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Hydrogeological Assessment - Newcastle Landfill Site, KwaZulu-Natal

Report

Version – 1

23 April 2018

Envitech Solutions

GCS Project Number: 17-0212

Client Reference: Newcastle landfill site EIA

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HYDROGEOLOGICAL INVESTIGATION - NEWCASTLE LANDFILL

Report
Version -1

23 April 2018

Envitech Solutions
17-0212

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DECLARATION OF INTEREST

The author of this report Marietjie Kruger, hereby declares that she is an independent specialist on this application and has no business, financial, personal or other interest in the activity, application or appeal in respect of which she was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of the specialist performing such work.

Marietjie Kruger
April 2018

DETAILS OF SPECIALIST

Details of the specialists who prepared the report are presented below. The CV's of all the specialists including reviewers are attached as Appendix E.

Details of Specialists

Person	Qualification & Registration	Years' experience
Alkie Marias	MSc (Pr.Sci.Nat)	20
Kobus Troskie	Hons. (Pr.Sci.Nat)	15
Claudia du Plessis	MSc (Pr.Sci.Nat)	9
Marietjie Kruger	Hons. (Cand. Pr.Sci.Nat)	4

EXECUTIVE SUMMARY

Introduction

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Envitech Solutions to conduct a hydrogeological investigation including a groundwater impact assessment that will form part of the Environmental Authorization for a proposed G:L:B+ landfill near Newcastle. A detailed, intrusive investigation was conducted for the Greenwich site located in Newcastle.

Site Details

The study area is located on farm portion Greenwich 8487, approximately 9km south of Newcastle in the KwaZulu-Natal Province.

The site is located on a topographical high sloping in a north westerly and north easterly direction. Several non-perennial drainage lines flows from the center of the site in a north westerly and north easterly direction. A dam is located north of the site.

Geological and Hydrogeological Setting

The site is underlain by a dolerite intrusive rock body (sill) overlying the sandstone, dark-grey mudstone and shale (coal beds in places) of the Vryheid Formation (Ecca Group of the Karoo Supergroup).

The underlining aquifer is defined as an intergranular and fractured aquifer which is classified as a minor aquifer which is moderately vulnerable.

Field Investigation

During the hydrocensus conducted on the 16th February 2018, six boreholes (HBH1 – HBH6) as well as a spring were identified on properties within a 2km radius of the site. Groundwater levels ranged between 4.75 and 25.9 meters below ground level (mbgl). HBH2, HBH5 and HBH6 are used for domestic purposes. Based on the topography and groundwater flow direction map, HBH2 and HBH6 are located downgradient of the proposed landfill. HBH5 and the spring are used for stock watering at the Gardinia dairy farm. HBH6 was used as water supply to the Newcastle Farmers Union whereby water is used for both domestic and stock watering.

A geophysical survey was conducted on the 5th and 6th February 2018. The electrical resistivity method is a non-intrusive method used for investigating subsurface conditions by means of inducing a current (I) through the subsurface.

Four traverses were done within the north east, north west and south western section of the study area. Two primary targets and two secondary targets were sited.

Three (3) monitoring boreholes (BH1, BH2 and BH3) were installed on or within close proximity to the geophysical drilling targets. The depths ranged from 19 to 31mbgl.

One existing borehole (BH NL2) and the three newly installed boreholes (BH1, BH2 and BH3) were inspected. Static groundwater levels ranged from 0.49 to 14.35mbgl and well depth was measured between 19 and 59.66mbgl. Groundwater samples were collected from BH1, BH2, BH3 and BH NL2.

A short duration Constant Rate (CR) test including a recovery test was conducted for each newly installed borehole. The recovery transmissivity in the monitoring boreholes was calculated to be between 0.06188 and 0.3838m/day. This is considered low transmissivity values representing fine sand to silt and would impede the flow and dispersion of contamination if it were present.

Laboratory Analysis

Colour and turbidity detected in all boreholes exceeded the SANS standards. The elevated turbidity in the newly installed boreholes are most likely associated with disturbance during drilling and is not representative of groundwater conditions.

Combined nitrate (NO_3) and nitrite (NO_2) detected in BH3 and BH NL2 marginally exceeded the SANS standard. The aluminium (Al) detected in BH2 and BH3, exceeded the SANS standard. The iron detected in BH1 and BH3 exceeded the aesthetic SANS standard, however was below the chorionic health SANS standard. Iron detected in BH2 however exceeded the chronic health standard. Manganese (Mn) detected in BH2 and exceeded the aesthetic standard, however was below the chronic standard.

Groundwater samples collected from BH1, BH2 and BH3 represent recently recharged groundwater rich in calcium, magnesium and bicarbonate. BH NL2 represents a dynamic regime with water rich in sodium, bicarbonate and chloride.

Risk Assessment

During the risk assessment potential areas of concern were identified. The following risks were identified during the construction phase:

1. Groundwater contamination during fuel spillages from construction vehicles or fuel storage areas. The impact will have a medium negative significance.

The following risks were identified during the operational phase:

1. Groundwater contamination during fuel spillages from heavy machinery and vehicle movement. The impact will have low to medium negative significance, however with implementation of mitigation measures the impact can be decreased to low;
2. Groundwater contamination due to leakages/spillages. The impact will have a high negative significance, however with implementation of mitigation measures the impact can be decreased to medium.

Recommendations

Based on the findings of this investigation, the following recommendations are made:

- It is recommended that groundwater quality monitoring be conducted to ensure water remains compliant with the DWAF Minimum Requirements for Waste Disposal by Landfill (DWAF, 1998). Boreholes to be monitored includes BH1, BH2, BH3, BH NL1 and BH NL2;
- Mitigation measures identified during the risk assessment should be implemented during both the construction and operational phase;
- Engineering and designs should be done to appropriate standards and current best practices for a G:L:B+ site so as to avoid contamination of the underlying aquifer.

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GLOSSARY

Aquifer: A formation, group of formations or part of a formation that contains sufficient saturated permeable material to store and transmit water, and to yield economic quantities of water to boreholes or springs.

Attributes: Geological and groundwater features that impart key hydrogeological characteristics to rock formations.

Borehole: Includes a well, excavation, or any other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer [from the National Water Act (Act No. 36 of 1998)].

Catchment: The area from which any rainfall will drain into the watercourse, contributing to the runoff at a particular point in a river system, synonymous with the term river basin.

Contamination: the introduction of pollutants (whether chemical substances, or energy such as noise, heat, or light) into the environment to such an extent that its effects become harmful to human health, other living organisms, or the environment.

Electrical Conductivity (EC): A measurement of the ease with which water conducts electricity due to the presence of dissolved salts/ions in the water, i.e. distilled water - low EC, poor conductor of electricity, sea water - high EC and salt content indicate a good conductor of electricity.

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

Formation: A general term used to describe a sequence of rock layers.

Fracture: Cracks, joints or breaks in the rock that can enhance water movement.

Groundwater flow: The movement of water through openings and pore spaces in rocks below the water table, i.e. in the saturated zone. Groundwater naturally drains from higher lying areas to low lying areas such as rivers, lakes and the oceans. The rate of flow depends on the slope of the water table and the transmissivity of the aquifer materials.

Groundwater: Water found in the subsurface in the saturated zone below the water table or piezometric surface, i.e. the water table marks the upper surface of groundwater systems.

Hazard Is any source of potential damage, harm or adverse health effects on something or someone under certain conditions.

Hydraulic conductivity (K) is the volume of water that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured perpendicular to the area [L/T]. Hydraulic conductivity is a function of the permeability and the fluid's density and viscosity.

Lineaments: A major, linear, topographic feature of regional extent of structural or volcanic origin, most easily appreciated from remote sensing data, e.g. a fault system or dyke.

Quaternary Catchment: Fourth order catchment within a primary river basin catchment.

Risk Is the chance or probability that a person will be harmed or experience an adverse health effect if exposed to a hazard. It may also apply to situations with property or equipment loss.

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

Static water level is the level of water in a borehole that is not being affected by withdrawal of groundwater. Also known as a "rest water level"

Total dissolved solids (TDS) is a term that expresses the quantity of dissolved material in a sample of water

Transmissivity: the rate at which a volume of water is transmitted through a unit width of aquifer under a unit hydraulic head (m2 /d); product of the thickness and average hydraulic conductivity of an aquifer.

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

Vulnerability: The tendency or likelihood for contaminants to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer.

Water table is the surface between the vadose zone and the saturated zone (i.e. groundwater). The water table is the surface of an unconfined aquifer at which the pressure is equal to that of the atmosphere

Wellfield: An area containing more than one pumping borehole that provides water to a public water supply system or single owner (e.g. a municipality).

ABBREVIATIONS

DWS	Department of Water and Sanitation (formerly the DWA and the DWAF)
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EC	Electrical conductivity (mS/m)
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
GIS	Geographical Information System
GRDM	Groundwater Resource Directed Measures (DWS, 2013)
K	Hydraulic conductivity
ℓ/sec	litres per second
m^2/day	Square metres per day
m^3/a	Cubic metres per annum
m^3/day	Cubic metres per day
mamsl	Metres above mean sea level
MAP	Mean Annual Precipitation
mbgl	Metres below ground level
mg/ℓ	Milligrams per litre
mS/m	milli-Siemens per metre
NGA	National Groundwater Archives
NWRS	National Water Resource Strategy
Q	Yield (ℓ/sec)
T	Transmissivity (m^2/day)
TDS	Total dissolved solids (mg/ℓ)
WARMS	Water Authorization Registration Management System

NATIONAL ENVIRONMENTAL MANAGEMENT ACT, 107 OF 1998 (NEMA): APPENDIX 6

REQUIREMENT	STATUS
1. A specialist report prepared in terms of these Regulations must contain—	
(a) details of—	
(i) the specialist who prepared the report; and	Refer to Details of Specialist, page iv
(ii) the expertise of that specialist to compile a specialist report including a curriculum vitae;	Refer to Details of Specialist, page iv and curriculum vitae's attached in Appendix E
(b) a declaration that the specialist is independent in a form as may be specified by the competent authority;	Refer to declaration of interest, page iii
(c) an indication of the scope of, and the purpose for which, the report was prepared;	Refer to Section 2
(cA) an indication of the quality and age of base data used for the specialist report;	Refer to Section 5
(cB) a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	Refer to Section 8
(d) the duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Refer to Section 6
(e) a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	Refer to Section 3
(f) details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	N/A
(g) an identification of any areas to be avoided, including buffers;	N/A

REQUIREMENT	STATUS
(h) a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	N/A
(i) a description of any assumptions made and any uncertainties or gaps in knowledge;	N/A
(j) a description of the findings and potential implications of such findings on the impact of the proposed activity or activities;	Refer to Section 8
(k) any mitigation measures for inclusion in the EMPr;	Refer to section 8 and 8.2
(l) any conditions for inclusion in the environmental authorization;	Refer to section 10
(m) any monitoring requirements for inclusion in the EMPr or environmental authorization;	Refer to section 8.2
(n) a reasoned opinion—	
(i) whether the proposed activity, activities or portions thereof should be authorised;	Refer to section 10
(iA) regarding the acceptability of the proposed activity or activities; and	Refer to section 10
(ii) if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	Refer to section 10
(o) a description of any consultation process that was undertaken during the course of preparing the specialist report;	N/A
(p) a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	N/A
(q) any other information requested by the competent authority.	N/A

	REQUIREMENT	STATUS
2.	Where a government notice gazetted by the Minister provides for any protocol or minimum information requirement to be applied to a specialist report, the requirements as indicated in such notice will apply.	-N/A

1 INTRODUCTION

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Envitech Solutions to conduct a hydrogeological investigation including a groundwater impact assessment that will form part of the Environmental Authorization for a proposed G:L:B+ landfill near Newcastle. A detailed, hydrogeological investigation was conducted for the Greenwich site located in Newcastle.

2 SCOPE OF WORK

The scope of work for the hydrogeological assessment was as follows:

- Review of existing data;
- Detailed desktop study;
- Hydrocensus/neighbouring land survey within a 2km radius of the sub-catchment containing the site, within accessible areas;
- Geophysical Survey;
- Monitoring borehole installation;
- Constant rate aquifer testing of the three newly installed monitoring boreholes;
- Groundwater sampling of newly installed boreholes;
- Risk assessment describing the potential impact of the facility and its activities on the natural environment; and
- Reporting.

3 METHODOLOGY

3.1 Desktop study

GCS assessed all available geological and hydrogeological data prior to the commencement of any fieldwork. All existing groundwater data was reviewed and assessed during the desktop study. The following data sources were used during the study:

- 1:50 000 Topographical Series: 2729;
- 1:250 000 map Geological Map Series 2728 Frankfort (Council for Geoscience, 1992);
- Groundwater Resource Directed Measures (GRDM, 2013) obtained from the Department of Water and Sanitation (DWS);
- Existing hydrogeological reports for the site or in the area;
    - Geomeasure (2015). Newcastle Municipality New Landfill Investigation – Final Geohydrological Investigation Report of Greenwich Farm Candidate Site (Ref. No.: 2012/328):
- Facility design details.

3.2 Hydrocensus

A hydrocensus was conducted within a 2km radius and within the sub-catchment containing the site. The following information was recorded during the hydrocensus, where possible:

- GPS co-ordinates and elevation of existing boreholes or springs;
- Water levels of the boreholes, where accessible;
- Estimated abstraction volumes, where provided;
- Any other information regarding the water reliability or quality;
- Identifying surface water bodies and usage;
- Determine groundwater usage and identify groundwater users.

3.3 Geophysical Investigation

A surface geophysical survey was conducted in order to identify potential groundwater-bearing structures and lithology units.

The electrical resistivity data was collected with the ABEM LUND Resistivity two-dimension (2D) Imaging System which measures the electrical resistivity of the rock. The resistivity measurements are dependent on the mineral content, water content and water quality. Resistivity data was collected using a combination of Wenner, Schlumberger and /or Dipole-Dipole array electrode configuration with 10 m electrode spacing.

3.4 Monitoring Borehole Drilling & Drilling Supervision

Three (3) monitoring boreholes were drilled at the site. The boreholes were constructed as “open boreholes”: 215mm drill hammer drilled down through the unconsolidated rock material into competent bedrock.

Steel casing (6m) was installed in the unconsolidated rock material to prevent the borehole from collapsing during the ongoing drilling process. Thereafter the remainder of the hole was drilled with a 165mm diameter drill bit down to the ideal depth of 30m. The boreholes were cased by means of 110mm PVC casing.

3.4.1 Aquifer Testing

A short duration Constant Rate (CR) test including a recovery test was conducted for each newly installed borehole. The boreholes were pumped at a constant rate. The water level within the borehole was monitored during pumping. This data was used to determine the aquifer characteristics, such as transmissivity and storage. After pumping the water levels with the borehole were monitored to determine the recovery of the water levels with time.

A recovery test was carried out up to 90% of the original water level or over a 2 hour period. This allows for a better understanding of the aquifer hydraulic characteristics of the geological formations.

3.5 Groundwater Sampling

A groundwater sample was collected from each newly installed borehole in order to determine the preliminary groundwater condition as well as one hydrocensus borehole. The methodology in the collection and preservation of groundwater samples are important for the reliability of the analysis. The samples were submitted to an accredited laboratory services for analysis and included the following analyses:

- Metals: Na, K, Ca, Mg, Al, Sb, As, Ba, B, Cd, Cr, Cu, Fe, Pb, Mn, Ni, Se & Zn;
- pH, Electrical conductivity, Alkalinity, Total dissolved solids, Bi-carbonate, Colour, Turbidity;
- Nitrate and nitrite, Chloride, Sulphate and Fluoride

3.6 Risk Assessment

A risk assessment was conducted based on the available data obtained during the previous phases of work in order to identify areas of concern.

4 SITE HISTORY

A geohydrological investigation was conducted by Geomeasure in 2014. The initial invasive investigation of the site located on the farm Greenwich, undertaken in November 2013 comprised a geophysical survey, a limited geohydrological investigation and a limited invasive geotechnical investigation with the aim of assessing the suitability of the preferred candidate site for the development of a new landfill site.

This investigation included installation of groundwater monitoring boreholes. The following was concluded in the report referenced as follows: Geomeasure (2015), Newcastle Municipality New Landfill Investigation – Final Geohydrological Investigation Report of Greenwich Farm Candidate Site (Ref. No.: 2012/328):

- The installation of an up-gradient borehole and a down-gradient borehole was undertaken at the geophysically sited drilling targets identified during the limited invasive investigation;
- A 12 hour calibration and monitored recovery test was conducted on up-gradient borehole BH NL 1. The inferred transmissivity value was estimated to be in the order of 0.665 m^2/day;
- A groundwater sample was collected from BH NL1. Based on the groundwater quality analysis, elevated turbidity and total coliform values were detected which exceeded their respective SANS 241:2011 standards for drinking water, however both levels were likely attributed to the drilling and pump testing investigations;
- A risk / impact assessment was undertaken, by means of an aquifer classification, and based on this classification and the lack of fatal flaws the proposed location of the landfill was deemed geohydrologically suitable for the development of the new landfill site. However, engineering and designs should be done to appropriate standards and current best practices for a G:L:B+ site so as to avoid contamination of the underlying aquifer;
- Based on an assessment of the available geohydrological data, should the liner be breached, then potential contaminants from the landfill site would take approximately 1830 years to travel the 1000 m from the site to the dam.

5 SITE DETAILS

5.1 Study Area

The study area is located in an agricultural area on farm portion Greenwich 8487, approximately 9km south of Newcastle in the KwaZulu-Natal Province (refer to Figure 5-1).

5.2 Topography and Hydrology

The topography of the area slopes in a general northerly direction. The site is located on a topographical high with drainage occurring radially in a north westerly and north easterly direction away from a central high located in the southern section of the site (refer to Figure 5-2). The elevation of the site ranges from 1400 to 1340 meters above mean sea level (mamsl).

Several non-perennial drainage lines flow from the center of the site in a north westerly and north easterly direction towards the Perennial Ncandu and iNgagane rivers. A dam is located north of the site.

5.3 Geological Setting

According to the 1:250 000 geological map series 2728 Frankfort (Council for Geoscience, 1992), the site is underlain by a dolerite intrusive rock body overlying the sandstone, dark-grey mudstone and shale (coal beds in places) of the Vryheid Formation (Ecca Group of the Karoo Supergroup) (refer to Figure 5-3).

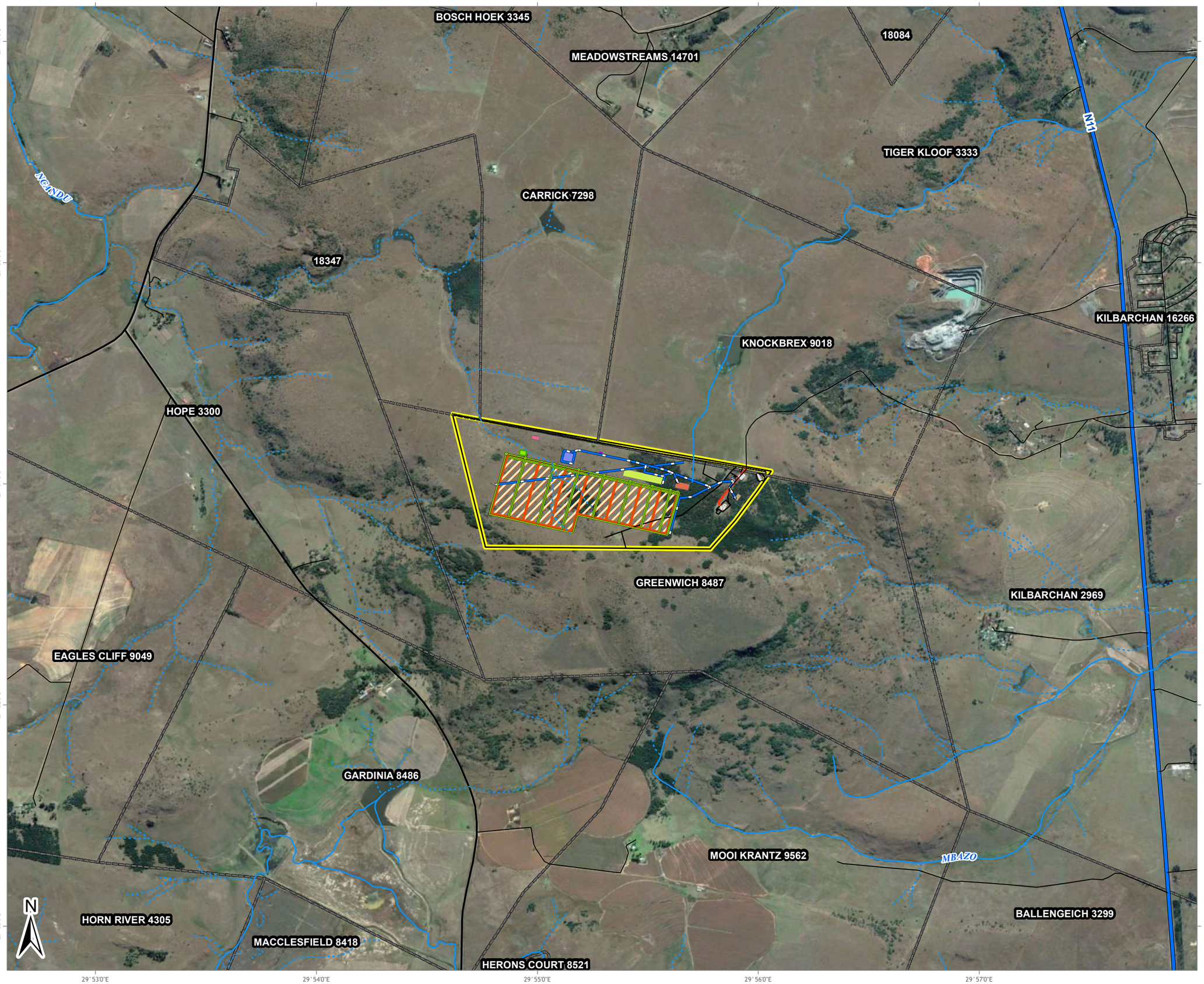
5.4 Hydrogeological Setting

According to the 1:500 000 hydrogeological map series 2726 Kroonstad (Baran and Jonck, 2000), the underlining aquifer is classified as an intergranular and fractured aquifer with average borehole yields between 0.5 and 2L/s.

