Report on Geotechnical and Geohydrological Investigations for the Proposed Decommissioning (Closure) of a Waste Landfill at Shakaville, KwaDukuza Local Municipality, KwaZulu-Natal Province

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DECLARATION OF INDEPENDENCE

I, *Clement Rikhotso*, declare that:

- I act as the independent practitioner in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting geotechnical and geohydrological assessments, including knowledge of the applicable Acts, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- I will ensure that information containing all relevant facts in respect of the application is distributed or made available to interested and affected parties and the public and that participation by interested and affected parties is facilitated in such a manner that all interested and affected parties will be provided with a reasonable opportunity to participate and to provide comments on documents that are produced to support the application;
- I will provide the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not;
- All the particulars furnished by me in this form are true and correct;
- I will perform all other obligations as expected in terms of the Acts and the constitutions of my affiliated professional bodies; and
- I realise that a false declaration is an offence in terms of applicable Regulations.

DECLARATION OF INTEREST

This report has been professionally and independently prepared by North Arrow Consulting and Advisory Services (Pty) Ltd (Nacas), a South African Consulting firm with experience and expertise in Mineral Exploration/Mining and Engineering Geology. I hereby declare that to the best of my knowledge that Nacas nor any of its members does not have any vested interest (either business, financial, personal or other) in the project or associated projects nor with the briefing client other than appropriate remuneration for work performed in terms of the Regulations.

I undertake to inform the responsible representative of the client of any change in this information or any new information that needs to be reported, which occurs before or during the meeting or work itself and through the period up to the publication of the final report.

Name: CT Rikhotso
Date: 20 November 2017

Signature________________________________

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EXECUTIVE SUMMARY

GA Environment (Pty) Ltd (GAE) has been appointed by the Department of Environmental Affairs (DEA) to undertake the Basic Assessment and Waste Management Licence Application for the proposed decommissioning (closure) and rehabilitation of the existing Shakaville landfill situated on the outskirts of the town of Shakaville, KwaZulu-Natal Province. The Department of Environmental Affairs (DEA) is assisting the KwaDukuza Local Municipality with this process. As part of the closure procedure geotechnical and geohydrological input is required for the conceptual end use plans. GAE, on behalf of the Client, requested North Arrow Consulting and Advisory Services (Nacas) to undertake combined geotechnical and geohydrological assessments at the site.

Waste disposed at landfills always carries the potential risk of contamination of the aquatic environment (e.g. groundwater) such that a suitably engineered landfill site which matches the risk profile of the waste should be designed accordingly. Geotechnical investigations of waste fills are rarely undertaken, and consequently the geotechnical community has little knowledge of their engineering properties. The investigations were aimed at identifying geotechnical and geohydrological factors that would have an impact on the development, to enable economic design and construction of the proposed closure development and to serve as a mitigating measure against unknown and/or variable ground conditions. The investigation comprised an initial desk study followed by a site walkover and an invasive test pitting investigation of the waste body and surrounds.

Shakaville has an unlicenced landfill site which ceased operations in 2010 prior to which it seems it operated for some 30 years by receiving general waste from Stanger and the surrounding areas. This landfill site occupies an area of ~80,000m^2 (~8a) on Erf 3595 Stanger which is within the KwaDukuza Local Municipality. The perimeter of the landfill is surrounded by the tributary of the Mbuzana river. The site is currently abandoned. A part of it is occupied by an informal settlement community with who keep some domestic animals and perform some basic vegetable planting activity. The landfill is completely covered by alien vegetation.

The Geological map of Durban shows the site to be underlain by quaternary alluvium, shale and post Karoo dolerite. A fault north-east to south-west striking fault is located approximately 1.5km north west of the landfill site. The fault is however not expected to play a crucial role in the local hydrogeology of the site.

The aquifer type is classified as minor aquifer class. Due to the nature of the alluvium expected below the site, the underlying aquifer is expected to be intergranular. However, the alluvial extent is limited and may not represent a significant aquifer. The NGA database does not have boreholes in very close proximity to the site but generally show an intergranular and fractured type aquifer. The water strikes are generally deeper than 30mbgl and are likely to be encountered between the two layers of rock. Recharge values range between 75 and 110mm/annum and the groundwater levels are expected between 31 to 40 mbgl. A NE-SW magnetic lineament cuts across the Shakaville site and the area is also surrounded by several NNW-SSE lineaments.

Eight (8) test pits were excavated (to 2m depth) on site on 3 November 2017. Test pits were dug and ended in residual soil or waste body. Some test pits have exposed light brown to khaki residual shale soils and in some cases brownish residual dolerite soils. An in-situ exposure of khaki brown shale rock was observed on site. In this respect, two samples each representing these two distinct soil types were

collected. No groundwater or perched leachate tables were encountered within the test pits excavated. The landfill does not have a basal liner.

Laboratory results indicate that in general, the two samples tested comprise the following:

<u>Brownish weathered dolerite</u>

- Gravel (9%), sand (56%), silt (21%) and clay (14%). The soil is therefore described as clayey, silty sand. In terms of the Unified Soil Classification system the soil classifies mainly as a "SC" soil type, these being clayey sand. The Grading Modulus of 1.11 seems to reflect the soils as of fairly fine coarseness nature, as corroborated with the sieving analysis results.
- The plasticity indices (a measure of the plasticity of the clay) recorded show medium values (13) which are indicative of medium activity (lower medium expansiveness) for the soils. These should therefore be noted to constitute some slight problems under conditions of moisture migration.
- Permeability (hydraulic conductivity) tests conducted in the laboratory on disturbed samples indicate values of 2.2×10^{-8}m/s. This soil is therefore suitable to use as capping material subject to further consolidation at optimum density and moisture content.

<u>Weathered khaki/light brown shale</u>

- Gravel (14%), sand (34%), silt (37%) and clay (14%). The soil is therefore described as sandy silts. In terms of the Unified Soil Classification system the soil classifies mainly as a "CL" soil type, these being clayey sands or silty clays. The Grading Modulus of 0.79 seems to reflect the soils as fairly fine nature, as corroborated with the sieving analysis results.
- The plasticity indices (a measure of the plasticity of the clay) recorded show low values (9) which are indicative of low activity (low expansiveness) for the soils. This should therefore not constitute any problems under conditions of moisture migration.
- Permeability (hydraulic conductivity) tests conducted on disturbed samples in the laboratory indicate values of 4.8×10^{-10}m/s. This soil is therefore suitable to use as capping material subject to further consolidation at optimum density and moisture content.

The potential risks that could impact the decommissioning of the landfill site comprise soil erosion, slope stability, and settlement of waste and potential surface and ground water pollution.

- The proximity of the landfill to the surrounding river down slope presents a leachate pollution risk to surface water and possibly ground water.
- In spite of the existing vegetation, slope failure due to the slope height and angles is a potential collapse risk, should wet conditions become excessive.
- The site does not reflect any risk for the formation of sinkholes or subsidence caused by the presence of water-soluble rocks (dolomite or limestone) and no evidence of mining activity beneath the site.

Based on the geological and geohydrological conditions of the area investigated it is worth noting whilst recognising that the identified risks can typically be mitigated to a certain extent by the implementation of an appropriate and effective Environmental Management Plan (EMP) as part of the closure process. These identified risk aspects as well as the outcomes of other specialist studies, should enable the appointed design engineers to determine the most cost effective conceptual closure design alternative for the landfill site.

