table 2-3: Summary of the monthly evaporation rates as compiled from the Bethal Weather Station, S-Pan Evaporation (1963-1987)

Evap. (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Max.	228	202	196	145	176	178	212	200	257	259	241	264	2558
Min.	93	68	60	76	71	61	8	89	118	140	140	156	1080
Ave.	173	147	139	110	100	89	102	135	171	181	179	195	1721

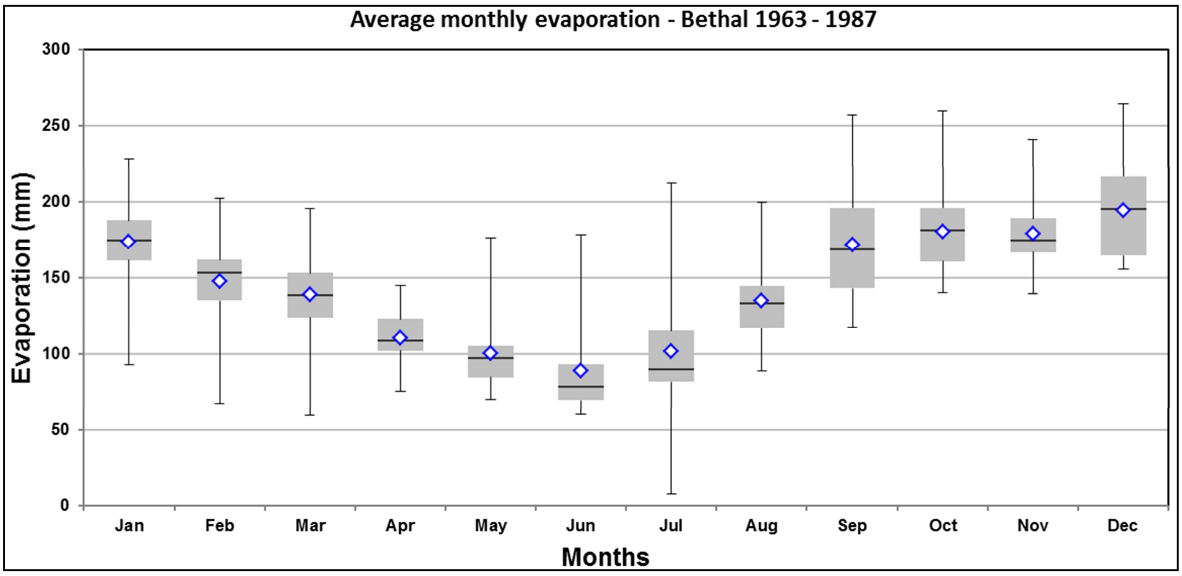

Figure 2-3: Box and whisker graph indicating the maximum, minimum and average ranges of evaporation data from the Bethal Weather Station, S-pan Evaporation (1963-1987)

2.3 Groundwater Recharge

Recharge to the weathered Ecca aquifer is estimated at 1 to 3% of the annual precipitation (Hodgson and Krantz, 1998). However, observed flow within the Olifants Catchment indicates highly variable recharge from one area to the next with isolated occurrences of 15% of the annual precipitation contributing to recharge. The main contributing factor to recharge is the composition of the weathered sediments. Hodgson and Krantz (1998) concluded that a recharge rate of 3% of annual precipitation is reasonable for the Olifants Catchment.

The average mean annual precipitation is calculated at 795.3 mm/a (Section 2.2.3) which results in an estimated recharge range of 7.95 to 23.85 mm/a.

2.4 Mine Plan

The proposed KPSX: Weltevreden project is planned as an opencast mine with two operational pits extracting coal concurrently. Extracted coal will be transported to the existing Klipspruit Colliery for processing at the Phola Coal Washing Plant (PCWP), via trucks at first, and then by conveyor when production increases. A temporary RoM stockpile will be established at the KPSX: Weltevreden project site. The expected life of mine for the project is 20 years.

The planned infrastructure for the proposed KPSX: Weltevreden project is presented as Plan 4 (Appendix A) and includes:

- Opencast pits (including ramps and boxcuts);
- Haul roads, access roads and maintenance roads;

- Conveyor system;
- Overburden and topsoil stockpiles;
- Run of mine (RoM) stockpile and tipping point;
- Pollution control dams (PCD);
- Storm water berms;
- Workshops and office infrastructure;
- Elevated raw water tank;
- Bulk and potable water supply;
- Substation; and
- Electricity supply to workshops and equipment.

2.5 Geology

2.5.1 Regional Geology

The proposed KPSX: Weltevreden project occurs within the Witbank Coalfield, exploiting the coal seams within the Vryheid Formation of the Ecca Group (of the Karoo Supergroup). The Karoo Supergroup in the project area comprises of the Ecca Group and underlying Dwyka Group. The regional geology is presented on Plan 5 (Appendix A).

The sediments typically found in the Ecca Group comprise of coarse to fine grained sandstone, siltstone, shale and coal which often occur as interbedded units. The Witbank Coalfield has five coal seams, numbered as No. 1 (lower most coal seam) to No. 5 (upper most coal seam) which are characterised as relatively shallow, thick and consistent. However, only the No. 2 and No. 4 coal seams are exploitable throughout most of the Witbank Coalfield. The remaining seams can reach economic widths and qualities, but are limited to localised areas.

The underlying Dwyka Group comprises predominantly of tillite, siltstone and occasionally shale. Underlying the Dwyka Group are a number of lithologies associated with the Bushveld Complex (in the north), Witwatersrand Supergroup (in the south), Waterberg Supergroup (in the northwest) and Transvaal Supergroup (in the west). Of the pre-Karoo lithologies, the Malmani dolomites would have the greatest significance to the project. The Malmani dolomites are associated with large volumes of good quality water. Intersecting the dolomites during mining operations could result in significant volumes of water that will need to be managed, as well as potential contamination to the pristine aquifer which can result in the development of karst topographies (sinkholes and cavities).

Structurally the Karoo Supergroup is relatively undisturbed. Presence of faults are uncommon, however fractures occur frequently in the competent sandstone and coal units. Dolerite intrusions are common throughout the entire Karoo Supergroup and occur predominantly as dykes and sills.

2.5.2 Site Specific Geology

The proposed KPSX: Weltevreden project is located on the northern extent of the Karoo Basin, with sediments pinching out against the pre-Karoo Transvaal Supergroup and Bushveld Complex lithologies to the north and west respectively.

Although the Karoo Supergroup is relatively undisturbed, slight undulations do occur within the coal seams as a result of the paleo highs and lows formed by the basement pre-Karoo lithologies. The western margin of the KPSX: Weltevreden project is positioned on a basement paleo high. In addition, the current surface topography controls or limits the presence and continuity of the coal seams from above via erosional processes.

KPSX: Weltevreden has all five coal seams preserved in the area, with No. 2 and No. 4 splitting into two seams. The main exploitable seams are the No. 2A and No. 4L, however the No. 1, No. 2, No. 4U and No. 5 seams are exploitable in localised areas (Radebe, 2015):

- No. 5 coal seam has an average thickness of 1.7 m at a depth of approximately 33.8 m bgl over the project area;
- No. 4U coal seam attains an average thickness of 1.2 m at an approximate depth of 44.8 m bgl;
- No. 4L coal seam attains an average thickness of 4.4 m at an approximate depth of 49.9 m bgl;
- No. 3 coal seam has an average thickness of 0.3 m at an approximate depth of 58.0 m bgl;
- No. 2 coal seam attains average thicknesses of 3.1 m at an average depth of 71.1 m bgl;
- No. 2A coal seam has an average thickness of 2.3 m at an approximate depth of 82.3 m bgl; and
- No. 1 coal seam has an average thickness of 1.5 m at an approximate depth of 94.3 m bgl, over the project area.

2.5.3 Structural Geology

Locally there are no major faults occurring within the project area. Dolerite activity is localised to the western and southern portions of the project area, with sills present in the west and southeast regions of the project. The Ogies Dyke cross cuts the southernmost portion of the reserve (Groundwater Square, 2009).

The Ogies Dyke has been traced with a strike length of approximately 100 km between Ogies (west) to Arnot (east). This dyke is associated with a thickness of roughly 15 m, dipping towards the south with an angle of 73 to 79 degrees (Lurie, 2004). Jasper Miller (JMA, 2005) observed the presence of splays and cross-cutting dykes associated with the Ogies Dyke which could result in the aquifer becoming locally compartmentalised.

2.6 Hydrogeological Environment

2.6.1 Aquifer types

Hodgson and Krantz (1998) identified three distinct groundwater systems for the Olifants Catchment, namely:

- Upper weathered aquifer;
- Fractured aquifer; and
- Pre-Karoo fractured aquifer.

The weathering profile of the Ecca Group sediments on average varies between 5 m to 12 m in thickness. The upper weathered aquifer occurs within this zone, usually as a perched aquifer overlying impermeable shale or clay layers. This aquifer is generally low yielding, but of good quality as a result of dynamic groundwater flow washing away leachable salts (Hodgson and Krantz, 1998).

The fractured aquifer occurs beneath the weathered aquifer, within fresh sediments. These sediments are typically well cemented, limiting significant permeation of water through, with the presence of secondary structures (fractures) providing the only pathway for groundwater movement. However, not all secondary structures are water bearing. The yields for this aquifer system are typically low with the coal seams frequently having the highest hydraulic conductivities. The water quality associated with this aquifer system contains higher salt loads as a result of longer residence times in the aquifer. The Dwyka tillite which underlay the Ecca Group sediments form a hydraulic barrier limiting the impact of mining activities (in the Ecca Group sediments) to the underlying aquifer systems (Hodgson and Krantz, 1998).

Pre-Karoo aquifers have only been intersected on a few occasions, as a result of great depths required to reach the aquifer. Boreholes which have intersected this aquifer are generally low yielding with inferior water quality and low recharge capabilities due to the overlying impermeable Dwyka tillite (Hodgson and Krantz, 1998). Where dolomites of the Transvaal Supergroup underlay the Karoo Supergroup, boreholes may obtain high yields with good water quality.

2.6.1.1 Aquifer Classification

The aquifers of South Africa are defined according to their water supply potential, water quality and local importance for strategic purposes within an aquifer classification scheme and map. The aquifer classification map (Parsons, 1993) identifies the Karoo aquifers as minor systems with relatively good water quality (TDS <300 mg/L), moderate vulnerability and medium susceptibility to contamination, where:

- Vulnerability is defined as the tendency or likelihood for contamination to reach a specified position in the aquifer; and
- Susceptibility is defined as a qualitative measure of the relative ease with which contamination can reach a groundwater aquifer.

3 Methodology

3.1 Desktop Study

The desktop study included a review of all available data including reports, data sheets and maps. Documentation from a number of related studies that have been undertaken in the area were included in the review.

A review process was conducted and interpretations performed to establish a conceptual idea of the groundwater occurrence and dynamics. This information was used to inform the field visits and technical surveys (geophysics, drilling and aquifer testing programmes). The following reports and documents were provided for this review process:

- Jasper Miller and Associates, 2005. Compilation of geology and groundwater inputs for the Beesting Project EMPR. Anglo Western Reserve Volume I and II. Report Ref 10281;
- Groundwater Square, 2009. Weltevreden RDP Coal Mine, groundwater baseline study; and
- Radebe, D. BHP Technical report, 2015. Identification phase. Chapter 3 – mining.

3.2 Field Investigations

The following sections present the 2014/2015 field work programmes without exploring the findings in great detail; this will be done later in the document.

3.2.1 Hydrocensus

The hydrocensus concentrated on identifying existing boreholes and springs throughout the project area to enhance the knowledge of the groundwater system and current groundwater users. This task included the following:

- A hydrocensus within a 5 km radius of the proposed pit boundaries; and
- Hydrochemical sampling of accessible boreholes and surface water bodies. These water samples were submitted to a South African National Accreditation System (SANAS) accredited laboratory.

The hydrocensus survey included interviews with landowners, visits to individual boreholes, measuring of water levels and yields (if possible), as well as the selective collection of groundwater samples. Information recorded on the field sheets include:

- Owner and property details;
- Borehole locality;
- Borehole depth;
- Rest water level;

- Borehole installation date;
- Borehole status and equipment;
- Groundwater abstraction rates;
- Primary groundwater usage; and
- Electrical conductivity, pH and groundwater sample details.

3.2.1.1 Groundwater sampling

Ten groundwater samples were taken in accordance with the Department of Water Affairs and Forestry (DWAF, currently known as the Department of Water and Sanitation - DWS); Department of Health (DoH); and Water Research Commission's (WRC) *Quality of Domestic Water Supplies: Volume 2: Sampling Guide (2000)*. Samples were collected from boreholes across the project area to ensure a good representation of upstream and downstream water qualities, as well as different geological or aquifer units.

Prior to sampling, all boreholes were purged followed by sampling using the following protocol:

- Groundwater levels were measured using a dip meter;
- Each borehole was purged using clean disposable polyethylene bailers. The purging involved abstracting three borehole volumes of water, or through continuous low volume pumping until the electrical conductivity (EC) value stabilised;
- Groundwater levels were allowed to stabilise prior to sampling. Each borehole was then sampled by collecting a 500 ml sample for laboratory analyses; and
- Samples were transferred to a cooler box in the field and kept below 5ºC prior to being submitted to the laboratory.

The pH and EC meters were calibrated daily using standard solutions obtained from the instrument supplier.

Samples were submitted to Aquatico Laboratory in Pretoria for chemical analysis of the following constituents:

- Total Dissolved Solids as TDS
- Nitrate and Nitrite as N
- Chlorides as Cl
- Total Alkalinity as $CaCO_3$
- Fluoride as F
- Electrical Conductivity in mS/m
- pH value
- Aluminium as Al
- Ammonium as NH_4
- Ortho Phosphate PO_4 as P

- Sulphate as SO_4
- Total Hardness as $CaCO_3$
- Bicarbonate Alkalinity
- Carbonate Alkalinity
- Calcium as Ca
- Magnesium as Mg
- Sodium as Na
- Potassium as K
- Iron as Fe
- Manganese as Mn
- Copper as Cu
- Nickel as Ni
- Cobalt as Co
- Cadmium as Cd
- Zinc as Zn
- Lead as Pb
- Total Chromium
- Arsenic as As
- Selenium as Se
- Boron as B

Water quality data are presented by means of tables, Piper and Schoeller Diagrams and maps. The Piper and Schoeller Diagrams were created using the WISH software.

3.2.1.1.1 Piper Diagram

The Piper Diagram uses the relationship of chemical parameters to classify water samples according to their dominant cations and anions, as well as allowing for the grouping of water according to hydrogeological facies. The Piper Diagram uses concentrations in meq/L calculated to represent a percentage of the total cations or anions. The cations and anions of each sample are plotted on the respective triangular plot and the points are then projected onto the central diamond graph (Figure 4-1). Depending where the sample point falls on the diamond graph, basic assumptions can be attributed to the sample, and for this reason the diamond graph is divided into quarters. Displaying numerous water qualities of the same sample on one plot gives the viewer an understanding of the changes occurring over time, whilst displaying multiple samples together provides a basis for comparison.

3.2.1.1.2 Schoeller Diagram

Schoeller Diagrams are semi-logarithmic diagrams displaying major ion analyses in meq/L, which is also used to identify different hydrochemical water types. This diagram displays the actual concentrations of the parameters, unlike the Piper Diagram. The concentrations are represented as points which can be used to compare between different samples, whilst the line that connects each parameter indicates the ratio between the two parameters (i.e. if a line joining two parameters of one sample is parallel to another line of a second sample – then the ratio of those parameters in both samples are equal).

3.2.1.2 Groundwater Level Measurements

Groundwater levels were measured by using a dip meter to measure the distance between the borehole collar level on surface and the water table depth within the borehole. The height of the borehole collar was subtracted from the measured water level to determine a groundwater level measured in metres below ground level (m bgl).

The m bgl measurement was subtracted from the borehole's surface elevation to define metres above mean sea level (m amsl) for all measurements.

3.2.1.3 Geosite Co-Ordinates and Elevations

All coordinates were taken with a hand-held Garmin GPS (Global Positioning System):

- Datum – WGS84; and
- Co-ordinate system: Geographic, decimal degrees.

All monitoring and production boreholes will have to be surveyed with a differential GPS system to ensure accurate reporting of the groundwater levels and potential drawdown cone. Hand-held GPS systems have a coordinate accuracy variation of approximately 5 m whereas the differential GPS system records the coordinates with an accuracy variation of better than one centimetre.

3.2.2 Geophysical Surveys

Ground geophysical surveys (magnetic and electromagnetic surveying techniques) have been applied to delineate geological structures that may act as preferential groundwater flow pathways or barriers to groundwater flow and contaminant transport.

3.2.2.1 Magnetic Method

Magnetic surveys were conducted to record spatial variations in the magnetic field and associated with the subsurface geological units. A one-man portable Geotron G5 magnetometer was employed to conduct the ground magnetic surveys.

The G5 instrument is a resonance, proton magnetometer and monitors the precession of atomic particles in an ambient magnetic field to provide an absolute measure of the earth's total magnetic field intensity in nanoTeslas (nT).

Many geological formations by virtue of their magnetic minerals content will behave like buried magnets and have associated with them a magnetic field. This very local magnetic field will be superimposed on the normal magnetic field of the earth. Measurements of the earth's magnetic field taken in the presence of such geological formations will show departures from the undisturbed earth's magnetic field. These changes or anomalies as they are called could be larger or smaller and could be either an increase or a decrease of the earth's field and will depend on the depth of burial, degree and direction of magnetisation, and the attitude of formation in relation to the direction of the earth's field at that locality.

3.2.2.2 Electromagnetic (EM) Method

A two-man portable EM34-4 (with 20 m coil separation) instrument was used for the electromagnetic survey. Both the horizontal (HD) and vertical (VD) dipole modes where applied. These modes measure the out-of-phase component of the induced electromagnetic field, which gives an indication of the subsurface conductivity.

In the frequency domain electromagnetic method, which the EM34-3 instruments is a typical example of, a transmitter coil is energized with an alternating current. This current generates a primary magnetic field, which in turn induces secondary eddy currents in the subsurface. These currents then generate a secondary magnetic field which is then measured together with the primary magnetic field by the receiver coil. When operating at low induction numbers (i.e. conductivity low enough for a fixed frequency), the ratio of the secondary magnetic field to the primary magnetic field is linearly proportional to the average subsurface conductivity.

Using the VD mode the maximum response originates from material at depth of approximately 0.4 x coil separation, while the surface material has a small contribution. Deeper than x 0.4 coil separation the VD mode has double the response of the HD. For the HMD the surface material down to a depth of 0.4 x coil separation contributes to most of the signal (McNeill, 1980).

The out-of-phase component measures the average electrolytic ground conductivity through the moisture-filled pores and passages of the sampled volume. A maximum error of 30% for the low induction number assumption is assumed, which allows for a maximum measured ground conductivity of 60 mS/m for the EM34-3. Provided the low induction number assumption is applicable, the effective depth of penetration is a function of the coil separation only (geometrically) and not of the skin depth (McNeill, 1980).

The different dipole set-ups have different depths of penetration and different coupling with horizontal and vertical structures. Both the vertical and horizontal dipole set-ups have the same response over a vertical structure. The response of the vertical dipole will however be much larger if the contrast in conductivity remains constant with depth (McNeill, 1983a).

Several basic assumptions are made when empirical topographic corrections (Monier-Williams et al., 1990) are applied. The most important being that the background value (regional) is purely a function of elevation and that the stratigraphy should be horizontal and uniform. Unfortunately such ideal geological conditions are very seldom realized. Thus, no elevation corrections applied during this survey.

3.2.3 Percussion Drilling Programme

Targets identified from the geophysical survey were investigated further by intrusive percussion drilling methods. The drilling programme aims to provide additional information on the geological features identified during the geophysical survey, as well as confirm the hydrogeological environment encountered for the project site.

3.2.4 Aquifer Testing Programme

Following the drilling programme an aquifer testing programme was initiated to assess the hydrogeological characteristics of the intersected aquifers. Blow yield estimates for the boreholes, established after drilling, indicated that the boreholes were low yielding with a maximum blow yield of 0.14 L/s from borehole BHPW08. It was therefore decided to test the boreholes via slug testing methods.

Prior to conducting the slug tests the static water level within the borehole to be tested is measured and an electronic level data logger installed to a depth of 50 m bgl within the borehole and set to take readings every 30 seconds. No observation boreholes are used during slug testing as these tests have limited impact on the water level of the testing borehole that the distance between the observation and testing borehole would nullify.

Slug tests are short tests used to assess the response of the borehole and intersected aquifer by the insertion of water or an object with a known volume into the borehole being tested. This insertion causes the water level inside the borehole to be instantly displaced, after which the recovery of the water level to the original position is monitored. The duration of the test was limited to an hour, however as the boreholes are low yielding, the recovery to pre-insertion water level can exceed this timeframe. 25 Litres of water were used as the insertion volume for the slug tests on each borehole.

Results from the slug tests were interpreted using the FC program for aquifer test analysis, 2013 version (developed by Gerrit van Tonder, Fanie de Lange and Modreck Gomo, affiliated with the University of the Free State).

The following hydraulic parameters can be interpreted from slug test analyses:

- First estimate of sustainable yield: defined as the amount of water which can be pumped from a borehole, within a given time. The sustainable yield is the amount of water which can be pumped over a long period (1 – 2 years) without the water level reaching the pump or water strike;
- Transmissivity (T-value): defined as the rate of horizontal flow under a hydraulic gradient within a unit width of the saturated aquifer; and
- Hydraulic Conductivity (K-value): defined as the ease with which a fluid can move through the pore spaces and fractures and is dependent on the intrinsic permeability of the porous material.

3.2.5 Geochemical Evaluations

Acid Mine Drainage is the process where mining and ore processing methods expose sulphates and metals in the source material to water and oxygen, producing low pH waters often associated with heavy metal contamination. By performing geochemical analysis on the source material, we are able to estimate the acid generating and neutralising potential of the source rocks as a basis for an impact assessment.

Eleven geochemical samples were selected from the overburden, coal seams and interburden rock units, which will comprise the surface spoils during operation and the proposed backfill material thereafter and provide the source material for potential AMD generation.

M&L Laboratories (Pty) Ltd was selected to perform the Acid Base Accounting analysis.

3.2.6 Conceptual Model

The conceptual model aims to describe the groundwater environment as accurately as possible in order to correctly represent the actual site conditions within a numerical model. The following parameters form part of the conceptual model and will be discussed under a source, pathway and receptor framework:

- The groundwater system:
  - Aquifers – these are rock units or open faults and fractures within rock units that are sufficiently permeable (porous) to allow water flow;
  - Interconnections between aquifers;
  - Surface water and groundwater interactions;
  - Definition of the groundwater source, pathway and receptors on site;
  - Boundaries that result in the change or interruption of groundwater flow; and
  - Hydro-stratigraphic units – these are formations, parts of formations, or a group of formations displaying similar hydrologic characteristics that allow for a grouping into aquifers and associated confining layers.
- The groundwater flow system:
  - Precipitation and evapotranspiration;
  - Run-off, groundwater head data which yields groundwater flow;
  - Hydraulic parameters;
  - Recharge and discharge areas, groundwater and surface water exchange; and
  - Geochemical data including major cations, anions and metals.

3.2.7 Numerical Model

The conceptual model is coded into a numerical model, using FEFLOW as the modelling code. The groundwater flow model was developed using the modelling package FEFLOW 6.0. FEFLOW was selected for construction of the model because it is a highly interactive groundwater modelling system capable of simulating flow in two or three dimensions for uncoupled, variably saturated, transient or steady state flow. Specifically, FEFLOW is a finite-element based model with the ability to simulate flow of groundwater through complex geology in three dimensions. Additionally, different pit geometries and dewatering strategies can be incorporated into the model so that the response of the groundwater system can be predicted.

The model domain will extend to the closest groundwater boundaries, not expected to be impacted on by mining. These can be groundwater divides or groundwater controls.

The model will be calibrated to the latest water levels (steady state), as well as historic water level monitoring (transient). The calibrated model will be utilised to run the required scenarios to determine the likely impacts from mining activities. Scenario modelling will cover the current and future mine plans with a period of 100 years after closure.

The following breakdown summarizes the numerical modelling steps:

- Model setup – as per the conceptual model;
- Steady state calibration – using the most recent water levels;
- Transient calibration – using historical water level data;
- Scenario modelling; and
- Reporting.

4 Investigation Results

4.1 Hydrocensus

A hydrocensus was conducted within a 5 km radius around the project site, and identified 53 boreholes and 2 springs. Ten water samples were selected and sent for analysis with Aquatico Laboratories, which is a SANAS (South African Accreditation System) accredited laboratory.

The locations of the 55 identified groundwater sources are represented on Plan 6 with the 10 sampled sites indicated with a different colour. The details pertaining to each site are summarised in Table 4-1, with the sampled boreholes highlighted for reference purposes.

Groundwater use identified during the hydrocensus indicates 30 boreholes are used for domestic purposes (including potable water supply), 9 boreholes were not used, 3 boreholes are used for monitoring purposes, 2 sites are springs and 11 boreholes were identified as unknown usage.

Of the 10 sample sites selected for water quality analysis, 8 samples represent domestic use, 1 site represents a monitoring location and 1 site was sampled from an unused borehole.

It is recommended that all identified boreholes, actively used for domestic and agricultural purposes be sampled to update the baseline assessment. The 10 analysed samples are scattered across the project site and indicate groundwater typical of the Karoo aquifers. The results of sample WELBH43 indicate a strong influence of contamination by mining activities with no clear indication of what could be the cause.

Eight boreholes are located within the proposed pit BD boundary; identified as WELBH02, WELBH03, WELBH04, WELBH05, WELBH06, WELBH07, WELBH27 and WELBH28. It is recommended that they be sampled for water quality and borehole depth prior to the commencement of mining to establish if they are connected to the underlying pre-Karoo aquifers potentially forming a link for contamination to migrate.