The aquifer vulnerability and classification maps of South Africa classify the underlying aquifer as minor aquifer which is a moderately vulnerable aquifer system. According to Parsons and Conrad (1998), a minor aquifer system can be defined as fractured or potentially fractured rocks which do not have a high permeability, or other formations of variable permeability. The aquifer extent may be limited and seldom produce large quantities of water.

No NGA (National Groundwater Archive) boreholes are located within a 1km radius of the site.

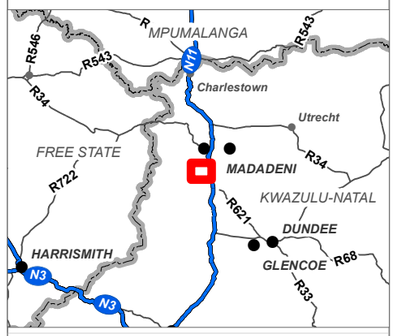
NEWCASTLE LANDFILL SITE: LOCALITY



LEGEND

Rivers and Streams
- Non-Perennial
- Perennial

Road Network
- National Route
- Main Road
- Secondary Road
- Street
- Leachate Lines
- Storm water chanel
- Other infrastructure
- Fence
- Road
- Parent farms
- Landfill Cells
- Cover material stockpile area
- Future landfilll gass extraction plant
- Future leachate treament plant
- Gas monitoring probe
- Leachate Collection Dam
- Perimeter Palisade Fence
- Recycling/Transfer area
- Wheel wash / workshop area



Data Sources:
Google Earth™ mapping service: 2018
Imagery Date:22/05/2017

0 0.25 0.5 1 Kilometers

SCALE: 1:30 000

FIGURE NO.:	-	MAP NUMBER:	17-0212-01-V3
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DATUM: PROJECTION:	WGS84 GEOGRAPHIC	DATE:	15 FEBRUARY 2018
PROJECT: CLIENT:	NEWCASTLE LANDFILL SITE EIA ENVITECH SOLUTIONS		

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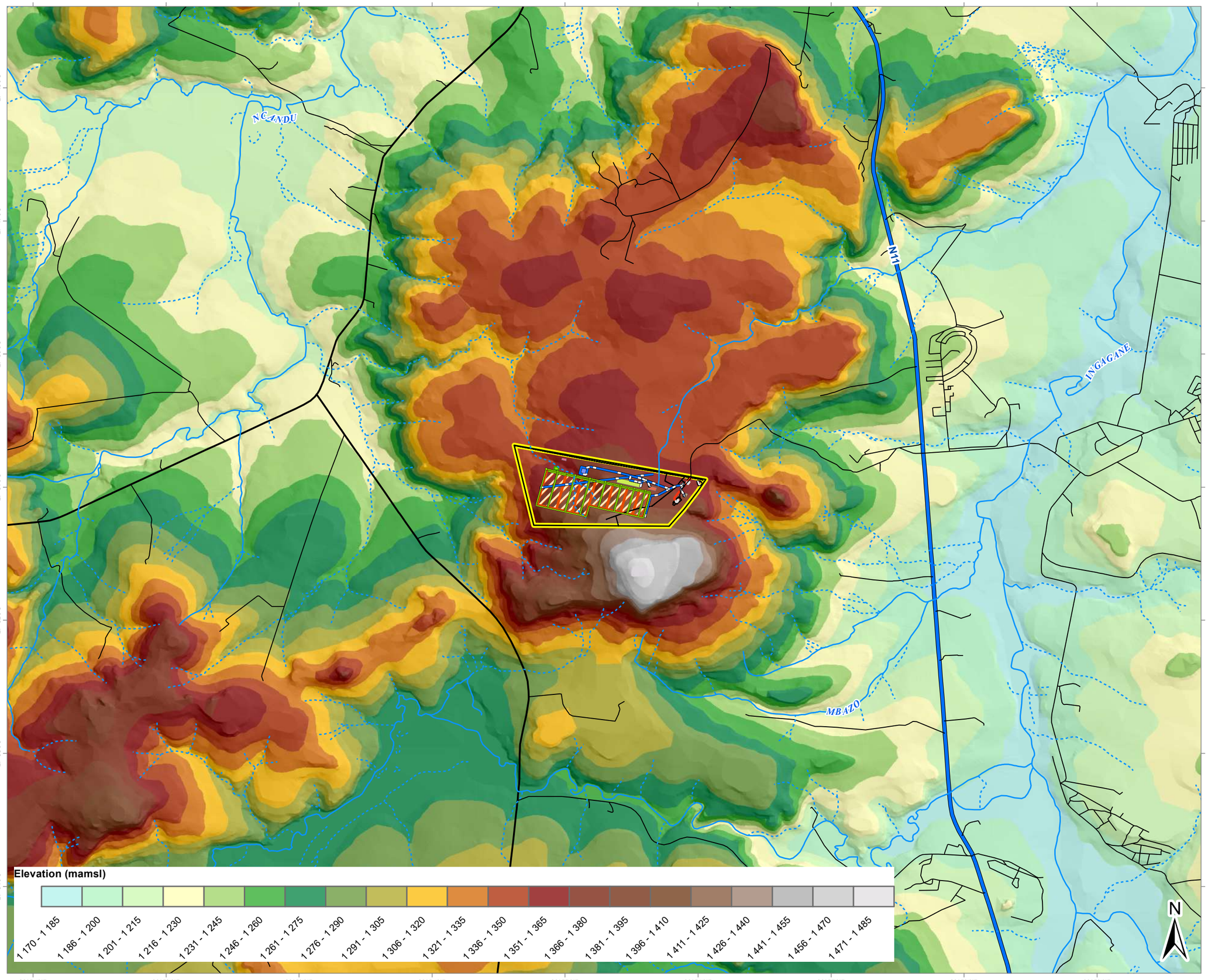
NEWCASTLE LANDFILL SITE: TOPOGRAPHY



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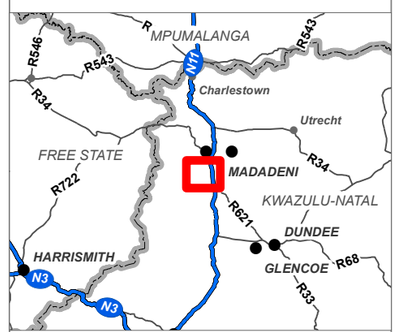

Data Sources:
RSA National Geospatial Institute
1:50 000 Topographical Series: 2729

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SCALE: 1:50 000

FIGURE NO.:	-	MAP NUMBER:	17-0212-05
DRAWN BY:	A BROWER GIS INTERN	REVIEWED BY:	P.CHETTY GIS SPECIALIST
DATUM: PROJECTION:	WGS84 GEOGRAPHIC	DATE:	15 FEBRUARY 2018
PROJECT: CLIENT:	NEWCASTLE LANDFILL SITE EIA ENVITECH SOLUTIONS		

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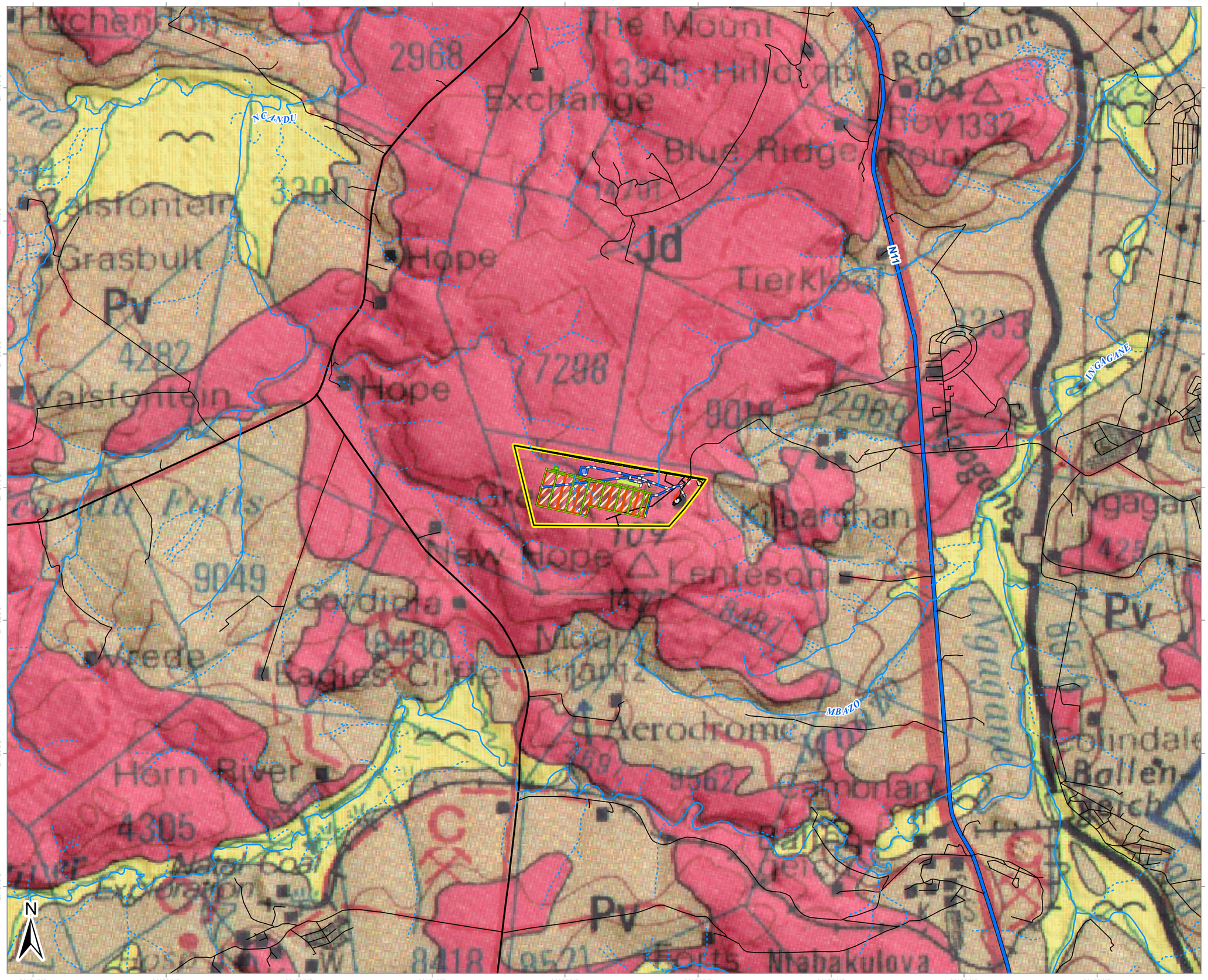
NEWCASTLE LANDFILL SITE: GEOLOGY



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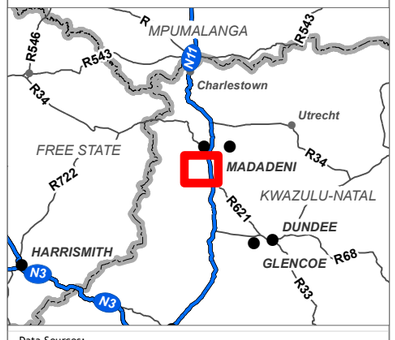
Lithology
- Alluvium
- Jd — Dolertie
- Pv — Sandstone, dark-grey mudstone and shale, coal beds in places



Data Sources:
Council for Geoscience
1:250 000 Geological Series: 2728

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SCALE: 1:50 000

FIGURE NO.:	-	MAP NUMBER:	17-0212-04
DRAWN BY:	A BROWER GIS INTERN	REVIEWED BY:	P.CHETTY GIS SPECIALIST
DATUM: PROJECTION:	WGS84 GEOGRAPHIC	DATE:	15 FEBRUARY 2018
PROJECT: CLIENT:	NEWCASTLE LANDFILL SITE EIA ENVITECH SOLUTIONS		

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6 FIELD INVESTIGATION

A field investigation, including a geophysical survey, monitoring borehole installation, aquifer testing, groundwater sampling and hydrocensus was conducted on the 5th and 6th as well as 12th to 16th February 2018. This investigation was conducted during the summer whereby rainfall was expected. Is did not have a significant impact on the investigation, however slight increased regional groundwater levels were expected.

6.1 Hydrocensus

A hydrocensus was conducted on the 16th February 2018. The details of the owners of the properties visited are presented in Table 6-1. A short interview was conducted on the 12th February 2018 with Craig Peterson, owner of RE 1 of Hope 3300, located north west of the study area. Mr. Peterson indicated that the owners in the area are concerned about the potential contamination that can arise from the landfill as the water source within the area is mainly groundwater. During the hydrocensus conduct on the 16th February 2018, Mr. Philips also raised the same concern as Mr. Peterson. The owner of Portion 4 of Hope 3300 was not present during the hydrocensus.

Table 6-1: Hydrocensus Property Owners

Borehole ID	Contact person	Address:	Telephone no.
HBH1	Craig Peterson	RE 1 of Hope 3300	0832539483
HBH2	Craig Peterson		0832539483
HBH3	Kobus	Portion 4 of Hope 3300	Unknown
HBH4	Kobus		Unknown
HBH5	Loyd Phillips	Gardinia 8486	0767223345
HBH6	Site manager: Loyd Phillips	Portion 10 of Hope 3300	0767223345

Six boreholes (HBH1-HBH6) as well as a spring were identified. Groundwater levels ranged between 4.75 and 25.9 meters below ground level (mbgl), refer to Table 6-2. HBH5 was in use during the assessment hence the deeper groundwater level. A spring was located on Farm portion Gardinia 8486, from which water is directed to a surface water dam on the farm. This water is used for stock watering.

Table 6-2: Hydrocensus Borehole Details

Borehole ID	Property	Latitude	Longitude	Collar Height (m)	SWL (mbgl)	Depth	Comments
HBH1	RE 1 of Hope 3300	-27.826461	29.893983	0.3	4.75	17	Not in use
HBH2		-27.826531	29.893563	0.1	15.9	Unknown	Sulphur smell and taste
HBH3		-27.855622	29.899557	0.2	8.2	Unknown	Not in use.

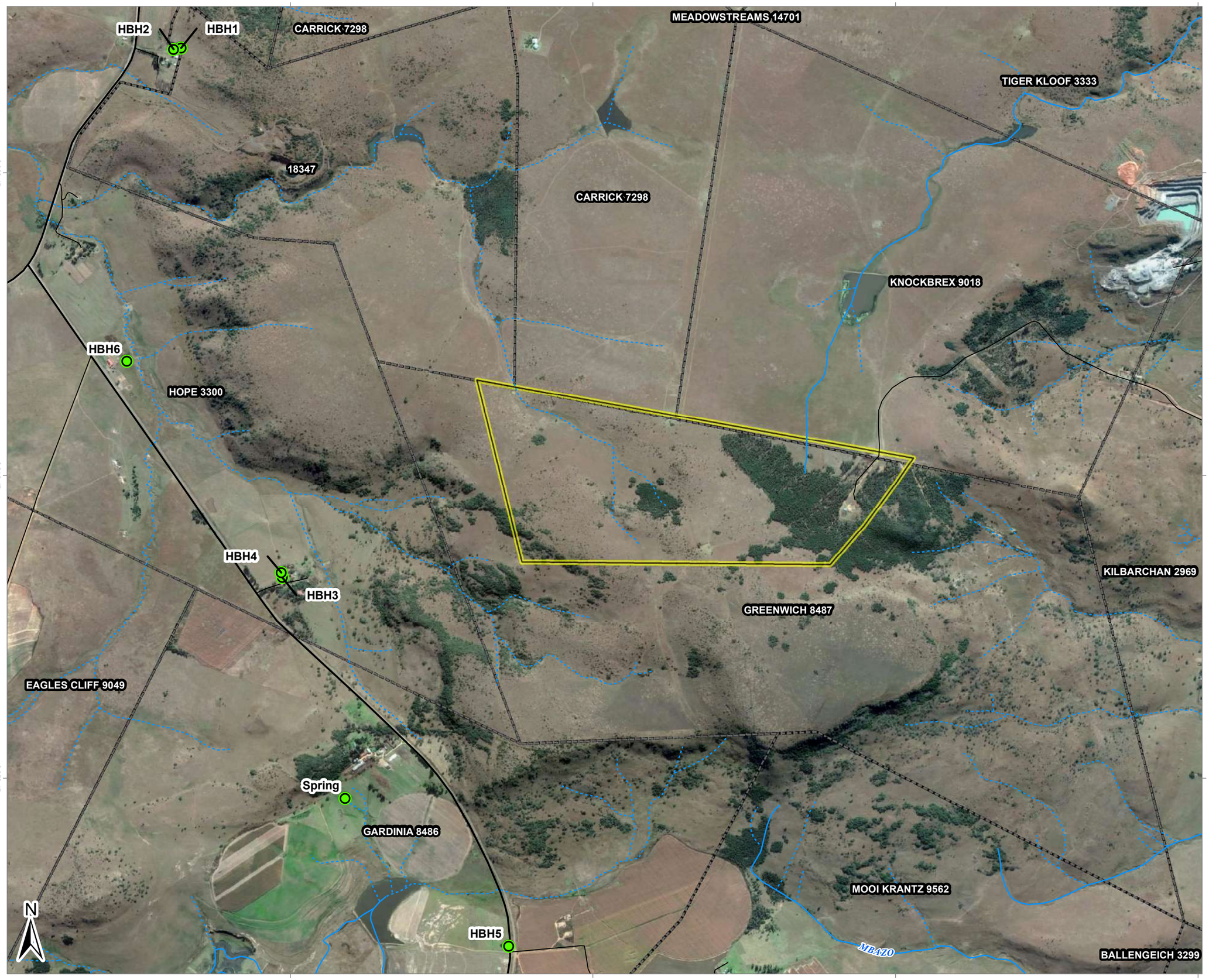
	Portion 4 of Hope 3300						Water supplied by Municipality
HBH4		-27.855353	29.899503	0.2	-	-	Welded closed
HBH5	Gardinia 8486	-27.875921	29.912022	0.1	25.9	40	Pumping during visit
HBH6	Portion 10 of Hope 3300	-27.843702	29.890985	0.1	4.9	30	Slight sulphur smell and taste
Spring	Gardinia 8486	-27.867783	29.903021	-	0	-	Water flowing from spring is diverted to dam

HBH2, HBH5 and HBH6 were used for domestic purposes. A sulphur smell was noted in HBH2 and HBH6. HBH5 and HBH6 were also used for stock watering purposes. This sulphur smell can be associated with the coal beds of the Karoo Supergroup. The locations of these boreholes are presented in Figure 6-1.