It is recommended that further detailed studies of the existing geological and geohydrological information available for the site and the surrounding areas are conducted at a Class 0 (+-45% accuracy) estimated inclusive (VAT & 10% contingency) cost of R1,674,000. The aim of the additional geohydrological work for this phase of the investigation will be three-fold:

- Clarify the groundwater flow and the likely migration of a pollution plume around landfill and determine the groundwater conditions of the existing site towards the river.
- Establish a more comprehensive groundwater monitoring system around the entire landfill area.
- Further determine the geotechnical and geohydrological properties of the soils and underlying bedrock.
- Follow up on sources of suitable capping material for the landfill as part of the closure and rehabilitation process.

Presently there are four monitoring boreholes on the landfill site. As part of the closure, a monitoring programme is recommended to be implemented. The outcomes from the aforementioned additional studies will be the basis for developing the monitoring programme. The development of a groundwater monitoring programme will be important for assessing the impacts of the decommissioned Landfill on the groundwater and the environment. Monitoring can be described as the repetitive and continued observation, measurement and evaluation of geohydrological information such as water level and groundwater quality to follow changes over a period to assess the efficiency of control measures.

DEFINITIONS AND ABBREVIATIONS

ACRONYM	Description
BA	Baseline Assessment
CBR	California Bearing Ratio
CEMP	Closure Environment Management Plan
CEMP	Construction Environmental Management Plan
CGS	Council for Geoscience
DEA	Department of Environmental Affairs
DO	Dissolved Oxygen
DWAF	Department of Water Affairs and Forestry
EC	Electrical conductivity
EDTEA	KwaZulu-Natal Province Department of Economic Development, Tourism and Environmental Affairs (EDTEA).
EIA	Environment Impact Assessment
GAE	Glad Africa Environment (Pty) Ltd
ha	Hectare = 10,000m^2
IWWMP	Integrated Water and Waste Management Plan
L/s	Litres per second
LTP	Leachate Treatment Plant
m	metres
m^2	Square metres
m^3	Cubic metres
MAP	Mean Annual Precipitation
mbgl	Metres below ground level
mm	millimetres
NEMA	National Environmental Management Act, 1998 (Act 107 of 1998)
NEMWA	National Environmental Management: Waste Act, 2008 (ACT No. 59 of 2008)
NGA	National Ground Aquifer database
NWA	National Water Act, 1998 (Act 36 of 1998)
ORP	Oxidation reduction potential
TLB	Tractor, Loader Backhoe
WCSF	Waste collection and sorting facility

1. INTRODUCTION

1.1 **Background and Project Description**

GA Environment (Pty) Ltd (GAE) has been appointed by the Department of Environmental Affairs (DEA) to undertake the Basic Assessment and Waste Management Licence Application for the proposed decommissioning (closure) and rehabilitation of the existing landfill situated on the outskirts of the town of Shakaville, KwaZulu-Natal Province. The Department of Environmental Affairs (DEA) is assisting the Shakaville local Municipality with this process. GAE have in turn appointed North Arrow Consulting and Advisory Services (Pty) Ltd (Nacas), to carry out supporting specialist geotechnical and geohydrological studies which is input required for the engineering conceptual end use plans, the basis for the closure process.

According to the NEM: WA, 2008 (Act No. 59 of 2008), the disposal of general waste at the landfill requires a Waste Management License as per Category B (Activity No. 8 & 9) of Government Notice 921 of 2013, and an Environmental Impact Assessment process, as stipulated in the NEMA EIA Regulations (2014) as amended, made under section 24(5) and 44 of the NEMA, 1998 (Act No. 107 of 1998) as amended. As the Shakaville landfill is located within the KwaZulu-Natal Province, the Waste Management Licence for the landfill will be issued by the KwaZulu-Natal Province Department of Economic Development, Tourism and Environmental Affairs (EDTEA).

The report reviews the geological and geohydrological conditions around the landfill based on published regional and local geological investigations as well as information collected during a site walkover carried out on 31 October 2017. The report forms part of the specialist studies required for an Environmental Impact Assessment (EIA) by GAE. The investigation has been undertaken to meet with the requirements of Chapter 6 of the document Minimum Requirements for Waste Disposal by Landfill (1). As such the report contains the following information:

- brief description of the position and access routes to the area, climate of the region,
- hydrology of the region
- a description of the regional and local geological conditions and other subsurface conditions,
- the results of a hydrocensus of the site and surrounds
- the regional and local geohydrological conditions,
- aquifer classification,
- groundwater use and quality, and
- an evaluation of geological and geohydrological conditions in terms of the suitability of the area for the closure waste disposal facility.

1.2 **Terms of Reference**

As an independent Environmental Practitioner, GAE are managing the Waste Management Process to ensure that the unlicensed landfills are licenced. The process entails the following:

- Submission of signed Application forms to Competent Authority.
- Undertaking of Basic Assessments or Environmental Impact Assessments as part of the Waste Licence project based on the NEMWA Waste Activities and.

- Management of the required specialists to support the BA's and EIA's as well as to fulfil the legislative requirements pertaining to the licensing of landfills.

In support of the above-mentioned legislative imperatives, Engineering Conceptual designs for the landfill are required. In turn associated geotechnical and geohydrological Studies (assessments) need to be undertaken on this site earmarked for decommissioning to support Engineering Conceptual designs which will eventually lead to construction.

1.3 **Objectives**

The objectives of the geotechnical investigation were to determine the nature, moisture content and stability of the upper portions of the existing waste bodies so to provide suitable recommendations with regards to proposed future developments (end use plan of landfill site). In this regard review information relating to the geology, geomorphology, geohydrological, geotechnical aspects, surface and underground water on the landfill and vicinities as well as the consequent impact on conceptual engineering design principles. The studies therefore seek to:

- identify geotechnical and geohydrological risks associated with the sites;
- evaluate geotechnical and geohydrological parameters of the sub-base soils at the sites;
- review the geotechnical and geohydrological requirements for the development of cells and associated infrastructure for a landfill at the sites;
- assess the requirements, and availability and suitability of cover material for the operations of the landfills and capping material for those landfills to be decommissioned for closure;
- assess and evaluate the requirements, and risk issues for the landfills including, slope stability and permeability of soils;

1.4 **Available Information**

The following information was supplied by GAE to facilitate the investigation:

- Location of the landfill in the form of Google Earth kmz files.
- Notes taken during meetings held with GAE personnel detailing the description of the site following their initial site visit.
- Notice of Basic Assessment Process for the closure of the landfill.
- No other landfill specific information/data (e.g. weighbridge records) was available for this study.

1.5 **Previous Work**

In February 2011, Dynamic Integrated Geo-Environmental Services (Diges), carried out a geotechnical assessment of the site. The outcomes from this assessment led to the drilling of 4 monitoring boreholes, 2 boreholes at each location. Detailed information about these borehole is presently not known. There are other 2 boreholes whose purpose or information is also not known.

2. LEGISLATIVE CONTEXT

The general objective of environmentally acceptable waste disposal is to avoid both short and long-term impacts and any degradation of the environment in which the disposal facility is located. More specific objectives are to prevent pollution of the surface water, groundwater and air and to ensure public acceptance by ensuring environmental acceptability. Current legislation is written in that spirit.