Table 4-1: Summary of hydrocensus information[1]

Site ID	X co-ords	Y co-ords	Elevation	Farm Name	Water Level	Groundwater Use
WEL31	29,136	-25,947	1576	Blaauwkrans 323 JS	1569	Domestic
WELBH 01	29,056	-26,026	1527	Oggiesfontein 4 IS	1512	Domestic
WELBH 02	29,068	-26,005	1533	Wildebeestfontein 327 JS	1525	Domestic
WELBH 03	29,069	-26,003	1580	Wildebeestfontein 327 JS	1570	Domestic - potable water supply
WELBH 04	29,068	-26,003	1578	Wildebeestfontein 327 JS	-	Unknown - equipped
WELBH 05	29,073	-26,004	1582	Wildebeestfontein 327 JS	1571	Domestic
WELBH 06	29,074	-26,003	1580	Wildebeestfontein 327 JS	1554	Domestic
WELBH 07	29,073	-26,000	1570	Wildebeestfontein 327 JS	1569	Not used
WELBH 08	29,050	-26,012	1539	Oggiesfontein 4 IS	-	Unknown - equipped
WELBH 09	29,040	-26,021	1532	Prinshof 2 IS	1525	Monitoring
WELBH 10	29,034	-26,016	1527	Prinshof 2 IS	1519	Monitoring
WELBH 11	29,024	-25,962	1505	Roodepoort 326JS	1482	Domestic
WELBH 12	29,023	-25,963	1506	Roodepoort 326JS	1481	Domestic

[1] Highlighted rows indicate boreholes sampled for water quality analysis

Site ID	X co-ords	Y co-ords	Elevation	Farm Name	Water Level	Groundwater Use
WELBH 13	29,019	-25,939	1500	Roodepoort 326 JS	1476	Domestic
WELBH 14	29,018	-25,940	1501	Roodepoort 326 JS	-	Unknown - equipped
WELBH 15	29,056	-25,951	1546	Hartebeestlaagte 325 JS	1538	Not used
WELBH 16	29,050	-25,956	1536	Roodepoort 326JS	-	Unknown
WELBH 17	29,062	-25,960	1553	Hartebeestlaagte 325 JS	1515	Domestic
WELBH 18	29,059	-25,960	1554	Hartebeestlaagte 325 JS	-	Unknown - equipped
WELBH 19	29,062	-25,954	1555	Hartebeestlaagte 325 JS	-	Unknown - equipped
WELBH 20	29,069	-25,899	1510	Elandsfontein 309 JS	1504	Not used
WELBH 21	29,069	-25,900	1509	Elandsfontein 309 JS	1502	Domestic
WELBH 22	29,068	-25,903	1499	Hartebeestlaagte 325 JS	1490	Not used
WELBH 23	29,069	-25,930	1523	Hartebeestlaagte 325 JS	-	Domestic - potable water supply
WELBH 24	29,087	-25,941	1510	Roodepoort 326JS	1485	Domestic
WELBH 25	29,056	-25,956	1555	Hartebeestlaagte 325 JS	-	Domestic - potable water supply
WELBH 26	29,049	-25,974	1548	Wildebeestfontein 327 JS	1540	Domestic
WELBH 27	29,076	-25,978	1589	Tweefontein 328 JS	-	Unknown - equipped
WELBH 28	29,084	-25,977	1553	Tweefontein 328 JS	1537	Domestic
WELBH 29	29,133	-25,974	1590	Vlaglaagte 330 JS	1583	Domestic
WELBH 30	29,134	-25,974	1589	Vlaglaagte 330 JS	1584	Domestic

Site ID	X co-ords	Y co-ords	Elevation	Farm Name	Water Level	Groundwater Use
WELBH 32	29,141	-25,968	1588	Vlaglaagte 330 IS	-	Unknown - equipped
WELBH 33	29,140	-25,971	1590	Vlaglaagte 330 IS	1584	Domestic
WELBH 34	29,140	-25,971	1591	Vlaglaagte 330 IS	1587	Domestic
WELBH 35	29,138	-25,970	1592	Vlaglaagte 330 JS	1581	Domestic
WELBH 36	29,134	-25,979	1591	Vlaglaagte 330 JS	1563	Domestic
WELBH 37	29,132	-25,979	1595	Vlaglaagte 330 JS	1575	Domestic
WELBH 39	29,131	-25,960	1574	Weltevreden 324 JS	1569	Not used
WELBH 40	29,117	-25,967	1566	Weltevreden 324 JS	1563	Not used
WELBH 41	29,117	-25,967	1567	Weltevreden 324 JS	1563	Not used
WELBH 42	29,118	-25,967	1567	Weltevreden 324 JS	1565	Domestic
WELBH 43	29,125	-25,989	1605	Vlaglaagte 330 JS	1603	Domestic
WELBH 44	29,126	-25,988	1604	Vlaglaagte 330 JS	1602	Not used
WELBH 45	29,130	-25,987	1606	Vlaglaagte 330 JS	-	Unknown
WELBH 46	29,125	-25,986	1606	Vlaglaagte 330 JS	1572	Not used
WELBH 47	29,128	-25,992	1612	Vlaglaagte 330 JS	1595	Domestic
WELBH 48	29,125	-25,993	1609	Tweefontein 328 JS	1581	Domestic
WELBH 49	29,088	-26,065	1580	Zaaiwarer 11 IS	1578	Monitoring
WELBH 50	29,071	-26,048	1606	Grootpan 7 IS	-	Unknown - equipped

Site ID	X co-ords	Y co-ords	Elevation	Farm Name	Water Level	Groundwater Use
WELBH 51	29,049	-26,070	1580	Goedevonden 10 IS	-	Unknown - equipped
WELPIT	29,140	-25,969	1587	Vlaglaagte 330 IS	1584	Domestic
WELPIT 01	29,141	-25,967	1589	Vlaglaagte 330 IS	1586	Domestic
WELSP R4	29,101	-25,950	1514	Weltevreden 324 JS	1514	Groundwater spring
WELWE L3	29,096	-25,952	1513	Weltevreden 324 JS	1513	Groundwater spring
WELWE L5	29,086	-26,057	1570	Zaaiwarer 11 IS	1563	Domestic

4.1.1 Groundwater Quality

The groundwater quality results for the 10 analysed samples are given in Table 4-2. The Piper Diagram is given as Figure 4-1 and the Schoeller Diagram as Figure 4-2. The methodology for interpreting the mentioned graphs is provided in Section 3.2.1.1.

Water quality results obtained from boreholes WELWEL5, WELBH01, WELBH05, WELBH15, WELBH24 and WELBH42 indicate parameters are within the SANS 241-1: 2011 standards for aesthetic, operational, acute and chronic health limits, and therefore no health risks are associated with this water quality group.

The sample from borehole WELBH43 indicates that sulphate exceeds the aesthetic limit (250 mg/L), but is still below the acute health limit (500 mg/L), with a concentration of 480 mg/L. The effects of drinking water with this concentration of sulphate are diarrhoea (in non-adapted individuals) and the water also has a salty to bitter taste (DWAF, 1996).

Boreholes WELBH09 and WELBH26 both indicate excessive iron concentrations which exceed the chronic health limit of 2 mg/L. Iron concentrations are 2.09 mg/L and 4.24 mg/L for WELBH09 and WELBH26, respectively. The South African Water Quality Guideline (DWAF, 1996) indicates that the health effects associated with an iron concentration ranging from 1 mg/L to 10 mg/L include pronounced taste and plumbing issues to slight health effects in young and sensitive individuals.

Borehole WELBH28 indicated a high fluoride concentration exceeding the chronic health limit of 1.5 mg/L, with a concentration of 1.65 mg/L. The threshold limit for mottling, tooth damage and softening of enamel is 1.5 mg/L. Concentrations of fluoride between 1.5 mg/L and 3.5 mg/L indicate noticeable mottling and tooth damage with continuous use, but no other health effects (DWAF, 1996).

The borehole owners for WELBH26, WELBH28 and WELBH43 need to be informed of the health effects associated with the water quality measured for their boreholes, especially if they are using the groundwater for potable water supply and drinking purposes.

Borehole WELBH09 is used for monitoring purposes, located approximately 1 km down gradient of the Klipspruit and Zibulo Collieries.

Table 4-2: Water quality results from the hydrocensus (concentrations in mg/L)

Sample Date	Sample ID	Total Dissolved Solids	Nitrate NO_3 as N	Chlorides as Cl	Total Alkalinity as $CaCO_3$	Sulphate as SO_4	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Iron as Fe	Manganese as Mn	Conductivity at 25° C in mS/m	pH-Value at 25° C	Aluminium as Al	Free and Saline Ammonia as N	Fluoride as F
	Aesthetic Standard	<1200	N/S	<300	N/S	<250	N/S	N/S	<200	N/S	<0,3	<0,1	<170	N/S	N/S	<1,5	N/S
	Operational Standard	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	>5 to <9,7	<0,3	N/S	N/S
	Acute Health Standard	N/S	<11	N/S	N/S	<500	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S
	Chronic Health Standard	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	<2	<0,5	N/S	N/S	N/S	N/S	<1,5
2014/08/01	WELWEL5	158,00	0,38	7,30	140,00	5,46	24,80	9,11	21,00	2,78	0,00	0,00	25,00	8,50	0,00	0,04	0,37
2014/07/28	WELBH01	143,00	0,27	8,06	116,00	6,78	15,90	5,96	28,90	3,82	0,00	0,01	23,40	8,31	0,00	0,26	0,65
2014/07/29	WELBH05	132,00	0,42	4,99	113,00	5,92	19,50	6,44	20,70	3,30	0,00	0,00	21,20	8,45	0,00	0,04	0,32
2014/07/29	WELBH15	41,00	1,54	6,08	14,50	4,14	5,44	2,18	4,54	2,45	0,00	0,00	7,03	7,65	0,00	0,06	0,16
2014/07/30	WELBH24	21,00	0,36	5,55	-2,48	5,63	1,59	0,61	3,08	2,59	0,00	0,00	3,12	7,18	0,00	0,07	0,14
2014/07/31	WELBH42	39,00	2,45	8,24	4,14	4,05	1,96	1,78	7,01	2,62	0,00	0,00	6,22	7,08	0,00	0,10	0,15
2014/07/31	WELBH43	731,00	2,04	11,00	40,50	480,00	128,00	52,10	14,60	11,60	0,00	0,00	91,70	7,87	0,00	0,21	0,17
2014/07/29	WELBH09	28,00	0,25	4,86	10,30	4,34	1,73	0,98	3,02	4,69	2,09	0,00	3,76	7,36	0,00	0,05	0,71
2014/07/30	WELBH26	45,00	0,25	4,74	28,80	4,98	7,56	2,12	2,80	2,61	4,24	0,03	6,96	7,41	0,00	0,12	1,32
2014/07/30	WELBH28	262,00	3,20	15,80	202,00	6,04	5,44	4,06	89,00	2,44	0,00	0,00	43,50	8,62	0,00	0,16	1,65

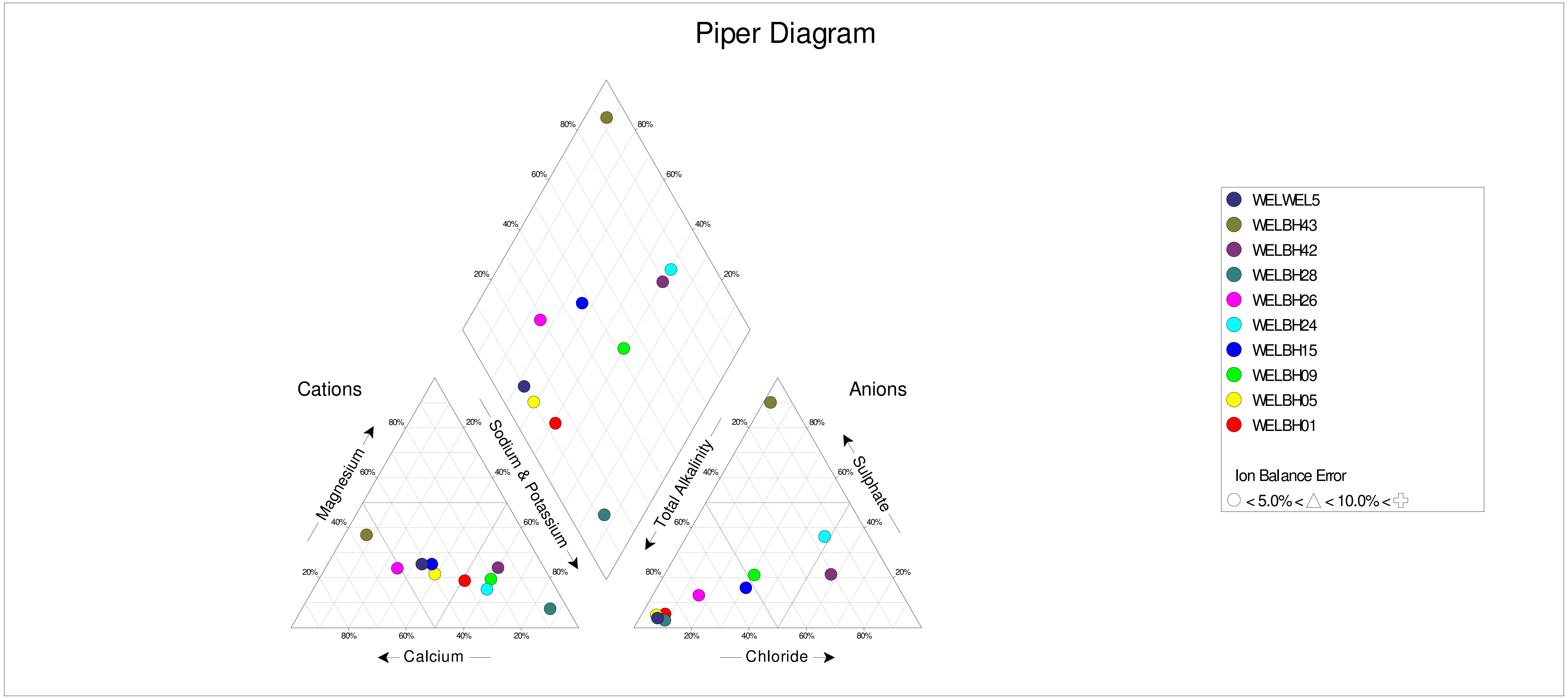

Figure 4-1: Piper Diagram for hydrocensus results

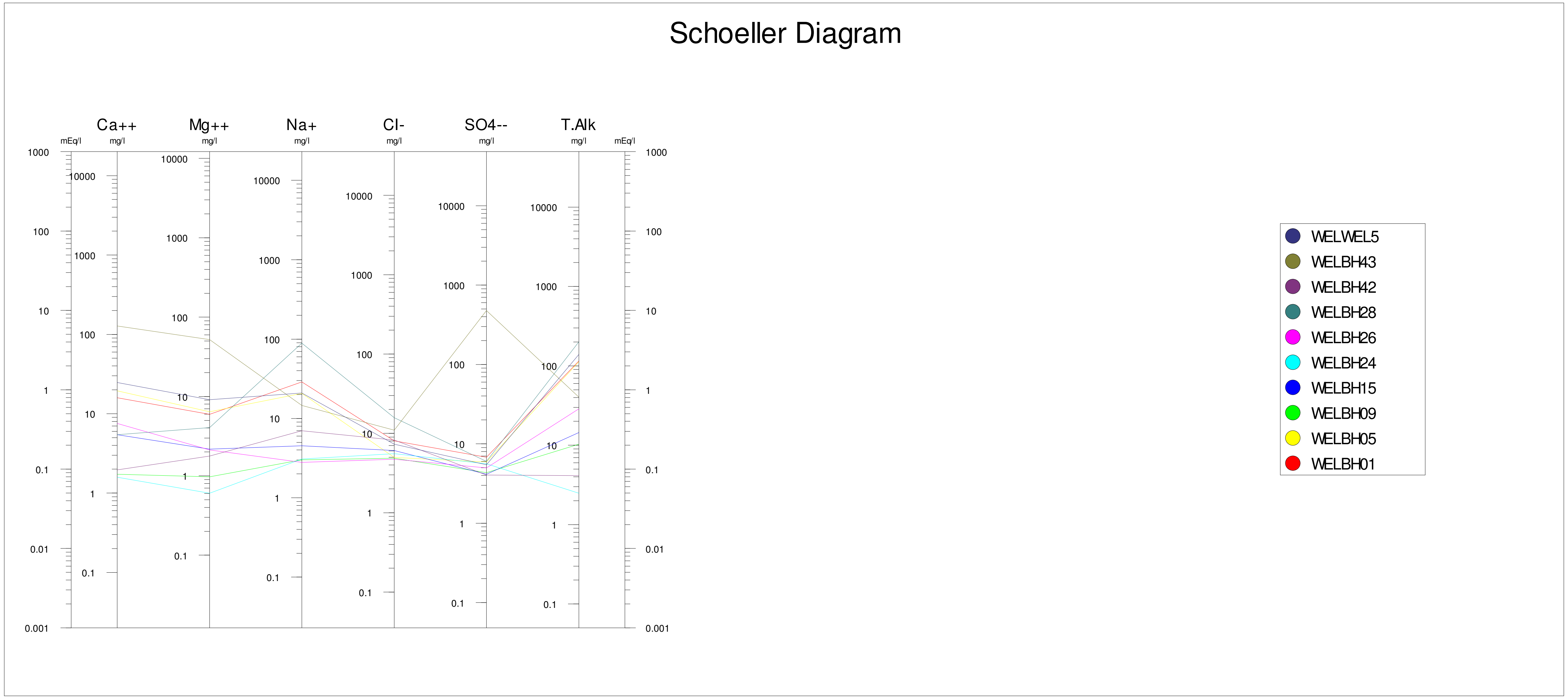

Figure 4-2: Schoeller Diagram for hydrocensus results

The Piper Diagram (Figure 4-1) indicates a Ca-Na-HCO_3-Cl groundwater type which is typical for Karoo aquifers. Samples range between freshly recharged to stagnant water types with the exception of WELBH43 which indicates contaminated water.

Sulphate concentration are low for samples from WELBH09, WELBH15, WELBH24, WELBH26 and WELBH42 . However, sulphate is the dominant anion for WELBH43. High sulphate concentrations could indicate a potential impact from mining related activities on the groundwater supply. It is not clear what the cause of this high sulphate concentration is (borehole WELBH43) or if it is isolated to just this site as no surrounding sites were analysed.

Presence of sodium and chloride in the water type is typical of groundwater with long residence times within Karoo aquifers, suggesting the borehole intersected a more stagnant aquifer.

The Schoeller Diagram (Figure 4-2) indicates that Ca, Mg, Na and alkalinity have the greatest variability between sample results. Cl and SO_4 indicate the least variability between samples, with the exception of WELBH43 which indicates a spike in SO_4 concentration in relation to the other samples.

Variations in results presented in the Piper and Schoeller Diagrams are potentially as a result of varying borehole construction, as well as different lithologies and aquifers being intersected. No information for the hydrocensus boreholes was provided in this regard, which limits the interpretation of the results.

It is recommended that all identified boreholes, actively used for domestic and agricultural purposes be sampled to update the baseline assessment. The 10 analysed samples are scattered across the project site and indicate groundwater typical of the Karoo aquifers. The results of sample WELBH43 indicate a strong influence of contamination by mining activities with no clear indication of what could be the cause.

4.2 Geophysical Surveys

Nine traverses (2.72 line kilometres) were completed around the proposed KPSX: Weltevreden project area and the locations are displayed on Plan 7 (Appendix A). The results of the survey are presented in Figure 4-3 through to Figure 4-11. A summary of the identified targets is provided in Table 4-3.

Table 4-3: Summary of identified target boreholes

Planned Borehole ID	X Co-ord	Y Co-ord	Priority	Traverse ID
BHP_P03 (BH3)	-26.0540	29.08346	High priority	T1 St 110
BHP_P04 (BH4)	-25.9853	29.12217	High priority	T3 St 230
BHP_P05 (BH5)	-25.9803	29.10743	High priority	T4 St 210
BHP_P06 (BH6)	-25.9490	29.10156	High priority	T6 St 170
BHP_P07 (BH7)	-25.9851	29.04700	High priority	T7 St 290
BHP_P08 (BH8)	-25.9442	29.05699	High priority	T8 St 170
BHP_P10 (BH10)	-26.0296	29.09578	Low priority	T2 St 120
BHP_P11 (BH11)	-25.9704	29.12360	Low priority	T5 St 90
BHP_P12 (BH12)	-25.9345	29.06912	Low priority	T9 St 110

Traverse one was conducted on the southern boundary of the KPSX: Weltevreden project, on the farm portion of Zaaiwater 11 IS (Glencore Operations South Africa). The traverse was walked from west to east for a distance of 250 m. One target was identified as BHP_P03 and given a high priority.

Traverse two was conducted on the farm Grootpan 7 IS (Truter Boerdery Trust), within the project boundary. The traverse was walked in a west to east direction for a distance of 400 m. One low priority target was identified as BHP_P10.

Traverse three was conducted on the Weltevreden 324 JS farm under ownership of the National Department of Land Affairs. The traverse was walked in a southwest to northeast direction with a length of 300 m. Only the magnetometer was used. One high priority target was identified as BHP_P04.

Traverse four was walked from southwest to northeast on the Tweefontein 328 JS farm (Truter Boerdery Trust), for a distance of 260 m. One high priority target was identified as BHP_P05.

Traverse five was conducted on the farm Weltevreden 324 JS, under ownership of the National Department of Land Affairs. The traverse was walked in a northwest to southeast direction for a distance of 390 m. One target was identified as BHP_P11 and is a low priority site.

Traverse six was walked from west to east on the Weltevreden 324 JS property, under ownership of the National Department of Land Affairs. The traverse was 240 m with one target (BHP_P06) identified as a high priority site.

Traverse seven was conducted on the Wildebeestfontein 327 JS farm which is owned by Ingwe Surface Holdings. The traverse was 330 m in length and walked in a southeast to northwest direction. BHP_P07 was the only identified target and is a high priority site.

Traverse eight was conducted on the Hartebeestlaagte 325 JS property (Sikhosana Thandi Joyce). The traverse was walked in an east to west direction with a distance of 210 m. BHP_P08 was the only identified target and given a high priority.

Traverse nine was walked on the Hartebeestlaagte 325 JS property owned by Lonerock Quarries CC. The line was walked from west to east for a distance of 340 m. One low priority site was targeted, identified as BHP_P12.