Table 6-3: Hydrocensus Borehole Details

Borehole ID	Known yield (L/hr)	Pump type	Powered by:	Reservoir	Volume abstracted (L/day)	Water used for	Approx population	Taste and smell
HBH1	<1000	None	N/A	N/A	N/A	N/A	N/A	N/A
HBH2	5000	Submersible	Electricity	5kl JoJo tank	15 000	Domestic	5	Sulphur smell and taste
HBH3	Unknown	Submersible	Electricity	None	N/A	N/A	N/A	N/A
HBH4	Unknown	Mono	Electricity	None	N/A	N/A	N/A	N/A
HBH5	10000	Submersible	Electricity	10kl JoJo tank	25000	Domestic, cattle watering, crop spraying	10	Good
HBH6	3000	Submersible	Electricity	5kl JoJo tank	5000	Domestic and cattle watering	1	Slight sulphur smell and taste
Spring	-	-	-	-	-	Stock watering	-	Good

NEWCASTLE LANDFILL SITE: HYDROCENSUS BOREHOLES LOCALITY



LEGEND

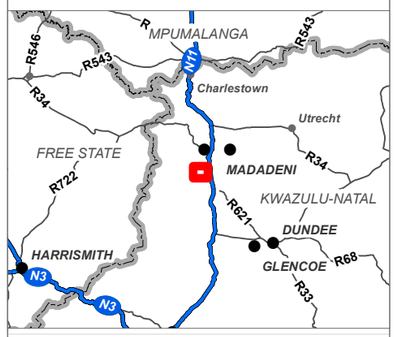
- Hydrocensus Boreholes

Road Network

- National Route
- Main Road
- Secondary Road
- Street

Rivers and Streams

- Non-Perennial
- Perennial
- Parent farms
- Site Boundary



Data Sources:
Google Earth™ mapping service: 2018
Imagery Date: 22/05/2017

0 0.25 0.5 1 Kilometers

SCALE: 1:22 000

FIGURE NO.:	-	MAP NUMBER:	17-0212-11
DRAWN BY:	AMT MKHWANAZI GIS INTERN	REVIEWED BY:	P CHETTY GIS SPECIALIST
DATUM: PROJECTION:	WGS84 GEOGRAPHIC	DATE:	09 MARCH 2018
PROJECT: CLIENT:	NEWCASTLE LANDFILL SITE EIA ENVITECH SOLUTIONS		

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6.2 Geophysical Survey

A geophysical survey was conducted on the 5th and 6th February 2018. The electrical resistivity method is a non-intrusive method used for investigating subsurface conditions by means of inducing a current (I) through the subsurface. Due to mineral and fluid constituents of rock, porosity and the degree of water saturation, the electrical resistivity (R) of rock can vary over several orders of magnitude.

The surface geophysical investigation was conducted over an intrusive rock body consisting of dolerite overlying the Karoo Supergroup. The electrical resistivity surface geophysical survey data is presented in Figure 6-2 to Figure 6-5 (2-D electrical resistivity cross-section of the subsurface).

The following limitation was encountered during the data acquisition and interpretation, including:

- *Survey configuration* – the position, arrangement and decision record of the geophysical survey configuration was influenced by site conditions (e.g. large scale of the project area, vegetation density).

Regardless of the above limitations, acceptable results were obtained from the surface geophysical methodology and instrument. The processed and interpreted electrical resistivity surface geophysical survey results are discussed in the following sections. Four traverses were done, as presented in Table 6-4.

Table 6-4: Geophysical Traverse Details

Traverse ID	Line Start		Line end		Length (m)
	Longitude	Longitude	Latitude	Latitude	
1A	-27.849610	29.911658	-27.844622	29.910526	563
1B	-27.847478	29.907590	-27.847599	29.914189	650
2	-27.853333	29.910193	-27.856512	29.915626	640
3	-27.851784	29.930234	-27.847762	29.933211	536

Based on the electrical resistivity data and GCS's current understanding of the project site's geological and hydrogeological environments, the following generalized correlation of the resistivity values was applied:

- The high resistive / low conductive zones in the geophysical profiles, at depth, are likely associated with un-weathered / competent rock types;
- The moderate resistive / conductive zones are likely associated with possible structural breaks in the otherwise competent bedrock, such as zones of increased groundwater content; and

- The low resistive / high conductive zones likely reflect a number of differing geology features (e.g. overburden, clay-rich residual weathering profiles, possible structural breaks in otherwise competent bedrock) and / or zones of increased groundwater content.

Traverse 1A: The ~560m traverse was conducted in an approximately south east - north west alignment. The subsurface across the surveyed length is characteristic of intermediate conductive signal response at shallow depths underlain by intermediate to high resistive / low conductive signal response between depths of ~18 to 45m. An intermediate to low resistive / high conductive area was identified between 400 and 440m and most likely depicts a weathered zone (fault or contact zone) with an increase in moisture content.

Traverse 1B: The ~650m traverse was conducted in an approximately west to east alignment. The subsurface across the surveyed length is characteristic of intermediate conductive signal response at shallow depths underlain by intermediate to high resistive / low conductive signal response between depths of ~18 to 55m. No ideal low resistive / high conductive area was identified that could depict a weathered zone with an increase in moisture content.

Traverse 2: The ~640m traverse was conducted in an approximately north west - south east - alignment. The subsurface across the surveyed length is characteristic of low resistive / high conductive signal response between 1 and 30m. Zones of intermediate to high resistive / low conductive signal response were noted between 200 and 360m. An intermediate to low resistive / high conductive area was identified between 160m and 200m as well as 360 and 480m and most likely depicts a weathered zone (fault or contact zone) with an increase in moisture content.

Traverse 3: The ~530m traverse was conducted in an approximately south west - north east alignment. The subsurface between 320m and 530m is characteristic of low resistive / high conductive signal response between 1 and 60m. Zones of intermediate to high resistive / low conductive signal response were noted between 0 and 320m at depths from 20m to 64m. An intermediate to low resistive / high conductive area was identified between 320m and 400m from a depth of 0 to 64m and most likely depicts a weathered zone (fault or contact zone) with an increase in moisture content.

Table 6-5: Geophysical Drilling Targets

Line ID	Coordinates		Station distance (m)	Proposed depth
	Longitude	Latitude		
1A	-27.845943	29.910803	415	80-100
1B	-27.847578	29.910952	335	80-100
2	-27.855208	29.913302	370	60-70
3	-27.849316	29.932064	330	80-100

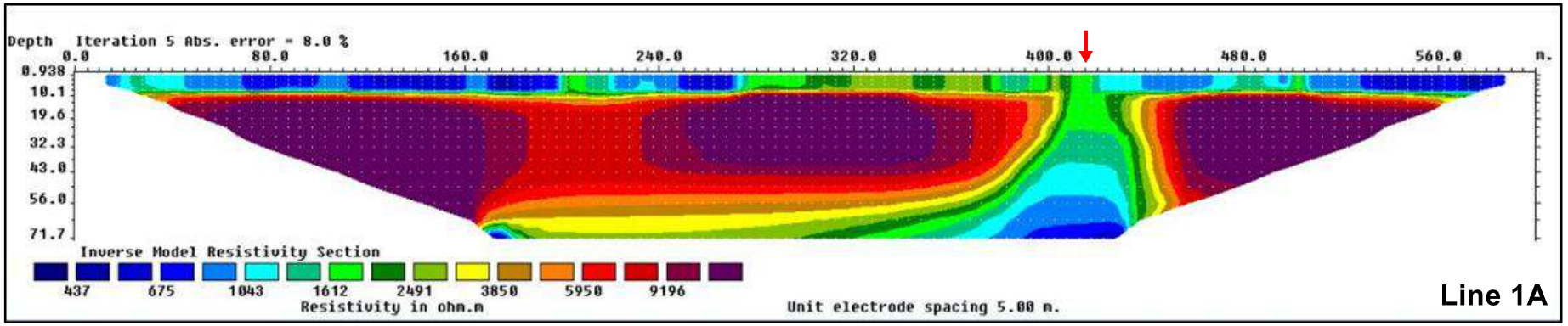


Figure 6-2: Geophysical Traverse – Line 1

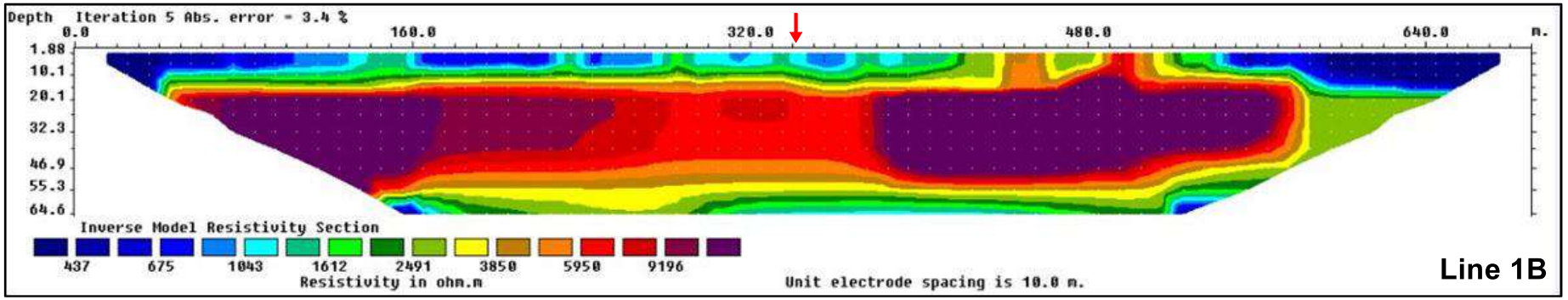


Figure 6-3: Geophysical Traverse – Line 1B

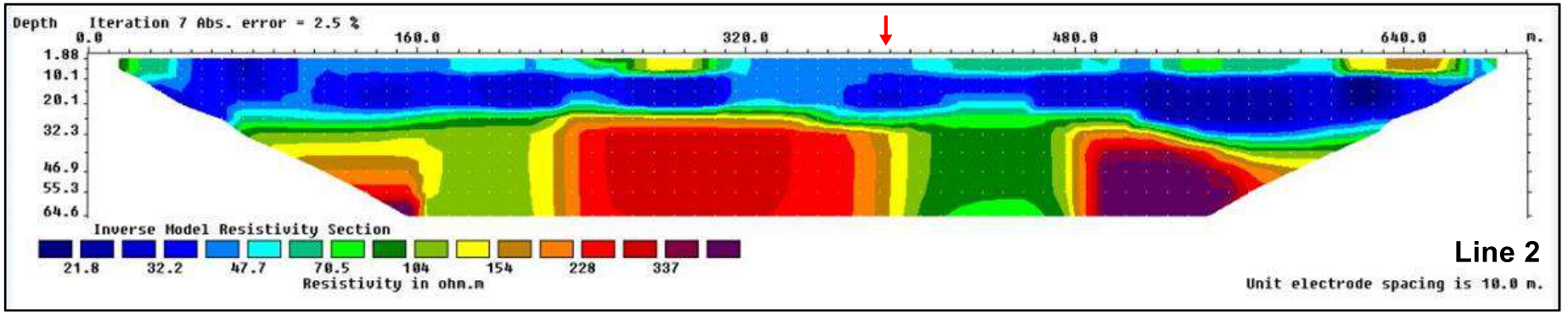


Figure 6-4: Geophysical Traverse – Line 2

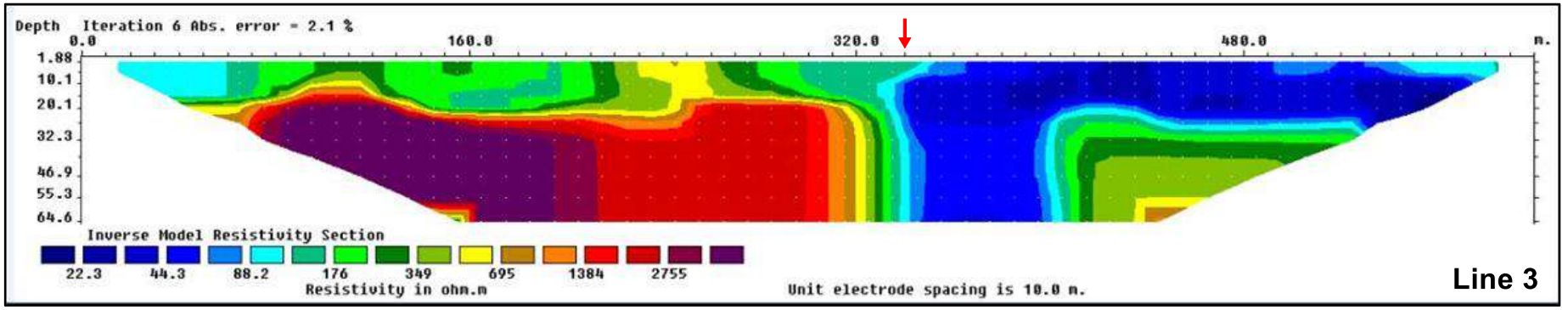
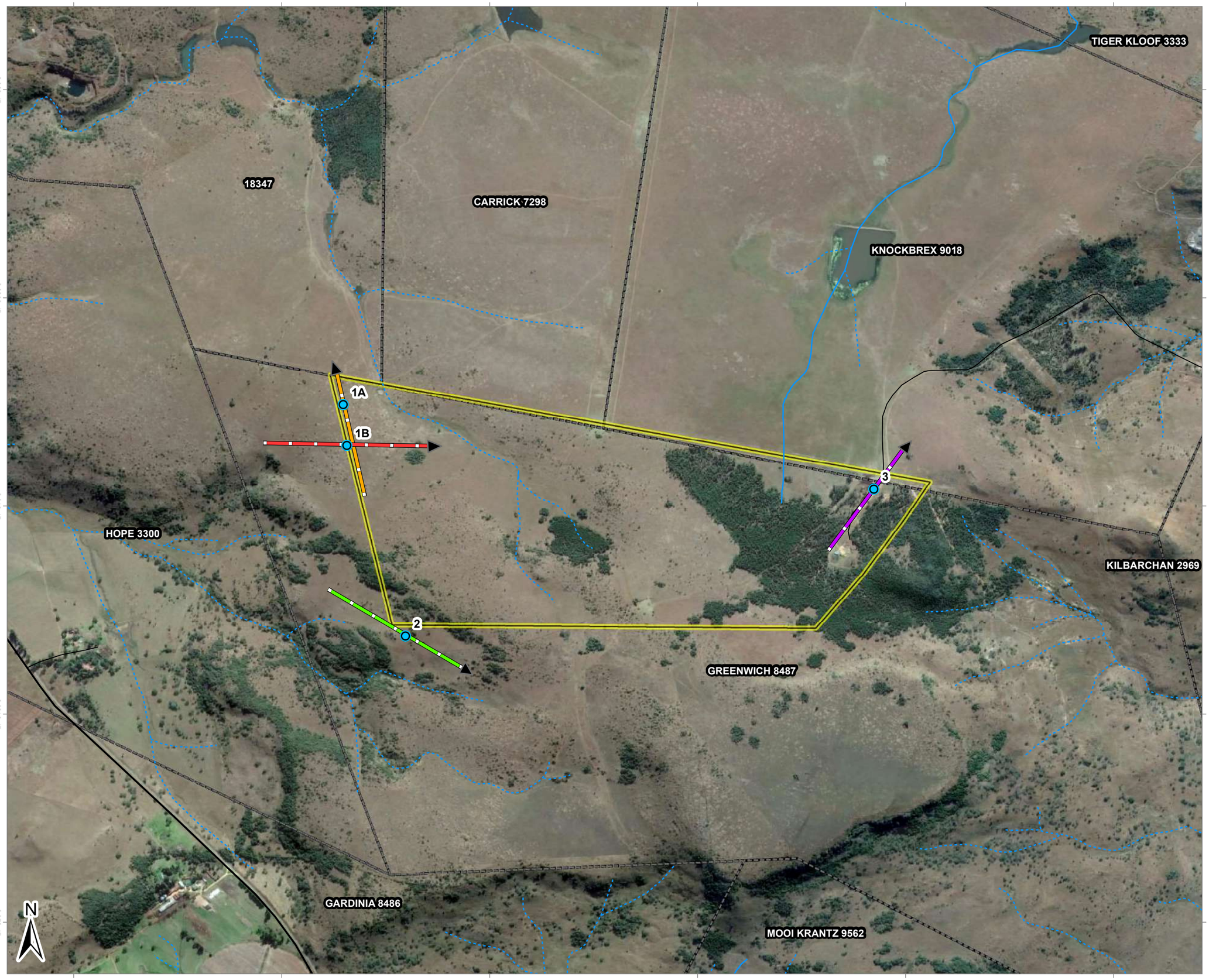


Figure 6-5: Geophysical Traverse – Line 3

NEWCASTLE LANDFILL SITE: GEOPHYSICAL SURVEY TRAVERSES



LEGEND

- Drill Targets

Traverses

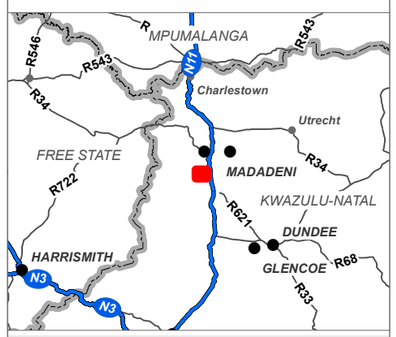
- T1A
- T1B
- T2
- T3

Road Network

- National Route
- Main Road
- Secondary Road
- Street

Rivers and Streams

- Non-Perennial
- Perennial
- Parent farms
- Site Boundary



Data Sources:
Google Earth™ mapping service: 2018
Imagery Date: 22/05/2017

0 200 400 800 Meters

SCALE: 1:16 000

FIGURE NO.:	-	MAP NUMBER:	17-0212-13
DRAWN BY:	AMT MKHWANAZI GIS INTERN	REVIEWED BY:	P CHETTY GIS SPECIALIST
DATUM: PROJECTION:	WGS84 GEOGRAPHIC	DATE:	09 MARCH 2018
PROJECT: CLIENT:	NEWCASTLE LANDFILL SITE EIA ENVITECH SOLUTIONS		

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6.3 Monitoring Borehole Installation

Three (3) monitoring boreholes were installed on or within close proximity to the geophysical drilling targets. The depth and locations of the boreholes were based on the on-site conditions (refer to Figure 6-8 for the localities and proposed infrastructure). The depths ranged from 19 to 31mbgl. The borehole details are presented in Table 6-6. Photographs of the boreholes are presented in Appendix A and the borehole logs are attached in Appendix B.

Table 6-6: Monitoring Borehole Details

BH ID	Latitude	Longitude	Depth (m)	Comments
BH1	-27.845718	29.910433	19	Located in the north western section of the site
BH2	-27.851088	29.910946	25.4	Located in the south western section of the site
BH3	-27.849137	29.932111	31	Located in the north eastern section of the site

6.4 Groundwater Investigation

One existing (BH NL2) and the three newly installed boreholes (BH1, BH2 and BH3) were inspected. Static groundwater levels ranged from 0.49 to 14.35mbgl and well depth was measured between 19 and 59.66mbgl as presented in Table 6-7.

Table 6-7: Monitoring Borehole Details

BH ID	Latitude	Longitude	Depth (m)	Collar Height (m)	SWL (mbgl)	Elevation (mamsl)	SWL Elevation (mamsl)	Comments
BH1	-27.845718	29.910433	19	1.01	0.49	1342.135	1341.645	Clear and odourless water
BH2	-27.851088	29.910946	25.4	0.6	12.9	1343.475	1330.575	
BH3	-27.849137	29.932111	31	0.6	14.35	1357.217	1342.867	
BH NL2	-27.846924	29.920811	59.66	0.6	10.22	1372.494	1362.274	Oily substance noted

***Groundwater sample collected**
(mbgl) meters below ground level
(mamsl) meters above mean sea level

Groundwater samples were collected from BH1, BH2, BH3 and BH NL2. The samples were submitted to an accredited laboratory services for analysis and included the following analyses:

- Metals: Na, K, Ca, Mg, Al, Sb, As, Ba, B, Cd, Cr, Cu, Fe, Pb, Mn, Ni, Se & Zn;
- pH, Electrical conductivity, Alkalinity, Total dissolved solids, Bi-carbonate, Colour, Turbidity;
- Nitrate and nitrite, Chloride, Sulphate and Fluoride.