Previously, landfill classification was based on:

- Type of waste
- Size of waste stream
- Potential for leachate generation (climate, etc)

New Landfill Classification focusses on barrier design (GNR 635) and chemical characteristics of the waste (SANS 10234, GNR 636, etc)

The Implications from a design perspective are as follows:

- Far more chemical analysis and laboratory testing of waste sample
- More cautious (simplified) approach to basal lining systems
- Improved record keeping and controls on sites

All studies were conducted in accordance with the latest Norms and Standards documents as published as part of the National Environmental Management: Waste Act, 2008, the Minimum Requirements for Waste Disposal by Landfill, 2005 compiled by the Department of Water Affairs, site Investigation Code of Practices by the South African Institution of Civil Engineering Geotechnical Division (however, there is no specific legislation relevant to the geotechnical work undertaken, specifically to the decommissioning of landfills). and the geotechnical mapping procedures of the Council for Geoscience amongst others.

3. NATURE OF INVESTIGATIONS

The respective investigations commenced with a desk study, which entailed obtaining as much information as possible of the site that may provide an indication of the most likely geotechnical and geohydrological conditions prevailing within the area. For example, by determining the underlying geological setting together with the prevailing topographical and climatic conditions, the weathering characteristics of the host rock can be estimated and an indication of the most likely geotechnical conditions underlying the site established. The information obtained from the desk study is discussed in in the Section below.

The desk study was followed by a site reconnaissance which was carried out on 2 November 2017 and entailed Nacas' senior engineering geologist visiting the site and walking over the entire area whilst noting and recording information from visible surface features. Limited invasive test pit excavations of the waste body, soil profiling and collection of samples for laboratory analyses were also carried out. Information from this phase of the investigation, together with the desk study, provided a preliminary assessment of the geotechnical and geohydrological conditions underlying the site and identified areas necessary for further investigation.

3.1 **Desk Study**

The purpose of the desk study was to provide background information and technical guidance as well as to refine the scope of works for the follow-up geotechnical and geohydrology assessment. The scope of study includes collecting available and public geological, geohydrological and geophysical data to identify the lithology, geological structures, potential aquifers or/and aquitards. A general briefing session with GAE personnel was attended to meet and collaborate with relevant team members to ensure that project milestones are feasible and to prevent possible duplication of work.

The geotechnical and geohydrological desk study involved the following literature review at regional and local scale:

- 1:250 000 geological map series of Durban 2930
- 1:500 000 Hydrogeological Map series of the Republic of South Africa 2928 (Durban)
- Department of Water and Sanitation - National Groundwater Archive (NGA)
- Department of Water and Sanitation – GRA2 Project maps
- Aquifer Classification Map of South Africa
- 1 km resolution airborne magnetic data
- Published relevant literature: Engineering Geology of South Africa (Brink, 1979 -1985), etc
- Weinert's climatic N-value, temperature, rainfall & wind direction of the area
- Reference to published literature on the characteristics of the anticipated rock and soils profiles (and related stability and permeability characteristics) to be encountered, as well as foundation solutions in such materials and potential construction materials.
- Geophysics and structural interpretations maps
- Limited Baseline hydrocensus within a 5km radius of the site - information regarding probable location of sources of surface and groundwater in the radius of 5km with potential to be polluted.
- Investigate conceptual placement of future groundwater monitoring boreholes.

The methodology adopted for the desk study was as follows:

3.1.1 **Geography - Location, size and land-use**

The landfill site is located on the Remainder of portion 3595, in Shakaville, approximately 2.5km north east from the central town of Stanger, KwaDukuza Municipality. The landfill occupies and area of approximately 8ha. Access to the site is limited via singular vehicle gate entrance along Mbozambo Street.

Figure 1: Location and extent (white outline) of the Shakaville landfill site near Stanger town.

3.1.1.1 Infrastructure

The infrastructure other than that of Shakaville and Stanger comprises informal settlement structures, ploughing fields, a palisade gate and partial fence, sewage manholes, a pipeline across the landfill, a water tap, 2 unmarked boreholes, 2 monitoring boreholes and illegal electricity connections.

3.1.1.2 Topography

The landfill is surrounded in all directions (except the north westerly direction, which is access route to the site) by a stream and a river. The landfill itself forms a flat surface except the steep waste slopes which follow the shape of the stream.

3.1.1.3 Climate

3.1.1.3.1 Precipitation and evaporation

The Stanger area normally receives rain of approximately 898mm mm/annum and evaporation of 1521 mm/annum (Table 1), with most rainfall occurring mainly during summer. It receives the lowest rainfall (16mm) in July and the highest (121mm) in January. Figure 2 shows the average rainfall values for Shakaville per month.

Table 1: Summary of climatic data.

Area (station)	Average Rainfall (mm/annum)	Average Evaporation (mm/annum)
Shakaville (U3E004)	897.9	1521.4

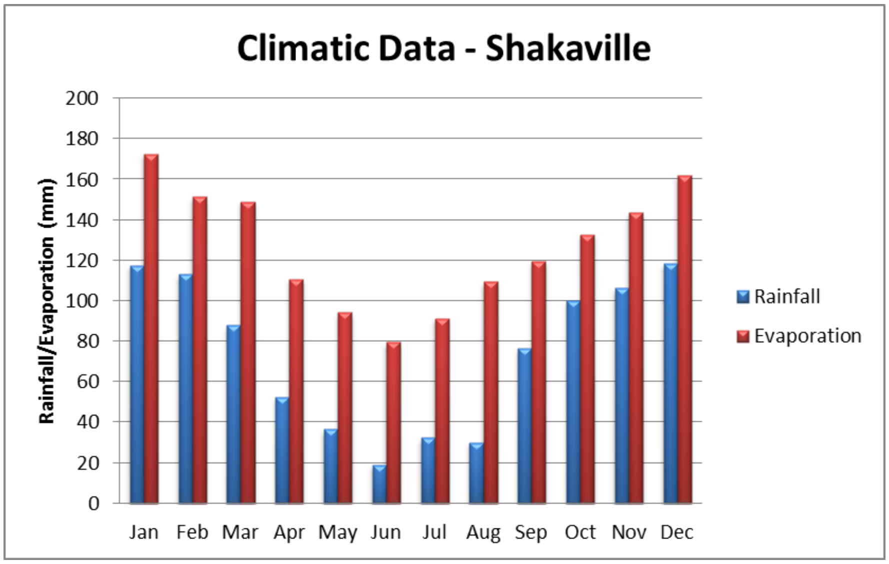

Figure 2: Rainfall data. Source weather station U3E004

3.1.1.3.2 Temperature

The monthly distribution of average daily maximum temperatures shows that the average midday temperatures for Stanger range from 22.4°C in July to 27.7°C in February. The region is the coldest during July when the mercury drops to 9.8°C on average during the night.

3.1.1.3.3 Vegetation

The landfill seems to have naturally rehabilitated itself as it is overgrown by alien vegetation and weeds since the stoppage of dumping operations. Figure 3 shows an example of the existing vegetation.

Figure 3: Typical vegetation covering the slope of the landfill as well as on the of the river (left) and on top of the landfill (right).

3.1.1.4 **Regional and Local Geology and Structural Conditions**

The Geological map of Durban shows the site to be underlain by quaternary alluvium, shale and post Karoo dolerite. A fault north-east to south-west striking fault is located approximately 1.5km north west of the proposed landfill site. The fault is however not expected to play a crucial role in the local hydrogeology of the site. The site is adjacent to a stream and the Mbuzana River.