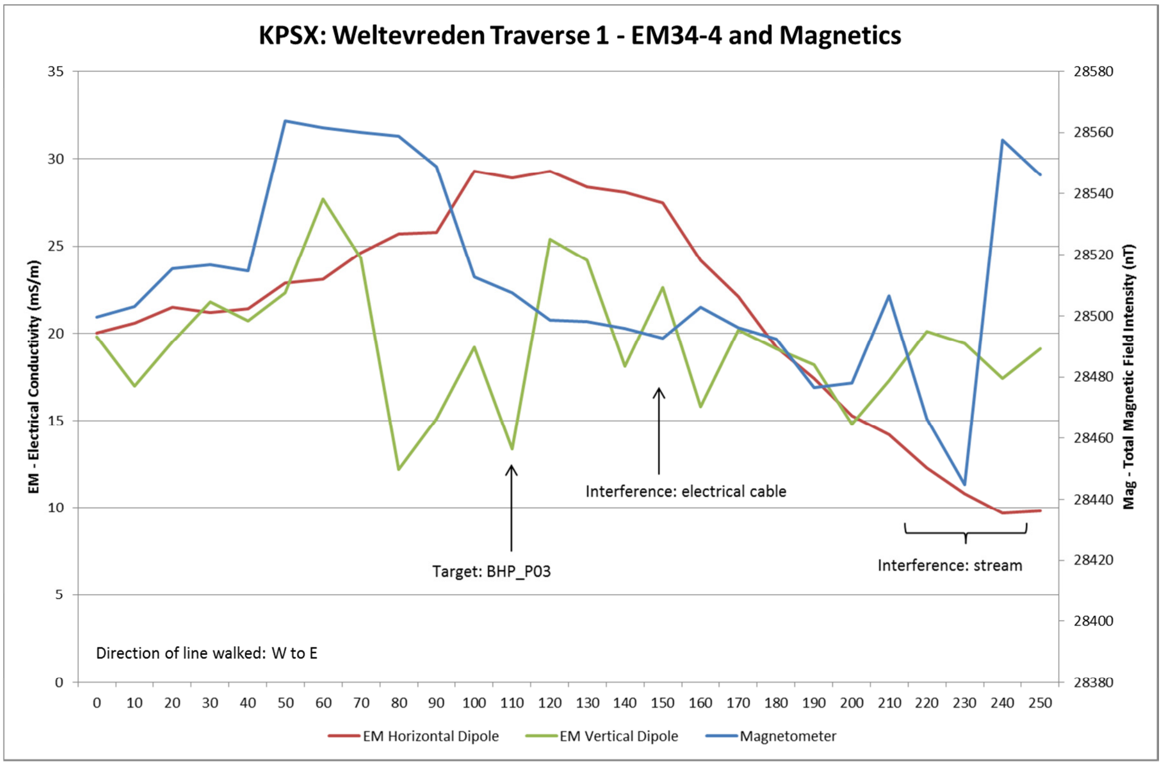

Figure 4-3: KPSX: Weltevreden traverse one

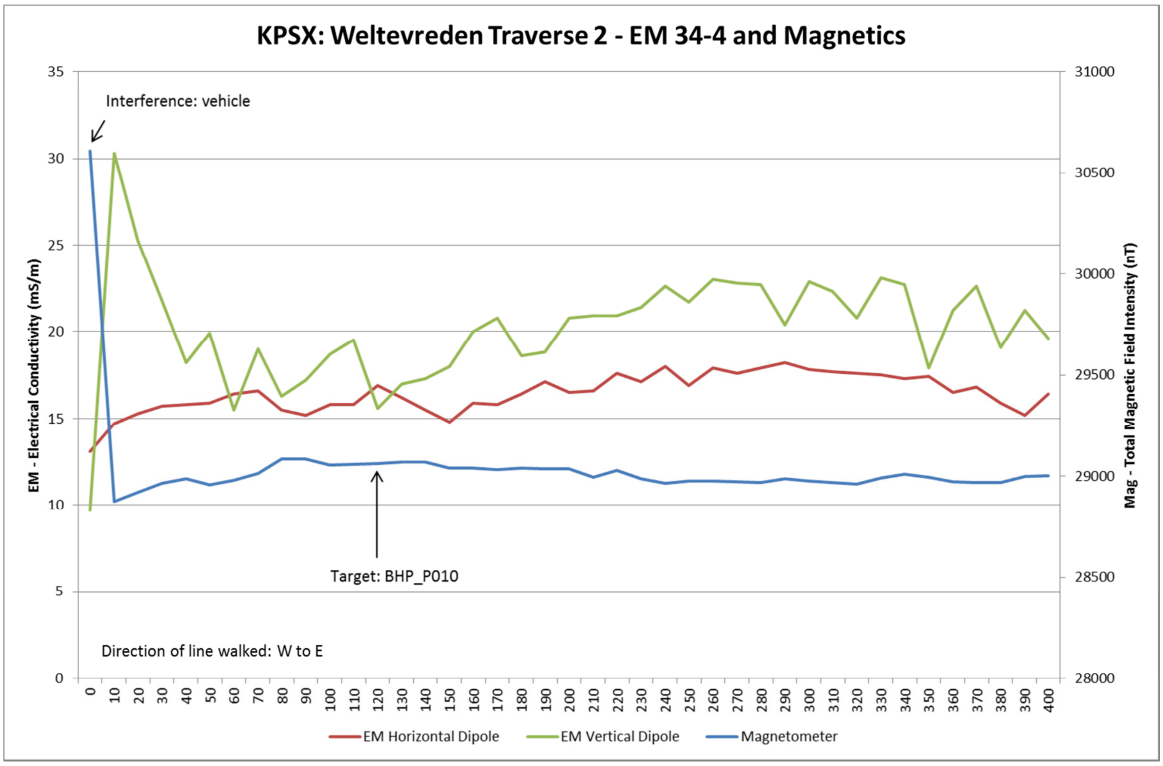

Figure 4-4: KPSX: Weltevreden traverse two

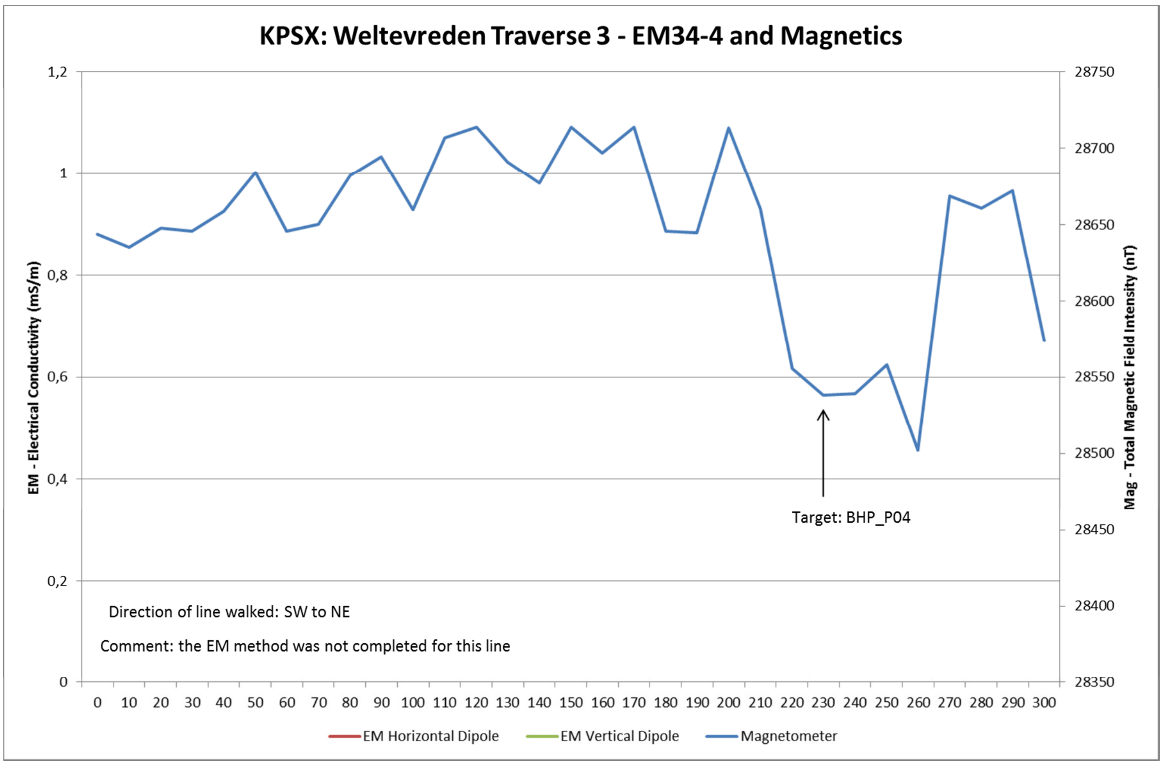

Figure 4-5: KPSX: Weltevreden traverse three

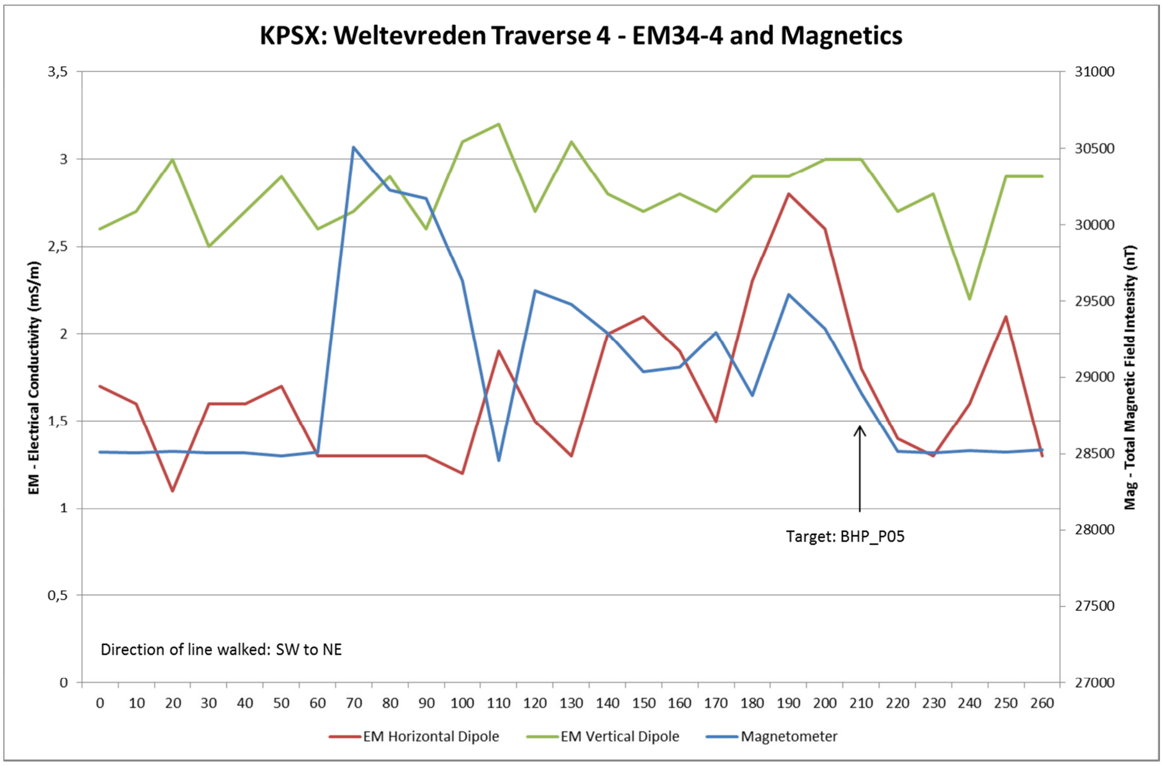

Figure 4-6: KPSX: Weltevreden traverse four

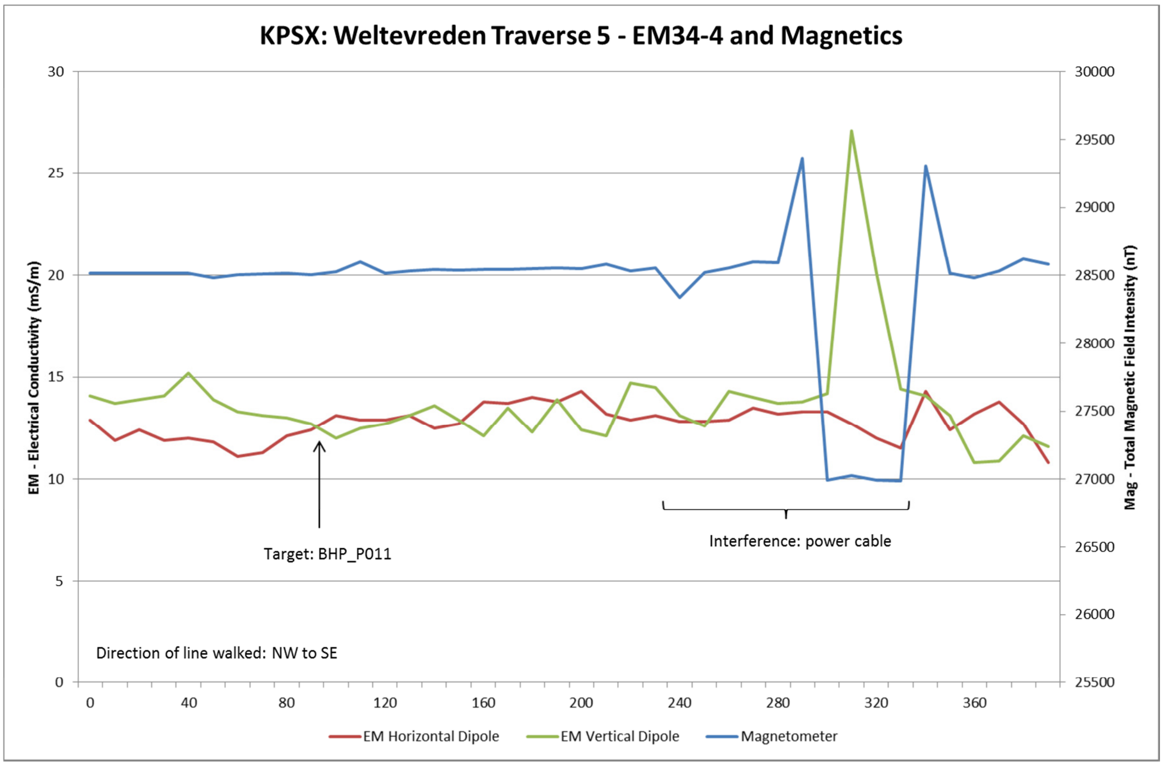

Figure 4-7: KPSX: Weltevreden traverse five

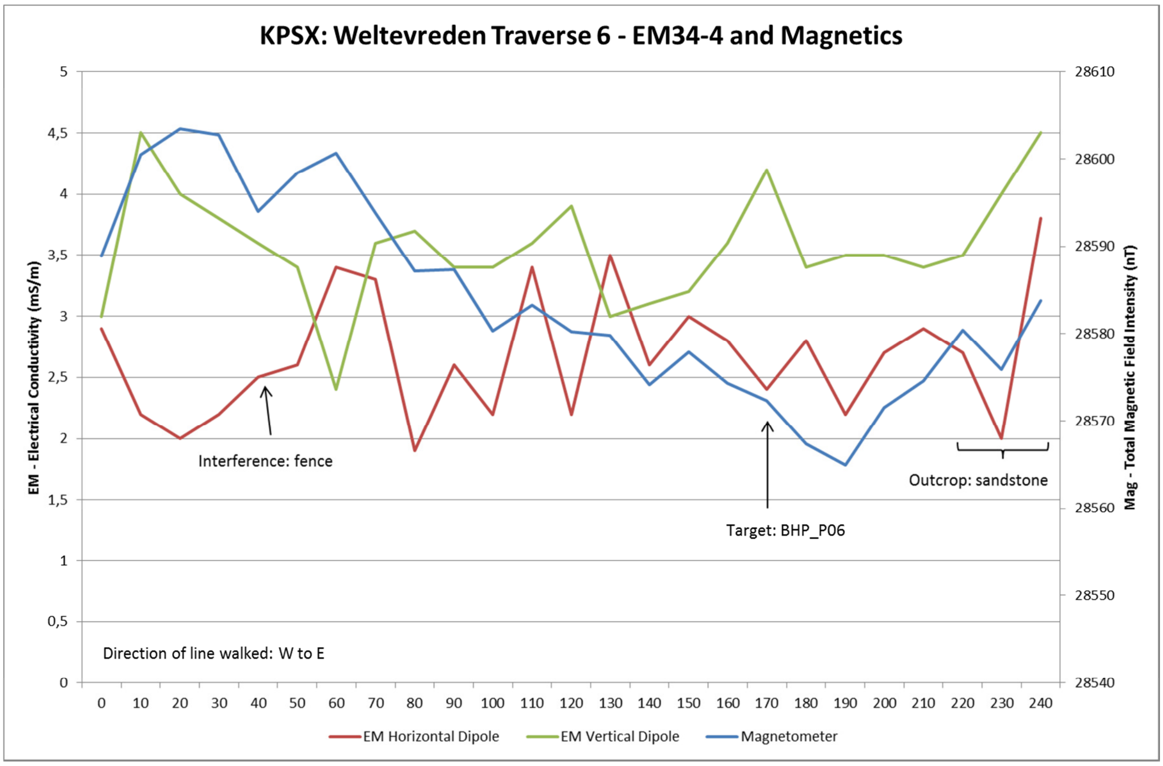

Figure 4-8: KPSX: Weltevreden traverse six

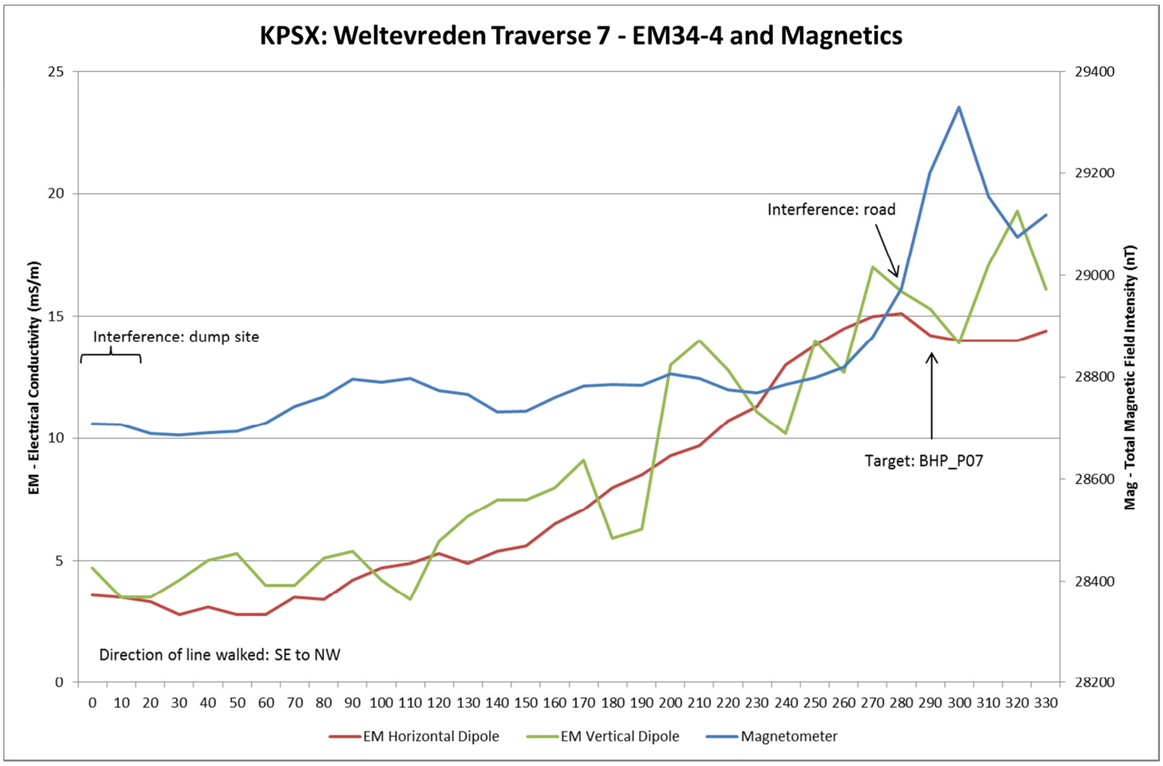

Figure 4-9: KPSX: Weltevreden traverse seven

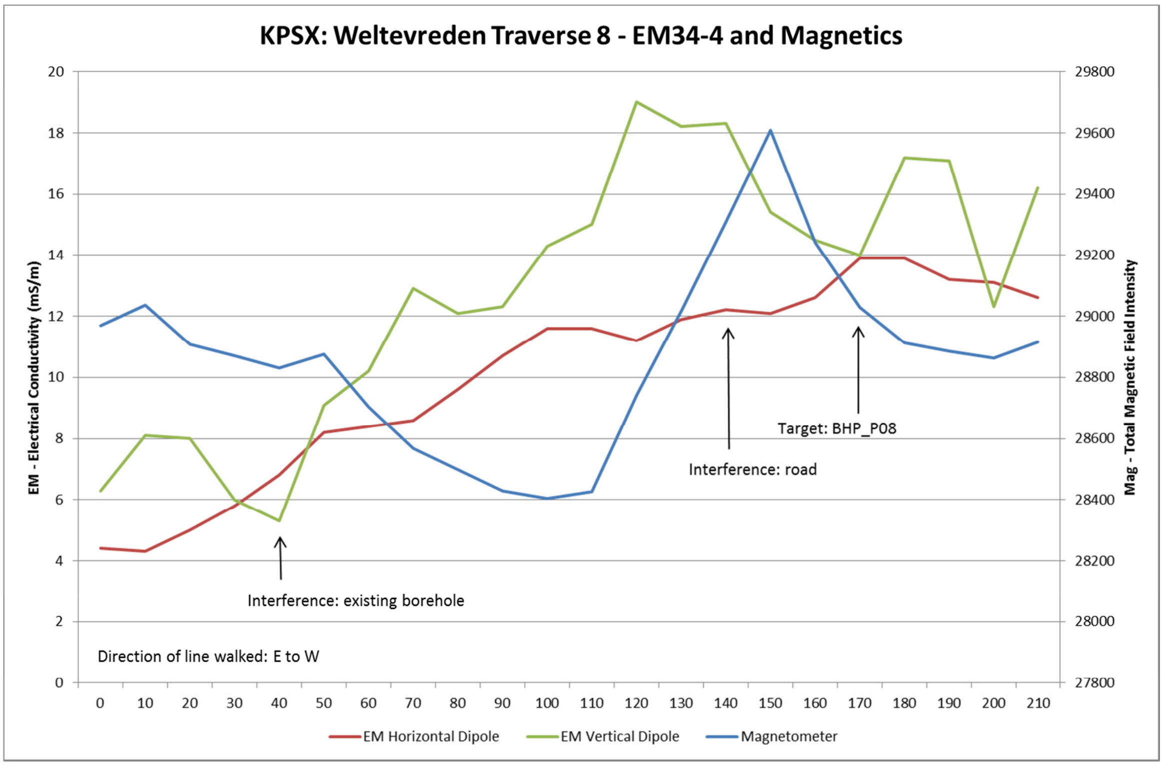

Figure 4-10: KPSX: Weltevreden traverse eight

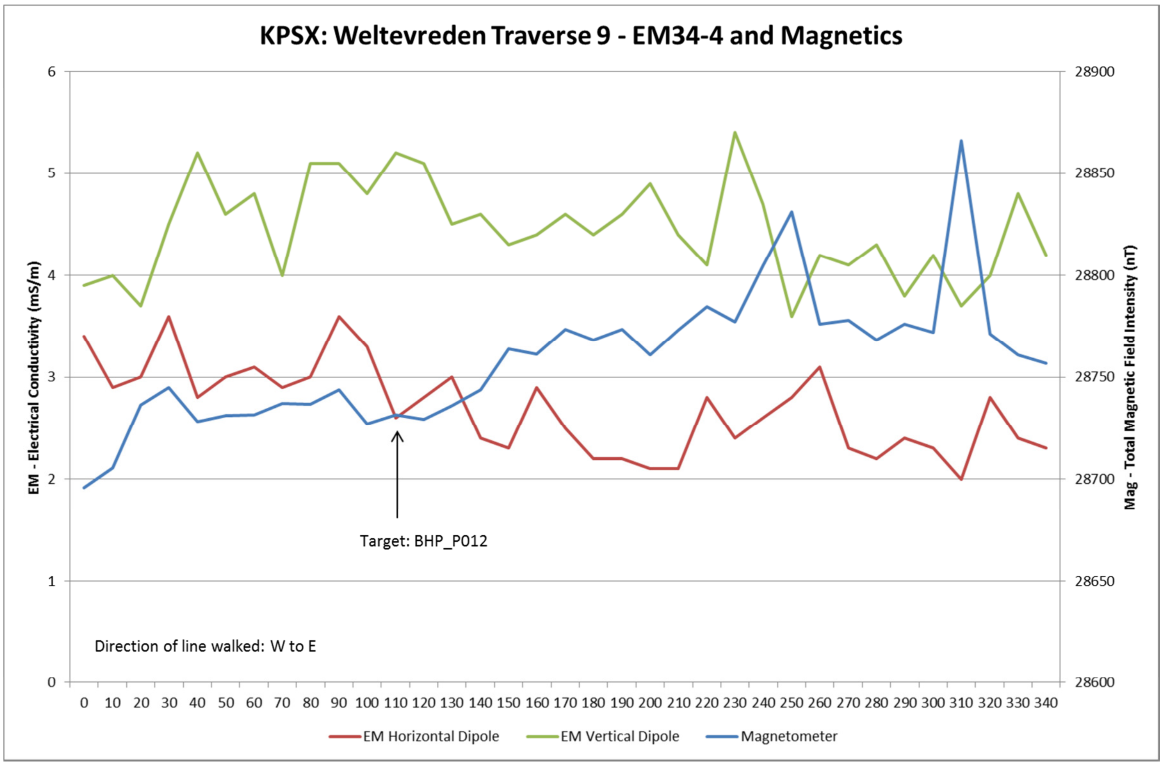

Figure 4-11: KPSX: Weltevreden traverse nine

4.3 Drilling Programme

Five of the nine targets identified during the geophysical survey were investigated further with percussion drilling methods (Plan 8, Appendix A). All boreholes were drilled to a final depth of 60 m below surface. The borehole logs indicating intersected geology and borehole construction details are provided in Appendix D. Borehole BHPW08 was the only borehole to intersect a low yielding fracture, with a blow yield estimate of 0.14 L/s at a depth of 33 m. Seepage was also intersected at 24 m within borehole BHPW08 and at 16 m within borehole BHPW05.

All boreholes where completed with 140 mm PVC casing for the full length of the borehole. The drilling diameter was 165 mm resulting in a 25 mm annulus, which was filled with gravel.

All boreholes were completed in the Ecca Group sediments comprising of sandstone, shale, mudstone and coal. Dolerite was intersected at a depth of 14 m within borehole BHPW07 and 19 m within borehole BHPW08. Seepage associated with BHPW08 occurs at the contact of weathered dolerite with fresh dolerite. The water strike occurred within the fresh dolerite.

The weathering profile varies between 3 to 14 m bgl within the drilled boreholes. This corresponds to the upper weathered aquifer identified by Hodgson and Krantz (1998). No seepage was noted within this weathered aquifer.

Below the weathered profile until a depth of 60 m, the boreholes only intersect Ecca Group sediments and later intrusions, with minor seepage and low yielding water strikes. This entire sequence is attributed to the fractured aquifer system. Sediments indicate moderate to high degree of weathering, indicating the presence of water within these lithological sequences. Noticeable seepage is associated with contact between sandstone and mudstone lithological units (BHPW05) and contact of weathered dolerite with fresh dolerite (BHPW08). A fracture within the fresh dolerite BHPW08 provides the highest yield intersected of 0.14 L/s.

No pre-Karoo aquifers were intersected by the boreholes during this drilling programme.

4.4 Aquifer Testing Programme

No significant groundwater strikes where intersected during the drilling programme, with only 0.14 L/s achieved in borehole BHPW08. The remaining boreholes only intersected zones of minor seepage. All newly drilled boreholes were slug tested to understand the aquifer parameters for the project area (Plan 8, Appendix A).

The slug test details are provided in Table 4-4 whilst the results are presented in Table 4-5.

The static groundwater levels at the commencement of the slug tests were measured at depths between 20.03 and 27.78 m bgl, which occur within the fractured aquifer. The response of the aquifer to the slug test will therefore be attributed to the fractured aquifer system.

The interpreted results for boreholes BHPW03, BHPW08 and BHPW10 confirm the low yielding potential of the fractured aquifer.

At the time of slug testing borehole BHPW05 the static water level had not yet recovered to its final level. Interpretation was completed on the recovery data of the borehole which resulted in an estimated yield of 0.023 L/s. The remaining interpretations could not be completed as these results depend on a 70% recovery time for calculations which could not be estimated for this borehole.

Table 4-4: Structure of slug tests

Borehole ID	Test Type	Test Duration	Water level at start of test (m bgl)	Depth change of water displaced by slug (m)	Time taken till recovered
BHPW03	Slug Test – Insert only	1 hr 05 min	23.67	1.53	Recovered by 27% after an hour.
BHPW05	Slug Test – Insert only	1 hr 00 min	24.82	0.90	Borehole water level hadn't recovered at the time of testing.
BHPW07	No water level had established itself at the time of testing. Borehole thus dry.				
BHPW08	Slug Test – Insert only	1 hr 26 min	27.78	0.72	Recovered to 100% in 1 hr 6 min.
BHPW10	Slug Test – Insert only	1 hr 01 min	20.03	1.14	Recovered by 31% after an hour.

Table 4-5: Results of slug test interpretation

Borehole ID	Yield of borehole (L/s)	1st estimate of sustainable yield (L/s)	T-value (m^2/d)				K-value (m/d)	
			Formation in vicinity of borehole	Average for formation	Fracture estimate from Svenson-equation	Fracture	Fracture	Formation in vicinity of borehole
BHPW03	0.017	0.003	0.105	0.010	0.332	0.011	0.053	0.003
BHPW05	0.023	Slug test was inconclusive as borehole was still recovering						
BHPW07	No test conducted on this borehole							
BHPW08	0.047	0.009	0.284	0.028	1.117	0.070	0.348	0.045
BHPW10	0.020	0.004	0.117	0.012	0.381	0.013	0.066	0.004

4.5 Geochemical Assessment

Eleven geochemical samples were collected from the newly drilled boreholes BHPW03, BHPW10 and BHPW05 and submitted to M&L Laboratory for basic ABA and NAG analysis. An outline of the collected samples is provided in Table 4-6. Plan 8 (Appendix A) indicates the location of the newly drilled boreholes.

Table 4-6: Geochemical Samples

BHPW03	Overburden	Composite of sandstone and soil
	First coal seam	First intersected coal seam
	Interburden	Composite of sandstone and carbonaceous shale
	Second coal seam	Second intersected coal seam
	Underburden of coal seam2	Composite of sandstone and carbonaceous shale
BHPW10	Overburden	Composite of sandstone, mudstone and shale
	First coal seam	First intersected coal seam
	Underburden of coal seam 1	Composite of sandstone and shale
BHPW05	Overburden	Composite of soil, sandstone and carbonaceous shale
	First coal seam	First intersected coal seam
	Underburden of coal seam 1	Composite of sandstone and carbonaceous shale

4.5.1 ABA and NAG Results

The ABA and NAG test results are summarized in Table 4-8.

The following can be concluded:

- Six samples have total Sulphur contents above the 0.3% guideline value, indicating that acid generation will start to occur during oxidation, if the neutralization potential of the rocks is not high enough. Five of these samples subsequently indicated an acid generating potential;
- Paste pH values of all rock samples except for BHPW03 (Interburden Coal Seam 1&2) are above 5.5; indicting an excess of base materials in the samples and therefore suggesting neutral to elevated alkalinity values will potentially be present in water quality samples initially;
- Samples BHPW03 (Overburden Coal Seam 1) and BHPW05 (Coal Seam 1) show a low tendency of acid generation with low acid potential (AP) and high neutralizing potential (NP). This implies that the material will be able to buffer acid forming reactions;
- However, sample BHPW05 (Coal Seam 1) shows a Net Acid Generation (NAG) value less than 0.1, indicating it could potentially generate acid in a long run; and

- The NAG values of samples BHPW03 (Coal Seam 1, Interburden Coal Seam 1&2, Coal Seam 2) and BHPW10 (Overburden Coal Seam 1 and Coal Seam 1) are high enough (more than 0.1) to be classified as acid generating. Combining this with the high sulphur content in these samples, it can be concluded that they can be classified as potentially acid generating.

In conclusion, 5 samples from BHPW03 (Coal Seam 1, Interburden Coal Seam 1&2, Coal Seam 2) and BHPW10 (Overburden Coal Seam 1 and Coal Seam 1) can be classified as potentially acid generating. Six samples from BHPW03 (Overburden Coal Seam 1, Underburden Coal Seam 2), BHPW10 (Underburden Coal Seam 1) and BHPW05 (Overburden Coal Seam 1, Coal Seam 1 and Underburden Coal Seam 1) can be classified as potentially acid neutralizing and thus non-acid generating. The criteria used were based on:

- Total Sulphur content (%S);
- Net Neutralization Potential (NNP);
- Neutralization Potential Ratio (NPR); and
- Net Acid Generation.

Table 4-7: Classification guidelines

	Potentially Acid generating	Uncertain/Marginal	Non-Acid Generating
Paste pH	<5.5	-	>5.5
NNP	<-20	-20 to 20	>20
NPR	<1	1 to 3	>3
S%	>0.3%	-	<0.3%
NAG	>0.1	-	<0.1

Table 4-8: Geochemical characterisation for KPSX: Weltevreden

Borehole	Sample ID	Total Sulphur, S %	Paste pH	Total Acidity Potential as $CaCO_3$ kg/tonne	Gross Neutralisation Potential as $CaCO_3$ kg/tonne	Net Neutralisation Potential as $CaCO_3$ kg/tonne (By Difference)	Neutralisation Potential Ratio (NP/AP)	Net Acid Generation as H_2SO kg/tonne (By Difference)	Classification
BHPW03	Overburden Coal Seam 1	0.02	8.8	0.62	31.2	30.6	50.3	<0.1	Non-acid generating
	Coal Seam 1	1.43	7.7	44.6	24.3	-20.3	0.5	25.7	Potentially Acid Generating
	Interburden Coal Seam 1&2	2.34	5.4	73	18.9	-54.1	0.3	17.1	Potentially Acid Generating
	Coal Seam 2	1.04	7.8	32.5	43.8	11.3	3.7	62.9	Potentially Acid Generating
	Underburden Coal Seam 2	0.42	8.3	13.1	22.3	9.2	1.7	<0.1	Low potential to non-acid generating
BHPW10	Overburden Coal Seam 1	0.39	6.6	12.2	1.97	-10.2	0.2	1.34	Potentially Acid Generating
	Coal Seam 1	1.4	7.4	43.7	51.3	7.6	1.2	22	Potentially Acid Generating
	Underburden Coal Seam 1	0.24	7.3	7.49	6.19	-1.3	0.8	<0.1	Non-acid generating
BHPW05	Overburden Coal Seam 1	0.08	7.3	2.5	12.1	9.6	4.8	<0.1	Non-acid generating
	Coal Seam 1	0.22	8.5	6.89	40.4	33.5	5.9	27.4	Non-acid generating
	Underburden Coal Seam 1	0.08	8.7	2.5	2.84	0.34	1.1	<0.1	Non-acid generating

No conclusive trend can be identified from the results of the geochemical analyses, with the results indicating five neutralising samples, five acid generating samples and one low potential to neutralising sample, with no particular preference to sample grouping.

Coal seams predominantly indicate an acid generating potential, with one sample (BHPW05) indicating a neutralising potential. Waste discard, overburden, interburden and underburden samples indicate acid generating potential to neutralising potential. Composite samples containing sandy quartzite typically indicate a neutralising potential for the project with two exceptions. BHPW03 (underburden sample) indicates a neutralising potential with no sandy quartzite identified, whilst BHPW10 (overburden sample) contains the sandy quartzite, but is classified as an acid generating sample. The composite samples with sandy quartzite indicated a neutralising potential even if the composite contains carbonaceous shale rock types; indicating there is a mineral contained within the sandy quartzite which is able to buffer the acid generating potential of these sampled units. The remaining BHPW03 interburden samples indicated an acid generating potential for a sandstone and carbonaceous shale composite.

Sampling was limited to three boreholes from the five newly drilled boreholes. The two boreholes which were not sampled intersected overburden and dolerite dyke or sill rock types which are not representative of the mining area. It is recommended that additional samples be taken from the project area, preferably from the planned pit areas to provide a more complete understanding of the site conditions. It is also recommended that 20 week kinetic testing of waste and potential discard material be conducted, as well as simulation of backfilling and stockpiling discard sequences to determine the long term buffering potential for the project.

4.5.2 Waste Classification

According to the new National Environmental Management: Waste Act (NEM: WA) 2008 (Act 59 of 2008) all waste that will be disposed of or stored needs to undergo a waste classification through the testing of the material by means of specified leachate procedures.

The waste rock and coal material from the Weltevreden pit will be stored on site and according to the NEM: WA guidelines needs to be classified. The material will be mono-disposed and thus distilled water leachate tests were performed with both the total concentrations (TC) and leachable concentrations (LC) in the abstraction method results classed against the total concentration threshold (TCT) and leachable concentration threshold (LCT) as given by the guidelines.

The LCT and TCT thresholds are used to class the waste type and determine the guidelines for liner requirements. Four (4) coal samples and two (2) waste rock samples were sent for distilled water abstractions and classed against the threshold values with the following outcomes as also given in Table 4-10 and Table 4-11.