6.4.1 Groundwater Flow Direction

A groundwater flow direction map was constructed using data obtained during the hydrocensus and monitoring borehole installation. The groundwater flow within the study area is in a general north westerly and north easterly direction (refer to Figure 6-7).

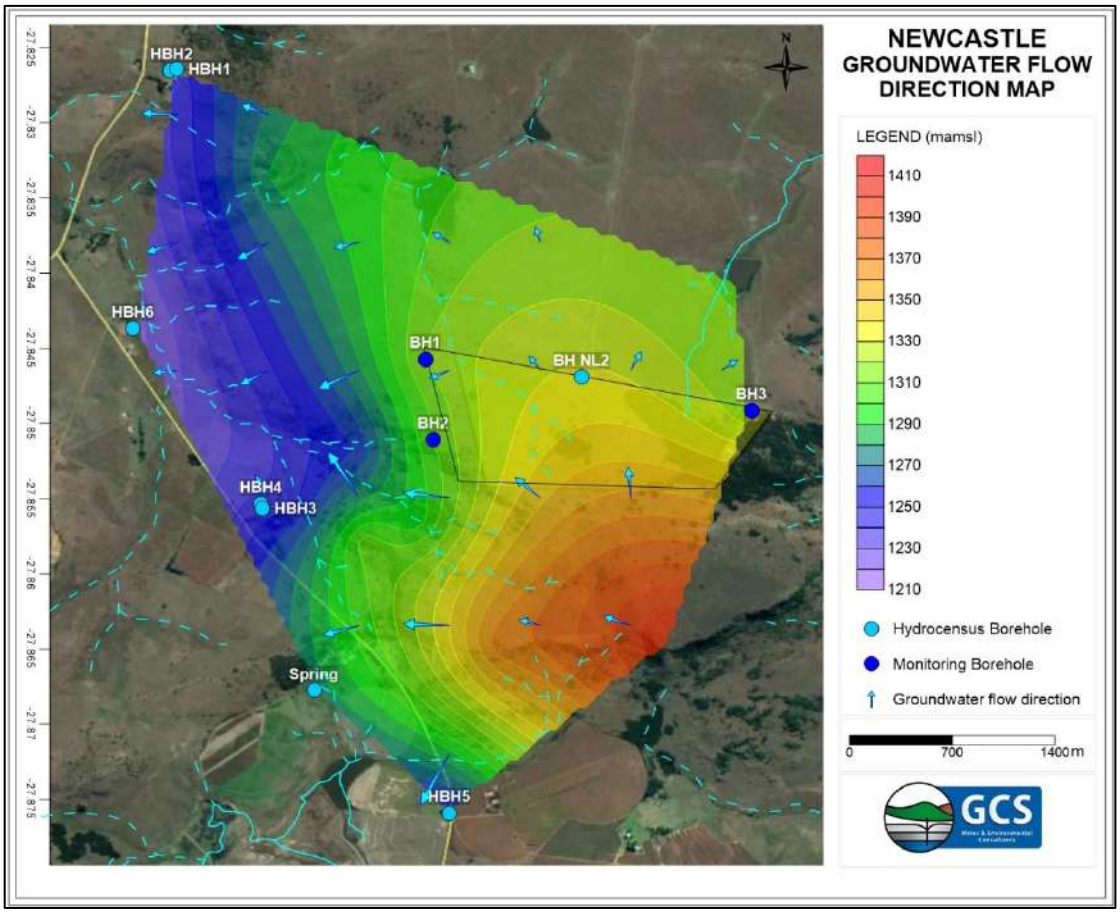
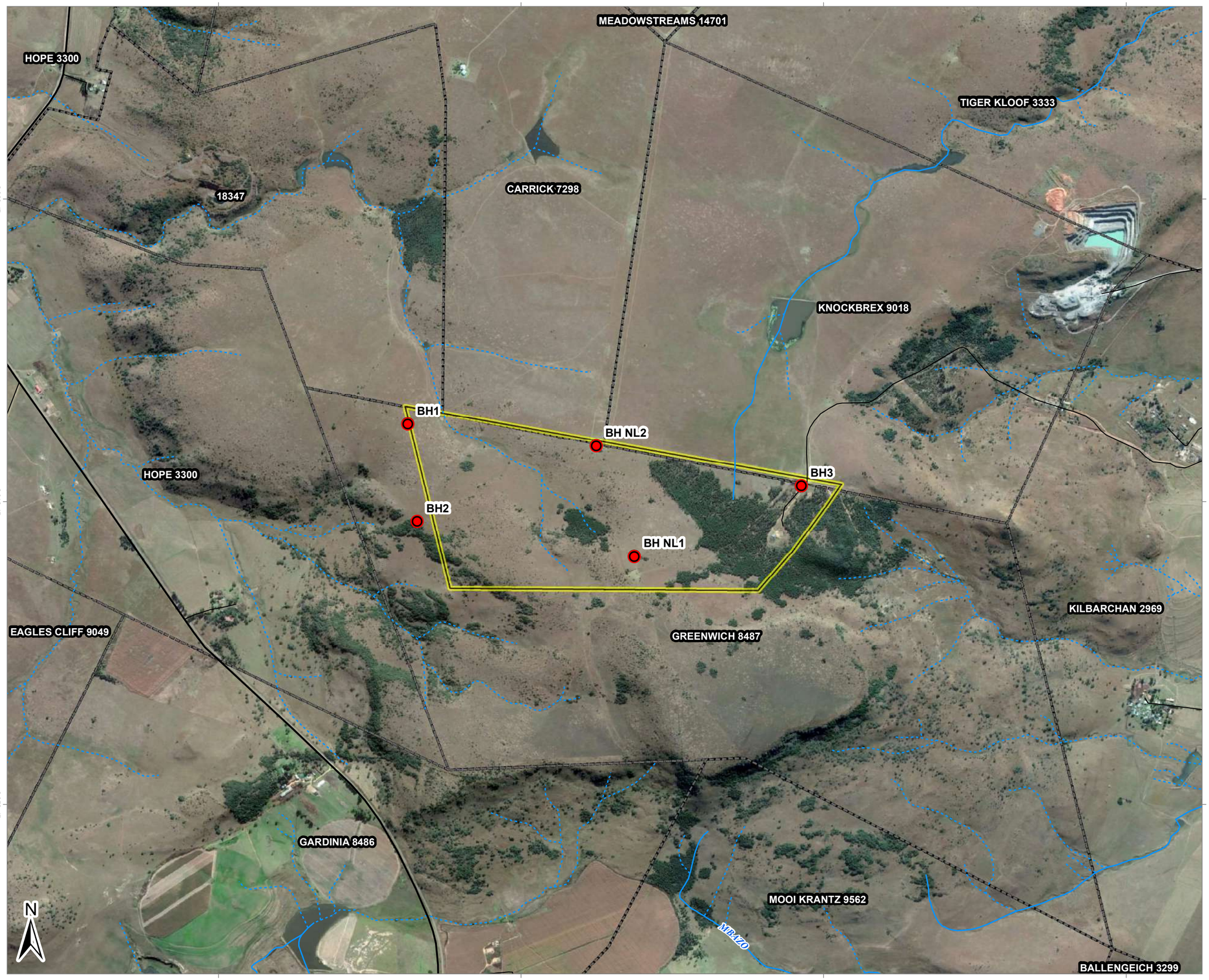


Figure 6-7: Groundwater Flow Direction Map

NEWCASTLE LANDFILL SITE: BOREHOLE LOCALITY



LEGEND

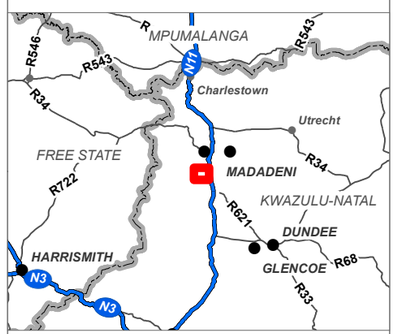
- Boreholes

Road Network

- National Route
- Main Road
- Secondary Road
- Street

Rivers and Streams

- Non-Perennial
- Perennial
- Parent farms
- Site Boundary



Data Sources:
Google Earth™ mapping service: 2018
Imagery Date: 22/05/2017

0 0.25 0.5 1 Kilometers

SCALE: 1:22 000

FIGURE NO.:	-	MAP NUMBER:	17-0212-12
DRAWN BY:	AMT MKHWANAZI GIS INTERN	REVIEWED BY:	P CHETTY GIS SPECIALIST
DATUM: PROJECTION:	WGS84 GEOGRAPHIC	DATE:	09 MARCH 2018
PROJECT: CLIENT:	NEWCASTLE LANDFILL SITE EIA ENVITECH SOLUTIONS		

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6.5 Aquifer Testing

A short duration Constant Rate (CR) test including a recovery test was conducted for each newly installed borehole.

A CR test is a field experiment in which a well is pumped at a controlled rate and water-level response (drawdown) is measured in the pumped well. The response data from the pumping tests are used to estimate the hydraulic properties of aquifers.

The drawdown and recovery curves for each borehole are presented in Figure 6-9, Figure 6-10 and Figure 6-11.

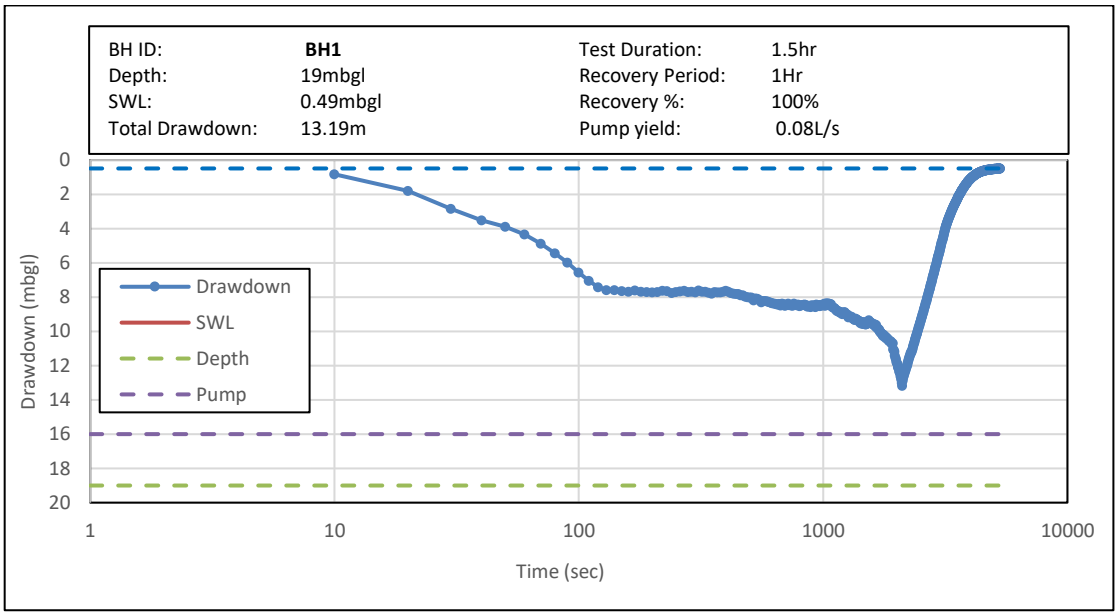


Figure 6-9: Aquifer Test Results - BH1

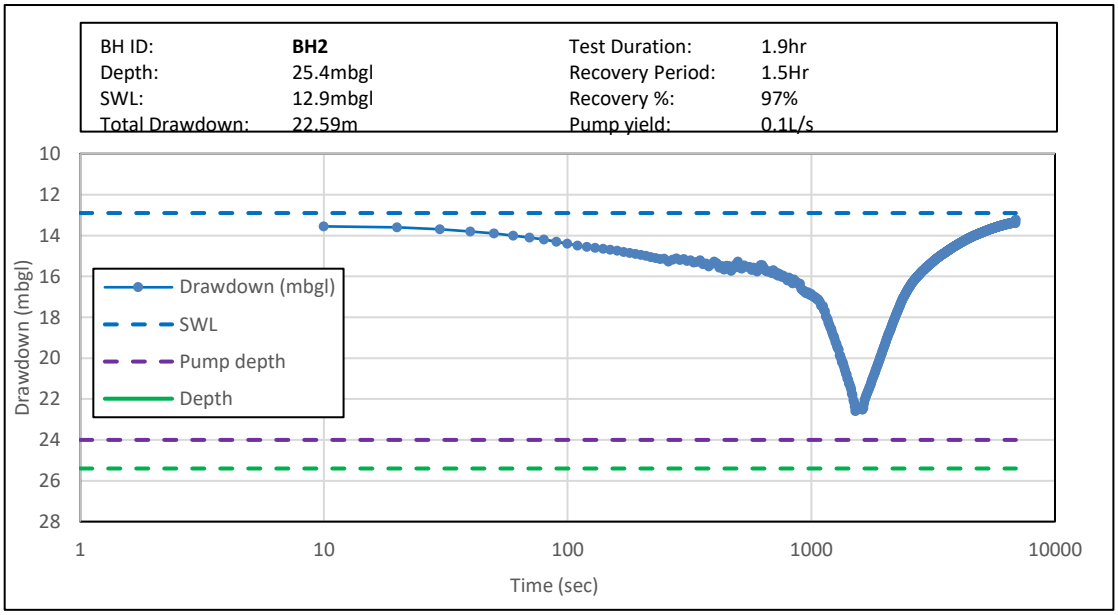


Figure 6-10: Aquifer Test Results - BH2

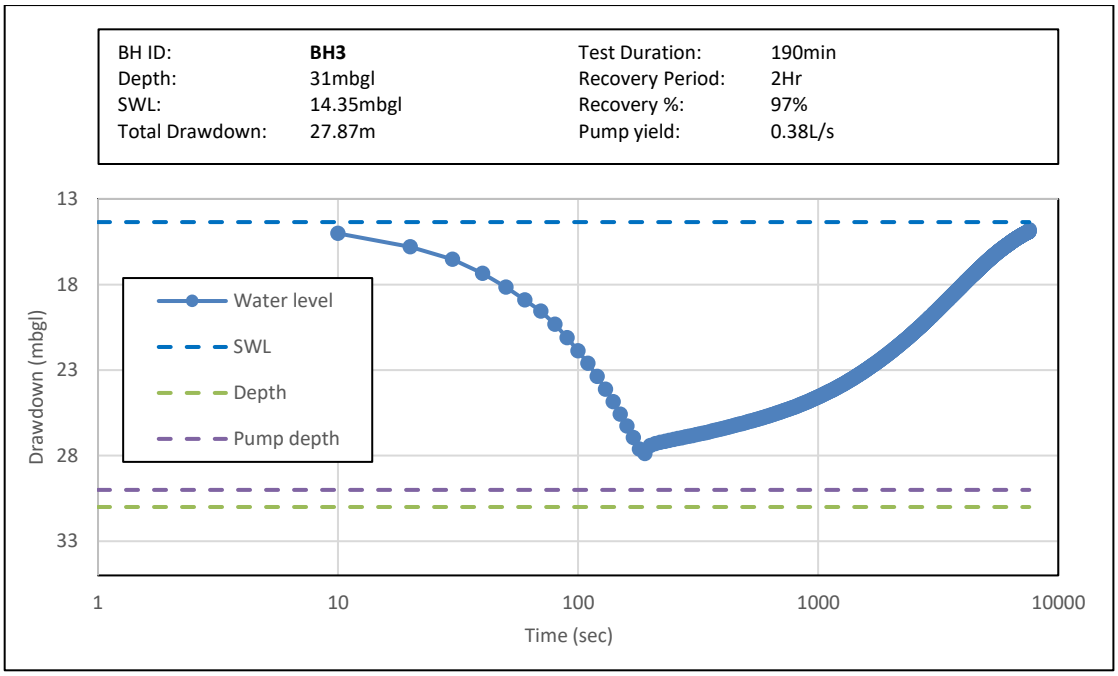


Figure 6-11: Aquifer Test Results - BH3

The results of the tests are presented in Table 6-8.

Table 6-8: Aquifer Test Details

Borehole ID	Test duration (hr)	Recovery duration (hr)	Recovery %	Early T (m^2/d)	Late T (m^2/d)	Recovery T (m^2/d)
BH1	1.5	1	100	0.236	0.9078	0.06188
BH2	1.9	1.5	97	1.504	0.1065	0.1642
BH3	2.1	2	97	1.944	0.7113	0.3838

The aquifer test data was analysed with using Aqtesolv v4.5 (AQuifer TEst SOLVer) software and the Cooper-Jacob method was used to determine the transmissivity based on the drawdown and recovery data. The transmissivity is defined as the measure of the ease with which water will pass through the earth's material; expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer. It therefore indicates the ease with which water moves through the subsurface and is used to calculate rates of groundwater movement.

The recovery transmissivity in the monitoring boreholes was calculated to be between 0.06188 and 0.3838m/day. This is considered a low transmissivity values representing fine sand to silt and would impede the flow and dispersion of contamination if it were present. The analysis of the pump test data is presented in Appendix C.

7 LABORATORY ANALYSIS

7.1 Groundwater Quality

Groundwater samples were collected from newly installed monitoring borehole, BH1, BH2, BH3 as well as hydrocensus borehole BH NL2. The laboratory results are presented in Table 7-1. The laboratory certificate is attached in Appendix D. The laboratory results were compared to the following applicable standards:

- South African National Standard (SANS) for drinking water purposes (SANS 241-1:2015) (SABS, 2015).

Table 7-1: Laboratory Certificate

Analyses in mg/ℓ (Unless specified otherwise)	SANS 241-1:2015	Sample Identification:			
		BH1	BH2	BH3	BH NL 2
General Parameters					
pH – Value at 25°C	≥ 5 to ≤ 9.7	6.15	8.04	7.27	7.26
Electrical Conductivity in mS/cm	≤ 1700	57.4	120.1	186.3	476
Total Dissolved Solids	≤ 1 200	50	60	160	201
Bicarbonate, HCO3	NS	20	72	82	96
P-Alk as CaCO3	NS	<0.6	<0.6	<0.6	<0.6
M-Alk as CaCO3	NS	16	59	67	78
Colour in PtCo Units *	≤ 15	26	836	209	24
Turbidity in N.T.U	Operational ≤ 1 Aesthetic ≤ 5	20.4	1320	3920	10.57
Anions					
Fluoride as F	≤ 1.5	<0.4	<0.4	<0.4	<0.4
Chloride as Cl	≤ 300	<1	<1	7.9	117.7
Nitrite, NO2	≤ 0.9	<2	<2	<2	<2
Nitrate, NO3	≤ 11	<2	<2	8.3	5.6
Combined NO3 and NO2	≤ 1	>0.45	<0.45	1.9	1.3
Sulphate as SO_4	Acute health ≤ 500 Aesthetic ≤ 250	<4	<4	7.3	7.5
Cations and metals					
Aluminium as Al	≤ 0.3	0.16	2.41	1.69	0.06
Arsenic as As	≤ 0.01	<1	<1	<1	<1
Boron as B	≤ 2.4	0.27	0.23	0.21	0.2
Barium as Ba	≤ 0.7	<0.05	<0.05	<0.05	<0.05
Calcium as Ca	NS	3.2	13.1	16.2	19.8
Cadmium as Cd	≤ 0.003	<0.05	<0.05	<0.05	<0.05
Total Chromium as Cr	≤ 0.05	<0.05	<0.05	<0.05	<0.05
Copper as Cu	≤ 2	<0.05	<0.05	<0.05	0.06
Iron as Fe	Chronic health ≤ 2 Aesthetic ≤ 0.3	0.37	**4.74**	0.89	0.05
Potassium as K	NS	0.1	1.1	1.9	1.7
Magnesium as Mg	NS	1.5	8	8	7.3

Analyses in mg/ℓ (Unless specified otherwise)	SANS 241-1:2015	Sample Identification:			
		BH1	BH2	BH3	BH NL 2
Manganese as Mn	Chronic health ≤ 0.4 Aesthetic ≤ 0.1	<0.05	0.14	0.06	<0.05
Sodium as Na	≤ 200	1.9	3.9	10.8	61.9
Nickel as Ni	≤ 0.07	<0.05	<0.05	<0.05	<0.05
Lead as Pb	≤ 0.01	<1	<1	<1	<1
Antimony as Sb	≤ 0.02	<1	<1	<1	<1
Selenium as Se	≤ 0.04	<1	<1	<1	<1
Zinc as Zn	≤ 5	<0.05	<0.05	<0.05	<0.05

*Exceeds SANS 241-1:2015 drinking water quality standard

7.1.1 General Parameters

Colour and turbidity detected in all boreholes exceeded the SANS standards. Turbidity is a measure of the light-scattering ability of water and is indicative of the concentration of suspended matter (inorganic matter, such as clay and soil particles, and organic matter) in water (DWAF, 1996). The elevated turbidity in the newly installed boreholes are most likely associated with disturbance during drilling and is not representative of groundwater conditions.