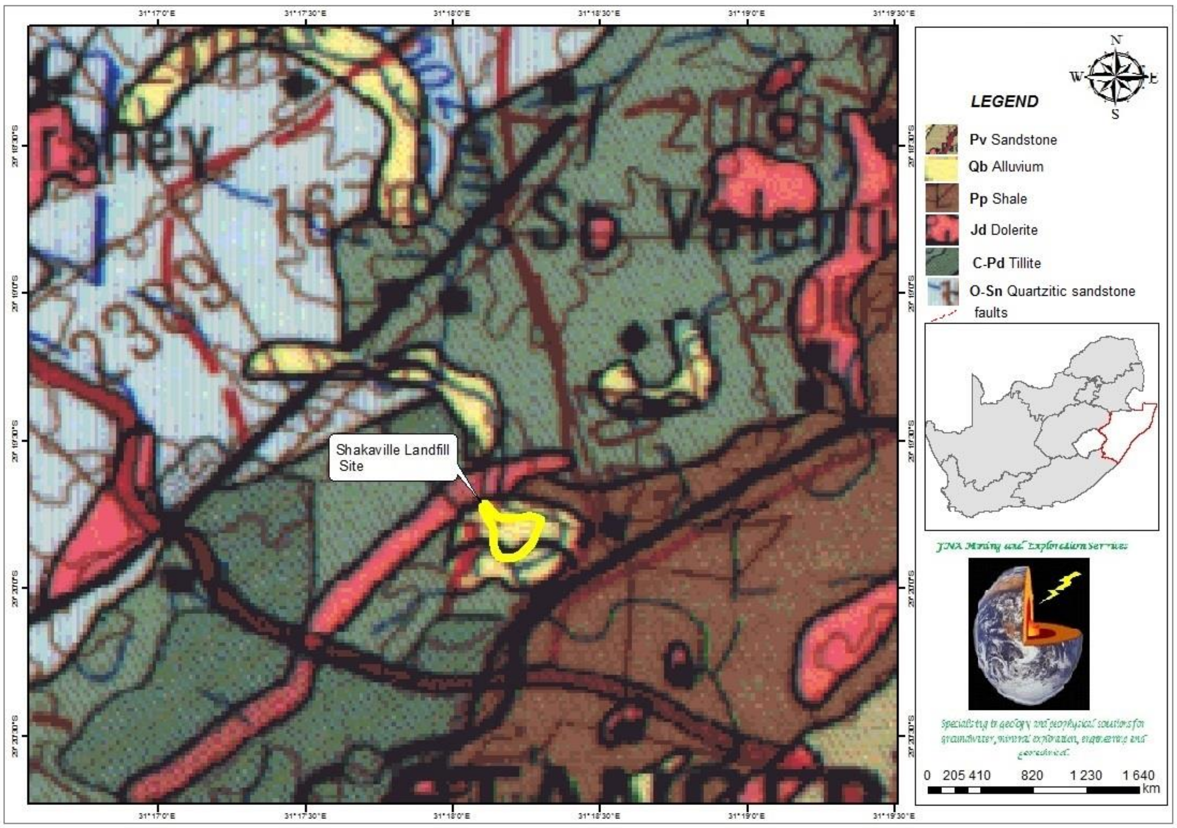

Figure 4: Geology Map of Durban showing the Shakaville Landfill site. Source (FNA Exploration).

3.1.1.5 **Seismic Zoning**

The site seems to be in an area of relatively low earthquake activity therefore low probability of it occurring (Figure 5).

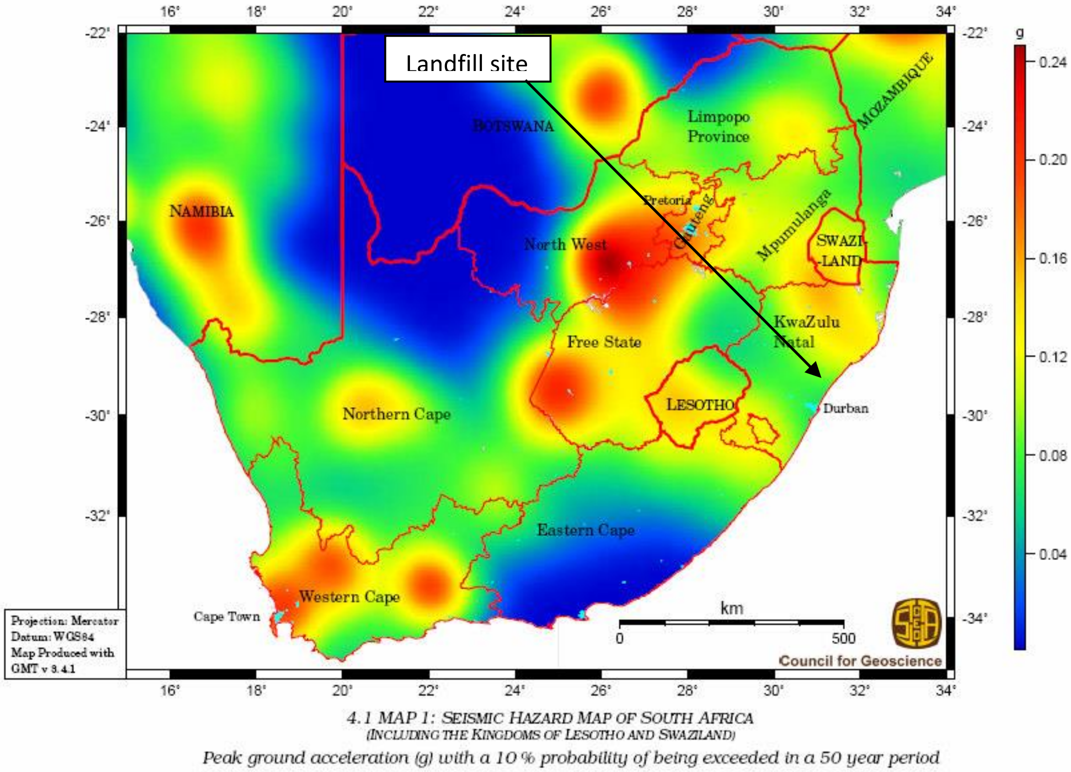

Figure 5: Seismic hazard map of South Africa. Source (CGS).

3.1.1.6 **Geophysics**

Freely available 1 km resolution data was interpreted to identify possibility of any structural geological feature which can act as preferential pathways for pollution from landfill to groundwater. The interpreted lineaments (black lines) are shown on Figure 6. A NE-SW magnetic lineament cuts across the Shakaville site and the area is also surrounded by several NNW-SSE lineaments.