Table 4-9: Summary of Waste Classification Summary

Classification	BHPW03 (CS1)	BHPW03 (CS2)	BHPW10 (CS1)	BHPW5 (CS1)	BHPW OB	BHPW IB
TC	TC≤TCT0	TC≤TCT0	TC≤TCT0	TCT0<TC<TCT1	TCT0<TC<TCT1	TCT0<TC<TCT1
LC	LCT0<TC<LCT1	LCT0<TC<LCT1	LCT0<TC<LCT1	LCT0<TC<LCT1	LCT0<TC<LCT1	LCT0<TC<LCT1
Waste Type	**Type 3**	**Type 3**	**Type 3**	**Type 3**	**Type 3**	**Type 3**

From the above classification the following can be concluded:

- Coal material (Samples BHPW03 CS1 and CS2, BHPW10 CS1 and BHPW5 CS1):
  - All four (4) the coal samples were classed as Type 3 waste (hazardous) and according to the NEM: WA guidelines should be disposed of at a Class C landfill site or a site designed with the liner requirements as shown in Figure 4-12; and
  - Although the all of the coal samples were classed as Type 3 waste the short term storage of the coal material on stockpiles and good storm water management should ensure that environmental impacts are kept to a minimum and contained to the stockpile sites. Based on these management protocols the liner illustrated in Figure 4-13 should be sufficient, however the decision lies with the Department of Environmental Affairs.

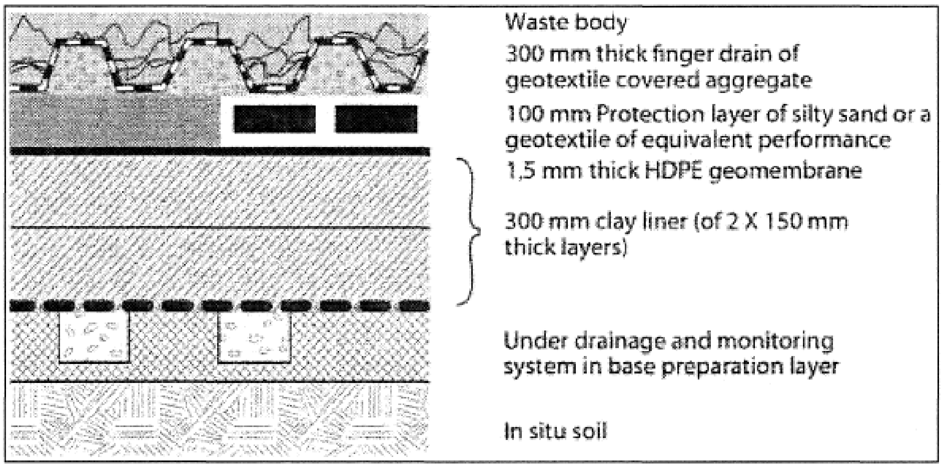

Figure 4-12: Class C landfill site liner requirements

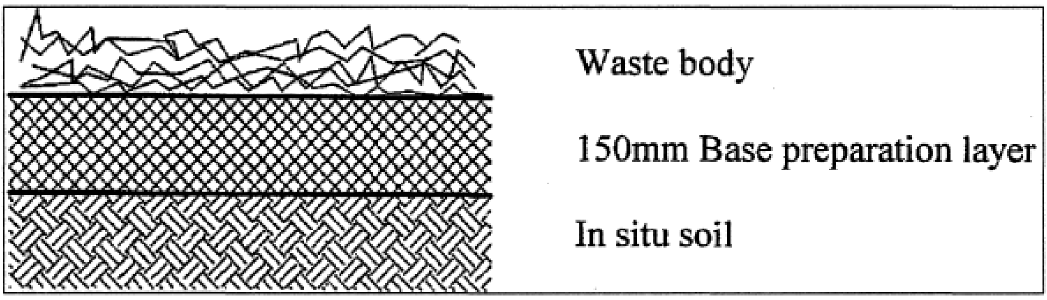

Figure 4-13: Class D landfill site liner requirements

- Waste rock material (Samples BHPW OB and IB):
  - Both waste rock samples were classed as Type 3 waste and should be disposed of at Class C landfill sites or sites designed with liner requirements illustrated in Figure 4-12.

Table 4-10: Total Concentration Thresholds and Classification

Element	TCT0	TCT1	TCT2	BHPW03 (CS1)	BHPW03 (CS2)	BHPW10 (CS1)	BHPW5 (CS1)	BHPW OB	BHPW IB
As	**5.8**	**500**	**2000**	3.6	1.5	2.1	5.7	1.4	5.9
B	**150**	**15000**	**60000**	99	89	87	79	103	122
Cd	**7.5**	**260**	**1040**	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Co	**50**	**5000**	**20000**	2.8	4.2	4.4	2.7	9.8	11
Cu	**16**	**19500**	**78000**	4.8	12.3	9.8	18.3	19	28
Hg	**0.93**	**160**	**640**	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Mo	**40**	**1000**	**4000**	1.2	0.43	0.38	<0.100	0.49	0.23
Ni	**91**	**10600**	**42400**	0.67	3.8	4.5	8.9	16	19.8
Pb	**20**	**1900**	**7600**	5.7	8.7	8.8	17.1	12.3	15.9
Sb	**10**	**75**	**300**	<1.000	<1.000	<1.000	<1.000	<1.000	<1.000
Se	**10**	**50**	**200**	<3.000	<3.000	<3.000	<3.000	<3.000	<3.000
V	**150**	**2680**	**10720**	13.5	27	20	24	45	66

Table 4-11: Leachable Concentration Thresholds and Classification

Element	LCT0	LCT1	LCT2	LCT3	BHPW03 (CS1)	BHPW03 (CS2)	BHPW10 (CS1)	BHPW5 (CS1)	BHPW OB	BHPW IB
As	**0.01**	**0.5**	**1**	**4**	<0.020	0.02	<0.020	<0.020	<0.020	0.02
B	**0.5**	**25**	**50**	**200**	0.54	0.62	0.59	0.69	0.66	0.68
Ba	**0.7**	**35**	**70**	**280**	0.11	0.15	0.12	1.1	0.16	0.1
Cd	**0.003**	**0.15**	**0.3**	**1.2**	0.007	0.004	0.005	0.006	0.004	0.005
Co	**0.5**	**25**	**50**	**200**	0.004	0.002	0.004	0.003	0.01	0.06
Cr	**0.1**	**5**	**10**	**40**	0.004	<0.003	<0.003	<0.003	<0.003	<0.003
Cu	**2**	**100**	**200**	**800**	0.009	0.008	0.009	0.009	0.008	0.009
Hg	**0.006**	**0.3**	**0.6**	**2.4**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mn	**0.5**	**25**	**50**	**200**	0.28	0.04	0.28	0.004	0.22	1.9
Mo	**0.07**	**3.5**	**7**	**28**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ni	**0.07**	**3.5**	**7**	**28**	<0.003	<0.003	<0.003	<0.003	<0.003	0.06
Pb	**0.01**	**0.5**	**1**	**4**	0.01	<0.010	<0.010	<0.010	<0.010	<0.010
Sb	**0.02**	**1**	**2**	**8**	<0.010	<0.010	<0.010	0.04	0.04	<0.010
Se	**0.01**	**0.5**	**1**	**4**	<0.030	0.04	<0.030	<0.030	<0.030	<0.030
V	**0.2**	**10**	**20**	**80**	<0.002	<0.002	<0.002	0.004	<0.002	<0.002
Zn	**5**	**250**	**500**	**2000**	0.03	0.01	0.03	0.02	0.02	0.06
Cl	**300**	**15000**	**30000**	**120000**	0.4	0.4	0.5	0.5	1.3	0.9
SO4	**250**	**12500**	**25000**	**100000**	267	121	270	4.6	93	284
F	**1.5**	**75**	**150**	**600**	<0.1	0.2	0.1	0.6	0.2	0.1

5 Conceptual Groundwater Model

5.1 Groundwater Sources

There are two types of sources which relate to the hydrogeological environment, namely:

- Sources of recharge; and
- Sources of contamination.

Both types of sources can have a natural or artificial (anthropogenic) origin. There are various anthropogenic processes which contribute to or effect groundwater environments, which can either provide benefits to the system, but more often are detrimental in nature.

5.1.1 Sources of recharge

5.1.1.1 Natural Contributions

There are currently no opencast mining activities taking place on the proposed KPSX: Weltevreden project area and therefore under current conditions the sources of recharge will be restricted to natural contributors. Historically, coal was mined by underground methods just south of the Minnaar Settlement, the location of which is presented on the infrastructure plan (Plan 4, Appendix A).

Precipitation is the main natural contributor to groundwater recharge. Recharge potential from precipitation is site dependant, relying on various variables such as quantity of precipitation, presence of fractures, permeability of lithologies, soil cover, vegetation cover, topographic slope and depth to the water table. Recharge contributions from precipitation are discussed under Section 2.2 and are estimated at between 7.95 to 23.85 mm/a.

Drainage systems can also be considered as potential recharge sources, depending on the characteristics of the river systems. River systems can be identified as losing, gaining or disconnected types of systems, which describes whether surface water in the river is lost (losing) via seepage to-, or gained (gaining) via seepage from- the groundwater environment. If there is no interaction between surface water and groundwater systems then the river is defined as disconnected. It is possible that a river system can vary between gaining and losing with seasonal changes.

The main drainage streams for the quaternary catchments occur outside the project boundary. Within the project boundary drainage occurs via non-perennial tributaries with the exception of the upper reach of the Grootspruit perennial river. It is unclear what contribution to recharge these tributaries give to the groundwater system, if any.

5.1.1.2 Artificial Contributions

Artificial sources of recharge will become a contributing factor once mining commences, and will occur as seepage from open mine voids, water storage dams (PCD), stockpiles (temporary or permanent) and backfilled opencast pits. Typically disturbed material stored above ground as stockpiles has the potential to raise the water level underlying stockpile material. This is achieved by increased recharge potential through the loosely packed stockpile material contributing to increased infiltration and seepage to the water table. The recharge potential of backfilled opencast voids is artificially increased in the same way, as a result of the backfilled material being less compact than the surrounding lithologies. Opencast pits expose the underlying aquifers directly to recharge contributors (precipitation, in-pit water sumps) which can result in 100% direct recharge to aquifers.

Although mining has not yet commenced at KPSX: Weltevreden, the area surrounding the project contains multiple operating opencast mines, where artificial recharge is most likely taking place already. The influence of artificial recharge from these operating mines on the planned KPSX: Weltevreden project could potentially be a contributing factor for this project.

5.1.2 Sources of Contamination

5.1.2.1 Artificial Contributions

The Witbank Coalfield has a long history of coal exploitation via mining, processing and power generation activities, which will contribute to regional sources of contamination. There are currently no mining activities on the KPSX: Weltevreden project area. However, once mining operations commence, seepage from the PCD, stockpiles (emergency coal, overburden and topsoil), as well as infrastructure (fuel storage) and work (tipping) areas, will become the main sources of contamination.

The geochemical assessment for the KPSX: Weltevreden project has been discussed under Section 4.5. The results of the geochemical evaluation indicate no specific trend in neutralising or acid generating potential of the sampled rock types. The coal seams are predominantly acid generating, whilst the overburden, interburden and underburden samples return results ranging from the potential to neutralise, to acid generating. Long term (20 week) kinetic tests are required to determine the long term acid generating or neutralising potential for the local geological units.

5.2 Aquifer (Pathway) Characterisation

The geological and hydrogeological environment for the project area is described in Section 2.5 and 2.6 respectively.

The aquifers were identified as low yielding during the drilling programme and confirmed by slug tests during the aquifer testing programme. Refer to Table 4-5 for the interpreted results. Slug tests provide an estimate for the hydraulic conductivity in the vicinity of the borehole being tested.

The hydraulic conductivity ranged from 0.053 to 0.348 m/d, with a fracture hydraulic conductivity ranging from 0.003 to 0.045 m/d. This indicates that seepage is the main contributor of water to the tested boreholes. The hydraulic conductivity results confirm that the aquifer is low yielding which will restrict the migration of contamination from the sources or limit the cone of dewatering to the vicinity of the pit, unless a fracture of significance is identified in these areas.

Although no significant fractures were intersected during the drilling programme, fractures are the main groundwater pathway for the fractured Karoo aquifers. Hydrogeological assessments for monitoring locations around contamination sources are required to confirm and monitor potential pathways allowing the migration of contaminants. Observation of structures within the exposed pit must be followed up by additional hydrogeological assessments to characterise the potential for groundwater contamination from the pit or groundwater supply to the pit.

5.3 Groundwater Receptors

Receptors are described as both receivers of groundwater and contamination, as contaminants are transported by groundwater via geological pathways to reach the receptor.

5.3.1 River Systems

As mentioned in Section 5.1.1.1, river systems can be gaining systems where groundwater contributes to the base flow of the river. In this case influencing the groundwater quality and quantity will have an effect on the surface water system, by increasing or decreasing water supply and/or causing the deterioration of water quality by contamination.

5.3.2 Private Boreholes

Private boreholes active within the area of influence around the project are considered as receptors. The numerical model will provide a prediction as to the extent of the drawdown cone and development of the contamination plume over time to assist with managing the impacts on private boreholes, with regards to:

- If boreholes are present within the cone of drawdown created by dewatering the mine workings there is the potential that the water supply drawn from the boreholes will cease as a result of the lowering of the water table; and
- If the boreholes are located nearby, downstream or are connected via fracture systems to sources of contamination, there is a possibility that these sites will become affected by the sources of contamination.

Monitoring of groundwater levels and qualities around these sites are required and should begin at least one year prior to the commencement of mining operations to establish a strong baseline reference for future comparisons.

Eight boreholes are located within the proposed pit BD boundary, identified as WELBH02, WELBH03, WELBH04, WELBH05, WELBH06, WELBH07, WELBH27 and WELBH28. It is recommended that they be sampled for water quality and groundwater depth prior to the commencement of mining to establish if they are connected to the underlying pre-Karoo aquifers potentially forming a link for contamination to migrate.

5.3.3 Proposed Pit

The proposed pit at KPSX: Weltevreden will only be considered a receptor once mining operations commence with dewatering activities. Dewatering of the pit will draw water from the surrounding groundwater environment towards the pit, reversing the flow direction in some cases. In terms of contamination in the vicinity of the pit, this can be seen as a potential benefit, with flow towards the pit assisting to restrict the migration of the contamination plume. However, this would result in an increased volume of groundwater being received by the pit.

6 Numerical Groundwater Model

The model was developed using 134,316 elements with 135,692 simulation nodes over a domain covering an area of 1,289 km^2. This domain was discretized into a finite element network with areas of varying sizes defined by the local hydrogeology. The quantities of obtuse angled triangles, as well as triangles which violate the Delaunay Criteria were limited to less than 10% of the total number of elements. This results in increased stability of the model and increases the accuracy of the simulations.

6.1 Model Limitations

A numerical groundwater flow model is a mathematical approximation of the actual groundwater conditions identified for a project area, of which a time stepping procedure is used to model the behaviour of the project system over time. Not all project conditions are known or can be represented by the model and therefore certain limitations and assumptions are defined to provide the best fit solution of the simulated data to the actual project conditions. The limitations and assumptions include:

- The Ogies Dyke was modelled as an impermeable linear zone with a low storativity value. The Ogies Dyke was modelled across the extent of the model domain, however the true extent and hydraulic conditions of the dyke are unknown;
- The dolerite sill to the west of the KPSX: Weltevreden was not included into the numerical model as a result of limited understanding on the thickness and aerial extent of the sill. The presence of this sill could have potential negative and positive implications for the project:

- Positive implication: the sill will act as an impermeable boundary to the project, limiting the potential inflow into the proposed pit and restricting the migration of the contamination plume, providing there are no fractures to act as preferred pathways;
- Negative implication: If the dolerite sill contains fractures, there is a potential for additional groundwater to be drawn towards the pit (depending on the yield of the fractures) and provide preferred pathways for contamination to spread;

- Dewatering operations were not incorporated into the base model for calibration purposes, thereby representing a system with no stresses to the aquifers (system was in equilibrium – steady state);
- After calibration the proposed pits where included into the model as drains;
- The local drainages were constrained so that seepage from the rivers to the groundwater system did not occur;
- During the transient model simulations relating to the dewatering cone and contamination plume migrations were simulated from the proposed pit and stockpile locations. Groundwater drawdowns associated with active groundwater users in the project vicinity were not simulated;
- A conservative approach was used to define modelling assumptions and referenced values used in the model so that the groundwater inflow and discharges to the proposed pits are overestimated; and
- The base of the model was assumed to be impermeable and therefore the depth of the layer was selected to be of sufficient depth so as to influence the simulated dewatering volumes.
  - The model was constructed with one layer representing 130 m in vertical thickness.

6.2 Model Design and Steady State Modelling Parameters

6.2.1 Model Boundaries

The edge of the model domain is represented by initial boundary conditions through which the response of the simulation is controlled. Boundaries can represent fluxes into or out of the model domain as well as constant heads. Model boundaries are selected (Plan 10, Appendix A) to represent a distance where the expected radius of influence of the project will not influence the conditions of the boundary, and are identified as follows:

- South eastern boundary: Identified as the watershed between quaternary catchments B11F and B11E and was set as a no flow boundary conditions;
- South west to Western boundary: Identified as the Wilger River. Boundary is set as a constant head outflow boundary (Dirichlet condition);
- Northern boundary: Identified as tributaries to the Wilger, Olifants and Saalboomspruit Rivers and set as an outflow constant head boundary (Dirichlet condition); and
- Eastern boundary: Identified as variations between tributaries to the Olifants River and surface water divides and represented as a combination of outflow and no flow boundary conditions (Dirichlet condition).

6.2.2 Recharge

Recharge estimates (discussed under Section 2.3 and Section 5.1.1) were used as initial estimates to the groundwater system. The recharge volumes were recalibrated in conjunction with the hydraulic conductivities for a better correlation. The model setup was tested through an iterative process which indicates 3% of mean annual precipitation is reasonable for the project area.

6.2.3 Hydraulic Conductivities

Field investigations provided the range of hydraulic conductivity values (discussed under Section 4.4 and Section 5.2) used to simulate sensitivity scenarios to obtain the best fit for the data during the calibration process.

6.2.4 Storativity / Storage Coefficient

Aquifer (slug) testing of the boreholes provided no information on the storativity values for the project area. A range of values were assumed and compared with similar hydrogeological settings from other studies. The assumed values indicate a storativity for a fractured aquifer to range from 0.001 to 0.005 and 0.01 to 0.05 for alluvial aquifers.

6.2.5 Drainage systems

River (drainage) systems were assigned constant head values to allow the rivers to receive baseflow from the groundwater environment during the model simulations. The constant head values were defined as the topographical elevations for the same locations along the river system. The constant head nodes representing the river system were held as constant throughout steady-state simulations so water would only drain from the aquifer towards the river systems. This configuration restricts flow conditions from reversing, so that water will not drain from the river systems to the aquifer.

6.3 Calibration

The steady state model was calibrated through an iterative process by adjusting recharge and hydraulic conductivity values until simulated heads indicated a reasonable correlation to the measured heads of 37 boreholes. The measured groundwater levels from the 2014 hydrocensus provided the measured head reference values for the 37 boreholes. The boreholes used to calibrate the model are provided on Plan 10 (Appendix A), whilst the initial calibrated hydraulic heads are present on Plan 11 (Appendix A).

The hydraulic conductivity values used for the calibration of the model domain vary between 0.0259 to 0.0382 m/d. The Ogies Dyke was represented with a value of $8.64e^{-6}$ m/d. The recharge volumes were recalibrated in conjunction with the hydraulic conductivities for a better correlation. The model setup was tested through an iterative process which indicates 3% of mean annual precipitation is reasonable for the project area.

The adequacy of the model calibration was assessed by determining the difference between the simulated and measured heads for each borehole (Figure 6-1), as defined by the following mathematical expressions:

- Mean error (ME): mean difference between the measured and simulated water levels;
- Mean absolute error (MAE): used to measure accuracy of simulate values to the measured outcomes, defined as an average of the absolute errors; and
- Root mean square error (RMSE): used to represent the sample standard deviation of the differences between simulated and measured values.

The RMSE expression is the method used most often in the industry to assess the adequacy of the calibrated model, as the differences between the measured and simulated water levels are normalised across the model domain. This method was used for this model calibration assessment.

The ME and MAE expressions are also calculated for this calibration assessment. However, the results from the ME and MAE expression don't often give a good indication of the calibration adequacy as a result of positive and negative values cancelling each other out.

For the steady state calibration assessment, the RMSE expression resulted in an error of 5.67%. The threshold error percentage of a well calibrated model is 10%. ME returned a result of 2.38% whilst the MAE expression achieved 8.27%. The calibration of the steady state model was within acceptable limits.

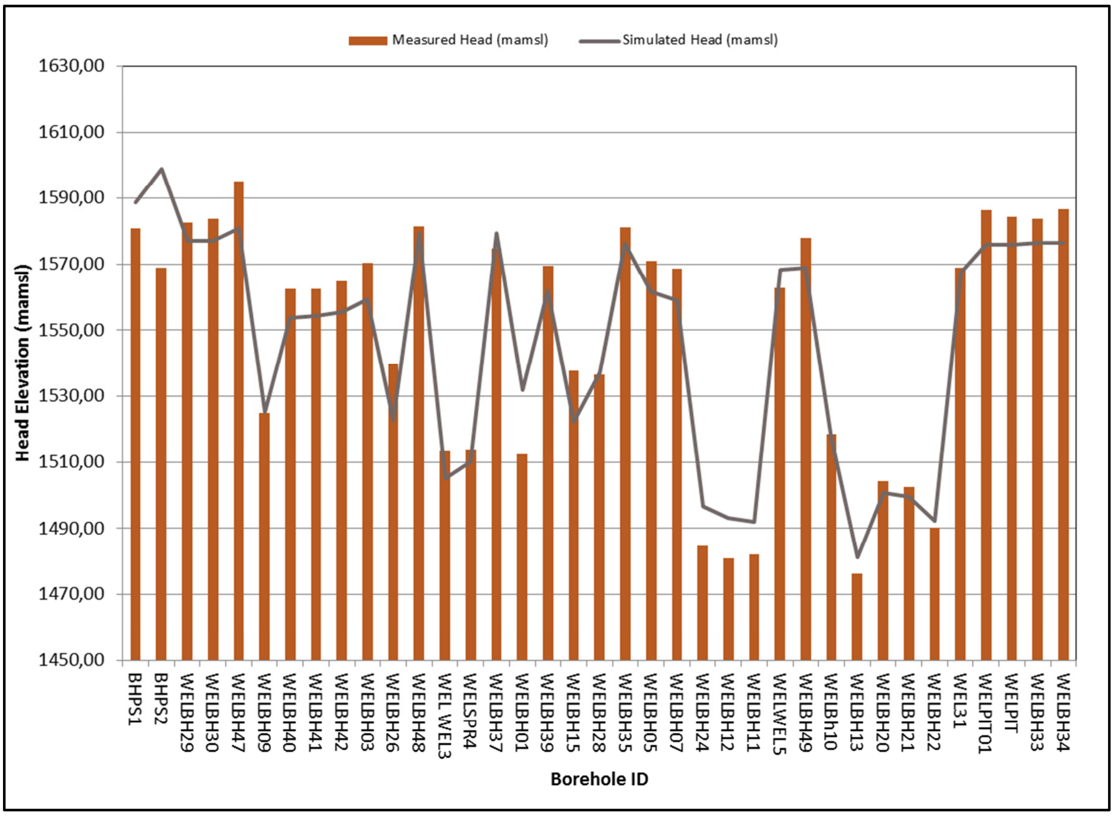

Figure 6-1: Graph indicating measured and simulated head for calibration checks

6.4 Predictive Simulations

The calibrated steady state model was used as base for the transient simulations. Transient simulations are used to introduce the activities and impacts that mining operations will have on the modelled domain. Transient simulations account for time dependent variables (recharge and storativity), as well as steady state variables which vary over a finite period of time.

Three simulations were run to represent the life of mine schedule of 22 years (Plan 9, Appendix A), and included:

- Simulation 1: Mine Dewatering;
- Simulation 2: Contaminant transport; and
- Simulation 3: Post operational decant and contaminant transport.

6.4.1 Simulation 1: Mine Dewatering

The life of mine plan was captured into the model via the X, Y and Z co-ordinates of the proposed pit for each successive mine period.

The modelled radius of influence (ROI) indicates drawdown of up to 100 m were simulated inside the pit decreasing to 0 m as the ROI moves away from the proposed pit footprint. The ROI extends for a maximum distance of 1.2 km away from the pit, based on the current model setup and available information. The simulated ROI did not extend to the modelled boundaries.

Table 6-1 lists the affected properties, whilst Plan 12, Plan 13 and Plan 14 (Appendix A) represent the development of the ROI over a 7, 14 and 22 year period, respectively. Plan 4 and Plan 9 (Appendix A) represent the infrastructure and life of mine plan for the project.

Table 6-1: Affected properties from the dewatering simulation

Property	Maximum simulated drawdown (m)	Number of identified boreholes in Radius of Influence	Potential Impact Rating
Tweefontein 328 JS	100	0	High
Wildebeestfontein 327 IS	100	0	High
Grootpan 7 IS	20	0	Low
Oogiesfontein 4 IS	10	0	Low

Dewatering volumes are simulated as a function of the mine schedule and groundwater levels in close proximity thereto. Simulating the proposed pit as a simple drain, with no dewatering wells applied, a peak of 70 L/s or 6,000 m^3/d is achieved within 12 years of operation. Simulated inflows for the life of mine are provided in Figure 6-2 and Table 6-2.

Table 6-2: Expected inflow volumes into the proposed pit

Year	Days	Inflow Volume	
		m^3/d	L/s
0	0	0	0
1	360	327	4
2	720	655	8
3	1080	2117	24

Year	Days	Inflow Volume	
		m^3/d	L/s
4	1440	2860	33
5	1880	3527	41
6	2160	4068	47
7	2520	3371	39
8	2880	2674	31
9	3240	4711	55
10	3600	5181	60
11	3960	5583	65
12	4320	6009	70
13	4680	5274	61
14	5040	4539	53
15	5400	4088	47
16	5760	3863	45
17	6120	3924	45
18	6480	2667	31
19	6840	2256	26
20	7200	1846	21
21	7560	5329	62
22	7920	5655	65
23	8280	6045	70

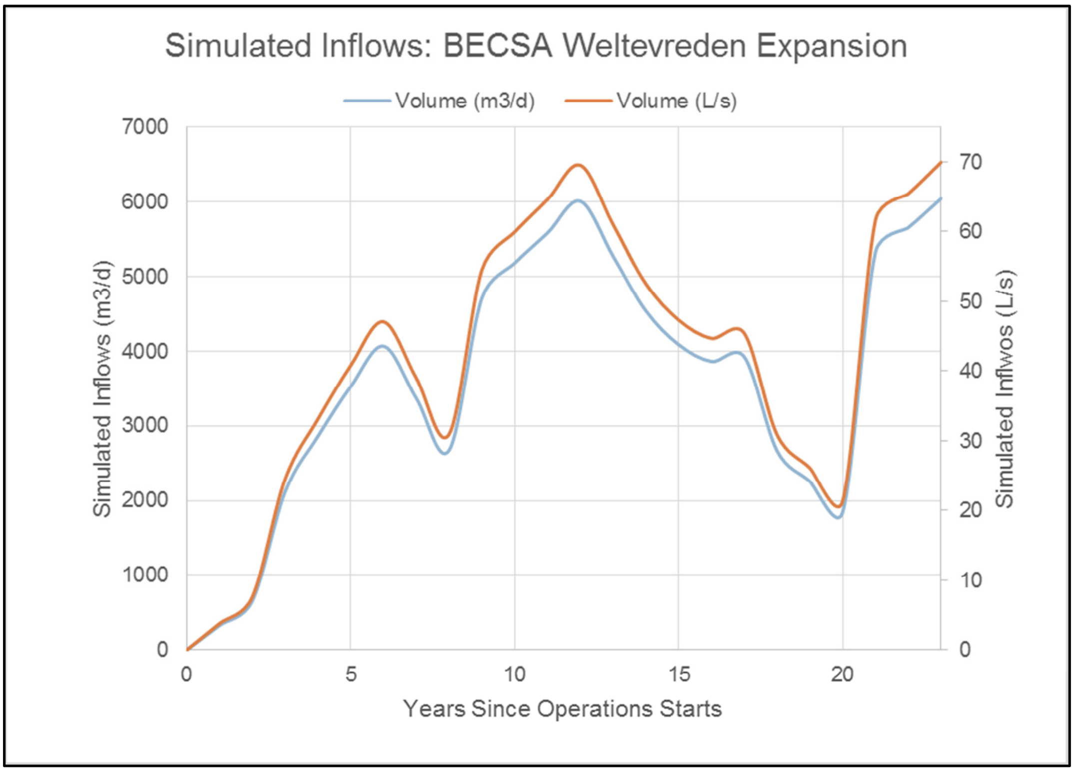

Figure 6-2: Simulated inflows for KPSX: Weltevreden

6.4.2 Simulation 2: Contaminant Transport

A source of contamination was simulated from the various waste stockpiles located around the project area. Sulphate (SO_4) was used to simulate the migration of contaminants into the underlying hydrogeological system. Sulphate is a conservative element commonly associated with AMD and leachate from coal mining operations. From the hydrocensus data the average SO_4 concentration in the groundwater is 380 mg/L. For the purposes of the model, SO_4 was simulated at a concentration of 1,895 mg/L based on the leachate associated with the waste stockpiles (1,895 mg/L was selected based on previous studies in similar hydrogeological settings). Sulphate leachate was simulated with a linearly increasing trend for the 22 years of the LoM. The waste stockpiles were assigned a flux to simulate the increased recharge expected over this facility.