7.1.2 Anions

Combined nitrate (NO_3) and nitrite (NO_2) detected in BH3 and BH NL2 marginally exceeded the SANS standard of 1mg/l. The remaining anions were compliant with the SANS standards.

7.1.3 Cations and Metals

The aluminium (Al) concentration of 2.41mg/l and 1.69mg/l detected in BH2 and BH3, respectively, exceeded the SANS standard of 0.3mg/l.

The iron concentrations of 0.37mg/l and 0.89mg/l detected in BH1 and BH3 exceeded the aesthetic SANS standard, however was below the chorionic health SANS standard of 2mg/l. Iron detected in BH2 however exceeded the chronic health standard.

A manganese (Mn) concentration of 0.14mg/l was detected in BH2 and exceeded the aesthetic standard of 0.1mg/l, however was below the chronic standard of 0.4mg/l.

7.2 Groundwater Classification

7.2.1 Piper Diagram

The chemical composition of groundwater reflects the processes which are responsible for the different constituents it contains. Trilinear diagrams such as Piper diagrams can assist in the chemical foot printing of water and often assist in understanding the hydrochemical processes or even the chemical evolution of groundwater.

The Piper diagram uses a combination of two trilinear diagrams and a central diamond field. After the cations and anions are plotted in the trilinear fields their position is projected in the central diamond field.

Groundwater samples collected from BH1, BH2 and BH3 represent recently recharged groundwater rich in calcium, magnesium and bicarbonate. BH NL2 represent a dynamic regime with water rich in sodium, bicarbonate and chloride.

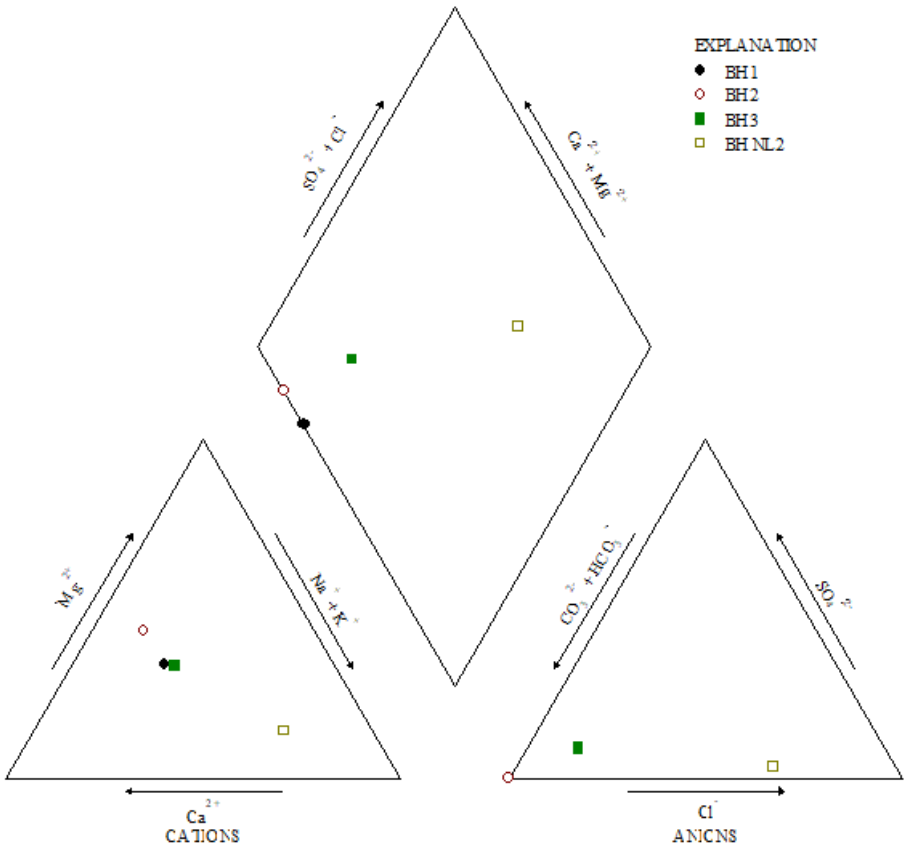


Figure 7-1: Piper Diagram

8 RISK ASSESSMENT

The following methodology was used to rank potential impacts. Clearly defined rating and rankings scales (Table 8-1 to Table 8-7) were used to assess the impacts associated with the proposed activities.

Each impact identified was rated according the expected magnitude, duration, scale and probability of the impact (Table 8-8).

Each impact identified will be assessed in terms of scale (spatial scale), magnitude (severity) and duration (temporal scale). Consequence is then determined as follows:

Consequence = Severity + Spatial Scale + Duration

The Risk of the activity is then calculated based on frequency of the activity and impact, how easily it can be detected and whether the activity is governed by legislation. Thus:

Likelihood = Frequency of activity + frequency of impact + legal issues + detection

The risk is then based on the consequence and likelihood.

Risk = Consequence x likelihood

In order to assess each of these factors for each impact, the ranking scales in Table 8-1 - Table 8-7 were used.

Table 8-1: Severity

Insignificant / non-harmful	1
Small / potentially harmful	2
Significant / slightly harmful	3
Great / harmful	4
Disastrous / extremely harmful / within a regulated sensitive area	5

Table 8-2: Spatial Scale - How big is the area that the aspect is impacting on?

Area specific (at impact site)	1
Whole site (entire surface right)	2
Local (within 5km)	3
Regional / neighboring areas (5km to 50km)	4
National	5

Table 8-3: Duration

One day to one month (immediate)	1
One month to one year (Short term)	2
One year to 10 years (medium term)	3
Life of the activity (long term)	4
Beyond life of the activity (permanent)	5

Table 8-4: Frequency of the activity - How often do you do the specific activity?

Annually or less	1
6 monthly	2
Monthly	3
Weekly	4
Daily	5

Table 8-5: Frequency of the incident/impact - How often does the activity impact on the environment?

Almost never / almost impossible / >20%	1
Very seldom / highly unlikely / >40%	2
Infrequent / unlikely / seldom / >60%	3
Often / regularly / likely / possible / >80%	4
Daily / highly likely / definitely / >100%	5

Table 8-6: Legal Issues - How is the activity governed by legislation?

No legislation	1
Fully covered by legislation	5

Table 8-7: Detection - How quickly/easily can the impacts/risks of the activity be detected on the environment, people and property?

Immediately	1
Without much effort	2
Need some effort	3
Remote and difficult to observe	4
Covered	5

Environmental effects will be rated as either of high, moderate or low significance on the basis provided in Table 8-8.

Table 8-8: Impact Ratings

RATING	CLASS
1 – 55	(L) Low Risk
56 – 169	M) Moderate Risk
170 – 600	(H) High Risk

8.1 Impact Assessment

8.1.1 Construction Phase

Nature of impact: Groundwater contamination during fuel spillages from heavy machinery and vehicle movement

Mitigation Measures: The mitigation measures would include containment for all fuel stored on site and implementing a groundwater monitoring programme. This would allow for the early detection of water quality deterioration associated with the site. Accurate oil records

must be kept (purchased, disposal, and recycled). Ensure that clean-up protocols are in place and adhered to.

Significance: The impact will have a medium negative significance.

8.1.2 Operational Phase

Nature of impact: Groundwater contamination during fuel spillages from heavy machinery and vehicle movement.

Mitigation Measures: The mitigation measures would include containment for all fuel stored on site and implementing a groundwater monitoring programme. This would allow for the early detection of water quality deterioration associated with the site. Accurate oil records must be kept (purchased, disposal, and recycled). Ensure that clean-up protocols are in place and adhered to.

Significance: The impact will have low to medium negative significance, however with implementation of mitigation measures the impact can be decreased to low.

Nature of impact: Groundwater contamination due to leakages/spillages

Mitigation Measures:

- Ensure adequate lining and drainage systems are installed. The landfill needs to be lined according to the requirements for a minimum Class B landfill in accordance with the legislation;
- Ensure surface water runoff is contained and treated before disposal;
- Groundwater monitoring to ensure early detection of pollution.

Significance: The impact will have high negative significance, however with implementation of mitigation measures the impact can be decreased to medium.

Based on the impact assessment determined from a Hydrogeological perspective it can be concluded that all impacts identified have a medium to high negative significance, however with implementation of mitigation measures the impact can be decreased between low and medium.

8.1.3 Closure and Decommissioning Phase

Nature of impact: Groundwater contamination due to leakages/spillages

Mitigation Measures:

- Ensure adequate lining and drainage systems are installed. The landfill needs to be lined according to the requirements for a minimum Class B landfill in accordance with the legislation;
- Ensure surface water runoff is contained and treated before disposal;
- Groundwater monitoring to ensure early detection of pollution.

Significance: The impact will have a medium negative significance, however with implementation of mitigation measures the impact can be decreased to low.

Based on the impact assessment determined from a Hydrogeological perspective it can be concluded that all impacts identified have a medium to high negative significance, however with implementation of mitigation measures the impact can be decreased between low and medium.

Table 8-9: Impact Summary Table

Impact description					Significance before mitigation		Significance after mitigation		Mitigation measures	Action plan	Responsible person
No.	**Phases**	**Activity**	**Aspect**	**Impact**							
1	Construction	Hydrocarbon spills	Heavy machinery and vehicle movement	Groundwater contamination	-	M	-	M	Containment for all fuel stored on site; Implementation of a groundwater monitoring programme. Accurate oil records must be kept (purchased, disposal, and recycled). Ensure that clean-up protocols are in place and adhered to.	refer to rehabilitation plan (Section 9.1)	Site manager
2	Operation	Hydrocarbon spills	Heavy machinery and vehicle movement	Groundwater contamination	-	M	-	L	Containment for all fuel stored on site; Implementation of a groundwater monitoring programme. Accurate oil records must be kept (purchased, disposal, and recycled). Ensure that clean-up protocols are in place and adhered to.	refer to rehabilitation plan (Section 9.1)	Site manager
3	Operation	Waste site operation	Spillages or leakages	Groundwater contamination	-	H	-	M	Ensure adequate lining and drainage systems are installed; Ensure surface water runoff is contained and treated before disposal; Groundwater monitoring to ensure early detection of pollution.	refer to rehabilitation plan (Section 9.1)	Site manager

4	Operation	Waste site operation	Spillages or leakages	Groundwater contamination	-	M	-	L	Ensure adequate lining and drainage systems are installed; Ensure surface water runoff is contained and treated before disposal; Groundwater monitoring to ensure early detection of pollution.	refer to rehabilitation plan (Section 9.1)	Site manager

8.2 Sensitive Receptors

Based on the hydrocensus conducted as well as groundwater flow direction map (refer to Figure 6-7), two groundwater users (HBH2 on RE 1 of Hope 3300 as well as HBH6 Portion 10 of Hope 3300) were identified as potential receptors downstream of the Greenwich Landfill site (refer to Table 8-10). The water use include domestic and stock watering.

The impact from the landfill will negatively impact these receptors if mitigation measures are not implemented.

Table 8-10: Potential receptors downstream of the proposed Greenwich Landfill site

Borehole ID	Owner	Property	Latitude	Longitude	Comments
HBH2	Craig Peterson	RE 1 of Hope 3300	-27.826531	29.893563	Used for domestic purposes
HBH6	Newcastle Farmers Union. Site manager: Loyd Phillips	Portion 10 of Hope 3300	-27.843702	29.890985	Slight sulphur smell and taste

9 MONITORING PROGRAMME

It is recommended that groundwater quality monitoring be implemented once the site is operational to ensure water remains compliant with the DWAF Minimum Requirements for Waste Disposal by Landfill (2nd Edition, 1998) (listed in Table 9-2). Boreholes to be monitored includes BH1, BH2, BH3, BH NL1 and BH NL2, as per Table 9-1.

Table 9-1: Monitoring Borehole Details

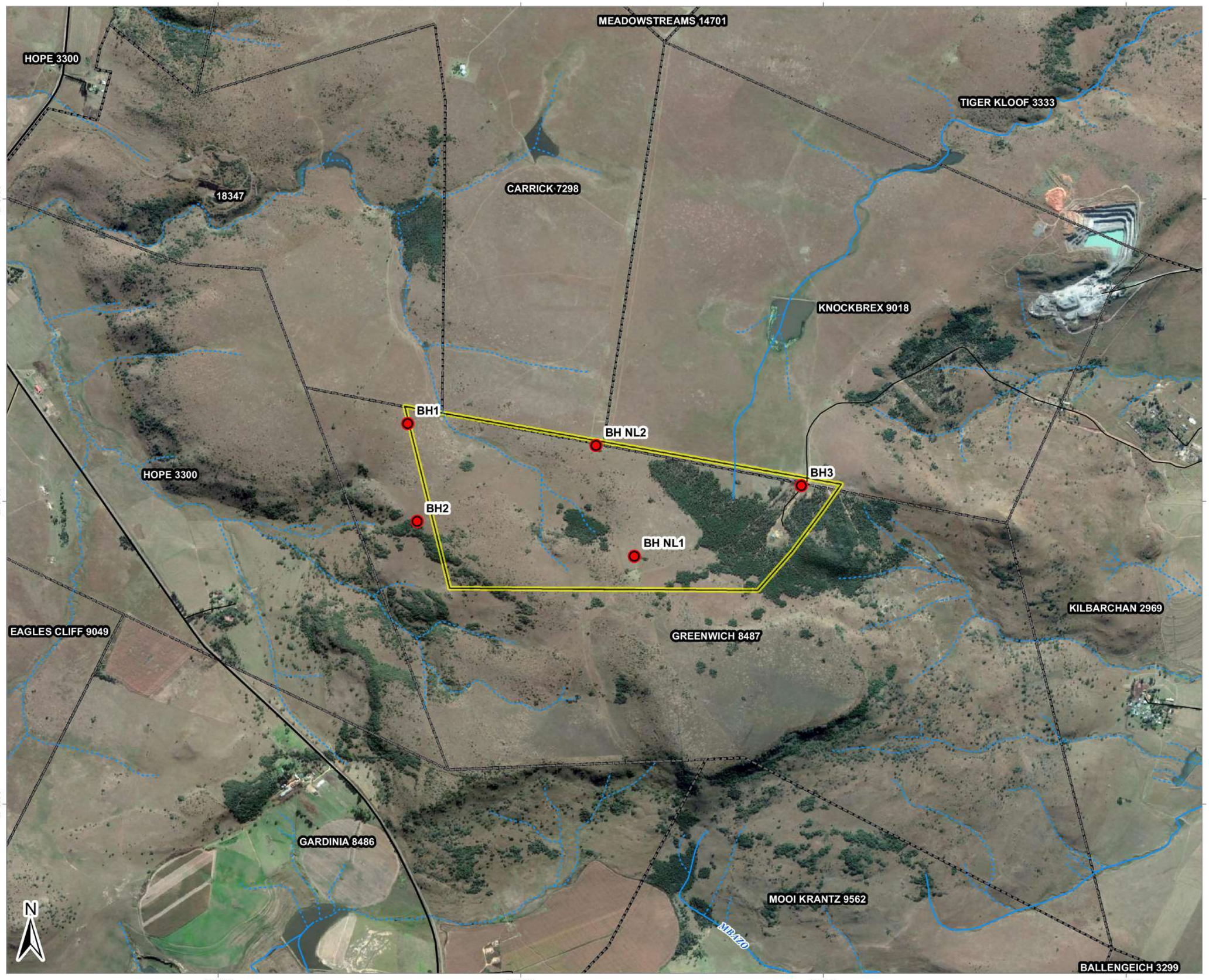
BH ID	Latitude	Longitude	Monitoring Frequency
BH1	-27.845718	29.910433	Quarterly
BH2	-27.851088	29.910946	
BH3	-27.849137	29.932111	
BH NL1	-27.853010	29.922917	
BH NL2	-27.846924	29.920811	

Table 9-2: Suggested Parameters for Detection Monitoring (DWAF, 1998)

Alkalinity (Total Alkalinity)	Calcium (Ca)
Ammonia (NH_3) as N	Fluoride as F
Chemical Oxygen Demand (COD)	Magnesium (Mg)
Chloride as Cl	Sodium as Na
Electrical Conductivity	Sulphate as SO_4
Nitrate (NO_3) as N	
Nitrite (NO_2) as N	
pH – Value	
Potassium (K)	
Total Dissolved Solids	

These results will be used for comparison purposes during all future monitoring events, in an effort to determine any effects on the environment as a result of the landfill construction and the operational activities of the landfill site.

NEWCASTLE LANDFILL SITE: PROPOSAL MONITORING POINTS



LEGEND

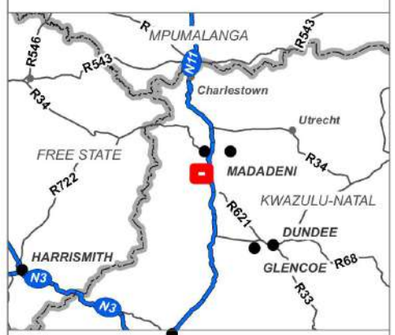
- Borehole monitoring points

Road Network

- National Route
- Main Road
- Secondary Road
- Street

Rivers and Streams

- Non-Perennial
- Perennial
- Parent farms
- Site Boundary



Data Sources:
Google Earth™ mapping service: 2018
Imagery Date: 22/05/2017

0 0.275 0.55 1.1 Kilometers

SCALE:	1:22 000		
FIGURE NO.:	-	MAP NUMBER:	17-0212-16-V2
DRAWN BY:	A BROWER GIS TECHNICIAN	REVIEWED BY:	P CHETTY GIS SPECIALIST
DATUM: PROJECTION:	WGS84 GEOGRAPHIC	DATE:	19 APRIL 2018
PROJECT:	NEWCASTLE LANDFILL SITE EIA		
CLIENT:	ENVITECH SOLUTIONS		

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9.1 Proposed Rehabilitation Plan

The following rehabilitation plan can be utilized should any contamination be detected during monitoring.

- **Source**
    - Identify the source of contamination;
    - Identify the nature and extent of contamination;
    - Eliminate or control source of contamination (if possible).
- **Exposure Pathways**
    - Establish preferential flow paths;
- **Receptor** (receptors include humans but may also include animals and plants.)
    - Identify risk to potential receptors;
    - Ensure end-users are aware of potential contamination;
    - Conduct quality analysis to ensure water remains within quality guidelines for intended use.

Routine maintenance of stormwater canals, monitoring boreholes etc. should be conducted on a regular basis. Any potential contamination detected should be reported and downgradient users should be notified of the potential concern. Should contamination be identified within an end-user water supply, remediation should be conducted and alternative water source should be provided.

10 REASONED OPINION AND CONDITIONS FOR AUTHORIZATION

- Given the potential hydrogeological impacts detailed in this report, the landfill project can only be viable if the mitigation measures, included in Section 8 are implemented and adhered to;
- Groundwater monitoring is imperative and necessary, in order to detect groundwater contamination before impacting nearby receptors;
- Based on this, the project can be granted environmental authorization.

10.1 Groundwater Abstraction

- The installation of a production borehole on the site would not be possible due to access constraints to potential drilling sites upgradient of the proposed landfill;
- It is also recommended that no groundwater abstraction takes place due to the potential groundwater contamination risks associated with a landfill;
- It is recommended that potable water be sourced from external water supply providers.