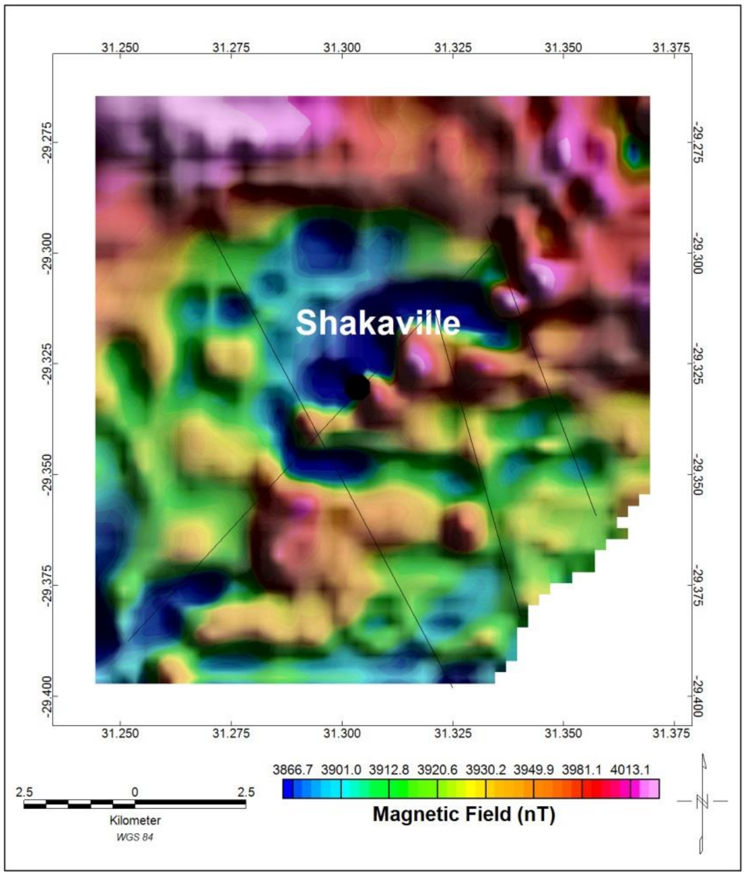

Figure 6: Airborne magnetic data surrounding the Shakaville Landfill site.

3.1.1.7 **Regional and Local Geohydrological Conditions**

The country rock on the landfill is shale and dolerite as per geological map. The contact between dolerite intrusions and surrounding country rock often tends to act as water conduits. A NW-SE magnetic lineament cuts across the Shakaville site and the area is also surrounded by several NNW-SSE lineaments. Due to their proximity and occurrence, these features would need to be assessed further with geophysics surveys to determine groundwater potential beneath the site. Should these structures be water-bearing, the direction of the water flow will probably be towards the streams. Any plume of polluted groundwater will also follow this similar path.

3.1.1.7.1 **Surface water**

The landfill is surrounded by a flowing stream with direction of water run-off and sediment flow downslope towards the rivers, there is high potential for silting of the river as well as contamination by leachate possibly emanating from the landfill.

3.1.1.7.2 **Aquifer Type**

The aquifer type of Shakaville is classified as minor aquifer class. Due to the nature of the alluvium expected below the site, the underlying aquifer is expected to be intergranular. However, the alluvial extent is limited and may not represent a significant aquifer. The NGA database does not have boreholes in very close proximity to the site but generally show an intergranular and fractured type aquifer. The water strikes are generally deeper than 30mbgl and are likely to be encountered between the two layers of rock. Recharge values range between 75 and 110 mm/annum and the groundwater levels are expected between 31 to 40 mbgl.

Table 2: Groundwater data from NGA (5km radius of Shakaville site).

Name	Latitude	Longitude	Geology	Water Strike (mbgl)	Yield (L/s)	Water Level (mbgl)
2931AD00003	-29.3171	31.28308	Sandstone Tillite	36	1.17	2.44
2931AD00074	-29.3107	31.32975	Shale Dolerite	15	0.6	6.18
2931AD00077	-29.3104	31.33335	Shale Dolerite	55	1.4	-
2931AD00075	-29.3079	31.33031	Shale Dolerite	32	0.14	7.2

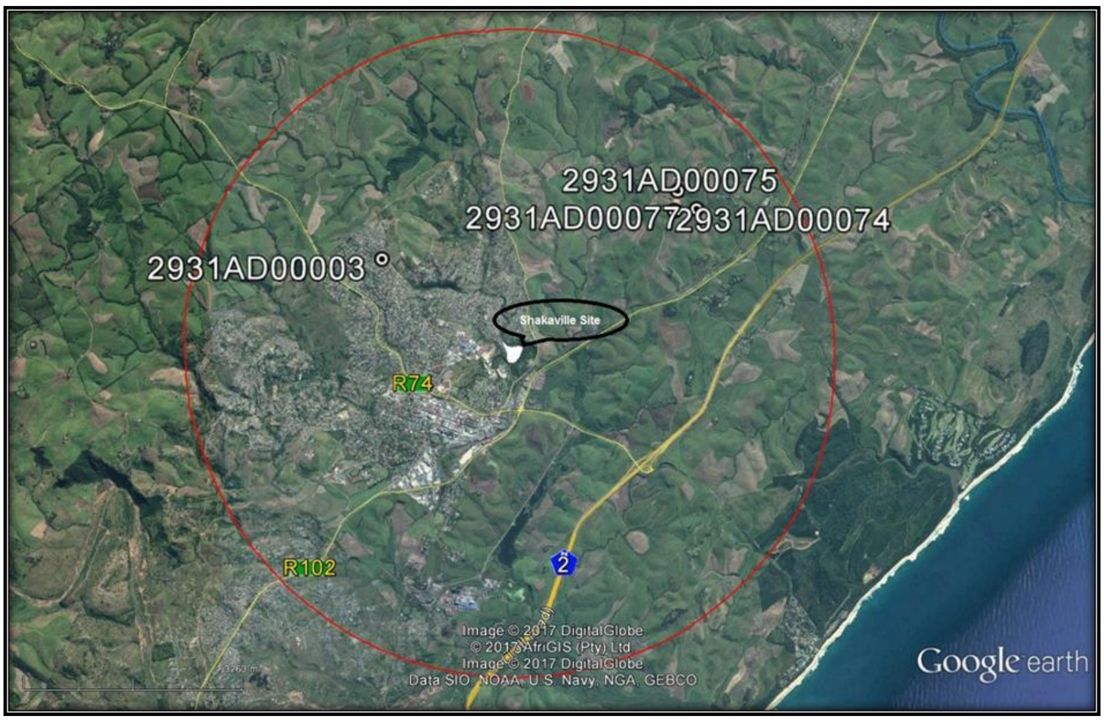

Figure 7: NGA boreholes relative to landfill site.

3.1.1.7.3 Groundwater Level and Recharge

Recharge values range between 75 and 110 mm/annum and the groundwater levels are expected between 31 to 40 mbgl.

3.1.1.7.4 Groundwater Use and Quality

Groundwater use in the area is unknown but there is a relatively large residential and industrial area close to the landfill some of whom might have boreholes not reflected on the NGA. It is recommended to do detailed follow-up hydrocensus to verify and supplement the available information from this initial

5km radius exercise. There was no access to the boreholes nor sampling (no information on quality of the water) of the boreholes was carried out for this investigation.

3.2 Site Investigations

Based on the outcomes of the Desk Study phase of the investigation, the information discussed below was obtained as part of the site walkover and follow-up investigations. To assess the requirements for the licensing of the sites, it is essential to gain perspective on the status of the site. A site visit was undertaken on 2 November 2017 during which the site was assessed as well as to gather facts to corroborate with scope of activities described below: While on site the following were carried out:

- Site walkover - description of the site and waste body. The following aspects were noted and considered (as per Table 8):
    - Potential Problem soils
    - Seepage
    - Construction material
    - Permeability
    - Excavation
    - Undermined ground
    - Instability in areas of soluble rock
    - Steep slopes
    - Areas of unstable natural slopes
    - Areas subject to seismic activity
    - Areas subject to flooding
    - Application of on-site soils for designed base and capping layers in landfills.
    - Identification of potential geotechnical significant features such as tension cracks, slope failures and bulging of faces.
- Field mapping to confirm the geology where there are outcrops.
- A limited hydrocensus to locate any groundwater monitoring boreholes on or near the site.
- Despite this being a Desk top study phase, limited excavation of test pits for soil profiling and collection of samples for description and for laboratory testing for suitability of soil was undertaken in order to obtain some information that would ordinarily be obtained only at the Preliminary Design stage.