Contaminant transport is largely controlled by the porosity of the local geological units, where increases in porosity correspond to decreasing velocities. Geological structures (i.e. faults and fractures) create preferential flow paths, increasing the potential for contaminant migration. No significant fractures were identified during the field investigation and therefore all units were assigned a porosity value of 3%. This porosity figure is a conservative value based on similar hydrogeological studies in the same geological setting. Increasing the porosity beyond 3% would result in slower transportation simulations.

The contamination plume after 22 years is given as Plan 15 (Appendix A). The proposed pit will act as a sink drawing the contamination plume towards the pit as a result of the change in hydraulic head created by dewatering activities. The contamination plume is expected to migrate in all directions from the stockpiles as a result of advection, dispersion and diffusion transport methods and therefore monitoring of the contamination plume between the waste stockpile and Phola Township and nearby drainage systems is required. Monitoring will act as an early warning indicator so that corrective and/ or treatment options can be investigated prior to impacts on the Phola Township and drainage streams are realised.

Active private boreholes in the vicinity of the mine and projected contamination plume, could draw the plume towards the borehole through the development of its cone of drawdown.

6.4.3 Simulation 3: Post Operational Decant and Contaminant Transport

This simulation models the potential influences of mining after the LoM, to 100 years post closure. The proposed pit will be backfilled concurrently to mining operations. As a result of mining, the rehabilitated pit area will be less compact than the surrounding undisturbed geological units. As a result the hydraulic conductivities and recharge rate over the rehabilitated pit will be considerably higher than the undisturbed geological units.

6.4.3.1 Contamination Transport

The backfilled pit will become a potential source of contamination as backfilling commences and as such the proposed pit was assigned as a point source to simulate contaminant migration and groundwater flow for 100 years after closure (Plan 16, Appendix A).

- Once natural groundwater levels recover to the pre-mining levels in the vicinity of the pit, original advection flow paths will be restored, pulling the contamination plume towards the main drainage systems to the north and west of the project;
  - Based on the current model setup and information, after 100 years the maximum extent of the contamination plume is approximately 2 km;
  - The monitoring network should focus between the Phola Township and drainage systems to the west, north and north-eastern portions of the project area;

- Active private boreholes in the vicinity of the mine and projected contamination plume could draw the plume towards the borehole through the development of its cone of drawdown;

6.4.3.2 Decant

Decant occurs when a mine void or a backfilled mine void is filled with groundwater to an elevation where the groundwater will discharge onto the surface or into the high hydraulic conductivity zone. In an opencast coal mining environment decanting onto surface will occur at the lowest surface elevation that is located within the mined out area. The time-to-decant is determined by the following factors:

- The total mined volume: the larger the mine void, the more water is required to fill the pit to the decant elevation, which will lead to an increase in the time-to-decant;
- The porosity of the backfill material: an increase in the porosity of the backfill material will lead to an increase in the void space, which will ultimately lead to an increase in the volume of water required to fill the pit to its decant elevation;
- Recharge to the backfilled mine void: an increase in recharge will lead to a decrease in the time-to-decant of a mine void;
- Geometry of the surface: decant onto surface will always occur at the lowest surface elevation that is intersected by the pit boundary. The distance between the lowest surface elevation and the pit floor elevation will therefore influence the time-to-decant, as a decrease in the distance will lead to a decrease in the time-to-decant and vice-versa.

The decant rate is determined by the following factors:

- Mean annual rainfall: an increase in the annual rainfall will lead to an increase in decant volumes, simply because more water enters the mined area; either via aquifers / preferred groundwater flow paths or surface water flow;
- The recharge percentage to a backfilled opencast pit: an increase in the effective recharge to a backfilled opencast pit will lead to an increase in decant volumes;
- The size of the disturbed surface area: an increase in the size of the surface area disturbed by opencast mining will lead to an increase in the effective recharge to the backfilled opencast pit; and
- The hydraulic conductivity of the weathered aquifer (in case of decant into weathered zone): the higher the hydraulic conductivity of the weathered zone, the higher the decant rate though the weathered aquifer.

6.4.3.2.1 Storage and Decant Point

Water level rise and inflows during the post-closure period in any backfilled pit is a function of only two features:

- The total recharge to the pit (i.e. the sum of rain-fed recharge and any head-dependent inflows from adjoining aquifers), and
- The distribution of storage capacity within the pit.

Plan 17 shows the pit BD S1 floor contours. The coal floor dips from the south west to the north east. The lowest elevation of the coal floor is 1446 mamsl. The pit surface elevation contours in Plan 18 depicts that decant point is located in the extreme north-eastern boundary of the pit. The coordinates of the potential decant is:

- X: 9096 m
- Y: -2872706 m; and
- Z: 1514 mamsl

It therefore means that the water level in the pit would have to rise by 68 m before decant occurs. A stage curve for the pit is given in Figure 6-3. A stage curve provides an indication of the volume of water plotted against elevation.

It is assumed that water in pit BD will be contained in the spoil. An estimated 25% capacity to contain water in the pores between the rocks, gravel and finer material has been used for calculations. This percentage has been estimated from the swell factor of spoil, before and after mining (Hodgson, 1998). Hence the volume of the void occupied by water in the pit will depend on the water level within the pit, backfill porosity, and the coal seam floor. With a 25 % void space, there will be 132 Mm^3 of space available to store water at the decant elevation.

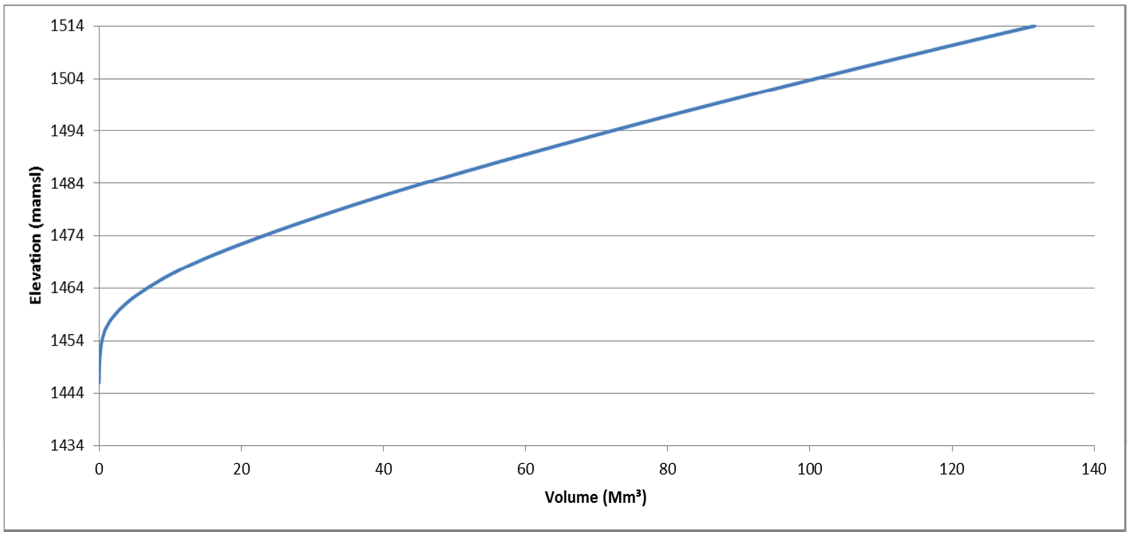

Figure 6-3: Stage curve for water holding capacity in pit BD

6.4.3.2.2 Decant Rate and Time to Decant

It is estimated that the recharge to the backfilled and rehabilitated pit will be in the order of 12-15 % of MAP. With a MAP of 750 mm/a and a pit area of 14502425 m^2, this translates to a recharge rate of between 3576 m^3/d and 4470 m^3/d. It is highly likely that during decant, the pit water level would be in equilibrium with the surrounding aquifers and therefore inflows from the groundwater system to the pit would be negligible. The only inflow to the pit would be from recharge, and thus decant rate will equal the recharge rate. A decant rate of between 3576 m^3/d and 4470 m^3/d is therefore estimated for pit BD.

In terms of the time to decant, the inflow from the surrounding aquifer during water level recovery was estimated analytically. The Dupuit-Forchheimer approximation (McWhorter and Sunada 1977) was used to account for change in saturated thickness due to recoevery of the water level. The following equation applies:

$$(1) h_o = \sqrt{h_p^2 + \frac{W}{K_{h1}}\left[r_o^2 Ln\left(\frac{r_o}{r_p}\right) - \frac{(r_0^2 - r_p^2)}{2}\right]}$$

- h_o is the decant water level above the pit floor;
- W is the distributed recharge (2% of MAP);
- r_p is the effective pit radius,
- h_p is the water level above the pit floor at r_p (changes as water level rises)

- r_o is the radius of influence (maximum extent of the cone of depression)
- K_{h1} is the horizontal hydraulic conductivity (Geometric Mean of 0.088 m/d)

Given input values of W, K_{h1}, r_p, h_p and h_o, the radius of influence (ro) was determined from Equation (1) by iteration. Once ro was determined, the pit inflow from the aquifer (Q) was computed by:

$$\text{(2) } Q = W\pi\left(r_o^2 - r_p^2\right)$$

The time to decant was evaluated from the relationship between the inflow rate and void space (after Johnson, 1985), as given below:

$$Time = \frac{Mined\ out\ Volume\ (M^3)}{Inflow\ Rate\ (M^3/D)}$$

The time to decant is given in Table 6-3 and Table 6-4. As indicated, it would take 23019 days (63 years) for pit BD to decant with a recharge rate of 12 % MAP, and 19826 days (54 years) with a recharge rate of 15 % MAP.

Table 6-3: Time to decant with recharge at 12% of Map

Water Level (mamsl)	Pit Volume with Backfill (25 % Porosity) m^3	Water Level Rise (m)	Change in Storage (m^3)	Inflow from Aquifers (m^3/d)	Recharge (m^3/d)	Total Inflow (m^3/d)	Cumulative Time (Days)
1446	0	0		3399	3576	6975	
1447	9592	1	9592	3397	3576	6973	1
1448	23250	2	13658	3395	3576	6971	3
1449	45600	3	22349	3392	3576	6968	7
1450	73178	4	27578	3389	3576	6965	10
1451	119235	5	46056	3388	3576	6964	17
1452	172009	6	52775	3381	3576	6957	25
1453	266560	7	94551	3376	3576	6952	38
1454	378224	8	111664	3370	3576	6946	54
1455	571835	9	193611	3363	3576	6939	82
1456	799205	10	227370	3352	3576	6928	115
1457	1183497	11	384292	3343	3576	6919	170
1458	1629328	12	445831	3336	3576	6911	235
1459	2239214	13	609886	3323	3576	6899	323
1460	2888675	14	649461	3309	3576	6885	417
1461	3708294	15	819619	3297	3576	6873	536
1462	4573733	16	865439	3283	3576	6859	662
1463	5622019	17	1048287	3271	3576	6847	815
1464	6721617	18	1099598	3253	3576	6829	976
1465	7932731	19	1211114	3237	3576	6813	1153
1466	9180743	20	1248012	3223	3576	6799	1336
1467	10592283	21	1411541	3203	3576	6779	1544
1468	12051201	22	1458918	3177	3576	6752	1759

Water Level (mamsl)	Pit Volume with Backfill (25 % Porosity) m^3	Water Level Rise (m)	Change in Storage (m^3)	Inflow from Aquifers (m^3/d)	Recharge (m^3/d)	Total Inflow (m^3/d)	Cumulative Time (Days)
1469	13683031	23	1631830	3159	3576	6735	2001
1470	15363902	24	1680870	3136	3576	6712	2250
1471	17203298	25	1839397	3114	3576	6690	2524
1472	19076669	26	1873371	3093	3576	6669	2804
1473	21042365	27	1965696	3065	3576	6641	3099
1474	23033451	28	1991087	3038	3576	6614	3399
1475	25104742	29	2071291	3012	3576	6588	3712
1476	27203421	30	2098679	2987	3576	6563	4031
1477	29373362	31	2169942	2953	3576	6529	4361
1478	31558601	32	2185239	2919	3576	6495	4696
1479	33805293	33	2246692	2896	3576	6472	5042
1480	36068481	34	2263188	2863	3576	6439	5392
1481	38398695	35	2330214	2830	3576	6406	5753
1482	40746419	36	2347724	2797	3576	6373	6120
1483	43179998	37	2433579	2757	3576	6333	6502
1484	45638970	38	2458972	2721	3576	6297	6890
1485	48162501	39	2523532	2674	3576	6250	7291
1486	50706332	40	2543831	2639	3576	6215	7698
1487	53298921	41	2592589	2594	3576	6170	8115
1488	55905657	42	2606736	2555	3576	6131	8538
1489	58550434	43	2644777	2508	3576	6084	8969
1490	61205625	44	2655192	2464	3576	6040	9405
1491	63892129	45	2686504	2414	3576	5990	9850
1492	66590958	46	2698830	2369	3576	5945	10301

Water Level (mamsl)	Pit Volume with Backfill (25 % Porosity) m^3	Water Level Rise (m)	Change in Storage (m^3)	Inflow from Aquifers (m^3/d)	Recharge (m^3/d)	Total Inflow (m^3/d)	Cumulative Time (Days)
1493	69321459	47	2730501	2312	3576	5888	10760
1494	72065269	48	2743810	2262	3576	5838	11226
1495	74838279	49	2773010	2205	3576	5781	11701
1496	77626340	50	2788061	2150	3576	5726	12183
1497	80447900	51	2821560	2089	3576	5664	12676
1498	83287114	52	2839214	2028	3576	5604	13177
1499	86163897	53	2876783	1962	3576	5538	13691
1500	89055159	54	2891263	1899	3576	5475	14213
1501	91977789	55	2922630	1823	3576	5398	14747
1502	94908560	56	2930771	1753	3576	5328	15289
1503	97866810	57	2958250	1675	3576	5251	15845
1504	100832860	58	2966050	1593	3576	5169	16410
1505	103824411	59	2991551	1510	3576	5086	16988
1506	106824271	60	2999860	1418	3576	4994	17578
1507	109850289	61	3026019	1322	3576	4898	18184
1508	112886111	62	3035822	1220	3576	4796	18804
1509	115950424	63	3064313	1111	3576	4687	19443
1510	119026611	64	3076187	984	3576	4560	20099
1511	122134640	65	3108029	845	3576	4421	20781
1512	125259927	66	3125288	685	3576	4261	21487
1513	128429938	67	3170011	475	3576	4051	22231
1514	131618616	68	3188678	43	3576	3619	23019

Table 6-4: Time to decant with recharge at 15% of MAP

Water Level (mamsl)	Pit Volume with Backfill (25 % Porosity) m^3	Water Level Rise (m)	Change in Storage (m^3)	Inflow from Aquifers (m^3/d)	Recharge (m^3/d)	Total Inflow (m^3/d)	Cumulative Time (Days)
1446	0	0		3399	4470	7869	
1447	9592	1	9592	3397	4470	7867	1
1448	23250	2	13658	3395	4470	7865	3
1449	45600	3	22349	3392	4470	7862	6
1450	73178	4	27578	3389	4470	7859	9
1451	119235	5	46056	3388	4470	7858	15
1452	172009	6	52775	3381	4470	7851	22
1453	266560	7	94551	3376	4470	7846	34
1454	378224	8	111664	3370	4470	7840	48
1455	571835	9	193611	3363	4470	7833	73
1456	799205	10	227370	3352	4470	7822	102
1457	1183497	11	384292	3343	4470	7813	151
1458	1629328	12	445831	3336	4470	7805	208
1459	2239214	13	609886	3323	4470	7793	286
1460	2888675	14	649461	3309	4470	7779	370
1461	3708294	15	819619	3297	4470	7767	475
1462	4573733	16	865439	3283	4470	7753	586
1463	5622019	17	1048287	3271	4470	7741	722
1464	6721617	18	1099598	3253	4470	7723	864
1465	7932731	19	1211114	3237	4470	7707	1020
1466	9180743	20	1248012	3223	4470	7693	1182
1467	10592283	21	1411541	3203	4470	7673	1366

Water Level (mamsl)	Pit Volume with Backfill (25 % Porosity) m^3	Water Level Rise (m)	Change in Storage (m^3)	Inflow from Aquifers (m^3/d)	Recharge (m^3/d)	Total Inflow (m^3/d)	Cumulative Time (Days)
1468	12051201	22	1458918	3177	4470	7646	1556
1469	13683031	23	1631830	3159	4470	7629	1769
1470	15363902	24	1680870	3136	4470	7606	1990
1471	17203298	25	1839397	3114	4470	7584	2232
1472	19076669	26	1873371	3093	4470	7563	2479
1473	21042365	27	1965696	3065	4470	7535	2739
1474	23033451	28	1991087	3038	4470	7508	3003
1475	25104742	29	2071291	3012	4470	7482	3279
1476	27203421	30	2098679	2987	4470	7457	3559
1477	29373362	31	2169942	2953	4470	7423	3850
1478	31558601	32	2185239	2919	4470	7389	4145
1479	33805293	33	2246692	2896	4470	7366	4449
1480	36068481	34	2263188	2863	4470	7333	4756
1481	38398695	35	2330214	2830	4470	7300	5074
1482	40746419	36	2347724	2797	4470	7267	5395
1483	43179998	37	2433579	2757	4470	7227	5730
1484	45638970	38	2458972	2721	4470	7191	6070
1485	48162501	39	2523532	2674	4470	7144	6421
1486	50706332	40	2543831	2639	4470	7109	6777
1487	53298921	41	2592589	2594	4470	7064	7142
1488	55905657	42	2606736	2555	4470	7025	7511
1489	58550434	43	2644777	2508	4470	6978	7888
1490	61205625	44	2655192	2464	4470	6934	8268
1491	63892129	45	2686504	2414	4470	6884	8655

Water Level (mamsl)	Pit Volume with Backfill (25 % Porosity) m^3	Water Level Rise (m)	Change in Storage (m^3)	Inflow from Aquifers (m^3/d)	Recharge (m^3/d)	Total Inflow (m^3/d)	Cumulative Time (Days)
1492	66590958	46	2698830	2369	4470	6839	9048
1493	69321459	47	2730501	2312	4470	6782	9447
1494	72065269	48	2743810	2262	4470	6732	9851
1495	74838279	49	2773010	2205	4470	6675	10263
1496	77626340	50	2788061	2150	4470	6620	10681
1497	80447900	51	2821560	2089	4470	6558	11107
1498	83287114	52	2839214	2028	4470	6498	11540
1499	86163897	53	2876783	1962	4470	6432	11983
1500	89055159	54	2891263	1899	4470	6369	12432
1501	91977789	55	2922630	1823	4470	6292	12891
1502	94908560	56	2930771	1753	4470	6222	13357
1503	97866810	57	2958250	1675	4470	6145	13832
1504	100832860	58	2966050	1593	4470	6063	14315
1505	103824411	59	2991551	1510	4470	5980	14809
1506	106824271	60	2999860	1418	4470	5888	15310
1507	109850289	61	3026019	1322	4470	5792	15824
1508	112886111	62	3035822	1220	4470	5690	16348
1509	115950424	63	3064313	1111	4470	5581	16887
1510	119026611	64	3076187	984	4470	5454	17438
1511	122134640	65	3108029	845	4470	5315	18008
1512	125259927	66	3125288	685	4470	5155	18596
1513	128429938	67	3170011	475	4470	4945	19211
1514	131618616	68	3188678	43	4470	4513	19856

6.5 Numerical Model Outcome

The following is a summary of the numerical model results:

- The calibrated steady state model achieved an RMSE of 5.67%. The threshold to identify a well calibrated model is less than 10%;
- The calibrated steady state model was used to populate the transient model simulations, of which three scenarios were investigated:
  - Simulation 1: Mine Dewatering;
  - Simulation 2: Contaminant transport; and
  - Simulation 3: Post operational decant and contaminant transport.
- Dewatering was simulated for the LoM (22 years) for the proposed pit. The simulated radius of influence (ROI) at the end of LoM indicates approximately 100 m of drawdown is expected at the proposed pit, reducing to zero drawdown at a maximum distance of 1.2 km from the pit (based on the current model setup and available data):
  - Expected inflows into the mining operation are expected to peak at approximately 6,000 m^3/d after 12 years of mining (Figure 6-2); and
  - No boreholes identified during the hydrocensus are located within the drawdown cone.
- The contamination plume was simulated using SO_4 as the potential leachate indicator:
  - The extent of the contamination plume at the LoM (22 years) reaches a maximum distance of 1.1 km from the stockpiles;
  - The change in hydraulic head created by dewatering the proposed pit will draw water from the surrounding aquifer towards the pit during operations. This will assist with containing a portion of the contamination plume;
  - Natural advection, dispersion and diffusion groundwater flow will still occur and cause the plume to move towards the nearby drainages, away from the proposed pit;
  - Post closure (simulation at 100 years), the simulated contamination plume from the backfilled pit and waste stockpiles extend to a maximum of 2 km from the pit. Natural groundwater flow will return to pre-mining flow paths causing the plume to extend towards the drainage systems to the north and west of the pit;
  - Private borehole WELBH08 (borehole) and WELWEL03 (spring) are located in the simulated contamination plume for 22 years and 100 years respectively. Monitoring needs to be conducted at these sites to establish baseline conditions

prior to operations commencing. Owners using groundwater from these locations will need to be notified and compensated accordingly;

  - Establishing a monitoring network between Phola Township and drainage systems is required as an early warning indicator so that corrective and/ or treatment options can be investigated prior to impacts on Phola Township and drainage streams are realised during mine operations and post closure; and
  - Active private boreholes in the vicinity of the mine and projected contamination plume, could draw the plume towards the borehole through the development of its own cone of drawdown.

- One decant point was identified at the topographical low in the north-eastern corner of the proposed pit:
  - Using a recharge rate of 12% of mean annual precipitation (MAP) the proposed pit BD is expected to decant 63 years post closure with a volume of 3,576 m^3/d; and
  - Using a recharge rate of 15% of MAP, the proposed pit BD is expected to decant in 54 years post closure with a volume of 4,470 m^3/d.
- This numerical model should be updated as more monitoring and hydrogeological information becomes available with the development of mining operations.

7 Environmental Impact Assessment

7.1 Summary of Infrastructure Requirements

A preliminary infrastructure layout plan is included in Appendix A, Plan 4. The proposed infrastructure associated with the opencast activities on KPSX: Weltevreden include:

- Opencast pit including ramps and box cuts;
- Haul roads;
- Conveyor system (when production increases);
- Overburden and topsoil stockpiles;
- PCD and associated pipelines to the Phola Plant;
- Clean water cut off canals;
- Run of Mine (ROM) stockpiles;
- Workshops and mobile offices; and
- Electricity supply to workshops and shovel.

7.2 Project Activities

The listed activities associated with the proposed KPSX: Weltevreden project are described below, per phase of the proposed project. Not all of the listed activities will have an impact on the groundwater environment and as such only listed activities which could have a potential impact on groundwater are discussed in Section 7.3.

Table 7-1: Activity list for KPSX: Weltevreden

Activity No.	Activity	Potential Impact to Groundwater
Construction Phase		
1	The recruitment, procurement and employment of construction workers, engineers and contractors.	No
2	The transportation of construction material to the Project site via national, provincial and local roads.	No
3	Storage of fuel, lubricant and explosives in temporary facilities for the duration of the construction phase. These substances are classified as hazardous in terms of the Hazardous Substances Act, 1973 (Act No. 15 of 1973) and will be managed accordingly.	Yes
4	Site clearance and topsoil removal prior to the commencement of physical construction activities, as well as the open pit mining. This activity refers to the conversion of undeveloped, vacant land into industrial use.	Yes
5	Construction of surface infrastructure will take place, including the offices and fuel bay, haul roads, PCDs, coal tip and conveyor belt, pipelines and clean water canals and a high mast radio communication tower.	Yes
6	The construction of stockpiles, including topsoil, overburden and discard and emergency coal stockpiles.	Yes
7	The establishment of the initial boxcut and access ramps to the open pit mining areas.	Yes
Operational Phase		
8	Limited employment of skilled and unskilled labour will be required for the operation of the mine and support infrastructure.	No
9	Storage of fuel in diesel tanks, as well as lubricant and explosives in facilities for the duration of Project. These substances are classified as hazardous in terms of the Hazardous Substances Act, 1973 (Act No. 15 of 1973) and will be managed accordingly.	Yes
10	Drilling and blasting of the overburden rock for easy removal by excavators and dump trucks.	No

Activity No.	Activity	Potential Impact to Groundwater
11	Coal removal by truck and shovel methods from the exposed coal seams. The coal is removed with shovels and transported to the plant by conveyor belt by trucks.	No
12	Vehicular activity on the proposed haul roads. Mining equipment will utilise the haul roads to access open pit areas, as well as to transport coal from the opencast pit to the plant and conveyor belt. The haul road will consist of wetland and stream crossings.	No
13	Mine water, or dirty water that is located within the opencast pits will need to be diverted by channels and berms to the PCDs to prevent clean water resources from being contaminated. Pipelines will pump the dirty water from the KPSX: Weltevreden PCDs to the KPS PCD.	Yes
14	Use of conveyor belts to transport the coal to the stockpiles at the KPS plant.	No
15	The PCDs will store all dirty water that has come into contact with the opencast pit, overburden stockpiles or emergency coal stockpile.	Yes
16	Operation and maintenance of the stockpiles, including topsoil, overburden and discard and ROM coal stockpiles.	Yes
17	Waste and sewage generation and disposal. All domestic, industrial and hazardous waste is produced during the mining process. Waste includes cans, plastics, used tyres and oil which must be disposed of in an appropriate manner by a contractor at a licensed waste disposal site. Sewage produced from the office buildings and ablutions will be treated at a sewage plant, septic tank or French drain system.	Yes
18	Concurrent replacement of overburden and topsoil and the re-vegetation of mined out strips. The mined strip will be backfilled with the overburden and compacted. Subsequently, the topsoil will be placed on top of the overburden and the area will be vegetated.	Yes
Decommissioning Phase		
19	Retrenchment of mine employees and staff will take place following the cessation of the mining operations and coal beneficiation activities.	No
20	Demolition of infrastructure will take place and includes the PCDs, haul roads, coal tip and conveyor belts, pipelines, high mast radio communication tower, fuel bay and mine offices and workshop.	Yes
21	Removal of fuel, lubricant and explosives will be required following the cessation of the mining activities to ensure that there is no health and safety risk to the environment and to people.	Yes

Activity No.	Activity	Potential Impact to Groundwater
22	Final replacement of overburden and topsoil and the establishment of vegetation on the final open cast void. Overburden will be backfilled into the final void and compacted. Subsequently, topsoil will placed and the area vegetated.	Yes
23	Waste handling of scrap metal and used oil as a result of the Decommissioning Phase will be undertaken.	Yes
Post-closure Phase		
24	Post-closure monitoring and rehabilitation will determine the level of success of the rehabilitation, as well as to identify any additional measures that have to be undertaken to ensure that the mining area is restored to an adequate state. Monitoring will include surface water, groundwater, soil fertility and erosion, natural vegetation and alien invasive species and dust generation from the coal discard dumps.	Yes

7.3 Description of Environmental Issues and Potential Impacts

Impacts identified per the activity list, e.g. site clearing.