11 CONCLUSIONS

Following the hydrogeological investigation, the following conclusions were made:

- The study area is located on farm portion Greenwich 8487, approximately 9km south of Newcastle in the KwaZulu-Natal Province;
- The site is located on a topographical high sloping in a north westerly and north easterly direction;
- Several non-perennial drainage lines flow from the center of the site in a north westerly and north easterly direction. A dam is located north of the site;
- The site is underlain by a dolerite intrusive rock body overlying the sandstone, dark-grey mudstone and shale (coal beds in places) of the Vryheid Formation (Ecca Group of the Karoo Supergroup);
- The underlining aquifer is defined as an intergranular and fractured aquifer witch is classified as a minor aquifer which is a moderately vulnerable;
- During the hydrocensus six boreholes (HBH1 – HBH6) as well as a spring were identified;
- Groundwater levels ranged between 4.75 and 25.9mbgl;
- HBH2, HBH5 and HBH6 were used for domestic purposes;
- Based on the topography and groundwater flow direction map, HBH2 and HBH6 are located downgradient of the proposed landfill;
- HBH5 and the spring are used for stock watering at the Gardinia dairy farm;
- An electrical resistivity survey was conducted within the north east, north west and south western section of the study area. Two primary targets and two secondary targets were sited;
- Three (3) monitoring boreholes (BH1, BH2 and BH3) were installed on or within close proximity to the geophysical drilling targets. The depths ranged from 19 to 31mbgl;
- In total four boreholes (BH1, BH2, BH3 and BL NL2) were located on site;
- Static groundwater levels ranged from 0.49 to 14.35 and well depth was measured between 19 and 60mbgl;
- A short duration Constant Rate test including a recovery test was conducted for each newly installed borehole. The recovery transmissivity in the monitoring boreholes was calculated to be between 0.06188 and 0.3838m/day. This is considered a low transmissivity value representing fine sand to silt and would impede the flow and dispersion of contamination if it were present;
- Groundwater samples were collected from BH1, BH2, BH3 and BH NL2;
- Colour and turbidity detected in all boreholes exceeded the SANS standards. The elevated turbidity in the newly installed boreholes are most likely associated with disturbance during drilling and is not representative of groundwater conditions;

- Combined nitrate (NO_3) and nitrite (NO_2) detected in BH3 and BH NL2 marginally exceeded the SANS standard;
- Aluminium (Al) detected in BH2 and BH3 exceeded the SANS standard. The iron detected in BH1 and BH3 exceeded the aesthetic SANS standard, however was below the chorionic health SANS standard;
- Iron detected in BH2 however exceeded the chronic health standard. Manganese (Mn) detected in BH2 and exceeded the aesthetic standard, however was below the chronic standard;
- Groundwater samples collected from BH1, BH2 and BH3 represent recently recharged groundwater rich in calcium, magnesium and bicarbonate;
- BH NL2 represent a dynamic regime with water rich in sodium, bicarbonate and chloride;
- During the risk assessment, groundwater contamination was identified as the main concern. Sources of contamination include fuel spillages during both construction and operational phases, as well as leakages or spillages of contained waste material;
- Mitigation measures includes:
    - Containment for all fuel stored on site;
    - Ensure that clean-up protocols are in place and adhered to;
    - Ensure adequate lining and drainage systems are installed;
    - Ensure surface water runoff is contained and treated before disposal;
    - Groundwater monitoring to ensure early detection of pollution.

11.1 Recommendations

Based on the findings of this investigation, the following recommendations are made:

- It is recommended that groundwater quality monitoring be conducted to ensure water remains compliant with the DWAF Minimum Requirements for Waste Disposal by Landfill (DWAF, 1998). Boreholes to be monitored includes BH1, BH2, BH3, BH NL1 and BH NL2;
- Mitigation measures identified during the risk assessment should be implemented during both the construction and operational phase;
- Engineering and designs should be done to appropriate standards and current best practices for a G:L:B+ site so as to avoid contamination of the underlying aquifer.

12 REFERENCE

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APPENDIX A: PHOTOGRAPHIC LOG

APPENDIX A - PHOTOGRAPHIC LOG

Client Name: Envitech Solutions	**Date:** March 2018	**Site Location:** Newcastle	**Project Number:** 17-0212

Photo No. 1

Description: General view of the study area. Photo taken from north to south

Photo No. 2

Description: General view of the study area. Photo taken from north to south

Photo No. 3

Description: Monitoring borehole, BH1

Photo No. 4

Description: Monitoring borehole, BH2

	
Photo No. 5	**Photo No. 6**
Description: Monitoring borehole, BH3	**Description**: Monitoring borehole, BH NL2

	
Photo No. 7	**Photo No. 8**
Description: View of BH NL2	**Description**: Hydrocensus Borehole, HBH1

	
Photo No. 9	**Photo No. 10**
Description: Hydrocensus Borehole, HBH2	**Description:** Hydrocensus Borehole, HBH3

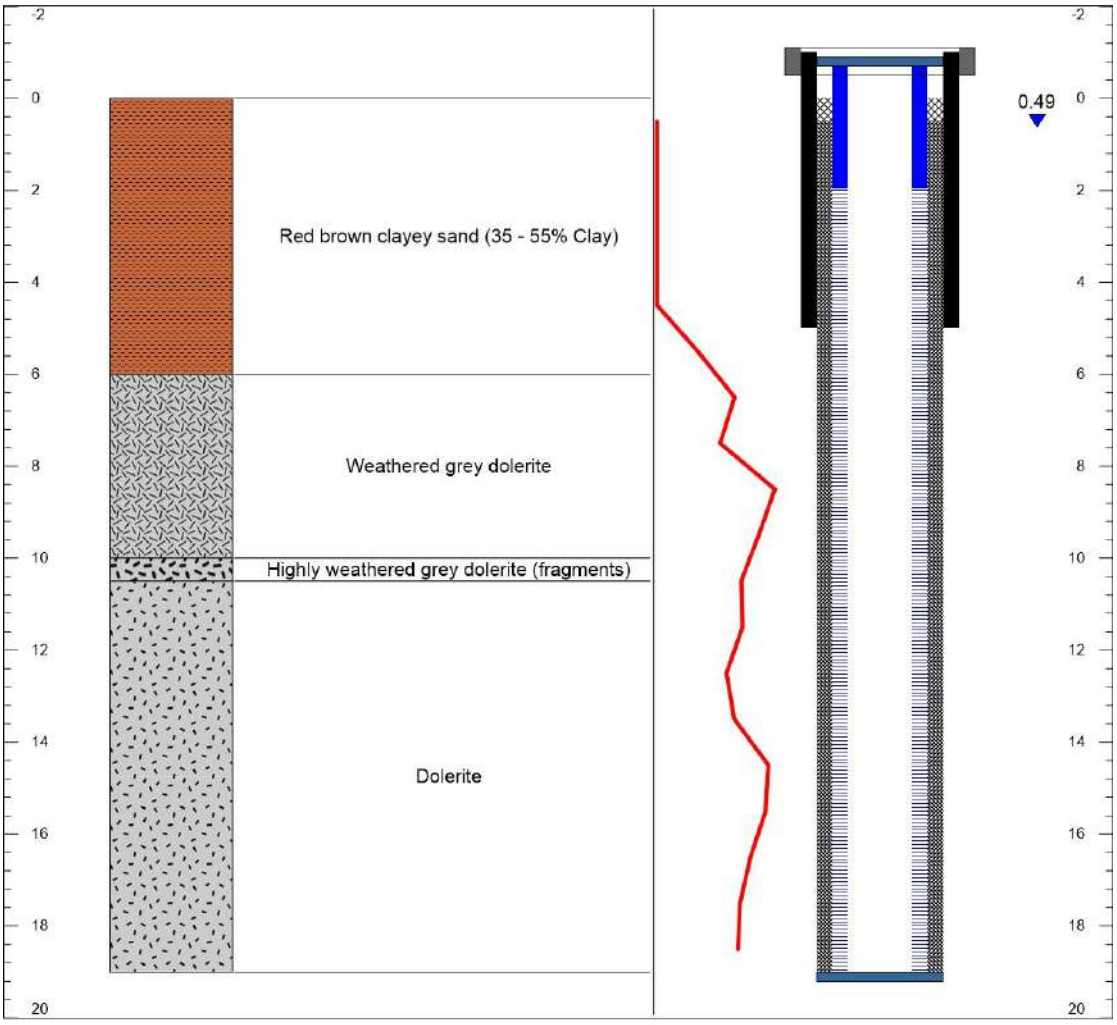
	
Photo No. 11	**Photo No. 12**
Description: Hydrocensus Borehole, HBH4	**Description**: Hydrocensus Borehole, HBH5

	
Photo No. 13	**Photo No. 14**
Description: Hydrocensus Borehole, HBH6	**Description:** View of old quarry located north west of the site

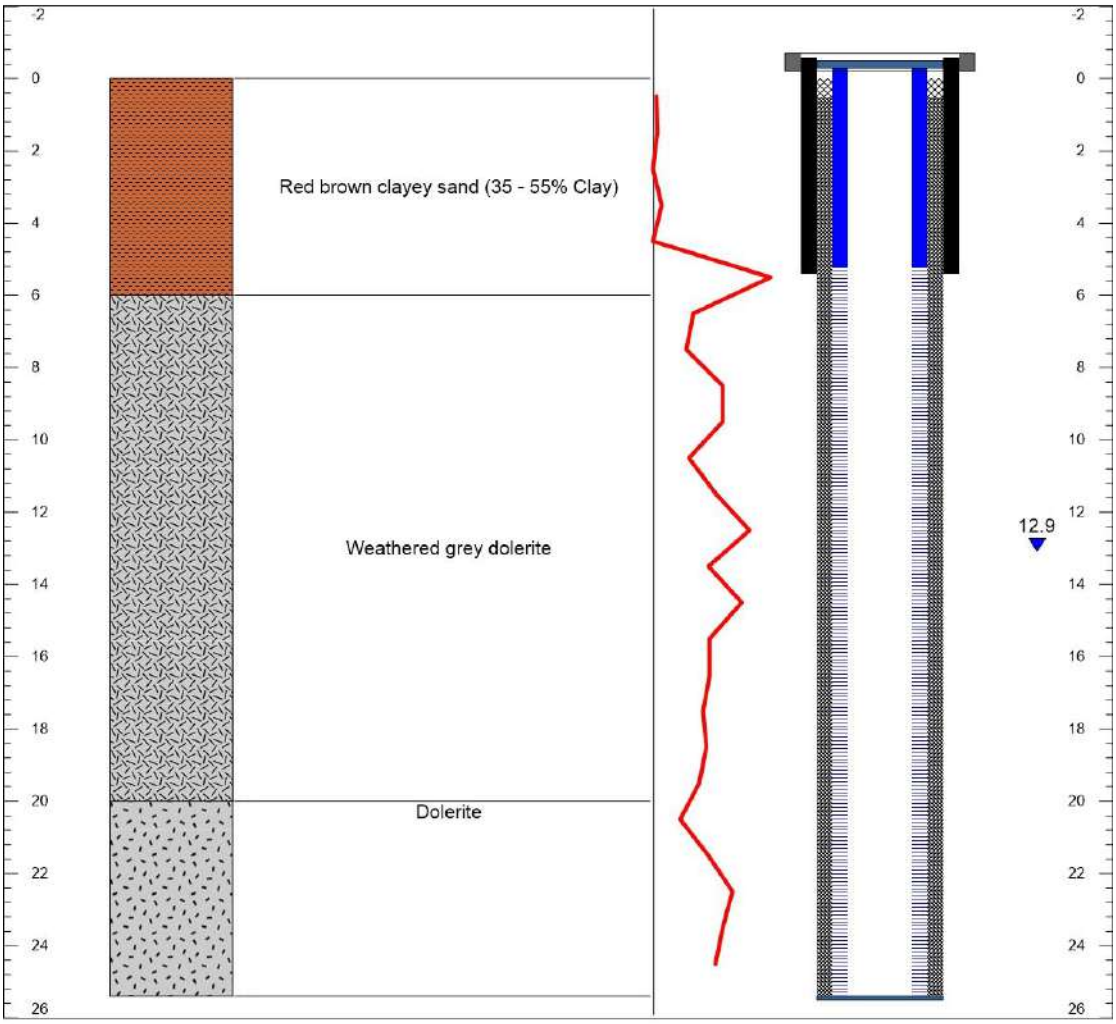
APPENDIX B: BOREHOLE LOGS

PROJECT:	17-0212	BOREHOLE ID:	**BH1**	
LOCATION:	Newcastle	LATITUDE:	-27.845718	
DRILLING CONTRACTOR:	Bentex	LONGITUDE:	29.910433	
DRILLING METHOD:	Percussion drilling	WATER LEVEL DEPTH:	0.5mbgl	
DATE COMPLETED:	Feb-18	DEPTH:	19m	

Depth (m)	Graphic log	Description	Penetration Rate (sec)	Well Construction	SWL (mbgl)



PROJECT:	17-0212	BOREHOLE ID:	**BH2**
LOCATION:	Newcastle	LATITUDE:	-27.851088
DRILLING CONTRACTOR:	Bentex	LONGITUDE:	29.910946
DRILLING METHOD:	Percussion drilling	WATER LEVEL DEPTH:	12.9mbgl
DATE COMPLETED:	Feb-18	DEPTH:	25.4m

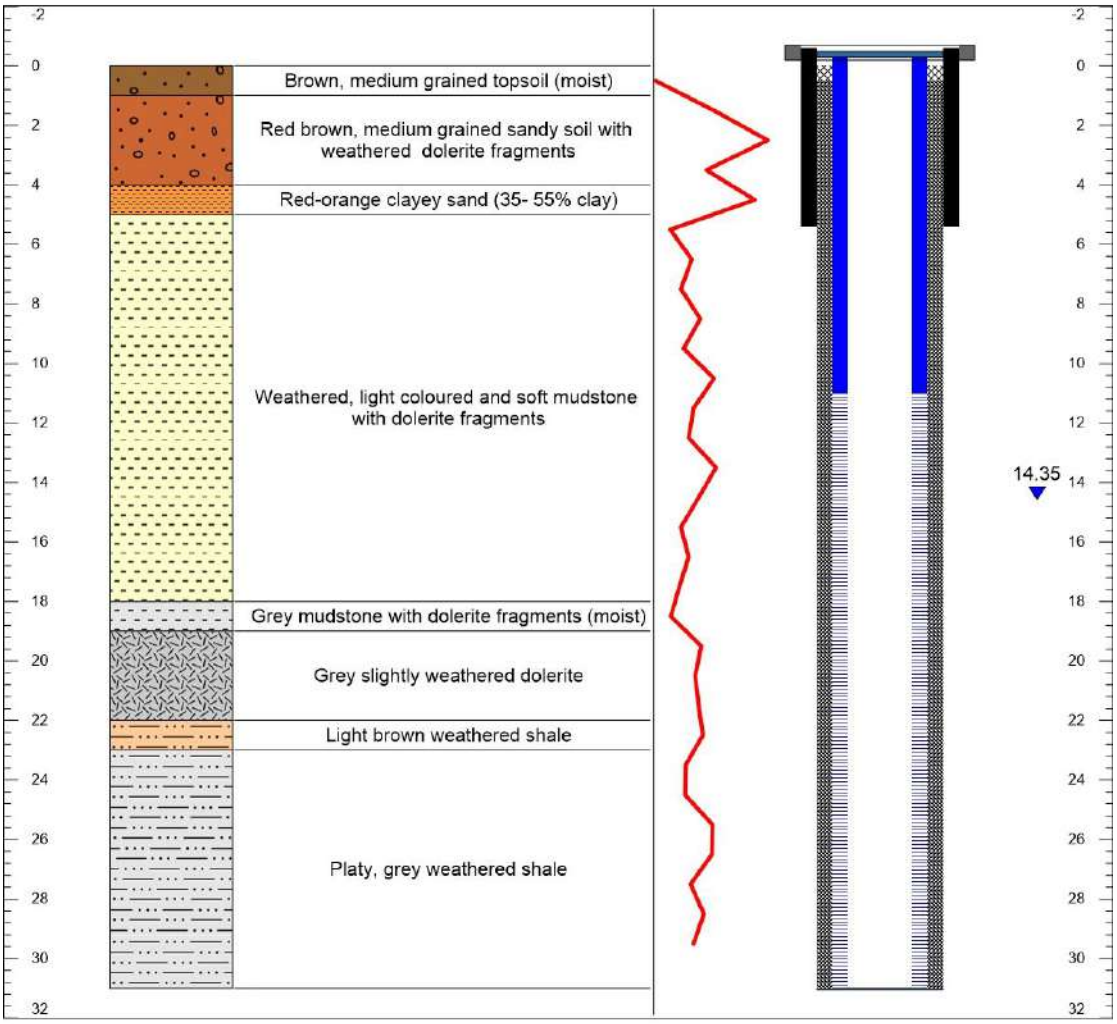


Well Construction Legend

Steel Lockable Cap	Solid Casing (177mm Steel)	Gravel Pack
Top Cap	Solid Casing (110mm PVC)	End Cap
Sanitary Seal	Perforated Casing (110mm PVC)	

PROJECT:	17-0212	BOREHOLE ID:	**BH3**
LOCATION:	Newcastle	LATITUDE:	-27.849137
DRILLING CONTRACTOR:	Bentex	LONGITUDE:	29.932111
DRILLING METHOD:	Percussion drilling	WATER LEVEL DEPTH:	14.35mbgl
DATE COMPLETED:	Feb-18	DEPTH:	31m

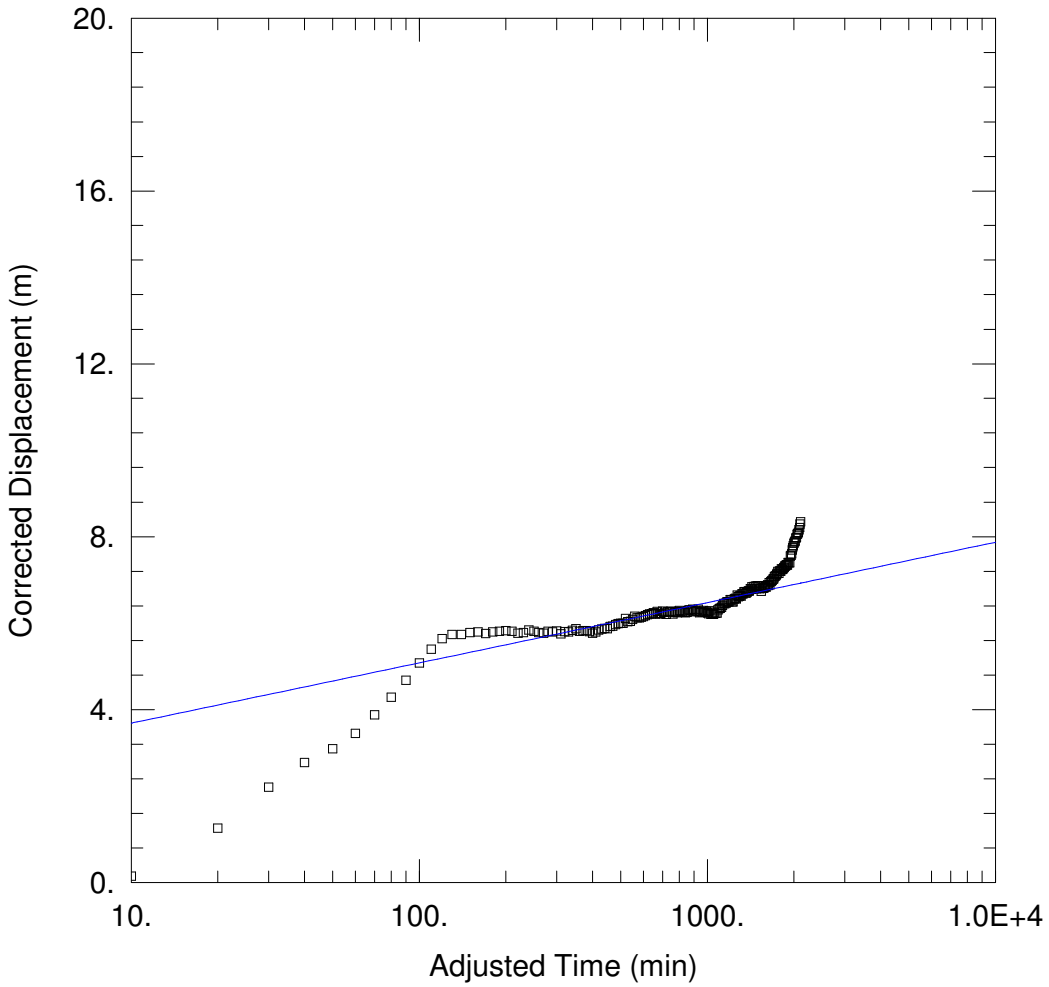
Depth (m)	Graphic log	Description	Penetration Rate (sec)	Well Construction	SWL (mbgl)



Well Construction Legend

Steel Lockable Cap	Solid Casing (177mm Steel)	Gravel Pack
Top Cap	Solid Casing (110mm PVC)	End Cap
Sanitary Seal	Perforated Casing (110mm PVC)	

APPENDIX C: AQUIFER TEST RESULTS



WELL TEST ANALYSIS

Data Set:
Date: 03/28/18 Time: 07:53:17

PROJECT INFORMATION

Company: GCS
Client: Envitech Solutions
Project: 17-0212
Location: Newcastle
Test Well: BH1
Test Date: February 2018