3.2.1 Site Classification and Description

It is an unlicenced landfill site (Table 3) which ceased operations in 2010 prior to which it seems it operated for some 30 years by receiving general waste from Stanger and the surrounding areas. This landfill site occupies an area of ~80,000m2 (~8a) on Erf 3595 Stanger which is within the KwaDukuza Local Municipality. The perimeter of the landfill is surrounded by the tributary of the Mbuzana river. The site is currently abandoned. A part of it is occupied by an informal settlement community with who keep some animals and perform some basic farming activity. The landfill is completely covered by alien vegetation and weeds masking away any top soil cover material.

Table 3: Landfill information.

Local Municipality	DWAF permit status	Monthly waste disposed (tons)	Description of wastes disposed	Expected lifespan
Shakaville	Unlicenced	720 tonnes per month	Domestic and garden refuse	Full capacity. Closed in 2010

3.2.1.1 ***The Nature of the Waste Body***

The site was used to dispose of municipal waste, predominantly domestic and garden waste, from Stanger and the surrounding areas. The landfilling operations on site apparently stopped in 2010 after operating for some 30 years. It is currently abandoned. According to previous studies carried out by (SiVest, 2004), the site received an average of 720 tonnes per month during its lifespan.

Farming is the major activity in the area and the site is bound by streams and the Mbuzana River on the south east and south west of the site. The streams and the Mbuzana River run adjacent to the toe of the landfill presenting major contamination concerns. Further south west lies an industrial area and in the north lies informal settlements. There are currently informal settlements and animals on the landfill site. There is currently a water supply to the site by means of a single stand pipe. There is no security on the site to prevent unauthorized entry and illegal dumping of waste. There is temporary concrete palisade fence and gate. There is a sewer pipe running across the landfill from in the NE-SW direction.

The landfill does not have a basal liner. The base of the waste is suspected to be residual shale and dolerite soil or alluvium towards the edge of the stream. There is no leachate management system.

3.2.1.1.1 **Current Slope Stability**

From the site walkover and investigations, the side slopes appear stable (Figure 8) due to the vegetation now in place. In the unlikely event that the waste body becomes deeply saturated, the risk of internal slope failure may present still itself.

3.2.1.1.2 Occurrence of Leachate

The potential for significant leachate production is based on whether the landfill is able to produce a significant amount of leachate. Leachate production is the main source of pollution of landfill. No flow (seepage) could be observed from the slope sidewalls.

3.2.1.1.3 Potential for Landfill Gas and Air Quality Problems

There are no air quality problems observed since the landfill is overgrown with vegetation. Whether the landfill has a build-up of gas remains to be proved as part of the conceptual design activity.

Figure 8: Vegetated landfill slope looking northwestwards.

3.2.1.1.4 Settlement of waste

It is surmised that most of the above settlement for has already taken place over the last 20-30 years of operation of the landfill. A smaller magnitude of settlement is anticipated to yet occur as part of an on-going process. Settlement may also increase because of water ingress causing saturation of waste.

3.2.2 **Surveys**

The site was surveyed to determine the general sloping of the ground within the site shape of the waste body and the location of any site infrastructure. To quantify the amount of waste within the landfill needs to be done as part of a detailed survey by a professional land surveyor.

The following surveys (see Figure 9 and Appendix A for the GPS metadata) were conducted (using a hand-held Garmin GPS 64s) to measure locations and elevations for:

- Mapping the boundary fence corners
- Determine the extent of the landfill - edges (crest and toe) of the benches/slopes.
- Mapping of geological outcrops
- Location of test pit excavations
- Any other feature worth locating for geo-referencing purposes

This preliminary information where relevant were passed on to the conceptual design engineer. Topographical surveys of sites were carried out to enable preliminary geometric designs. This forms an important part of the geotechnical evaluation of sites, since ground elevations will be altered, due to the cut/fill construction activities for closure.

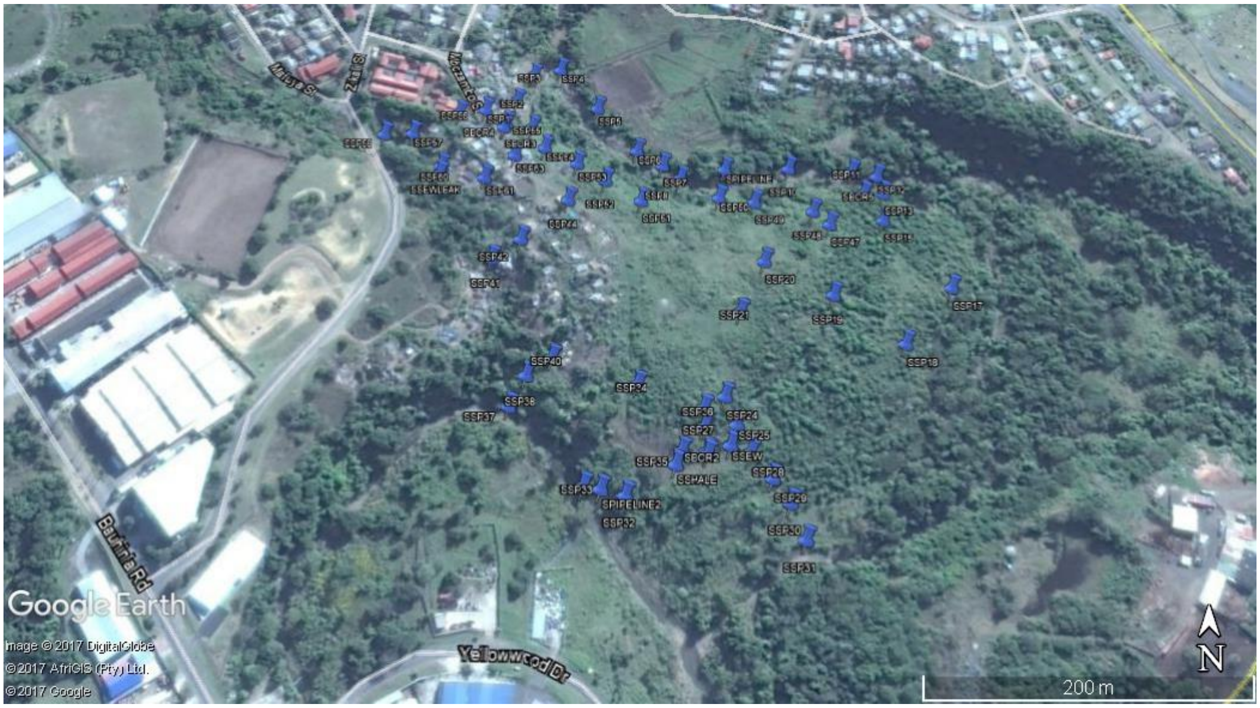

Figure 9: Locations of survey points (geology exposures, boreholes, sewage manholes, surface elevations).

3.2.3 **Geological and Geotechnical Investigations**

3.2.3.1 **Geological Mapping**

Site mapping shows that there is surface exposure of shale rock as per geological map. Figure 10 show the location of outcropping shale as well as sub-surface exposure of shale and weathered dolerite rock from test pit excavations. The weathered rocks are the product and source of the soils found on the site.