7.3.1 Construction Phase

Activity No. 3: Storage of fuel, lubricant and explosives in temporary facilities for the duration of the construction phase.					
Criteria	**Details / Discussion**				
Description of impact	■ Incorrect storage and handling of hazardous substances could result in contamination to the underlying aquifers. Impacts are volume dependant.				
Mitigation required	■ All temporary structures and facilities used for the storage of hazardous substances are to be appropriate for the substance being stored and bunded, according to the specific substance's MSDS sheet. ■ Proper operation techniques and maintenance procedures need to be applied.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	3	6	4	3	39
Post-Mitigation	3	3	4	2	20

Activity No. 4: Site clearance and topsoil removal prior to the commencement of physical construction activities and opencast mining.	
Criteria	**Details / Discussion**

Description of impact	■ Exposing the weathered and fractured aquifer allowing greater potential for contaminants to enter the groundwater environment. ■ Development of the opencast pit resulting in potential dewatering of the surrounding aquifer, affecting the neighbouring groundwater users.				
Mitigation required	■ Monitor changes in water levels and quality around the project area, so as to be aware of changes in groundwater conditions. ■ Engage with groundwater users within the influence of dewatering and arrange for alternative water supply if water supply sites are dewatered, if required. ■ Down gradient groundwater users need to be made aware of changes in water quality which could impact on their health, and an alternative water supply source be provided, if required.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	3	3	2	5	40
Post-Mitigation	3	2	2	5	35

Activity No. 5: Construction of surface infrastructure, including offices, fuel bays, haul roads, PCD and storm water catchment dams, coal tip, conveyor belt, pipeline and clean water canals.					
Criteria	**Details / Discussion**				
Description of impact	■ Infrastructure construction activities typically do not have a direct impact on the groundwater environment; however poor construction of infrastructure facilities (including fuel bays and PCD dams) could result in poor performance and therefore potential contamination to the underlying aquifer.				
Mitigation required	■ Ensure infrastructure construction follows engineering specifications. ■ Appoint a reputable contractor. ■ Ensure appropriate maintenance of facilities where and when required. ■ Where storage facilities are being constructed for hazardous substances include bunded linings where accidental spillage may occur, and proper operation techniques are used. ■ Where spillages of hazardous substances have occurred, the affected site (if not within bunded work area) should be cleaned (or dug out in the case of soil) and disposed of at a facility capable of handling the specific hazardous waste.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	3	3	3	4	36
Post-Mitigation	2	2	2	4	24

Activity No. 6: The construction of stockpiles, including topsoil, overburden and emergency coal stockpiles.					
Criteria	**Details / Discussion**				
Description of impact	■ Stockpile storage of removed topsoil, overburden and emergency coal reserves exposes soil and rock types to conditions which increase the potential for AMD development.				
Mitigation required	■ Develop an appropriate groundwater monitoring system and test regularly for changes in water quality and water levels. The monitoring network will act as an early warning indicator for the contamination plume migration, after which corrective and/or treatment options need to be investigated. ■ Buffer acid generating discard material with acid neutralising discard material. ■ Backfill overburden and interburden stockpiles at earliest opportunity and ensure compaction to limit the space available for oxygen and water to interact with sulphate minerals. ■ Where coal discard (stockpiles with the highest potential for AMD) stockpiles are foreseen as long term requirements the base needs to be lined with neutralising material and drainage system designed to capture surface runoff and seepage to be channelled to the nearest PCD. ■ Implement passive or active treatment options where water quality is unacceptable for release into the environment.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	3	6	5	6	84
Post-Mitigation	2	6	4	6	72

Activity No. 7: The establishment of the initial boxcut and access ramps to the open pit mining areas.	
Criteria	**Details / Discussion**
Description of impact	■ Exposing the weathered and fractured aquifer allowing greater potential for contaminants to enter the groundwater environment: ▪ Breakdowns and mechanical repairs conducted in pit could result in potential hydrocarbon contamination to the exposed weathered and fractured aquifer.
Mitigation required	■ Develop an appropriate groundwater monitoring programme and test regularly for changes in water quality and water levels. ■ Down gradient groundwater users need to be made aware of changes in water quality which could impact on their health, and an alternative water supply source be provided, if required.

	■ Develop work procedures in case of incidents requiring in pit work involving hydrocarbons and other hazardous substances. Use MSDS sheets for proper storage, handling and clean up and disposal of hazardous substances. ■ Where spillages of hazardous substances have occurred, the affected site (if not within bunded work area) should be cleaned (or dug out in the case of soil) and disposed of at a facility capable of handling the specific hazardous waste.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	3	3	3	4	36
Post-Mitigation	3	2	2	4	28

Activity No. 7: The establishment of the initial boxcut and access ramps to the open pit mining areas.					
Criteria	**Details / Discussion**				
Description of impact	■ Commencement of dewatering activities (if not initiated during the top soil removal phase) will result in the development of a cone of depression around the pit potentially affecting neighbouring groundwater users. ▪ Dewatering could result in the reversal of groundwater gradients.				
Mitigation required	■ Develop an appropriate groundwater monitoring programme to assess changes in water levels within 200m of the pit to monitor the development of the dewatering cone. ■ Engage with groundwater users within the influence of dewatering and arrange for alternative water supply if water supply sites are dewatered, if required.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	3	5	5	5	65
Post-Mitigation	2	2	2	4	24

7.3.2 Operational Phase

Activity No. 9: Storage of fuel in diesel tanks, as well as lubricants and explosives in facilities for the duration of the project.	
Criteria	**Details / Discussion**
Description of impact	■ Incorrect storage and handling of hazardous substances could result in contamination to the underlying aquifers. Impacts are volume dependant.
Mitigation required	■ All permanent structures and facilities used for the storage of hazardous substances are to be appropriate for the substance being stored and bunded in case of accidental spillage. Use MSDS sheets for each substance for appropriate

	storage, handling and disposal requirements. ■ Proper operation techniques and maintenance procedures need to be applied. ■ Where spillages of hazardous substances have occurred, the affected site (if not within bunded work area) should be cleaned (or dug out in the case of soil) and disposed of at a facility capable of handling the specific hazardous waste.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	3	6	4	3	39
Post-Mitigation	3	3	4	2	20

Activity No. 13: Mine (dirty) water located in the pit will need to be diverted by channels and berms to the PCD.					
Criteria	**Details / Discussion**				
Description of impact	■ Seepage of dirty water from the main pit sump or via leakage from diversion channels in route to the PCD storage facility.				
Mitigation required	■ In pit and PCD storage ponds water qualities should be monitored monthly to understand the impact (if any) that they could potentially have on the groundwater environment should seepage occur. ■ Lining the PCD pond with a heavy duty, durable plastic sheeting which will prevent seepage of dirty water into the underlying aquifer. ■ Where poor quality water needs to be pumped to the PCD pond, a network of pipes should be considered as an alternative to channels and berms, as water can be contained limiting seepage. ■ Implement passive or active treatment options where water quality is unacceptable for release into the environment.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	2	3	3	4	32
Post-Mitigation	1	3	2	4	24

Activity No. 15: The PCD will temporarily store all dirty water that has been in contact with the open pit and various stockpiles.	
Criteria	**Details / Discussion**
Description of impact	■ Leakage of dirty water stored within the PCD due to inadequate lining and construction.
Mitigation	■ Lining the PCD pond with a heavy duty, durable plastic sheeting which will

required	prevent seepage of dirty water into the underlying aquifer. ■ Ensure PCD pond is constructed to engineering specifications and able to contain expected volumes of dirty water. ■ Ensure maintenance of lining and monitoring equipment. ■ Complete and maintain a water use balance for the PCD, to ensure potential leakages are identified at the earliest opportunity. ■ Monitor volumes (entering and leaving the PCD) and water quality on regular basis to update the water balance and understand the potential impacts of any seepage that could occur. ■ Establish monitoring boreholes downstream of the PCD. The monitoring network will act as an early warning indicator for the contamination plume migration, after which corrective and/or treatment options need to be investigated. ■ Implement passive or active treatment options where water quality is unacceptable for release into the environment.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	2	5	2	4	36
Post-Mitigation	2	1	2	3	15
Activity No. 16: Operation and maintenance of the stockpiles including top soil, overburden, discard and ROM coal stockpiles					
Criteria	**Details / Discussion**				
Description of impact	■ Contamination of groundwater via seepage of dirty water from the top soil, overburden, discard and ROM coal stockpiles.				
Mitigation required	■ Develop an appropriate groundwater monitoring system and test regularly for changes in water quality and water levels. The monitoring network will act as an early warning indicator for the contamination plume migration, after which corrective and/or treatment options need to be investigated. ■ Buffer acid generating discard material with acid neutralising discard material. ■ Full geochemical investigation is required for the proposed pit area to understand site specific conditions and implications of backfilling. Geochemical sampling and analyses should be completed on an annual basis to update the closure and rehabilitation plans and costs. ■ Backfill (if deemed acceptable by additional geochemical investigations) overburden and interburden stockpiles at earliest opportunity and ensure compaction to limit the space available for oxygen and water to interact with sulphate minerals. ■ Where overburden and interburden (stockpiles with the highest potential for AMD) stockpiles are foreseen as long term requirements the base needs to be lined with neutralising material and drainage system designed to capture surface runoff and seepage to be channelled to the nearest PCD.				

	■ Implement passive or active treatment options where water quality is unacceptable for release into the environment.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	3	6	5	6	84
Post-Mitigation	2	6	4	6	72

Activity No. 17: Waste and sewage generation and disposal. Domestic, industrial and hazardous waste is produced during the mining process. Waste must be disposed of in an appropriate manner (according to type) by a contractor at a licensed waste facility. Sewage must be treated at a sewage plant, septic tank or French drain system.					
Criteria	**Details / Discussion**				
Description of impact	■ Contamination of the aquifer via seepage of waste water, sewage spills or hazardous substances.				
Mitigation required	■ Hazardous substances must be stored, handled and disposed of according to their specific MSDS sheet. ■ Infrastructure built to contain waste and sewage or store hazardous substances must be constructed to engineering specification by a reputable contractor. ■ Infrastructure must be maintained according to the engineering specifications, when and where required, or on a regular basis. ■ A reputable contractor is required to remove waste to a disposal facility capable of handling the waste or hazardous substance.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	2	2	2	4	36
Post-Mitigation	1	1	2	3	12

Activity No. 18: Concurrent replacement of overburden and topsoil and re-vegetation of mined out strips.	
Criteria	**Details / Discussion**
Description of impact	■ Disturbed land surfaces and backfilled voids have increased recharge rates. Increased recharge has the potential to introduce more oxygen into the groundwater environment increasing the potential for AMD development.
Mitigation required	■ Compact backfilled material where possible and create a free draining surface. ■ Continue with groundwater monitoring post closure of water levels and quality, so as to understand the impacts arising from the project area. The monitoring

	network will act as an early warning indicator for the contamination plume migration, after which corrective and/or treatment options need to be investigated. ■ Down gradient groundwater users need to be made aware of changes in water quality which could impact on their health, and an alternative water supply source be provided, if required. ■ Implement passive or active treatment options where water quality is unacceptable for release into the environment.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	4	6	5	4	60
Post-Mitigation	3	6	4	4	52

7.3.3 Decommissioning Phase

Activity No. 20: Demolition of infrastructure will take place and includes the PCDs, haul roads, coal tip and conveyor belts, pipelines, high mast radio communication tower, fuel bay, mine offices and workshop					
Criteria	**Details / Discussion**				
Description of impact	■ Removal of infrastructure (including PCDs and fuel bays) will minimise the potential risk of contamination to the groundwater environment, by eliminating a contamination source.				
Mitigation required	■ Dirty water remaining in the system must be treated by active or passive methods if planned for release into the environment, so as to be of acceptable quality to not detrimentally impact on the environment. ■ Dirty water that can't be treated for released, must be disposed of or evaporated and the remaining salts contained and removed from site. ■ It is recommended that site assessments of the ground underlying the fuel bay are conducted after removal, by an authorised individual, to determine the presence or absence of hydrocarbon contamination and determine suitable rehabilitation measures, if required.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	2	2	2	3	18
Post-Mitigation	1	2	1	2	8

Activity No. 21: Removal of fuel, lubricant and explosive storage.					
Criteria	**Details / Discussion**				
Description of impact	■ Incorrect removal and handling of hazardous substances could result in contamination to the underlying aquifers. Impacts are volume dependant.				
Mitigation required	■ Use a reputable contractor to remove remaining fuel, lubricant or explosives. ■ Clean or remove surface where the hazardous substance has spilled and dispose at a facility capable of storing that waste type.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	2	3	3	3	24
Post-Mitigation	1	1	2	2	8

Activity No. 22: Final backfilling of overburden and top soil as well as the establishment of vegetation on the final opencast void.					
Criteria	**Details / Discussion**				
Description of impact	■ Disturbed land surfaces and backfilled voids have increased recharge rates. Increased recharge has the potential to introduce more oxygen into the groundwater environment increasing the potential for AMD development.				
Mitigation required	■ Compact backfilled material where possible and create a free draining surface. ■ Continue with groundwater monitoring post closure of water levels and quality, so as to understand the impacts arising from the project area. ■ Down gradient groundwater users need to be made aware of changes in water quality which could impact on their health, and an alternative water supply source be provided, if required. ■ Implement passive or active treatment options where water quality is unacceptable for release into the environment.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	4	6	5	4	60
Post-Mitigation	3	6	4	4	52
Activity No. 23: Waste handling of scrap metal and used oil as a result of the decommissioning phase.					
Criteria	**Details / Discussion**				
Description of impact	■ Contamination of aquifers with used oil.				

Mitigation required	■ Use a reputable contractor to remove used oil. ■ Clean or remove surface where the hazardous substance has spilled and dispose at a facility capable of storing that waste type.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	2	6	3	3	33
Post-Mitigation	1	3	1	2	10

7.3.4 Post Closure Phase

Activity No. 24: Post closure monitoring and rehabilitation to ensure the mining area is restored to an adequate state.					
Criteria	**Details / Discussion**				
Description of impact	■ Flooding of the backfilled pit will result in a potential decant point, with the potential for contaminated water to impact on surface water sites downstream as well as the local ecosystem. Re-establishment of the water table and groundwater flows could result in migration of contamination from the backfilled pit.				
Mitigation required	■ Continued monitoring of the groundwater environment for water levels and quality as well as the decant points once decanting commences. ■ A full geochemical study of the proposed pit area is required to assess the specific site conditions for acid generating potential of the waste and coal discard. This should provide input into what material can be backfilled and the implications thereof; ■ Compact backfilled material where possible and create a free draining surface. ■ Down gradient groundwater users need to be made aware of changes in water quality which could impact on their health, and an alternative water supply source be provided, if required. ■ Implement passive or active treatment options where water quality is unacceptable for release into the environment.				
Parameters	*Spatial*	*Duration*	*Severity*	*Probability*	*Significant rating*
Pre-Mitigation	4	6	5	6	90
Post-Mitigation	4	6	5	5	75

8 Cumulative Impacts

8.1 Dewatering

Dewatering of the local aquifers are not limited to the project requirements, but can be compounded by the presence of other mines nearby, as well as the presence of active groundwater users. In the vicinity of the proposed KPSX: Weltevreden project the known collieries are Klipspruit, Zibulo, Nokuhle and Goedgevonden. There are multiple opencast collieries west of the KPSX: Weltevreden project.

Combined dewatering of the aquifers by adjacent mines could potentially result in a net loss of water supply to shallow groundwater boreholes and springs. Should groundwater supply to affected groundwater users be depleted as a result of dewatering, a water supply of equal or better water quality must be provided by the mine to the affected party. If municipal water supply systems are to be used to cover the loss of shallow groundwater resources there will be cost implications associated with the project.

The numerical model indicates that after 22 years the extent of the simulated drawdown cone will reach a maximum distance of 1.2 km away from the proposed pit. Drawdown over the proposed pit location is expected to decrease by 100 m, which reduces to zero at the maximum extend of the cone of depression. No boreholes identified during the hydrocensus are located within the drawdown cone boundaries.

The ROI is relatively contained around the proposed pit, and therefore the cumulative dewatering impacts from nearby opencast mining operations are not expected to be significant.

Establishing monitoring boreholes (Section 9) around the pit are required to assess the implications of dewatering from the KPSX: Weltevreden project on the aquifers in the vicinity of the pit. The monitoring data recorded as mining operations progress must be used to update the numerical model on an annual basis for the first five years of operation. Any additional geological and hydrogeological information gathered during the development of the mine also needs to be incorporated into the model updates. After the first five years of annual numerical model updates, the model can be updated over a period of 5 years.

8.2 Acid Mine Drainage

The cumulative impacts of AMD development from mining activities will only be fully understood once decanting commences from all decommissioned mines around the area. Decanting water qualities will vary depending on the geochemistry of the individual mines, mining methods, and rehabilitation and treatment methods used by the individual mines.

The geochemical analysis indicates there is some potential for waste (overburden, interburden and underburden) rock to buffer the acid generating material; however kinetic tests are required to determine the long term buffering potential for the project. The coal seams return predominantly acid generating material that will form the coal discard material which would require management in the long term, through rehabilitation and treatment methods, should the neutralising potential not be sufficient to buffer the acid generating potential.

The numerical model indicates the potential plume migration during the LoM (22 years) is expected to extend a distance of 1.1 km from the contamination sources. After mining operations cease at the 100 year timeframe, the contamination plume is expected to reach a maximum distance of 2 km from the sources of contamination. As the groundwater levels and flow paths recover the pollution plume will be drawn towards the drainage systems located to the north and west of the project site.

Private borehole WELBH08 (borehole) and WELWEL03 (spring) are located in the simulated contamination plume for 22 years and 100 years respectively. Monitoring needs to be conducted at these sites to establish baseline conditions prior to operations commencing. Owners using groundwater from these locations will need to be notified and compensated accordingly.

One decant point was identified where the pit boundary intersects the lowest surface topographical point at the north-eastern corner of the proposed pit. Assuming an increased recharge rate of between 12 and 15% of mean annual precipitation, the proposed pit BD is expected to decant between 63 and 54 years respectively, with a volume of 3,576 and 4,470 m^3/d, respectively.

Establishing a monitoring network around the sources of contamination towards the down gradient drainage systems will allow for early detection of the contamination plume allowing corrective and/ or treatment options to be investigated prior to negative impacts to down gradient groundwater users and drainage systems being realised.

It is recommended that the decant water quality be managed by passive or active treatment options to return the water acceptable water quality standards if decant is planned for release into the environment.

9 Groundwater Monitoring Programme

Groundwater monitoring does not currently take place within the KPSX: Weltevreden project area. The groundwater monitoring locations presented on Plan 19 (Appendix A) have been selected from the identified hydrocensus and newly drilled boreholes locations. A total of nine locations were chosen (Table 9-1). Areas where no existing boreholes were identified, which are potential areas of concern have also been highlighted on Plan 19. Water quality and levels should be measured at selected locations for at least a year before the project commences to establish a baseline standard for the project.

Table 9-1: Recommended monitoring boreholes (existing)

Borehole	X co-ord	Y co-ord	Comment
BHPW05	-25.9803	29.10743	Newly drilled
BHPW07	-25.9851	29.04700	Newly drilled
BHPW08	-25.9442	29.05699	Newly drilled
WELWEL03	-25.952	29.096	Hydrocensus
WELBH01	-26.026	29.056	Hydrocensus
WELBH08	-26.012	29.050	Hydrocensus
WELBH16	-25.956	29.050	Hydrocensus
WELBH23	-25.930	29.069	Hydrocensus
WELBH24	-25.941	29.087	Hydrocensus

As an outcome of the numerical modelling an additional six monitoring locations (Table 9-2) are recommended to monitor the potential impacts associated with dewatering and contamination plume migration.

As mining operations progress, it is recommended that samples be taken from seepage into the pit and dirty water storage locations (PCD) to provide a basis for comparison.

Table 9-2: Proposed new monitoring locations from the numerical model

Site Id	X co-ord	Y co-ord
BHP_M01	29.08108	-26.01265
BHP_M02	29.08683	-26.02083
BHP_M03	29.09134	-25.95766
BHP_M04	29.09361	-25.95149
BHP_M05	29.05783	-25.98515
BHP_M06	29.04583	-26.00747

9.1.1 Sampling Protocols and Quality Control

The water sampling programme must be implemented with strict field QA/QC measures, including the collection of duplicate samples, correct labelling for the samples and chain of custody documentation from the field to laboratory. Whilst in the field samples should be kept in a cool dark container and dispatched to the laboratory at the earliest opportunity. The chosen laboratory must be accredited.

As part of the overall sampling, QA/QC package chain of custody travel documents need to be completed for each sample. This will allow tracking of the samples from acquisition through to analysis. These forms are enclosed in the sample coolers shipped to the laboratory.

9.1.2 Water Level Measurement

Groundwater level measurements must be measured monthly for each monitoring location. The following method is to be applied when taking a manual water level reading:

- At each borehole it is necessary to take a manual reading of the static water level before any measurement is carried out. This is done using a dip meter.
- Lower the probe into the borehole and allow the tape to unwind slowly.
- A loud continuous beep is heard when the probe makes contact with the water.
- Draw the probe up by winding in the tape.
- Take the measurement as the noise (continuous beep) stops (i.e. the surface of the water).
- The measurement must be recorded from the top of the borehole casing.
- Records should be kept of the casing height.
- Always ensure to wind up the dip meter carefully so the wire running through the tape does not get twisted and damaged.

9.1.3 General Sampling and Decontamination Procedures

Prior to the collection of the groundwater samples (after measuring the water level), the standing water from each of the monitoring boreholes need to be removed to ensure that the sample collected is representative of the current groundwater conditions.

The purging and collection of samples from the monitoring boreholes will be facilitated using a new disposable hand bailer, or a whale or Grundfos MP20 pump with disposable tubing, at every location to prevent the cross contamination of samples.

Samples for inorganic analysis are collected in 1 litre bottles, without preservation. Samples for metal analyses are filtered in the field using a membrane filter system fitted with 0.45 m aperture filters to remove all suspended materials. Water samples are collected in clean bottles obtained from the laboratory. The sample jars must be completely filled to minimise aeration of the groundwater, where after samples will be transferred immediately to cooler boxes containing pre-frozen ice bricks before they are transferred to the laboratory.

During sampling and decontamination activities, disposable nitrile gloves will be worn to minimise transfer of contaminants. Any disposable equipment, such as nitrile gloves and single used bailers will be dedicated to a sampling location and disposed of after use.

9.1.4 Constituents to be analysed

Groundwater quality samples should be collected on a quarterly basis whilst surface water monitoring locations must be monitored monthly. Water quality results need to be compared against the SANS 241-1: 2011 water quality standards.

The analytical schedule for inorganic and metal analyses should include the following constituents:

- Aluminium
- Ammonium
- Cadmium
- Calcium
- Chloride
- Cobalt
- Copper
- Electrical Conductivity
- Fluoride
- Iron
- Lead
- Magnesium
- Manganese
- Nickel
- Nitrate
- pH
- Phosphate
- Potassium
- Sodium
- Sulphate
- Total Alkalinity
- Total Chromium
- Total Dissolved Solids
- Total hardness
- Turbidity
- Zinc

10 Gap Analysis

The geochemical evaluation provided an initial assessment of the basic ABA and NAG conditions at the site. This study is not comprehensive as samples were collected from three boreholes drilled as part of the groundwater investigation and are not locate near the proposed pit. Significantly more samples need to be collected and analysed from the proposed pit locations to give indications of the site specific conditions. Kinetic leachate testing must be included as part of the analyses to provide an indication of long term acid generating or neutralising potential.

- The recommended comprehensive geochemical modelling and evaluation will need to address the options to backfill the mine voids or not and the implications associated with the various types of waste material (overburden, interburden and coal discard).

The groundwater quality for all private boreholes used for domestic, agricultural and livestock watering purposes need to be sampled to update the hydrocensus baseline results to provide a better understanding of the baseline conditions around the project site. Currently the hydrocensus results indicate a general range from freshly recharged to stagnant groundwater types with one sample indicating contamination by mining operations (with no clear indication as to why).

11 Conclusions

BECSA appointed Digby Wells Environmental to undertake an integrated regulatory process to enable BECSA to commence mining in the proposed KPSX: Weltevreden project area. A groundwater investigation was undertaken to provide baseline information into the Identification Phase Study (IPS) EIA and associated environmental authorisation documents.

The groundwater investigation included a review of available documentation, field work programmes, numerical modelling and a final report. Field work programmes comprised of a hydrocensus, geophysical survey, drilling and aquifer testing programmes, as well as geochemical and hydro-chemical sampling and analyses.

11.1 Field Work Outcomes

The hydrocensus identified a total of 55 groundwater sites, of which 53 were boreholes and 2 were springs. Groundwater use associated with the boreholes was related predominantly to domestic use (30 boreholes), including use as a potable water supply. Groundwater monitoring (3 boreholes) was the other confirmed use, if boreholes were used at all (9 boreholes unused). Eleven boreholes were identified with an unknown purpose.

Nine geophysical traverses were surveyed across the project area using electromagnetic and magnetic ground surveying methods. Nine potential drilling targets were identified for further investigation by percussion drilling. Of the 9 potential targets 6 were identified as high priority and 3 as low priority sites.

The geophysical programme was followed by the percussion drilling programme where 5 target locations were drilled and constructed to a final depth of 60 m. Boreholes intersected the coal bearing Ecca sediments and associated intrusive rocks (dykes and sills). The drilled depths did not extend into the Dwyka tillite or Pre-Karoo basement rocks.

The intersected weathered profile extends to a depth of between 3 and 14 m bgl, which would correspond to the upper weathered aquifer. No seepage was identified within this aquifer zone. From the end of the weathered profile till a depth of 60 m the fractured Karoo aquifer was intersected comprising of dolerite, sandstone, mudstone, shale, carbonaceous shale and coal rock types. The fractured Karoo aquifer resulted in minor seepage and 1 low yielding fracture with an estimated yield of 0.14 L/s.

The 5 drilled boreholes were aquifer tested using the slug test method as a result of the intersected yields being too low to sustain either step tests or constant discharge tests. Static water levels prior to slug testing ranged from 20.03 to 27.78 m bgl. Borehole BHPW05 was still recovering to the static level at the time of aquifer testing, thereby limiting the results that could be obtained from this borehole. Interpreted hydraulic conductivities for the remaining 4 boreholes ranged from 0.053 to 0.348 m/d. The fracture hydraulic conductivity ranged from 0.003 to 0.045 m/d, indicating that seepage is the main contributor for groundwater supply to the boreholes. It must be noted that fractures are the main pathways for groundwater supply and contamination migration and even though no significant fractures were intersected during this investigation their presence in the project area should not be ruled out or be considered as negligible. The hydraulic conductivity results confirm that the aquifer is low yielding which will restrict the migration of contamination from the sources or limit the cone of dewatering to the vicinity of the pit, unless a fracture of significance is identified in these areas.

11.2 Laboratory Outcomes

11.2.1 Hydro-chemical Results

Ten water quality samples were selected from the 55 hydrocensus results for analyses. Six of the samples (WELWEL5, WELBH01, WELBH05, WELBH15, WELBH24 and WELBH42) returned results which do not exceed the SANS 241-1: 2011 guidelines for aesthetic, operational, acute health and chronic health limits. These samples represent ideal water quality and no health risks are expected from these boreholes.

Water sampled from WELBH43 returned a sulphate value of 480 mg/L which exceeds the aesthetic limit (250 mg/L), but is still below the acute health limit (500 mg/L).

Samples from WELBH09 and WELBH26 both exceed the chronic health limit (2 mg/L) for iron with concentrations of 2.09 and 4.24 mg/L respectively.

The water sample from WELBH28 exceeds the chronic health limit of 1.5 mg/L for fluoride, with a concentration of 1.65 mg/L.

The groundwater type identified from the Piper Diagram suggests a Ca-Na- HCO_3-Cl type with sulphate having a minor influence on samples from WELBH09, WELBH15, WELBH24, WELBH26 and WELBH42. Sulphate is the dominant anion for WELBH43. The Schoeller Plot however indicates that there is very little variability between the 10 sulphate samples (with the exception of WELBH43) suggesting that it is the ratio between the remaining anions and cation distribution which is causing the sulphate influence in the Piper Diagram.

11.2.2 Geochemical Results

Eleven geochemical samples were submitted for basic ABA and NAG analyses. Results indicate that the coal seams are typically acid generating with the overburden, interburden and underburden varying between acid generating to neutralising with no particular preference for sampled groups. The samples indicate that there is the potential for acid generating environment to develop with some potential to buffer the system provided from the overburden, interburden and underburden units, however kinetic testing is required to determine the long term buffering capacity for the project.