AQUIFER DATA

Saturated Thickness: 18.51 m Anisotropy Ratio (Kz/Kr): 0.5

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
.	0	0

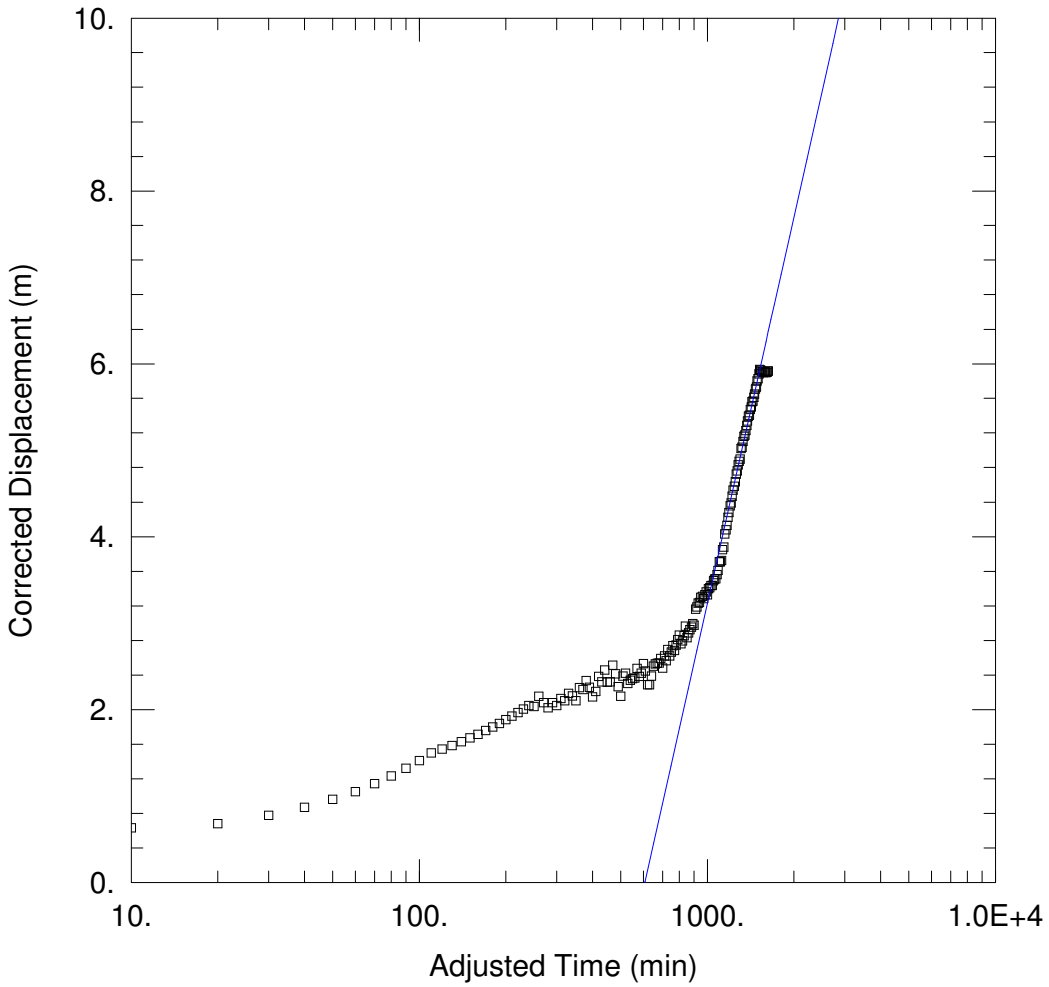
Observation Wells

Well Name	X (m)	Y (m)
.	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 0.9078 m^2/day S = 0.01598



WELL TEST ANALYSIS

Data Set: Q:\...\BH2.aqt
Date: 03/28/18 Time: 07:54:37

PROJECT INFORMATION

Company: GCS
Client: Envitech Solutions
Project: 17-0212
Location: Newcastle
Test Well: BH2
Test Date: February 2018

AQUIFER DATA

Saturated Thickness: 12.5 m Anisotropy Ratio (Kz/Kr): 0.5

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
.	0	0

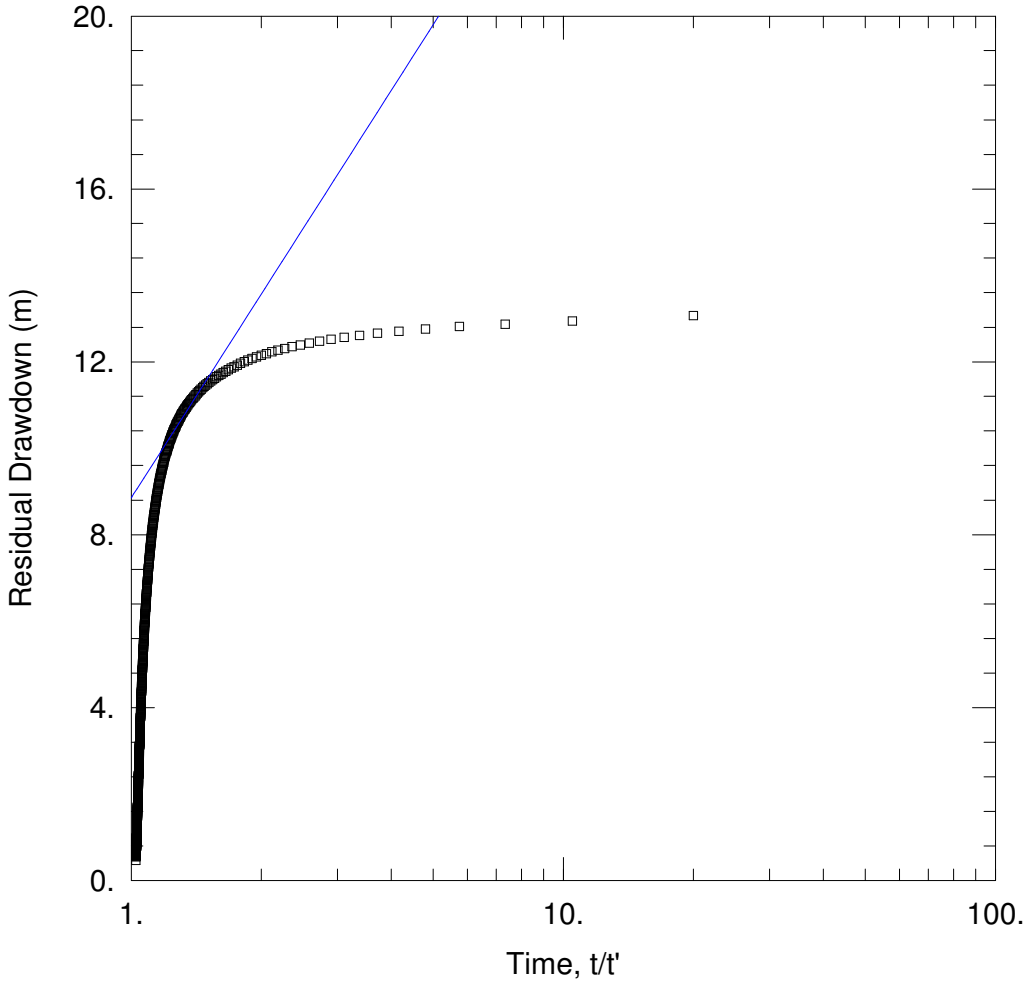
Observation Wells

Well Name	X (m)	Y (m)
.	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 0.1065 m^2/day S = 14.8



WELL TEST ANALYSIS

Data Set: Q:\...\BH3.aqt
Date: 03/28/18 Time: 07:55:07

PROJECT INFORMATION

Company: GCS
Client: Envitech Solutions
Project: 17-0212
Location: Newcastle
Test Well: BH3
Test Date: February 2018

AQUIFER DATA

Saturated Thickness: 16.65 m Anisotropy Ratio (Kz/Kr): 0.5

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
.	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ .	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.3838 m^2/day S/S' = 0.2725

APPENDIX D: LABORATORY CERTIFICATE

CLIENT INFORMATION
GCS (Pty) Ltd
Attention: Claudia Brites
PO Box 2597
Rivonia

Water Test Report

LABORATORY NUMBER 6476A **DATE RECEIVED** 19-Feb-18

SAMPLE NUMBER BH1

REPORTING UNITS mg/l [ppm] **(unless stated elsewhere)**

TASK PO Nr 17-0212 Newcastle Landfill

Cations and Metals

(Method UISSL-WL-007) [NA]

Al*	0.16	Cd*	<0.05	Mg*	1.5	Sb*	<1
As*	<1	Cr*	<0.05	Mn*	<0.05	Se*	<1
B*	0.27	Cu*	<0.05	Na*	1.9	Zn*	<0.05
Ba*	<0.05	Fe*	0.37	Ni*	<0.05		
Ca*	3.2	K*	0.1	Pb*	<1		

Anions

(Method UISSL-WL-005)

F*	<0.4
Cl	<1
NO2*	<2
NO3	<2
NO2 + NO3 as N	<0.45
SO4	<4

Other Parameters

pH	(Method UISSL-WL-003 @ 25 deg C)	6.15
EC (µs/cm)	(Method UISSL-WL-001 @ 25 deg C)	57.40
P-Alk as CaCO3	(Method UISSL-WL-002)	<0.6
M-Alk as CaCO3	(Method UISSL-WL-002)	16
TDS	(Method UISSL-WL-004 @ 110 deg C)	50
HCO3*		20
Colour (HAZEN)*		26
Turbidity (NTU)*		20.40

Results approved by *WJ Havenga (Technical Manager)*

Reporting date: *Thursday, February 22, 2018*

T 0584

Parameters marked " ** "in this report are outsourced results.
Parameters marked " * "in this report are non-accredited results.

CLIENT INFORMATION
GCS (Pty) Ltd
Attention: Claudia Brites
PO Box 2597
Rivonia

Water Test Report

LABORATORY NUMBER 6476A **DATE RECEIVED** 19-Feb-18

SAMPLE NUMBER BH2

REPORTING UNITS mg/l [ppm] **(unless stated elsewhere)**

TASK PO Nr

Cations and Metals

(Method UISSL-WL-007) [NA]

Al*	2.41	Cd*	<0.05	Mg*	8.0	Sb*	<1
As*	<1	Cr*	<0.05	Mn*	0.14	Se*	<1
B*	0.23	Cu*	<0.05	Na*	3.9	Zn*	<0.05
Ba*	<0.05	Fe*	4.74	Ni*	<0.05		
Ca*	13.1	K*	1.1	Pb*	<1		

Anions

(Method UISSL-WL-005)

F*	<0.4
Cl	<1
NO2*	<2
NO3	<2
NO2 + NO3 as N	<0.45
SO4	<4

Other Parameters

pH	(Method UISSL-WL-003 @ 25 deg C)	8.04
EC (µs/cm)	(Method UISSL-WL-001 @ 25 deg C)	120.10
P-Alk as CaCO3	(Method UISSL-WL-002)	<0.6
M-Alk as CaCO3	(Method UISSL-WL-002)	59
TDS	(Method UISSL-WL-004 @ 110 deg C)	60
HCO3*		72
Colour (HAZEN)*		836
Turbidity (NTU)*		1320.00

Results approved by *WJ Havenga (Technical Manager)*

Reporting date: *Thursday, February 22, 2018*

T 0584

Parameters marked " ** "in this report are outsourced results.
Parameters marked " * "in this report are non-accredited results.

CLIENT INFORMATION
GCS (Pty) Ltd
Attention: Claudia Brites
PO Box 2597
Rivonia

Water Test Report

LABORATORY NUMBER 6476A **DATE RECEIVED** 19-Feb-18

SAMPLE NUMBER BH3

REPORTING UNITS mg/l [ppm] **(unless stated elsewhere)**

TASK PO Nr

Cations and Metals

(Method UISSL-WL-007) [NA]

Al*	1.69	Cd*	<0.05	Mg*	8.0	Sb*	<1
As*	<1	Cr*	<0.05	Mn*	0.06	Se*	<1
B*	0.21	Cu*	<0.05	Na*	10.8	Zn*	<0.05
Ba*	<0.05	Fe*	0.89	Ni*	<0.05		
Ca*	16.2	K*	1.9	Pb*	<1		

Anions

(Method UISSL-WL-005)

F*	<0.4
Cl	7.9
NO2*	<2
NO3	8.3
NO2 + NO3 as N	1.9
SO4	7.3

Other Parameters

pH	(Method UISSL-WL-003 @ 25 deg C)	7.27
EC (µs/cm)	(Method UISSL-WL-001 @ 25 deg C)	186.30
P-Alk as CaCO3	(Method UISSL-WL-002)	<0.6
M-Alk as CaCO3	(Method UISSL-WL-002)	67
TDS	(Method UISSL-WL-004 @ 110 deg C)	160
HCO3*		82
Colour (HAZEN)*		209
Turbidity (NTU)*		3920.00

Results approved by *WJ Havenga (Technical Manager)*

Reporting date: *Thursday, February 22, 2018*

T 0584

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Parameters marked " * "in this report are non-accredited results.

CLIENT INFORMATION
GCS (Pty) Ltd
Attention: Claudia Brites
PO Box 2597
Rivonia

Water Test Report

LABORATORY NUMBER 6476A **DATE RECEIVED** 19-Feb-18

SAMPLE NUMBER HBH1

REPORTING UNITS mg/l [ppm] **(unless stated elsewhere)**

TASK PO Nr

Cations and Metals

(Method UISSL-WL-007) [NA]

Al*	0.06	Cd*	<0.05	Mg*	7.3	Sb*	<1
As*	<1	Cr*	<0.05	Mn*	<0.05	Se*	<1
B*	0.20	Cu*	0.06	Na*	61.9	Zn*	<0.05
Ba*	<0.05	Fe*	0.05	Ni*	<0.05		
Ca*	19.8	K*	1.7	Pb*	<1		

Anions

(Method UISSL-WL-005)

F*	<0.4
Cl	117.7
NO2*	<2
NO3	5.6
NO2 + NO3 as N	1.3
SO4	7.5

Other Parameters

pH	(Method UISSL-WL-003 @ 25 deg C)	7.26
EC (µs/cm)	(Method UISSL-WL-001 @ 25 deg C)	476.00
P-Alk as CaCO3	(Method UISSL-WL-002)	<0.6
M-Alk as CaCO3	(Method UISSL-WL-002)	78
TDS	(Method UISSL-WL-004 @ 110 deg C)	201
HCO3*		96
Colour (HAZEN)*		24
Turbidity (NTU)*		10.57

Results approved by *WJ Havenga (Technical Manager)*

Reporting date: *Thursday, February 22, 2018*

T 0584

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APPENDIX E: SPECIALIST CV

Albertus (Alkie) WC Marais

TECHNICAL DIRECTOR

CORE SKILLS

- Mining related hydrogeological investigations;
- Groundwater contaminant studies;
- Modelling impacts on the groundwater regime in terms of flow and contaminant transport;
- Hydro-geochemical characterisations;
- Mine dewatering studies and design;
- Engineering related groundwater modelling studies;
- Environmental management program reports;
- Groundwater and aquifer assessments; and
- Water-balance studies.

DETAILS

Qualifications

MSc (Geohydrology), IGS (UFS) Bloemfontein, SA, 1997 BSc (Hons)

(Geology), UFS Bloemfontein, SA, 1993 BSc

(Geology, Geochemistry), UFS Bloemfontein, SA, 1992

Memberships

Groundwater Division of South Africa;

International Mine Water Association;

Water Institute of Southern Africa (Mine Water);

International Association of Hydrogeologists

Pr Sci Nat (40001206).

Languages

English – fluent

Afrikaans -fluent

Countries worked in

South Africa, Botswana, Niger, Ghana, Burkina Faso, Democratic Republic of Congo (DRC), Malawi, Madagascar , Zimbabwe, Lesotho, Namibia, Mozambique

PROFILE

Alkie Marais is a specialist in groundwater services and manages the Water Group as Director. The Water Group has specialists in terms of hydrology, contaminant site management, water resources and management of mine water.

He has 20 years' experience and specialises in Mining related hydrogeological investigations, Groundwater contaminant studies, Flow and contaminant transport modelling, Hydro-geochemical waste studies, Mine dewatering studies and design, Engineering related groundwater modelling studies, Environmental management studies, Groundwater monitoring programmes and hydrochemical analyses, Groundwater and aquifer assessments and Water-balance studies.

Previous Work Experience

KEY PROFESSIONAL AND PROJECT EXPERIENCE:

- **MOATIZE COAL MINE, Mozambique, Vale, 2015 Groundwater numerical model review.**

- **MOLO GRAPHITE PROJECT, Madagascar, Energizer, 2014. Undertook the groundwater, modelling and hydro-geochemical components of the Bankable Feasibility Study. Managing the hydrological and dam yield analysis components.**

- **KAYELEKERA URANIUM MINE, Malawi, Paladin, 2013 to 2014. Geochemical assessment of waste rock, tailings and marginal ore facilities. The study includes geochemical testing modelling and radio-active analysis.**

- **NKOMATI MINE DEWATERING STUDY, South Africa, ARM & Norilsk Nickel, 2007 to 2015. Design and management of the Nkomati Mine open pit section groundwater dewatering. Groundwater model simulations and design of future mine dewatering requirements.**

- **NKOMATI MINE HYDRO-GEOCHEMICAL STUDIES, South Africa, ARM - Norilsk , 2007 to 2015. Evaluated the ARD and leach potential of waste rock and tailings, followed by detailed hydrogeochemical modelling, advised the client and engineering team in terms of construction material, mitigation measures and water management. Groundwater flow and contaminant transport modelling were used as part of these studies.**

- **BOMI HILLS IRON PROJECT IA, Liberia, Vedanta, 2013. The Impact Assessment and water management study for the proposed iron ore feasibility project. Groundwater numerical modelling was undertaken as part of the IA.**

- **VAAL RIVER OPERATIONS TAILINGS SOURCE TERM STUDY, Anglo Gold Ashanti, 2012 . Managing the geochemical test work and seepage modelling for the West Wits Tailings Complex source term study. Evaluating different closure scenarios in terms of potential impacts.**

- **DUKWE COAL PROJECT: Geochemical Scoping Assessment, Botswana (2010). Geochemical testing and Scoping Phase review.**

- **MODIKWA MINE DEWATERING MODEL, South Africa (2009). Groundwater numerical model simulations of dewatering at proposed open pit mine.**

- **REVIEW OF HYDROGEOLOGICAL AND GEOCHEMICAL COMPONENTS OF THE STORA SAHAVAARA AND TAPULI IRON ORE PROJECTS, 2009, Sweden. Review of Feasibility Study and gap analysis.**

- **MMAMABULA POWER STATION AND COAL MINE BOTSWANA EIA, Botswana, 2007 - 2009.The project involved an environmental impact assessment of mining and power station activities located near the town of Mmaphashalala. Environmental geochemical assessment of mine and power station residue material. Assessment of long-term ARD backfill scenario.**

- **BUGDAINSKOYE PROJECT, Russia, Norilsk(2009). Environmental groundwater and geochemical review for feasibility study.**

- **FORTIER MINE: Identification of Groundwater Dewatering Target Sites, DRC, FQM, 2008. Identification of optimal dewatering sites for the Fortier Mine open pit.**

- **SHEBA'S RIDGE PROJECT, South Africa, Ridge Mining, 2008, Bankable Feasibility Study for proposed nickel and PGE project. Groundwater and geochemical investigation. Evaluation of mitigation measures, including liner – no liner options.**

- **KAYELEKERA URANIUM PROJECT, Malawi, Paladin, 2006. The project was aimed to produce a bankable feasibility study document for the Kayelekera Uranium Project in Malawi. It involved a baseline data study and site management. Development of a conceptual and numerical model of the site to identify and quantify potential impacts and to assist in water resource management.**

- **AMBATOVY NICKEL PROJECT, Madagascar,2004 – 2006. The project involved various phases, including an environmental impact assessment, bankable feasibility study, mitigation measures design and detailed design study. Two areas of investigation included the surface mine (Ambatovy) and the tailings storage facility (Toamasina). A field investigation was undertaken to characterise the baseline hydrogeology. Waste characterisation and seepage modelling were undertaken for the tailings storage facility. An impact assessment was undertaken. Mitigation measures investigated included geochemical source alteration and containment (liner, drain. pump-back system and grout curtain scenarios).**

KOBUS TROSKIE

SENIOR HYDROGEOLOGIST

CORE SKILLS

- Project planning and management
- Proposal writing
- Conceptualisation, planning, management and coordination, financials
- Data analysis and interpretation
- Technical report writing
- Project and staff management

DETAILS

Qualifications

- BSc (Biochemistry, Microbiology, Ecology)
- BSc (Hons) Hydrogeology

Memberships

- Registered Natural Scientist S.A (Reg. No. 400218/05)
- NICOLA: Service Provider Technical Committee Member
- Member of: Geological Society of South Africa
- Borehole Water Association of Southern Africa
- Landfill Interest Group – Gauteng RSA

Languages

- English – fluent
- Afrikaans – fluent

Countries worked in:

South Africa, Angola, Botswana, DRC, Lesotho, Madagascar, Malawi, Mozambique, Namibia, Nigeria, Oman, Sierra Leone, Swaziland, Tanzania, Uganda, Zambia

PROFILE

Kobus is a Senior Hydrogeologist at GCS (Pty) Ltd with 15 years' experience and manages the CSM Unit as a Unit Head. Experience includes hydrogeology and contaminated land investigations including soil and groundwater contamination. Kobus is registered at the South African Council for Natural Scientific Professions (Pri. Sci. Nat) and has undertaken projects including hydrogeological investigations, due diligence studies and remediation of contaminated land for Arcelor Mittal , SASOL, Transnet, BP and several industrial clients.