3.2.3.2 **Test Pit Excavations**

Tests pits were excavated in order to assess the local soils for suitability for basal as well as top capping material for the landfill as well as study the geological profile around the waste body. The test pits were excavated to several depths ranging from 0.3. to 2,0m depth below surface all ending in deep red sandy clay. The detailed descriptions of the soil profiles encountered in the test pits are presented in Table 4 and the subsoil conditions discussed summarised below. No groundwater or perched leachate tables were encountered within the test pits excavated. Each pit was profiled in-situ in accordance with the standard methods prescribed in the document Guidelines for Soil and Rock Logging in South Africa (1990)(2) prepared by the Geotechnical Division of the South African Institute of Civil Engineers and the Association of Engineering Geologist of South Africa.

Eight (8) test pits (STP1 to STP8) were excavated using a Tractor Loader Backhoe (Volvo BL31B) on 3 November 2017 (Figure 10). The test pit GPS coordinates and related information are presented in Table 4.

Figure 10: Location of 8 test pits (blue), Monitoring boreholes (green), unknown boreholes (brown) and shale geological exposures (navy).

Table 4: Summary of test pit profiles.

Test Pit ID	Co-ordinate			Depth From (m)	Depth To (m)	Description	Sample collected	Reference to pictures	TLB Equipment used	Date Excavated
	Latitude (S)	Longitude (E)	Elevation (m)							
STP1	-29,3301	31,3026	44	0	0.37	Competent brown soil with vegetation	None	Figure 11	Volvo BL31B	3 November 2017
				0.37	0.74	Old waste material	None			
STP2	-29,3296	31,3023	44	0	0.15	Thin soil layer and vegetation	None	Figure 12	Volvo BL31B	3 November 2017
				0.15	0.3	Sub-exposed khaki brown shale	None			
STP3	-29,3296	31,3026	44	0	1	Thin vegetated soil horizon, underlying moist waste	None	Figure 13	Volvo BL31B	3 November 2017
				1	2	Weathered to competent moist brownish dolerite. Breaks up into fine gritty/silty soil	SSTP3001			
STP4	-29,3302	31,3031	40	0	0.7	Vegetated khaki fine sand and reddish soil and	None	Figure 14	Volvo BL31B	3 November 2017
				0.7	1.3	Waste material				
STP5	-29,3302	31,3023	37	0	0.8	Vegetated grey soil and waste	None	Figure 15	Volvo BL31B	3 November 2017
				0.8	1.5	Dark khaki fine to medium moist sandy clay (weathered dolerite)				
STP6	-29,3308	31,3023	34	0	0.55	Organic-rich soil and thin waste layer	None	Figure 16	Volvo BL31B	3 November 2017
				0.55	1	Moist brownish sandy clay from weathered dolerite. Big rounded boulders of unweathered dolerite in place				
STP7	-29,3311	31,3028	29	0	1	Slightly altered shale overlain by a thin (0.15m) vegetated top soil	None	Figure 17	Volvo BL31B	3 November 2017
STP8	-29.329063	30.301727	45	0	0.7	Vegetated grey soil and waste	None	Figure 18	Volvo BL31B	3 November 2017
				0.7	1.4	Weathered khaki to light brown sandy soil	SSTP8001			

Figure 11: STP1 test pit profile showing soil cover over waste.

Figure 12: STP2 test pit profile showing sub-surface shale.

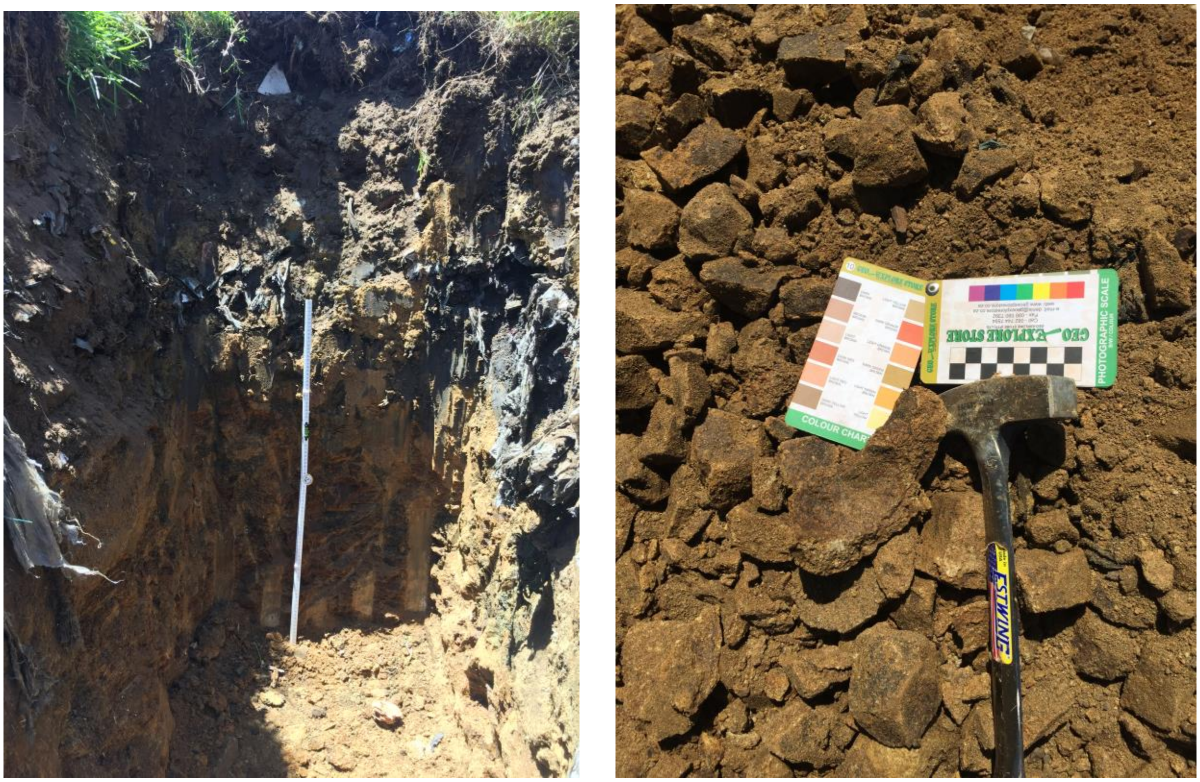

Figure 13: STP3 test pit profile showing weathered dolerite.

Figure 14: STP4 test pit profile showing capping soil over waste.

Figure 15: STP5 test pit profile showing capping soil over waste.

Figure 16: STP6 test profile.

Figure 17: STP7 test pit profile showing subsurface shale.

Figure 18: STP8 test profile.

3.2.3.2.1 Capping soil material availability

There is no material on site to use for capping considering the geographic location of the site. However, during rehabilitation, some of this material will be exposed and re-used as part of the construction. However, to re-use some existing soil material might be a constraint due to expected excavation difficulties at shallow depth due to decomposing as well as some non-biodegradable waste matter. Adequate material will need to be obtained from external sources.

3.2.3.3 Surface water

The site is bound by streams and the Mbuzana River on the south east and south west of the site respectively and they run adjacent to the toe of the landfill thereby posing a possibly the leachate run-off from the landfill. Similarly, there is serious pollution into the river systems the sources being the local informal settlement poor sanitation conditions These two factors present a major risk of water contamination. Figure 19 shows and example of an existing burst sewage pipe.