11.3 Numerical Model Outcome

- The calibrated steady state model achieved an RMSE of 5.67%. The threshold to identify a well calibrated model is less than 10%.
- The calibrated steady state model was used to populate the transient model simulations, of which three scenarios were investigated:
  - Simulation 1: Mine Dewatering;
  - Simulation 2: Contaminant transport; and
  - Simulation 3: Post operational decant and contaminant transport.
- Dewatering was simulated for the LoM (22 years) for the proposed pit. The simulated radius of influence (ROI) at the end of LoM indicates approximately 100 m of drawdown is expected at the proposed pit reducing to 0 at the extent of the ROI at a maximum distance of 1.2 km from the pit (based on the current model setup and available data):
  - Expected inflows into the mining operation are expected to peak at approximately 6,000 m^3/d after 12 years of mining; and
  - No boreholes were identified during the hydrocensus are located the drawdown cone.
- The contamination plume was simulated using SO_4 as the potential leachate indicator:
  - The extent of the contamination plume at the LoM (22 years) reaches a maximum distance of 1.1 km from the stockpiles;
  - The change in hydraulic head created by dewatering the proposed pit will draw water from the surrounding aquifer towards the pits during operations. This will assist with containing a portion of the contamination plume;
  - Natural advection, dispersion and diffusion groundwater flow methods will still occur which causes the plume to move towards the nearby drainages, away from the proposed pit;
  - Post closure (simulation at 100 years), the simulated contamination plume from the backfilled pit and waste stockpiles extends to a maximum of 2 km. Natural groundwater flows will return to pre-mining flow paths causing the plume to extend towards the drainage systems to the north and west of the proposed pit;

  - Private borehole WELBH08 (borehole) and WELWEL03 (spring) are located in the simulated contamination plume for 22 years and 100 years respectively. Monitoring needs to be conducted at these sites to establish baseline conditions prior to operations commencing. Owners using groundwater from these locations will need to be notified and compensated accordingly;
  - Establishing a monitoring network between the Phola Township and drainage systems is required an early warning indicator so that corrective and/ or treatment options can be investigated prior to impacts on the Phola Township and drainage streams are realised during mine operations and post closure; and
  - Active private boreholes in the vicinity of the mine and projected contamination plume, could draw the plume towards the borehole through the development of its own cone of drawdown.

- One decant point was identified at the topographical low in the north-eastern corner of the proposed pit:
  - Using a recharge rate of 12% of mean annual precipitation (MAP) the proposed pit BD is expected to decant 63 years post closure with a volume of 3,576 m^3/d; and
  - Using a recharge rate of 15% of MAP, the proposed pit BD is expected to decant in 54 years post closure with a volume of 4,470 m^3/d.

- This numerical model should be updated as more monitoring and hydrogeological information becomes available with the development of mining operations.

12 Recommendations

The following recommendations are made:

- It is recommended that all identified hydrocensus boreholes, used for domestic and agricultural purposes be sampled to update the baseline assessment. The 10 analysed samples are scattered across the project site and indicate groundwater typical of the Karoo aquifers. The results of sample WELBH43 indicate a strong influence of contamination by mining activities with no clear indication of what could be the cause.
- Eight boreholes are located within the proposed pit BD boundary, identified as WELBH02, WELBH03, WELBH04, WELBH05, WELBH06, WELBH07, WELBH27 and WELBH28. It is recommended that they be sampled for water quality and borehole depth prior to the commencement of mining to establish if they are connected to the underlying pre-Karoo aquifers potentially forming a link for contamination to migrate.
- No boreholes, identified during the hydrocensus were located in the simulated cone of depression, however WELBH08 (borehole) and WELWEL03 (spring) are within the 22 year and 100 year simulated contamination plume. Monitoring of groundwater levels and qualities of these sites are required and should begin one year prior to the commencement of mining operations to establish a strong baseline reference for future comparisons.
- Additional geochemical samples should be collected from the proposed pit areas, to get a better understanding of the actual waste discard acid or neutralising potential. The geochemical evaluation undertaken in this report provides an initial indication of the acid generating and neutralising conditions, however significantly more samples are required from the proposed pit locations to full understand and assess the implications of backfilling.
- Long term (20 week) geochemical kinetic tests are required to understand the long term buffering or acid generating potential of the project.
- Monitoring should commence at least one year prior to the commencement of mining to establish seasonal variations in the baseline water quality and level results.
- Nine monitoring locations were identified from the hydrocensus and newly drilled borehole lists, however there are locations around the pits were no boreholes were identified. These zones must be investigated further for potential fractures which could bring groundwater into the pit or allow the migration of contamination away from the sources:
  - The numerical model proposes six new monitoring locations around the waste stockpile and proposed pits to supplement the gaps in the monitoring network.

- Should private groundwater users become affected by the mining operations, either by unacceptable water quality as a result of the contamination plume or insufficient groundwater supply as a result of dewatering, the mine will need to supply them with equal or better quality water:
  - Groundwater users must be notified of changes to the water quality or levels at the earliest indication.
- The numerical model must be updated yearly for the first five years of mining operations to accommodate the changes identified by the newly collected information. Thereafter the model can be updated over a period of five years.
- Hazardous substances must be handled and stored according to best practise, with bunding to prevent spillage:
  - Standard operating procedure must be developed for the clean-up of hazardous substances should bunding fail or accidental spillage occur outside of the bunded areas.
- PCD and coal discard stockpile locations must be lined to prevent seepage of contaminated water to the groundwater environment:
  - PCD's must be designed for sufficient storage volume required for the project dirty water requirements; and
  - PCD's must be designed to catch potential overflow.
- Provision must be made for the treatment of decanting water, to a quality that is acceptable for release into the environment.

13 References

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Appendix A: Plans

Plan 1: Regional Setting

Plan 2: Local Setting

Plan 3: Topography

Plan 4: Infrastructure

Plan 5: Regional Geology

Plan 6: Hydrocensus

Plan 7: Geophysics Traverses and Identified Targets

Plan 8: Drilled Boreholes

Plan 9: Life of Mine

Plan 10: Model Boundary and Calibration Boreholes

Plan 11: Calibrated Initial Hydraulic Head

Plan 12: Dewatering - Radius of Influence after 7 Years

Plan 13: Dewatering - Radius of Influence after 14 Years

Plan 14: Dewatering - Radius of Influence after 22 Years (LoM)

Plan 15: Contaminant Transport Plumes after 22 Years (LoM)

Plan 16: Contaminant Transport Plumes after 100 Years

Plan 17: Coal Seam 1 Floor Contours

Plan 18: Decant Location

Plan 19: Recommended Monitoring Locations for the KPSX: Weltevreden Project

Appendix B: Hydrochemical Data

aquatico Laboratories (Pty). Ltd.
ilac-MRA sanas Testing Laboratory T0374

Test Report

Client: Digby Wells & Associates
Address: 359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg
Report no: 19788
Project: Digby Wells & Associates

Date of certificate: 18 August 2014
Date accepted: 12 August 2014
Date completed: 15 August 2014
Revision: 0

Lab no:				180508	180509	180510	180511	180512
Date sampled:				29-Jul-14	29-Jul-14	29-Jul-14	29-Jul-14	29-Jul-14
Sample type:				Water	Water	Water	Water	Water
Locality description:				WEL WEL 5	WELBH9	WELBH01	WELBH05	WELBH26
	Analyses	**Unit**	**Method**					
A	pH	pH	ALM 20	8.50	7.36	8.31	8.45	7.41
A	Electrical conductivity (EC)	mS/m	ALM 20	25.0	3.76	23.4	21.2	6.96
A	Total dissolved solids (TDS)	mg/l	ALM 26	158	28	143	132	45
A	Total alkalinity	mg $CaCO_3$/l	ALM 01	140	10.3	116	113	28.8
A	Chloride (Cl)	mg/l	ALM 02	7.30	4.86	8.06	4.99	4.74
A	Sulphate (SO_4)	mg/l	ALM 03	5.46	4.34	6.78	5.92	4.98
A	Nitrate (NO_3) as N	mg/l	ALM 06	0.384	0.246	0.268	0.424	0.245
A	Ammonium (NH_4) as N	mg/l	ALM 05	0.043	0.048	0.256	0.044	0.123
A	Orthophosphate (PO_4) asP	mg/l	ALM 04	0.024	0.021	0.027	0.023	0.018
A	Fluoride (F)	mg/l	ALM 08	0.366	0.714	0.646	0.317	1.32
A	Calcium (Ca)	mg/l	ALM 30	24.8	1.73	15.9	19.5	7.56
A	Magnesium (Mg)	mg/l	ALM 30	9.11	0.975	5.96	6.44	2.12
A	Sodium (Na)	mg/l	ALM 30	21.0	3.02	28.9	20.7	2.80
A	Potassium (K)	mg/l	ALM 30	2.78	4.69	3.82	3.30	2.61
A	Aluminium (Al)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003
A	Iron (Fe)	mg/l	ALM 31	<0.003	2.09	<0.003	<0.003	4.24
A	Manganese (Mn)	mg/l	ALM 31	<0.001	<0.001	0.009	<0.001	0.031
A	Total chromium (Cr)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Copper (Cu)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Nickel (Ni)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Zinc (Zn)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002
A	Cobalt (Co)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Cadmium (Cd)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Lead (Pb)	mg/l	ALM 31	<0.004	<0.004	<0.004	<0.004	<0.004
A	Turbidity	NTU	ALM 21	1.69	198	2.38	0.271	218
A	Total hardness	mg $CaCO_3$/l	ALM 26	99	8	64	75	28
N	Suspended solids (SS)	mg/l	ALM 25	<1	70	18	<1	159

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

aquatico Laboratories (Pty). Ltd.

ilac-MRA sanas Testing Laboratory T0374

Test Report

Client: Digby Wells & Associates
Address: 359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg
Report no: 19789
Project: Digby Wells & Associates

Date of certificate: 18 August 2014
Date accepted: 12 August 2014
Date completed: 15 August 2014
Revision: 0

Lab no:				180513	180514	180515	180516	180517
Date sampled:				01-Aug-14	01-Aug-14	01-Aug-14	01-Aug-14	01-Aug-14
Sample type:				Water	Water	Water	Water	Water
Locality description:				WELBH28	WELBH15	WELBH24	WELBH42	WELBH43
	Analyses	**Unit**	**Method**					
A	pH	pH	ALM 20	8.62	7.65	7.18	7.08	7.87
A	Electrical conductivity (EC)	mS/m	ALM 20	43.5	7.03	3.12	6.22	91.7
A	Total dissolved solids (TDS)	mg/l	ALM 26	262	41	21	39	731
A	Total alkalinity	mg $CaCO_3$/l	ALM 01	202	14.5	<2.477	4.14	40.5
A	Chloride (Cl)	mg/l	ALM 02	15.8	6.08	5.55	8.24	11.0
A	Sulphate (SO_4)	mg/l	ALM 03	6.04	4.14	5.63	4.05	480
A	Nitrate (NO_3) as N	mg/l	ALM 06	3.20	1.54	0.362	2.45	2.04
A	Ammonium (NH_4) as N	mg/l	ALM 05	0.159	0.056	0.071	0.099	0.212
A	Orthophosphate (PO_4) asP	mg/l	ALM 04	0.022	0.020	0.020	0.020	0.019
A	Fluoride (F)	mg/l	ALM 08	1.65	0.159	0.143	0.146	0.173
A	Calcium (Ca)	mg/l	ALM 30	5.44	5.44	1.59	1.96	128
A	Magnesium (Mg)	mg/l	ALM 30	4.06	2.18	0.606	1.78	52.1
A	Sodium (Na)	mg/l	ALM 30	89.0	4.54	3.08	7.01	14.6
A	Potassium (K)	mg/l	ALM 30	2.44	2.45	2.59	2.62	11.6
A	Aluminium (Al)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003
A	Iron (Fe)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003
A	Manganese (Mn)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Total chromium (Cr)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Copper (Cu)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Nickel (Ni)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Zinc (Zn)	mg/l	ALM 31	<0.002	<0.002	0.091	<0.002	0.012
A	Cobalt (Co)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Cadmium (Cd)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A	Lead (Pb)	mg/l	ALM 31	<0.004	<0.004	<0.004	<0.004	0.078
A	Turbidity	NTU	ALM 21	0.502	7.02	11.7	0.296	0.516
A	Total hardness	mg $CaCO_3$/l	ALM 26	30	23	6	12	535
N	Suspended solids (SS)	mg/l	ALM 25	<1	1	3	<1	4

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

Appendix C: Geophysical Data

Traverse	Station	MAG	EM HD	EM VD	Latitude	Longitude	Altitude	Comments
One	0	28499,5	20,0	19,8	-26,0542	29,0825	1575,26	
One	10	28503	20,6	17,0	-26,0542	29,0826	1574,92	
One	20	28515,5	21,5	19,5	-26,0542	29,0827	1575,05	
One	30	28516,6	21,2	21,8	-26,0541	29,0828	1574,63	
One	40	28514,8	21,4	20,7	-26,0541	29,0829	1574,66	
One	50	28563,7	22,9	22,3	-26,0541	29,0829	1574,2	
One	60	28561,6	23,1	27,7	-26,0541	29,0830	1575,58	
One	70	28560	24,6	24,3	-26,0541	29,0831	1574,52	
One	80	28558,9	25,7	12,2	-26,0540	29,0832	1574,57	
One	90	28548,9	25,8	15,1	-26,0540	29,0833	1574,22	
One	100	28512,7	29,3	19,2	-26,0540	29,0834	1574,27	
One	110	28507,5	28,9	13,4	-26,0540	29,0835	1574,29	
One	120	28498,7	29,3	25,4	-26,0540	29,0835	1573,72	
One	130	28498	28,4	24,2	-26,0539	29,0836	1573,74	
One	140	28495,9	28,1	18,1	-26,0539	29,0837	1573,77	
One	150	28492,6	27,5	22,6	-26,0539	29,0838	1573,78	wire
One	160	28502,7	24,2	15,8	-26,0539	29,0839	1573,82	
One	170	28496,1	22,1	20,2	-26,0539	29,0840	1573,82	
One	180	28492,4	19,2	19,1	-26,0539	29,0841	1573,43	
One	190	28476,5	17,4	18,2	-26,0538	29,0841	1573,45	
One	200	28477,9	15,3	14,8	-26,0538	29,0842	1573,47	
One	210	28506,5	14,2	17,3	-26,0538	29,0843	1573,49	
One	220	28466,4	12,3	20,1	-26,0538	29,0844	1573,52	stream
One	230	28444,7	10,8	19,4	-26,0537	29,0845	1573,83	stream
One	240	28557,5	9,7	17,4	-26,0537	29,0846	1573,86	stream
One	250	28546,3	9,8	19,1	-26,0537	29,0847	1573,91	
Two	0	30608,6	13,1	9,7	-26,0294	29,0948	1589,56	car
Two	10	28875,4	14,7	30,3	-26,0294	29,0949	1589,56	
Two	20	28921,4	15,3	25,3	-26,0294	29,0950	1589,56	
Two	30	28963,4	15,7	21,8	-26,0294	29,0951	1589,63	
Two	40	28987,5	15,8	18,2	-26,0294	29,0951	1589,66	
Two	50	28957,5	15,9	19,9	-26,0294	29,0952	1589,67	
Two	60	28978,7	16,4	15,5	-26,0294	29,0953	1589,65	
Two	70	29012,9	16,6	19,0	-26,0294	29,0954	1589,63	
Two	80	29086,7	15,5	16,3	-26,0295	29,0955	1589,62	
Two	90	29083,3	15,2	17,2	-26,0295	29,0956	1589,6	
Two	100	29054,7	15,8	18,7	-26,0295	29,0956	1589,58	
Two	110	29059,9	15,8	19,5	-26,0296	29,0957	1589,57	
Two	120	29063,8	16,9	15,6	-26,0296	29,0958	1588,88	
Two	130	29069,7	16,2	17,0	-26,0297	29,0958	1588,87	
Two	140	29070,2	15,5	17,3	-26,0297	29,0959	1588,43	
Two	150	29041,1	14,8	18,0	-26,0297	29,0960	1588,39	
Two	160	29040	15,9	20,0	-26,0298	29,0961	1588,33	
Two	170	29032,5	15,8	20,8	-26,0298	29,0962	1587,89	
Two	180	29041,8	16,4	18,6	-26,0298	29,0963	1587,85	
Two	190	29037,2	17,1	18,8	-26,0299	29,0963	1587,81	
Two	200	29034,5	16,5	20,8	-26,0299	29,0964	1587,39	
Two	210	28996	16,6	20,9	-26,0300	29,0965	1587,35	

Traverse	Station	MAG	EM HD	EM VD	Latitude	Longitude	Altitude	Comments
Two	220	29029,3	17,6	20,9	-26,0300	29,0966	1586,9	
Two	230	28986,3	17,1	21,4	-26,0301	29,0967	1586,85	
Two	240	28963,2	18,0	22,6	-26,0301	29,0968	1587,49	
Two	250	28977,4	16,9	21,7	-26,0301	29,0968	1586,14	
Two	260	28977,8	17,9	23,0	-26,0301	29,0969	1586,05	
Two	270	28973,2	17,6	22,8	-26,0302	29,0970	1585,96	
Two	280	28969,4	17,9	22,7	-26,0302	29,0971	1585,87	
Two	290	28986,5	18,2	20,4	-26,0302	29,0972	1585,82	
Two	300	28976	17,8	22,9	-26,0303	29,0973	1585,36	
Two	310	28970,1	17,7	22,3	-26,0303	29,0974	1585,31	
Two	320	28960,6	17,6	20,8	-26,0303	29,0974	1585,26	
Two	330	28992,3	17,5	23,1	-26,0303	29,0975	1585,21	
Two	340	29011,4	17,3	22,7	-26,0303	29,0976	1585,72	
Two	350	28994,7	17,4	17,9	-26,0303	29,0977	1585,68	
Two	360	28971,5	16,5	21,2	-26,0304	29,0978	1585,63	
Two	370	28967,6	16,8	22,6	-26,0304	29,0979	1585,57	
Two	380	28968,7	15,9	19,1	-26,0304	29,0980	1585,54	
Two	390	28997,9	15,2	21,2	-26,0304	29,0981	1584,34	
Two	400	29002	16,4	19,6				
Three	0	28643,6			-25,9868	29,1209	1590,56	
Three	10	28635,2			-25,9867	29,1210	1590,18	
Three	20	28647,6			-25,9866	29,1211	1591,48	
Three	30	28645,8			-25,9866	29,1211	1591,4	
Three	40	28658,9			-25,9865	29,1211	1591,38	
Three	50	28684,1			-25,9865	29,1212	1591,36	
Three	60	28645,8			-25,9864	29,1212	1591,35	
Three	70	28650,2			-25,9863	29,1213	1591,81	
Three	80	28682,1			-25,9863	29,1213	1591,79	
Three	90	28694,2			-25,9862	29,1214	1591,77	
Three	100	28659,8			-25,9862	29,1215	1592,32	
Three	110	28706,8			-25,9861	29,1215	1592,3	
Three	120	28713,9			-25,9860	29,1216	1592,27	
Three	130	28691,1			-25,9860	29,1216	1592,26	
Three	140	28677			-25,9859	29,1217	1592,7	
Three	150	28713,6			-25,9858	29,1217	1592,64	
Three	160	28696,8			-25,9858	29,1218	1592,61	
Three	170	28713,5			-25,9857	29,1218	1593,15	
Three	180	28645,7			-25,9856	29,1219	1593,13	
Three	190	28644,9			-25,9856	29,1220	1593,11	
Three	200	28713,2			-25,9855	29,1220	1593,09	
Three	210	28660			-25,9855	29,1221	1593,46	
Three	220	28555,5			-25,9854	29,1221	1593,45	
Three	230	28538,2			-25,9853	29,1222	1593,94	
Three	240	28539,3			-25,9853	29,1222	1592,83	
Three	250	28558,3			-25,9852	29,1223	1594,27	
Three	260	28501,9			-25,9851	29,1223	1594,25	
Three	270	28668,7			-25,9851	29,1224	1595,27	
Three	280	28660,5			-25,9850	29,1224	1595,27	

Traverse	Station	MAG	EM HD	EM VD	Latitude	Longitude	Altitude	Comments
Three	290	28672,1			-25,9849	29,1225	1595,25	
Three	300	28573,7			-25,9849	29,1225	1595,25	
Four	0	28510,4	1,7	2,6	-25,9815	29,1060	1553,45	
Four	10	28506	1,6	2,7	-25,9814	29,1061	1552,48	
Four	20	28513,6	1,1	3,0	-25,9814	29,1062	1552,17	
Four	30	28506,1	1,6	2,5	-25,9813	29,1062	1554,29	
Four	40	28505,8	1,6	2,7	-25,9813	29,1063	1554,15	
Four	50	28484,3	1,7	2,9	-25,9812	29,1064	1555,17	
Four	60	28512,2	1,3	2,6	-25,9811	29,1064	1555,31	
Four	70	30506,3	1,3	2,7	-25,9811	29,1065	1555,34	
Four	80	30223,8	1,3	2,9	-25,9810	29,1065	1556,25	
Four	90	30168,4	1,3	2,6	-25,9810	29,1066	1556,04	
Four	100	29633	1,2	3,1	-25,9809	29,1067	1556,51	
Four	110	28454,1	1,9	3,2	-25,9809	29,1067	1556,5	
Four	120	29565,4	1,5	2,7	-25,9808	29,1068	1556,32	
Four	130	29478,3	1,3	3,1	-25,9808	29,1069	1557,93	
Four	140	29287,3	2,0	2,8	-25,9807	29,1069	1558,05	
Four	150	29035,7	2,1	2,7	-25,9807	29,1070	1558,35	
Four	160	29067,1	1,9	2,8	-25,9806	29,1071	1558,87	
Four	170	29293,5	1,5	2,7	-25,9806	29,1071	1557,75	
Four	180	28881,2	2,3	2,9	-25,9805	29,1072	1559,31	
Four	190	29540,4	2,8	2,9	-25,9805	29,1073	1559,68	
Four	200	29317,1	2,6	3,0	-25,9804	29,1074	1561,42	
Four	210	28897	1,8	3,0	-25,9803	29,1074	1560,41	
Four	220	28516,5	1,4	2,7	-25,9803	29,1075	1561,44	
Four	230	28503,7	1,3	2,8	-25,9802	29,1076	1561,54	
Four	240	28521	1,6	2,2	-25,9802	29,1076	1562,74	
Four	250	28509,1	2,1	2,9	-25,9802	29,1077	1562,67	
Four	260	28523,7	1,3	2,9	-25,9801	29,1078	1561,98	
Five	0	28514,3	12,9	14,1	-25,9700	29,1229	1582,37	
Five	10	28517,1	11,9	13,7	-25,9700	29,1230	1581,14	
Five	20	28517,1	12,4	13,9	-25,9701	29,1231	1581,66	
Five	30	28515,6	11,9	14,1	-25,9701	29,1232	1583,82	
Five	40	28517,4	12,0	15,2	-25,9702	29,1232	1583,21	
Five	50	28483,9	11,8	13,9	-25,9702	29,1233	1583,1	
Five	60	28506,9	11,1	13,3	-25,9703	29,1234	1584,54	
Five	70	28510,7	11,3	13,1	-25,9703	29,1235	1584,61	
Five	80	28514,1	12,1	13,0	-25,9704	29,1235	1584,65	
Five	90	28505,7	12,4	12,7	-25,9704	29,1236	1583,84	
Five	100	28527,8	13,1	12,0	-25,9705	29,1237	1584,14	
Five	110	28597	12,9	12,5	-25,9705	29,1238	1585,32	
Five	120	28514	12,9	12,7	-25,9706	29,1238	1585,34	
Five	130	28531	13,1	13,1	-25,9707	29,1239	1585,91	
Five	140	28545,9	12,5	13,6	-25,9707	29,1240	1586,98	
Five	150	28534,9	12,7	12,9	-25,9708	29,1241	1587,01	
Five	160	28542,3	13,8	12,1	-25,9708	29,1242	1586,32	
Five	170	28543,6	13,7	13,5	-25,9709	29,1242	1586,66	
Five	180	28550,5	14,0	12,3	-25,9709	29,1243	1587,88	

Traverse	Station	MAG	EM HD	EM VD	Latitude	Longitude	Altitude	Comments
Five	190	28555,5	13,8	13,9	-25,9710	29,1244	1588,47	
Five	200	28549,9	14,3	12,4	-25,9710	29,1244	1588,93	
Five	210	28582,2	13,2	12,1	-25,9711	29,1245	1588,96	
Five	220	28533,6	12,9	14,7	-25,9711	29,1246	1589,47	
Five	230	28553,9	13,1	14,5	-25,9712	29,1247	1589,5	
Five	240	28338,6	12,8	13,1	-25,9712	29,1248	1589,98	power lines
Five	250	28523,3	12,8	12,6	-25,9713	29,1248	1590,41	power lines
Five	260	28555,9	12,9	14,3	-25,9713	29,1249	1590,46	
Five	270	28599,5	13,5	14,0	-25,9714	29,1250	1590,49	
Five	280	28594,3	13,2	13,7	-25,9714	29,1250	1591,38	power lines
Five	290	29365,4	13,3	13,8	-25,9715	29,1251	1590,86	power lines
Five	300	26993,6	13,3	14,2	-25,9715	29,1252	1592,18	power lines
Five	310	27026,9	12,7	27,1	-25,9716	29,1252	1591,45	power lines
Five	320	26993,7	12,0	20,1	-25,9716	29,1253	1591,49	power lines
Five	330	26986	11,5	14,4	-25,9717	29,1254	1591,56	power lines
Five	340	29308,8	14,3	14,1	-25,9717	29,1255	1591,37	
Five	350	28515,7	12,4	13,1	-25,9718	29,1255	1591,88	
Five	360	28479,4	13,2	10,8	-25,9719	29,1256	1591,88	
Five	370	28534,7	13,8	10,9	-25,9719	29,1257	1591,91	
Five	380	28623	12,7	12,1	-25,9720	29,1258	1593,29	
Five	390	28584,5	10,8	11,6	-25,9720	29,1259	1593,79	
Six	0	28588,9	2,9	3,0	-25,9489	29,0999	1528,39	
Six	10	28600,5	2,2	4,5	-25,9489	29,1000	1528,34	
Six	20	28603,5	2,0	4,0	-25,9489	29,1001	1528,16	
Six	30	28602,8	2,2	3,8	-25,9489	29,1002	1527,52	
Six	40	28594	2,5	3,6	-25,9489	29,1003	1527,36	fence
Six	50	28598,4	2,6	3,4	-25,9489	29,1004	1527,92	
Six	60	28600,7	3,4	2,4	-25,9490	29,1004	1527,75	
Six	70	28593,8	3,3	3,6	-25,9490	29,1005	1527,16	
Six	80	28587,2	1,9	3,7	-25,9490	29,1006	1526,58	
Six	90	28587,3	2,6	3,4	-25,9490	29,1008	1526,84	
Six	100	28580,3	2,2	3,4	-25,9490	29,1009	1525,61	
Six	110	28583,3	3,4	3,6	-25,9490	29,1010	1525,26	
Six	120	28580,2	2,2	3,9	-25,9490	29,1011	1524,91	
Six	130	28579,8	3,5	3,0	-25,9490	29,1012	1524,79	
Six	140	28574,2	2,6	3,1	-25,9490	29,1013	1525,83	
Six	150	28577,9	3,0	3,2	-25,9490	29,1014	1525,72	
Six	160	28574,3	2,8	3,6	-25,9490	29,1014	1525,54	
Six	170	28572,3	2,4	4,2	-25,9490	29,1016	1524,74	
Six	180	28567,4	2,8	3,4	-25,9490	29,1017	1524,17	
Six	190	28565	2,2	3,5	-25,9490	29,1018	1524,07	
Six	200	28571,6	2,7	3,5	-25,9490	29,1019	1524,56	
Six	210	28574,6	2,9	3,4	-25,9490	29,1020	1524,24	
Six	220	28580,4	2,7	3,5	-25,9490	29,1021	1523,75	sandstone outcrop
Six	230	28575,9	2,0	4,0	-25,9490	29,1022	1523,89	sandstone outcrop
Six	240	28583,8	3,8	4,5	-25,9491	29,1022	1523,81	sandstone outcrop
Seven	0	28707,7	3,6	4,7	-25,9869	29,0491	1548,4	dumping area
Seven	10	28706,9	3,5	3,5	-25,9869	29,0491	1547,33	dumping area