Kobus has specialist skills in the following areas:

- Geophysical site investigations for contaminated land delineation studies
- Detailed site characterisation studies, Phase 2 Intrusive investigations
- Risk assessments with regard to soil and groundwater contamination,
- Compilation of site remediation plans and sign off from the local authorities on remediation plans.
- In-situ remediation of contaminated sites.
- Groundwater monitoring programmes – design and implementation
- Groundwater and aquifer assessments, management and protection plans

PROFESSIONAL EXPERIENCE - IMPACT AND AUDITING STUDIES

- RSA 2016 (Unit Manager) (Confidential Client) – In situ remediation of a hydrocarbon contaminated site.
- RSA 2016 (Unit Manager) (Confidential Client) – Due Diligence Study – Organic contaminants, ESA reports phase I/II (4 sites).
- RSA 2015 (Project Manager) (Confidential Client) – In-situ remediation of a hydrocarbon contaminated site.
- RSA 2015 (Project Manager) (BP Remediation Management) – Remediation Project Manager RSA 6 –Month Secondment Portfolio included several retail filling stations.
- RSA 2012 (Project Manager) (Confidential Client) – In-situ remediation of a hydrocarbon contaminated site.
- Zambia 2012 – (Senior hydrogeologist) - Due Diligence Study – Organic contaminants, ESA reports phase I/II (2 sites).
- RSA SASOL 2011 - (Senior hydrogeologist) - Phase I Hydrocarbon Site Characterisation and risk assessment of 130 fuel stations across South Africa.
- Sasol: Groundwater & Soil Contamination Study.
- RSA, 2011 (Phase I / 2 Hydrocarbon Site Characterization and risk assessment of 70 sites within Gauteng Province.
- RSA, 2011 - (Senior hydrogeologist) - Thabazimbi Hydrocarbon Assessment: Field work, data compilation, data interpretation, RBCA.
- RSA, February 2010 (Senior hydrogeologist) - Due Diligence Study – Organic contaminants, ESA reports phase I/II (2 sites).
- RSA, September 2009 (Project hydrogeologist) - Due Diligence Study – Organic contaminants ESA reports phase I/II (4 sites).
- RSA, September 2009 (Project hydrogeologist) - Organic contaminants, Due Diligence Study, Water quality objectives and sign off from the Department of Water Affairs and Forestry (DWAF).
- NIGERIA, September 2009 (Project hydrogeologist) - Due Diligence Study – Organic contaminants, ESA reports phase I/II.
- NIGERIA, March 2008 (Project hydrogeologist) - Due Diligence Study – Organic contaminants, ESA reports phase I/II.
- RSA, November 2007 (Project hydrogeologist) - Due Diligence Study – Organic contaminants, ESA reports phase I/II.
- RSA, October 2007 (Project hydrogeologist) - Due Diligence Study – Organic contaminants, ESA reports phase I/II.
- RSA, July 2007 (Project hydrogeologist) - Due Diligence Study, ESA reports phase I/II.

- RSA, March 2007 (Project hydrogeologist) - Organic contamination, remediation and monitoring.
- RSA, March 2007 (Project hydrogeologist) - Organic contamination, soil and water study.
- ZAMBIA, 2006 (Project hydrogeologist) - Site selection and feasibility study – Livingstone, Zambia.
- RSA, 2005 (Hydrogeologist) - Site suitability study, permit application for an Ash Disposal Facility.
- RSA, 2006 (Hydrogeologist) - Contamination studies for on-site sanitation.
- MOZAMBIQUE, 2004 (Hydrogeologist) - Temane CPF, Villunkolos Mozambique: The project involved Geophysical investigations, designing a monitoring network, drilling supervision and Aquifer test supervision.
- MOZAMBIQUE, 2003 (Hydrogeologist) - Mozal Mozambique, The project involved monitoring and evaluation of onsite conditions to a hazardous waste disposal site.

SPECIFIC EXPERIENCE IN THE MINING INDUSTRY

- ZAMBIA, 2009 – Mine Dewatering assessment of a Gold Mine.
- RSA, 2008 - 2009 - EIA Application for various Gold Heap leach Pad sites, Groundwater impact assessments, site selection from a groundwater perspective.
- MALAWI, 2006 - Kayelekera Uranium Project: The project involved geophysical investigations, designing a monitoring network, drilling supervision and aquifer test supervision. The report compilation included commenting on catchment characteristics, identification of hydrogeological units from previous studies and borehole logs, assessing the aquifer(s) surrounding the proposed surface mine and determining the impact of mine infrastructure including waste rock dumps, tailings storage facilities, and open pit mining on the regional aquifer(s).
- RSA, 2005 - 2006 - Six month secondment to Anglo Gold Ashanti in Vaal Reefs. Position held as Senior Environmental Coordinator. Responsibilities included management of the groundwater as part of the water unit for the Vaal Reefs, West Wits, and Ergo mining operations.
- RSA, 2003 - 2010 - Data collection, data analysis and report writing for the groundwater sections, and surface water quality of environmental management program reports (EMPRs) for various types of mines, including: coal, gold, platinum, nickel, uranium mines.
- RSA, 2001 - 2005 - Groundwater monitoring and audit reports. The evaluation of groundwater level fluctuation and hydrochemical data and the compilation of monthly, quarterly and annual monitoring reports.
- RSA, 2006 - Site suitability studies and designing a monitoring network for permit application and closure of a Ash Disposal Facility (Rand Water).

Claudia du Plessis

CSM Unit Manager

CORE SKILLS

- Contamination assessments (hydrocarbon and inorganics);
- General soil and water sampling (cation/anion, metals, bacteriological, hydrocarbon);
- Groundwater investigations;
- Hydrocarbon site investigations;
- Due diligence studies;
- Assessments of groundwater availability and sustainable abstraction rates

DETAILS

Qualifications

MSc Hydrogeology

BSc Honours – Geology

BSc Geology and Chemistry

Memberships

Registered Natural Scientist S.A (Reg. No. 400241/15)

The Groundwater Division of the Geological Society of South Africa

Network for Industrially Contaminated Land in Africa (NICOLA)

Languages

English – fluent

Afrikaans – (speak & read)

Countries worked in

South Africa
Tanzania
South Africa

PROFILE

Claudia has been an employee since 2010. She has experience in Project management; Contamination assessments (hydrocarbon and inorganic related contaminants); General soil and water sampling (cation/anion, metals, bacteriological, hydrocarbon); Groundwater investigations; Hydrocarbon site investigations; Due diligence studies; Assessments of groundwater availability and sustainable abstraction rates; Evaluation of water chemistry; Water supply projects; Resource determinations; Assessment of water supply needs; Waste disposal site suitability studies; Soil vapour surveys to aid in hydrocarbon plume delineation; Aquifer classification; Catchment delineations; Hydrogeological investigations for EIA's and WULA's; Data interpretation; and Report writing.

Claudia has specialist skills in the following areas:

- Contamination assessments (hydrocarbon and inorganic related contaminants);
- General soil and water sampling (cation/anion, metals, bacteriological, hydrocarbon);
- Groundwater investigations;
- Hydrocarbon site investigations;
- Due diligence studies;
- Assessments of groundwater availability and sustainable abstraction rates;
- Evaluation of water chemistry;
- Water supply projects;
- Resource determinations;
- Assessment of water supply needs;
- Waste disposal site suitability studies;
- Soil vapour surveys to aid in hydrocarbon plume delineation;
- Aquifer classification;
- Catchment delineations;

Notable Professional Experience

Client	Location	Year	Description
Malibongwe Game Lodge	Zimbabwe	2010	Geophysical investigation for Water Supply
Kangra	South Africa	2010	Panbult Hydrogeological Assessment: Hydrogeological investigation as part of a Water Use License Application. Field work conducted included hydrocensus, aquifer testing and groundwater sampling.
Xstrata Boshoek	South Africa	2010-2014	Xstrata Boshoek Monitoring: Quarterly surface and groundwater monitoring at the Xstrata Boshoek Mining Operation located near Rustenburg.
SASOL	South Africa	2010-2012	Phase 1 ERA, groundwater and soil screening risk assessment: Data compilation, data interpretation, report writing, project management
BKS	South Africa	2010	Uitenhage Hydrocarbon Assessment: Contaminated land assessment conducted for a car manufacturing plant and identifying historical contamination
Kumba Iron Ore	South Africa	2010	Thabazimbi Hydrocarbon Assessment: Regular groundwater monitoring of boreholes located on the Thabazimbi mine identifying organic contamination within the boreholes.
SASOL	South Africa	2010	Phase 1 ERA, groundwater and soil screening risk assessment: Data compilation, data interpretation, report writing, project management
Kwezi V3 Engineers	South Africa	2011	Lekubu Village Water Supply Project: Hydrogeological investigation conducted to determine the borehole yields of production boreholes used for water supply.
Akulu Marchon	South Africa	2011	Akulu Marchon Groundwater and Soil remediation for Akulu Marchon: Data compilation, data interpretation, report writing
SiVEST	South Africa	2011	Grootvlei Power Station Hydrogeological Investigation: Hydrocensus, groundwater sampling, data interpretation and risk assessment
AECOM	South Africa	2011	Johnsons Diversey Hydrocarbon Monitoring: Groundwater monitoring and reporting of organic analysis for the Johnson Diversey factory

BKS	South Africa	2011	Uitenhage Hydrocarbon Assessment: Hydrocarbon risk assessment conducted for a car manufacturing plant and identifying historical contamination
SSI Engineers	South Africa	2011	Middelburg WWTW Hydrogeological Study: Hydrogeological Study conducted for a Waste Water Treatment Works
Proplan Engineers	South Africa	2011	Mohlakeng, Toekomsrus, Randfontein, Kocksoord and Greenhills cemetery Hydrogeological investigation: Hydrogeological study to determine the potential groundwater contamination arising from cemeteries
Aurecon	South Africa	2011	NamPower Coal Fired Power Station Specialist Report: Scoping report in terms of hydrogeological, geotechnical, soils & hydrology
WorleyParsons	South Africa	2011	Tosca Landfill Site Selection: Site selection for a landfill in terms of hydrogeology and geotechnical aspects
Clean Stream Environmental Consultants Inyanda Siding Hydrogeological	South Africa	2011	Investigation: Hydrogeological study to determine the potential groundwater contamination arising from a coal siding
Madibeng Local Municipality	South Africa	2012	Brits Waste Water Treatment Works Hydrogeological Study: Hydrogeological study forming part of the Water Use License Application
WorleyParsons	South Africa	2012	Lephalale Landfill Site Selection: Site selection for a landfill in terms of hydrogeology and geotechnical aspects
AECOM	Tanzania	2012	Due Diligence Investigation – Tanzania: Due diligence study in terms of groundwater and soil contamination. Field work conducted included soil augering, installation of monitoring wells, and sampling.

Newtown Landscape architects	South Africa	2012	Magalies Waste Water Treatment Works Hydrogeological Study: Hydrogeological study forming part of the Water Use License Application
RoyalHaskoning DHV	South Africa	2013	Matimba Ash Dump Hydrogeological Investigation: Hydrogeological study to determine the most suitable site for a Power Station
SASOL	South Africa	2013-2014	Sasol Retail ERA Project. The project involves geohydrological investigations for 14 retail Environmental Risk Assessment projects, which were selected and recommended for further investigations based on the findings of the Phase I studies conducted in 2011.
Transnet Pipelines.	South Africa	2013 - 2015.	Geohydrological and Contaminated Land Assessment Services for 2 years for various depots. Included ongoing groundwater monitoring of all Transnet pipeline depots and pump stations.
SASOL	South Africa	2014	Sasol Divestment sites. Environmental assessments, monitoring well siting and drilling. The project involved an environmental risk profile for Sasol for six sites that Sasol divesting from. Soil and hydrogeological investigations as well as monitoring well installation and monitoring thereof was performed in 2014.
Royal Haskoning DHV.	South Africa	2014	Sasol Sludge Hydrogeological Study Update. Project involves a hydrogeological study as part of a baseline study for an EIA prior to deposition of sludge for agricultural purposes.
Royal Haskoning DHV.	South Africa	2014	Sand Draai CSP (SOLAR POWER). The project involved a baseline hydrogeological assessment as part of an EIA.
Seton Auto Leather.	South Africa	2015	Seton Leather GW Assessment (Nigel). The project involved soil and groundwater quality assessment and the installation of monitoring wells.
Chemetall.	South Africa	2016	Chemetall Annual Groundwater Sampling. Project involved sampling and analysing groundwater

			quality.
Transnet Engineering	South Africa	2016	Integrated Water Quality Management Plan for a locomotive depot. Detailed soil and groundwater investigations at the locomotive depot whereby soil augering was conducted to identify contaminated areas, monitoring wells were drilled to map contamination plumes within the groundwater.
Transnet Pipelines	South Africa	2016 - 2017	Geohydrological and Contaminated Land Assessment for 31 depots for a period of two years. Groundwater monitoring, soil investigations, Phase I & Phase II investigation. Remediation plan compilation as per Remediation Order requests.
Transnet Engineering	South Africa	2016	Remediation of historical organic bitumen related substances within the contaminated soil area. The project involved in-situ and ex-situ remediation of contaminated soil.

Marietjie Kruger

Hydrogeologist

CORE SKILLS

- Contaminated Land Investigations:
  - Conceptual Site Modelling;
  - Groundwater and soil sampling;
  - Hydrocensus;
  - Reporting.
- Hydrogeological Investigations:
  - Groundwater Resource Determination;
  - Aquifer Testing;
  - Geophysical Surveys;
  - Reporting.

DETAILS

Qualifications

- BSc Hons (Hydrology)
- BSc (Environmental and Biological science: Geology and Geography)

Memberships

- Groundwater Division of the Geological Society of South Africa
- Cand. Natural Scientist: Water Resource Science (Reg. no. 117644)

Languages

- English – Fluent
- Afrikaans – Fluent

Countries Worked In

South Africa

PROFILE

Marietjie Kruger is a Hydrogeologist with 4 years' experience in water resource development and contaminated land investigations. Marietjie has experience in site assessments, source term characterisation, geophysical groundwater exploration, aquifer testing, environmental audits, conceptual site modelling and risk assessments with regard to soil and groundwater contamination.

Marietjie has specialist skills in the following areas:

- Geological and hydrogeological site characterisation using geophysics
- Aquifer characterisation by means of aquifer testing
- Risk assessments with regard to surface- and groundwater contamination
- Conceptual site modelling
- Soil and Groundwater sampling
- Hydrocarbon Studies
- Hydrocensus investigations
- Groundwater contour mapping
- Hydrogeological and geological map generation with the use of Global Mapper
- Groundwater Reserve Determination
- Reporting

Key Professional Experience

Client	Period	Description
North West University of Potchefstroom	2013	Hydrogeological investigation of groundwater in the East Rand Basin.
Sasol	2013 - 2014	Sasol Retail ERA Project. The project involves hydrogeological investigations for 14 retail Environmental Risk Assessment projects, which were selected and recommended for further investigations based on the findings of the Phase I studies conducted in 2011.
Sasol	2013 - 2014	Sasol ERA. The project involves an environmental risk profile for Sasol Oil for a total of 27 various retail filling stations across the inland areas of South Africa during the course of 2013 and 2014, whereby monitoring is conducted over a period of 6 months.
Transnet Pipelines	2013 - 2014	The project involves a contaminated land assessment at current operational facilities (depots) where crude oil, petrol and diesel are stored and transported from.
Transnet Pipelines	2013 - 2014	The project involves Phase II contaminated land assessments and remediation plan developments at current operational facilities (depots) where crude oil, petrol and diesel are stored and transported from.
VIP Consulting	2014	The project involved a hydrogeological Study for the drilling and construction of the borehole in Kempton Park, Gauteng Province.
SiVest	2014	The project involved a hydrogeological audit at the Kusile Power Station in order to comply with the Water Use License (WUL) including disposing of waste in a manner which may determinably impact on a water resource.
Royal HaskoningDHV	2014	The project involved a hydrogeological impact assessment for the proposed Solafrica Sand Draai Solar Power (CSP) and Photovoltaic project, located near Upington in the Northern Cape Province
Q4 Fuels	2014	The project involved a geophysical and hydrogeological investigation in order to comply with the Water Use License Application (WULA) process for the development of the Q4 Fuel city, located between Pretoria and Brits on the N4 highway.
SiVest	2014	The project involved a hydrogeological water use license audit at the Kusile Power Station in the Mpumalanga Province, in order to comply with the WUL including disposal of waste in a manner, which may have an impact on the water resource.
Sasol	2015	The project involved a contaminated site investigation in order to determine any residual contamination of a 300L diesel spill at the Hernic Commercial Site (Zizwe).
Bombela Concession Company (BCC)	2016	The project involved a contaminated site investigation in order to determine surface water and soil conditions at the Gautrain Rapid Rail Link in the Modderfontein Area.

Key Professional Experience

Client	Period	Description
Triplo4	2016	The project involved a Phase II contaminated site investigation and remediation plan for the BP Sunpark Motors in Chartsworth.
Chemspec	2016	The project involved a contaminated site investigation at the Chemspec industrial site in Durban.
ArcelorMittal	2016	The project involved a geophysical survey (resistivity and EM) to determine most suitable locations for monitoring wells at the ArcelorMittal Vereeniging Waste Dump Site.
ArcelorMittal	2016	The project involved a contaminated site investigation for the ArcelorMittal Vereeniging steel manufacturer to determine the soil and groundwater conditions.
Zitholele Consulting	2016	The project involved a hydrogeological investigation (installation of monitoring wells, production boreholes, aquifer testing, groundwater sampling, risk assessment etc.) for the proposed Lanseria Waste Water Treatment Works as part of the Water Use Licensee Application.
Sasol	2016 – 2017	Sasol ERA. The project involves Phase II environmental risk assessments for Sasol Energy for various retail filling stations across the inland areas of South Africa, whereby remediation plans were submitted.
Milnex	2016 – 2017	The project involved hydrogeological investigations at seven alluvium diamond mines in Schweitzer Reneke as prat of the Water Use License Application.
Milnex	2017	The project involved a hydrogeological investigation as prat of the Water Use License Application.
Bokamosa Landscape Architects & Environmental Consultants CC	2017	The project involved a water supply investigation for a proposed residential development.
Private	2017	The project involved an investigation of the source of shallow groundwater levels within close proximity to residential properties.
Enviro-Insight	2017	The project involved a hydrogeological investigation including a hydrocensus, aquifer testing, groundwater sampling, groundwater reserve determination and groundwater risk assessment for a proposed agricultural development.
Bryanston Country Club	2017	Water supply investigation that included a geophysical survey, borehole drilling, aquifer testing and reporting

Key Professional Experience

Client	Period	Description
Mpact Paper	2017	Investigation of the groundwater conditions and evaluation of previous data to determine if activities have any detrimental effect on the environment
Highveld Mushrooms	2017	Water supply investigation including a geophysical survey, drilling supervision, aquifer testing and reporting
Royal HaskoningDHV	2017	Groundwater investigation as part of a water balance investigation for the Witpan dam.