Traverse	Station	MAG	EM HD	EM VD	Latitude	Longitude	Altitude	Comments
Seven	20	28689,5	3,3	3,5	-25,9868	29,0490	1546,63	
Seven	30	28686,7	2,8	4,2	-25,9867	29,0490	1547,49	
Seven	40	28690,4	3,1	5,0	-25,9867	29,0489	1547,52	
Seven	50	28693,3	2,8	5,3	-25,9866	29,0488	1547,58	
Seven	60	28709,9	2,8	4,0	-25,9866	29,0487	1545,58	
Seven	70	28742,9	3,5	4,0	-25,9865	29,0487	1546,82	
Seven	80	28762,5	3,4	5,1	-25,9864	29,0486	1541,25	
Seven	90	28796,6	4,2	5,4	-25,9864	29,0485	1540,78	
Seven	100	28790,4	4,7	4,2	-25,9863	29,0484	1541,41	
Seven	110	28796,8	4,9	3,4	-25,9862	29,0484	1540,67	
Seven	120	28774,1	5,3	5,8	-25,9862	29,0483	1541,2	
Seven	130	28765,6	4,9	6,8	-25,9861	29,0482	1540,09	
Seven	140	28731,6	5,4	7,5	-25,9860	29,0481	1539,69	
Seven	150	28732,9	5,6	7,5	-25,9860	29,0481	1539,19	
Seven	160	28760	6,5	8,0	-25,9859	29,0480	1538,72	
Seven	170	28782,3	7,1	9,1	-25,9859	29,0479	1540,09	
Seven	180	28785,4	8,0	5,9	-25,9858	29,0478	1539,52	
Seven	190	28783,9	8,5	6,3	-25,9857	29,0477	1538,64	
Seven	200	28805,9	9,3	13,0	-25,9856	29,0476	1538,88	
Seven	210	28797,9	9,7	14,0	-25,9856	29,0476	1538,96	
Seven	220	28775,5	10,7	12,8	-25,9856	29,0475	1539,09	
Seven	230	28769,1	11,3	11,1	-25,9855	29,0474	1537,99	
Seven	240	28786,1	13,0	10,2	-25,9854	29,0473	1537,31	
Seven	250	28799,3	13,8	14,0	-25,9853	29,0473	1537,94	
Seven	260	28819,5	14,5	12,7	-25,9853	29,0472	1539,97	
Seven	270	28878,6	15,0	17,0	-25,9852	29,0472	1537,87	
Seven	280	28973,8	15,1	16,0	-25,9851	29,0471	1538,31	road
Seven	290	29202,8	14,2	15,3	-25,9851	29,0470	1537,6	
Seven	300	29329,2	14,0	13,9	-25,9850	29,0469	1537,47	
Seven	310	29154,5	14,0	17,1	-25,9849	29,0469	1537,85	
Seven	320	29074,8	14,0	19,3	-25,9849	29,0468	1538,89	
Seven	330	29118	14,4	16,1	-25,9848	29,0467	1538,44	
Eight	0	28968,2	4,4	6,3	-25,9446	29,0586	1545,45	
Eight	10	29036,4	4,3	8,1	-25,9445	29,0585	1545,19	
Eight	20	28908	5,0	8,0	-25,9445	29,0584	1542,99	
Eight	30	28870,5	5,8	6,0	-25,9445	29,0583	1543,15	
Eight	40	28829,5	6,8	5,3	-25,9445	29,0582	1542,48	found bh
Eight	50	28874,6	8,2	9,1	-25,9445	29,0581	1542,74	
Eight	60	28705,1	8,4	10,2	-25,9444	29,0580	1541,85	
Eight	70	28568,3	8,6	12,9	-25,9444	29,0579	1541,8	
Eight	80	28499,3	9,6	12,1	-25,9444	29,0578	1542,62	
Eight	90	28430	10,7	12,3	-25,9444	29,0578	1542,04	
Eight	100	28403,3	11,6	14,3	-25,9443	29,0577	1541,64	
Eight	110	28426,2	11,6	15,0	-25,9443	29,0576	1540,49	
Eight	120	28740,3	11,2	19,0	-25,9443	29,0575	1541,46	
Eight	130	29017,4	11,9	18,2	-25,9443	29,0574	1540,74	
Eight	140	29309,6	12,2	18,3	-25,9443	29,0573	1540,61	road
Eight	150	29608,5	12,1	15,4	-25,9443	29,0572	1539,26	

Traverse	Station	MAG	EM HD	EM VD	Latitude	Longitude	Altitude	Comments
Eight	160	29242,7	12,6	14,5	-25,9442	29,0571	1539,1	
Eight	170	29029	13,9	14,0	-25,9442	29,0570	1537,64	
Eight	180	28911,2	13,9	17,2	-25,9442	29,0569	1537,89	
Eight	190	28885,7	13,2	17,1	-25,9442	29,0568	1537,86	
Eight	200	28863,2	13,1	12,3	-25,9442	29,0567	1538,3	
Eight	210	28913,9	12,6	16,2	-25,9441	29,0566	1537,93	
Nine	0	28695,9	3,4	3,9	-25,9344	29,0682	1537,46	
Nine	10	28705,4	2,9	4,0	-25,9344	29,0683	1539,65	
Nine	20	28736,3	3,0	3,7	-25,9344	29,0683	1539,19	
Nine	30	28744,9	3,6	4,5	-25,9343	29,0684	1539,09	
Nine	40	28728	2,8	5,2	-25,9344	29,0685	1538,67	
Nine	50	28731,2	3,0	4,6	-25,9344	29,0686	1538,13	
Nine	60	28731,4	3,1	4,8	-25,9344	29,0687	1537,83	
Nine	70	28737	2,9	4,0	-25,9344	29,0688	1539,07	
Nine	80	28736,8	3,0	5,1	-25,9344	29,0689	1538,1	
Nine	90	28743,9	3,6	5,1	-25,9344	29,0689	1538,75	
Nine	100	28727	3,3	4,8	-25,9344	29,0690	1538,21	
Nine	110	28731,4	2,6	5,2	-25,9345	29,0691	1537,86	
Nine	120	28729,3	2,8	5,1	-25,9345	29,0692	1537,46	
Nine	130	28736,1	3,0	4,5	-25,9345	29,0693	1537,4	
Nine	140	28743,9	2,4	4,6	-25,9345	29,0694	1537,36	
Nine	150	28763,9	2,3	4,3	-25,9345	29,0695	1538,57	
Nine	160	28761,3	2,9	4,4	-25,9345	29,0696	1536,9	
Nine	170	28773,5	2,5	4,6	-25,9345	29,0696	1536,85	
Nine	180	28768,2	2,2	4,4	-25,9345	29,0697	1537,92	
Nine	190	28773,5	2,2	4,6	-25,9346	29,0698	1537,86	
Nine	200	28760,9	2,1	4,9	-25,9346	29,0699	1536,92	
Nine	210	28773,3	2,1	4,4	-25,9346	29,0700	1536,99	
Nine	220	28784,6	2,8	4,1	-25,9346	29,0701	1536,52	
Nine	230	28777,2	2,4	5,4	-25,9346	29,0702	1536,92	
Nine	240	28804,7	2,6	4,7	-25,9347	29,0703	1537,6	
Nine	250	28831,3	2,8	3,6	-25,9347	29,0704	1536,44	
Nine	260	28776,2	3,1	4,2	-25,9347	29,0705	1535,71	
Nine	270	28778,1	2,3	4,1	-25,9347	29,0706	1535,81	
Nine	280	28768,3	2,2	4,3	-25,9347	29,0707	1535,77	
Nine	290	28776	2,4	3,8	-25,9347	29,0708	1535,67	
Nine	300	28772,2	2,3	4,2	-25,9347	29,0709	1536,38	
Nine	310	28866,2	2,0	3,7	-25,9347	29,0710	1536,18	
Nine	320	28771,4	2,8	4,0	-25,9347	29,0711	1537,05	
Nine	330	28760,8	2,4	4,8	-25,9347	29,0711	1537,02	
Nine	340	28756,8	2,3	4,2	-25,9348	29,0712	1535,61	

Appendix D: Borehole Logs

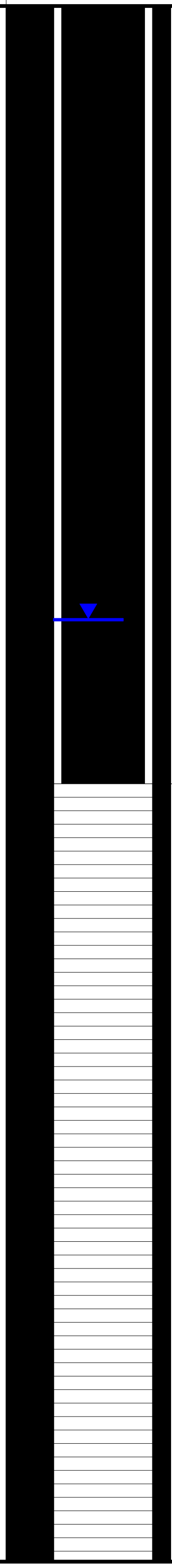
DIGBY WELLS ENVIRONMENTAL

Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:	**BECSA**	**BOREHOLE ID:**	**BHPW3**
Project Name:	Monitoring_Boreholes	Coordinate System:	WGS84
Project Code:	BHP2690 & BHP1591	X-Coordinate:	-26.054014
Location:	Ogies	Y-Coordinate:	29.083428
Drilled By:	EDRS	Z-Coordinate:	1574
Date Drilled:	15 January 2015	Final Depth (m):	60
Logged By:	M.D Mahlangu		

Depth (m)	Geological Profile	Description	Weathering	Water Strike (m)	Blow Yield (L/s)
0	SOIL	"Reddish, Dry, Top soil"	Very	0	
	SANDY QUARTZITE	"cream white, coarse-grained sedimentary rock composed of firmly cemented quartz grains"	Very		
12				12	
	SANDSTONE	light gark gray, coarse-grained sedimentary rocks	Moderate		
24				24	
		dark black organic sedimentary rock	Moderate		
	SANDSTONE	light gark gray, coarse-grained sedimentary rocks	Moderate		
36	SHALE	dark gray, fine-grained, carbonaceous clastic sedimentary rock	Moderate	36	
	SANDSTONE	light gray, coarse-grained sedimentary rocks	Moderate		
		dark black organic sedimentary rock	Moderate		
48				48	
	SANDSTONE	light gray, coarse-grained sedimentary rocks	Slight		
	SHALE	dark gray, fine-grained, carbonaceous clastic sedimentary rock	Slight		
60	SANDSTONE	light gray, coarse-grained sedimentary rocks	Slight	60	

Borehole Construction and Water level



Drilled radius - 165 mm, Solid PVC cased - 140 mm

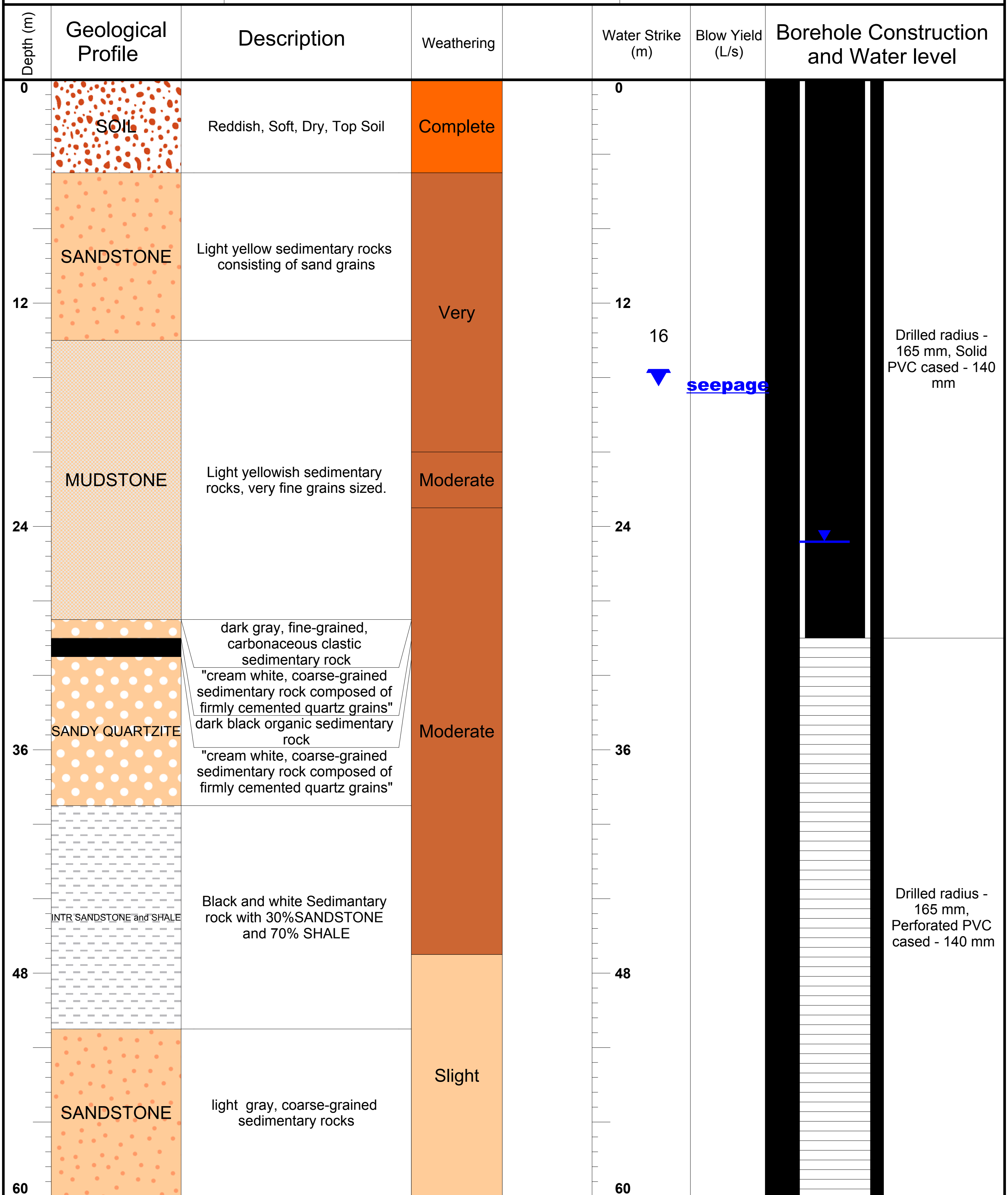
Drilled radius - 165 mm, Perforated PVC cased - 140 mm

Comment:

DIGBY WELLS
ENVIRONMENTAL
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:	**BECSA**
Project Name:	Monitoring_Boreholes
Project Code:	BHP2690 & BHP1591
Location:	Ogies
Drilled By:	EDRS
Date Drilled:	6 February 2015
Logged By:	M.D Mahlangu

BOREHOLE ID:	**BHPW5**
Coordinate System:	WGS84
X-Coordinate:	-25.980403
Y-Coordinate:	29.107477
Z-Coordinate:	1593
Final Depth (m):	60



Comment:

DIGBY WELLS ENVIRONMENTAL

Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:	**BECSA**	**BOREHOLE ID:**	**BHPW7**
Project Name:	Monitoring_Boreholes	Coordinate System:	WGS84
Project Code:	BHP2690 & BHP1591	X-Coordinate:	-25.985038
Location:	Ogies	Y-Coordinate:	29.047013
Drilled By:	EDRS	Z-Coordinate:	1537
Date Drilled:	16 January 2015	Final Depth (m):	60
Logged By:	M.D Mahlangu		

Depth (m)	Geological Profile	Description	Weathering	Water Strike (m)	Blow Yield (L/s)	Borehole Construction and Water level
0	SOIL	orenge top soil	Complete			Drilled radius - 165 mm, Solid PVC cased - 140 mm
12	SANDSTONE	light orenge, coarse-grained sandy soil				
24			Slight			
36	DOLERITE	Dark gray, coarse-grained , intrusive igneous rock consisting of plagioclase feldspar and a pyroxene				Drilled radius - 165 mm, Perforated PVC cased - 140 mm
48						
60						

Comment:

DIGBY WELLS ENVIRONMENTAL

Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT: BECSA

Project Name:	Monitoring_Boreholes
Project Code:	BHP2690 & BHP1591
Location:	Ogies
Drilled By:	EDRS
Date Drilled:	15 January 2015
Logged By:	M.D Mahlangu

BOREHOLE ID: BHPW8

Coordinate System:	WGS84
X-Coordinate:	-25.944253
Y-Coordinate:	29.057141
Z-Coordinate:	1537
Final Depth (m):	60

Depth (m)	Geological Profile	Description	Weathering	Water Strike (m)	Blow Yield (L/s)
0	SOIL	Reddish, Soft, Dry, Top Soil	Very		
12	MUDSTONE	yellowish red sedimentary rocks, very fine grains sized.	Very		
	DOLERITE	Dark gray, coarse-grained , intrusive igneous rock consisting of plagioclase feldspar and a pyroxene	Moderate	23	0.14L/s
24 – 60	DOLERITE	Dark gray, coarse-grained , intrusive igneous rock consisting of plagioclase feldspar and a pyroxene	Slight		

Borehole Construction and Water level

- Drilled radius - 165 mm, Solid PVC cased - 140 mm
- Drilled radius - 165 mm, Perforated PVC cased - 140 mm
- Drilled radius - 165 mm, Solid PVC cased - 140 mm
- Drilled radius - 165 mm, Perforated PVC cased - 140 mm
- Drilled radius - 165 mm, Solid PVC cased - 140 mm

Comment:

DIGBY WELLS ENVIRONMENTAL

Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:	**BECSA**
Project Name:	Monitoring_Boreholes
Project Code:	BHP2690 & BHP1591
Location:	Ogies
Drilled By:	EDRS
Date Drilled:	6 February 2015
Logged By:	M.D Mahlangu

BOREHOLE ID:	**BHPW10**
Coordinate System:	WGS84
X-Coordinate:	-26.029667
Y-Coordinate:	29.095644
Z-Coordinate:	1588
Final Depth (m):	60

Geological Profile	Description	Weathering
SOIL	Reddish, Soft, Dry, Top Soil	Complete
SANDY QUARTZITE	"cream white, coarse-grained sedimentary rock composed of firmly cemented quartz grains"	Very
SHALE	gray, fine-grained, carbonaceous clastic sedimentary rock	Very
	dark black organic sedimentary rock	Moderate
SANDY QUARTZITE	"cream white, coarse-grained sedimentary rock composed of firmly cemented quartz grains"	Moderate
SHALE	gray, fine-grained, carbonaceous clastic sedimentary rock	Moderate
SANDSTONE	light orenge, coarse-grained sandy soil	Moderate
SHALE	gray, fine-grained, carbonaceous clastic sedimentary rock	Moderate
SANDSTONE	light orenge, coarse-grained sandy soil	Moderate
SHALE	gray, fine-grained, carbonaceous clastic sedimentary rock	Moderate
SANDSTONE	light orenge, coarse-grained sandy soil	Moderate

Depth (m): 0, 12, 24, 36, 48, 60

Water Strike (m) | Blow Yield (L/s)

Borehole Construction and Water level

Drilled radius - 165 mm, Solid PVC cased - 140 mm

Drilled radius - 165 mm, Perforated PVC cased - 140 mm

Comment:

Appendix E: Geochemical Data

Ref.No. :8661467

Issued at : Johannesburg
Date :2015-02-12

COMPANY NAME : DIGBY WELLS & ASSOCIATES (SA) PTY LTD

ADDRESS : PRIVATE BAG X10046 RANDBURG 2125

SUBJECT : ANALYSIS OF 11 SAMPLES OF COAL

MARKED : AND AS BELOW

INSTRUCTED BY : MEGAN EDWARDS

ORDER NO. :

RECEIVED ON : 2015-02-09

LAB NO(S) : E26447 - E26457

DATE ANALYSED : 2015-02-13

Analysis on the dried and milled samples:

ACID-BASE ACCOUNTING

SAMPLE MARKS:	LAB NO:	Total Sulphur, S %	Total Acidity Potential as $CaCO_3$ kg/tonne	Gross Neutralisation Potential as $CaCO_3$ kg/tonne	Net Neutralisation Potential as $CaCO_3$ kg/tonne (By Difference)
BHPWO3 OVERBURDEN OF COAL SEAM 1	E26447	0.02	0.62	31.2	30.6
BHPWO3COAL SEAM 1	E26448	1.43	44.6	24.3	-20.3
BHPWO3 INTERBURDEN OF COAL SEAM 1&2	E26449	2.34	73.0	18.9	-54.1
BHPWO3 COAL SEAM 2	E26450	1.04	32.5	43.8	11.3
BHPWO3 UNDERRBURDEN COAL SEAM 2	E26451	0.42	13.1	22.3	9.20
BHPW10 OVEERBURDEN OF COAL SEAM 1	E26452	0.39	12.2	1.97	-10.2
BHPW10 COAL SEAM 1	E26453	1.40	43.7	51.3	7.60
BHPW10 UNDERBURDEN OF COAL SEAM 1	E26454	0.24	7.49	6.19	-1.30
BHPW05 OVERBURDEN OF COAL SEAM 1	E26455	0.08	2.50	12.1	9.60
BHPW05 COAL SEAM 1	E26456	0.22	6.89	40.4	33.5
BHPW05 UNDERBURDEN COAL SEAM 1	E26457	0.08	2.50	2.84	0.34

Method Reference:

Lawrence, R.W., Polling, G.P. and Marchant, P.B., 1989. Investigation of predictive techniques or acid mine drainage, Report on DSS Contract No. 23440-7-9178/01-SQ, Energy Mines and Resources, Canada, MEND Report 1.16.1(a).

Sobek, A.A., Schuller, W.A., Freeman, J.R. and Smith, R.M., 1978. Field and Laboratory Methods Applicable to Overburden and Minesoils, EPA 600/2-78-054, 203 pp.

M&L LABS

COMPANY NAME : DIGBY WELLS & ASSOCIATES (SA) PTY LTD

ADDRESS : PRIVATE BAG X10046 RANDBURG 2125

SUBJECT : ANALYSIS OF 11 SAMPLES OF COAL

MARKED : AND AS BELOW

INSTRUCTED BY : FRANCIS KOM

ORDER NO. :

RECEIVED ON : 2015-01-22

LAB NO(S) : E26447 - E26457

DATE ANALYSED : 2015-02-13

Analysis on the dried and milled samples:

SAMPLE MARKS:	LAB NO:	pH Value @ 21°C (on a saturated paste)	NET ACID GENERATION pH Value@ 21°C	NET ACID GENERATION AS H_2SO Kg/tonne
BHPWO3 OVERBURDEN OF COAL SEAM 1	E26447	8.8	8.3	<1
BHPWO3COAL SEAM 1	E26448	7.7	2.2	25.7
BHPWO3 INTERBURDEN OF COAL SEAM 1&2	E26449	5.4	2.3	17.1
BHPWO3 COAL SEAM 2	E26450	7.8	2.3	62.9
BHPWO3 UNDERRBURDEN COAL SEAM 2	E26451	8.3	6.0	<1
BHPW10 OVEERBURDEN OF COAL SEAM 1	E26452	6.6	3.4	1.34
BHPW10 COAL SEAM 1	E26453	7.4	2.8	22.0
BHPW10 UNDERBURDEN OF COAL SEAM 1	E26454	7.3	4.6	<1
BHPW05 OVERBURDEN OF COAL SEAM 1	E26455	7.3	6.8	<1
BHPW05 COAL SEAM 1	E26456	8.5	3.0	27.4
BHPW05 UNDERBURDEN COAL SEAM 1	E26457	8.7	6.1	<1

Method Reference:

Miller, S., Robertson, A. and Donohue, T. (1997). Advances in Acid Drainage Prediction. Prediction using The Net Acid Generation (NAG) Test. Report on Acid Mine Drainage published in Vancouver, BC., Canada.

COMPANY NAME :DIGBY WELLS & ASSOCIATES (SA) PTY LTD
ADDRESS :PRIVATE BAG X10046 RANDBURG 2125
SUBJECT :ANALYSIS OF 6 SAMPLES OF SOLID
MARKED :BHP AND AS BELOW
INSTRUCTED BY :MEGAN EDWARDS
ORDER NO. :
RECEIVED ON :2015/03/10
LAB NO(S) :E22612 - E22617
DATE ANALYSED :2015/03/25

The Analyses were carried out on 20% Aqueous Extracts of the samples as received.

Lab No:	E22612	E22613	E22614	E22615
SAMPLE MARKS	BHPW03(COAL SEAM1)	BHPW03(COAL SEAM2)	BHPW10(COAL SEAM1)	BHPW05(COAL SEAM1)
pH Value @ 21°C	7.4	7.3	7.6	7.7
Conductivity mS/m @ 25°C	57.1	30.3	58.3	10.6
Calcium,Ca	93	42	103	12.5
Magnesium, Mg	17.2	9.2	16	2.0
Sodium,Na	3.1	3.0	2.8	3.0
Potassium,K	2.8	1.6	2.9	3.8
Total Alkalinity as CaCO3	63	27	58	44
P Alk as CaCO3	Nil	Nil	Nil	Nil
Bicarbonate,HCO3	77	33	71	54
Carbonate, CO3	Nil	Nil	Nil	Nil
Chloride,Cl	0.4	0.4	0.5	0.5
Sulfate,SO4	267	121	270	4.6
Fluoride,F	<0.1	0.2	0.1	0.6

The results are expressed in mg/l where applicable.

Note: 1.The 1:5 Solid: Aqueous Extractions were carried out using deionised water.

The Analyses were carried out on 20% Aqueous Extracts of the samples as received.

Lab No:	E22616	E22617
SAMPLE MARKS	BHPW(OVERBURDEN COAL SEAM1)	BHPW(INTERBURDEN COAL SEAM1)
pH Value @ 21°C	7.3	7.2
Conductivity mS/m @ 25°C	27.5	56.2
Calcium,Ca	33	76
Magnesium, Mg	9.8	25
Sodium,Na	3.8	3.7
Potassium,K	5.0	3.7
Total Alkalinity as CaCO3	30	23
P Alk as CaCO3	Nil	Nil
Bicarbonate,HCO3	37	28
Carbonate, CO3	Nil	Nil
Chloride,Cl	1.3	0.9
Sulfate,SO4	93	284
Fluoride,F	0.2	0.1

The results are expressed in mg/l where applicable.

Note: 1.The 1:5 Solid: Aqueous Extractions were carried out using deionised water.

Method reference: A list Appended.

M&L LABS

COMPANY NAME :DIGBY WELLS & ASSOCIATES (SA) PTY LTD

ADDRESS :PRIVATE BAG X10046 RANDBURG 2125

SUBJECT :ANALYSIS OF 6 SOLID SAMPLES

MARKED :BHP AND AS BELOW

INSTRUCTED BY :MEGAN EDWARDS

ORDER NO. :

RECEIVED ON :2015-03-09

LAB NO(S) :E22612 – E22617

DATE ANALYSED :2015-03-23

After representative sampling using a riffle splitter, the samples were milled in a tungsten carbide vessel and prepared according to the standardized Panalytical backloading system, which provides nearly random distribution of the particles. They were analyzed using a PANalytical X'Pert Pro powder diffractometer in θ–θ configuration with an X'Celerator detector and variable divergence- and fixed receiving slits with Fe filtered Co-Kα radiation (λ=1.789Å). The phases were identified using X'Pert Highscore plus software.

The relative phase amounts (weight %) were estimated using the Rietveld method (Autoquan Program). Errors are on the 3 sigma level in the column to the right of the amount. Amorphous phases, if present were not taken into consideration in the quantification. The quantitative results are listed below.
Please contact me should you have any questions.

Quantitative Results:

E22612 BHPW03 (COAL SEAM10			**E22613 BHPWO3 (COAL SEAM20**			**E22614 BHPW10 (COAL SEAM1)**		
	weight%	3 σ error		weight%	3 σ error		weight%	3 σ error
Calcite	3.66	0.84	Calcite	6.95	0.75	Calcite	5.65	0.78
Kaolinite	43.3	1.5	Dolomite	8.67	0.96	Dolomite	1.64	0.72
Microcline	12.25	1.71	Kaolinite	49.86	1.5	Kaolinite	47.72	1.53
Pyrite	9.7	0.51	Microcline	9.47	1.53	Microcline	9.44	1.83
Quartz	31.1	1.38	Pyrite	4.65	0.45	Pyrite	5.15	0.48
			Quartz	20.4	1.23	Quartz	30.4	1.44

E22615 BHPW05 (COAL SEAM1)			**E22616 BHPW (OVERBURDEN COAL SEAM1)**			**E22617 BHPW (INTERBURDEN COAL SEAM)**		
	weight%	3 σ error		weight%	3 σ error		weight%	3 σ error
Calcite	4.92	1.11	Dolomite	1.55	0.3	Kaolinite	34.59	0.9
Dolomite	0	0	Kaolinite	26.77	0.96	Microcline	9.8	0.75
Kaolinite	83.8	1.74	Microcline	3.64	0.48	Muscovite	5.97	0.48
Microcline	5.63	1.38	Muscovite	5.53	0.54	Pyrite	1.61	0.21
Pyrite	1.05	0.36	Quartz	57.62	0.99	Quartz	42.45	0.78
Quartz	4.61	0.66	Siderite	4.88	0.42	Siderite	5.58	0.42

Ideal Mineral Composition:

Anatase	TiO_2
Calcite	$Ca(CO_3)$
Dolomite	$CaMg(CO_3)_2$
Kaolinite	$Al_2(Si_2O_5)(OH)_4$
Microcline	$KAlSi_3O_8$
Muscovite	$KAl_3Si_3O_{10}(OH)_2$
Pyrite	FeS_2
Quartz	SiO_2
Rutile	TiO_2
Siderite	$FeCO_3$

Comments:

- Due to preferred orientation effects, mainly in micas and clay minerals (kaolinite), results may not be as accurate as shown in the table.
- In case the results do not correspond to results of other analytical techniques, please contact me for re-evaluation of XRD results.
- Some of the samples may contain large amount of amorphous material (amorphous graphite). The amount of the crystalline phases might be overestimated, because of the presence of amorphous material.