Figure 19: A burst sewage pipe leaking straight into a stream.

3.2.3.4 Ground water

No water seepage was encountered in any of the trial holes excavated, however, moist conditions of the were noted in the test pits. A shallow, perched water table may be encountered on the waste layers during the rainy seasons.

There are 4 boreholes drilled on the waste body. Two are indicated to have been drilled after 2011 as part of outcomes of previous geotechnical investigations presumably to serve as monitoring boreholes for the landfill. Figure 10 above and Figure 20 below show the locations of the 4 boreholes. There is no detailed information available for these monitoring as well as the other 2 boreholes. It is recommended that these boreholes are accessed and tested as part of the recommended borehole monitoring scope, prior to the drilling of any new holes.

A private borehole (not in the NGA list of boreholes with 5 km radius) was also identified (Figure 21). It is said to be owned by a local farmer for irrigation purposes. Due to access reasons, a GPS location could not be taken. In future it could also serve as a potential monitoring borehole together with the others existing.

Figure 20: Sealed x2 monitoring boreholes (top) and x2 drilled boreholes (bottom).

Figure 21: Location of a local farmers borehole on the east side of the landfill and across the stream

3.3 Laboratory Testing

Disturbed samples (Table 2) of approximately 70kg each were collected from the test pits at distinct soil horizons. The samples were submitted to Civilab in Centurion, Gauteng where tests were carried out in a controlled certified (SANAS or ISO) laboratory environment, using standardized equipment and procedures to provide quantitative and qualitative data for material classification, as well as characteristic parameters for design purposes. Table 3 below shows the type of tests carried out, quantities of samples and objective of each test.

Table 5: Summary of laboratory tests conducted for the samples collected.

Test Type	Number of samples	Type & Objective
Foundation Indicator: • Atterberg limits, • Sieve analysis (grading to 0,075mm)	1	Classification tests to confirm field soil descriptions and quantify variations in the ground profile laterally and vertically and to determine basic engineering properties.
• Permeability	1	• stability analysis of slopes, earth dams, and earth retaining structures • estimation of quantity of underground seepage water under various hydraulic conditions • design of the clay layer for a landfill liner.

3.3.1 Laboratory Results

3.3.1.1 **Indicator Tests**

The detailed laboratory test results per sample are given in Appendix B and summarized in Table 6 below.

Brownish weathered dolerite

Gravel (9%), sand (56%), silt (21%) and clay (14%). The soil is therefore described as clayey, silty sand. In terms of the Unified Soil Classification system the soil classifies mainly as a “SC” soil type, these being clayey sand. The Grading Modulus of 1.11 seems to reflect the soils as fairly fine coarseness nature, as corroborated with the sieving analysis results. The plasticity indices (a measure of the plasticity of the clay) recorded show medium values (13) which are indicative of medium activity (lower medium expansiveness) for the soils. These should therefore be noted to constitute some slight problems under conditions of moisture migration.

Weathered khaki/light brown shale

Gravel (14%), sand (34%), silt (37%) and clay (14%). The soil is therefore described as sandy silts. In terms of the Unified Soil Classification system the soil classifies mainly as a “CL” soil type, these being clayey sands or silty clays. The Grading Modulus of 0.79 seems to reflect the soils as fairly fine nature, as corroborated with the sieving analysis results. The plasticity indices (a measure of the plasticity of the clay) recorded show low values (9) which are indicative of low activity (low expansiveness) for the soils. This should therefore not constitute any problems under conditions of moisture migration.

3.3.1.2 **Permeability Tests**

Capping of the waste is to minimise water ingress into the waste underneath. Permeability (hydraulic conductivity) tests conducted in the laboratory on disturbed samples using the constant head method to arrive at an order of magnitude of coefficient permeability of $2.2x10^{-8}$m/s for the brownish weathered dolerite. This soil is therefore suitable to use as capping material subject to further consolidation at optimum density and moisture content. Permeability values for the weathered khaki/light brown shale soil is $4.8x10^{-10}$m/s. This soil is therefore suitable to use as capping material. To put this value in perspective, the liner requirements at waste disposal sites specified in the DWAF Minimum Requirements for Waste Disposal by Landfill (1998), specify permeability of 1×10^{-6}cm/s for the geosynthetic layer system.

Table 6: Summary of results of laboratory results (Also refer to Appendix B).

Pit ID	Sample ID	Sample Interval (m)	Field Sample Description	Sieving Analysis				Atterberg Limits					Mod AASHTO		% CBR				
				% gravel	% sand	% silt	% clay	LL%	PI	LS	Overall PI	GM	MDD (Kg/ m3)	OMC %	90%	93%	95%	98%	100 %
STP3	SSTP3001	1-2	Weathered residual dolerite brownish medium to fine gritty/silty soil	9	56	21	41	48	23	10.5	13	1.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A
STP8	SSTP8001	0.7-1.4	Weathered khaki to light brown sandy soil	14	34	37	14	29	12	6.5	9	0.79	N/A	N/A	N/A	N/A	N/A	N/A	N/A

LL - Liquid Limit. OMC - Optimum Moisture Content. PI - Plasticity Index. LS - Linear Shrinkage. GM - Grading Modulus. MDD - Maximum dry density. CBR – California Bearing Ratio. AASHTO-American Association of State Highway and Transportation Officials. Unified- Unified soil classification;

Table 7: Summary of permeability test results.

Test Pit ID	Sample No	Depth To-From (m)	USCS	Dry Density (kg/m3)	Optimum Moisture Content (%)	Head of Water (cm)	Coefficient of Permeability (m/s)
STP3	SSTP3001	1-2	SC	1592	N/A	N/A	$2.2x10^{-8}$
STP8	SSTP8001	0.7-1.4	CL	1902	N/A	N/A	$4.8x10^{-10}$

3.4 **Geotechnical and Geohydrological Appraisal**

Table 8 below summarizes the findings from the site investigations of the waste body and surrounding geology. In general, the following comments are made:

- Soil quality - reflects the suitability of the available material for use as cover. Based on laboratory test results, the in-situ materials are generally suitable for use as capping material.
- Soil depth and availability – there is however not enough of this material on site to use for capping considering the geographic location of the site. However, during rehabilitation, some of this material will be exposed and re-used as part of the construction. Adequate material will need to be sourced from elsewhere. There will be excavation difficulties that are expected at shallow depth due to decomposing as well as some non-biodegradable waste matter.
- In-situ permeability - is the ease with which water seeps through the underlying surface soil and bedrock and into the ground water. The tested soils are sufficiently impermeable but an an additional capping system is however still suggested. Before final capping, the waste must be compacted and shaped in such a way as to promote run-off and to prevent any ponding of water on the landfill site. A leachate collection and cut-off drain is required at the toe of the landfill. Should the water monitoring results show signs of any contamination of the stream or river, a deeper, more sophisticated and expensive leachate cut-off wall solution will be required.
- The site does not reflect any risk for the formation of sinkholes or subsidence caused by the presence of water-soluble rocks (dolomite or limestone) and no evidence of mining activity beneath the site.
- There is serious pollution into the proximal river system currently taking place, sources being the local informal settlement's poor sanitation conditions as well as possibly the leachate run-off from the landfill. A leachate collection and cut-off drain is required at the toe of the landfill.

Table 8: Summary of geotechnical and geohydrology appraisal.

Aspect	**Description of findings**
1. Problem soils	There are no potentially problematic soils observed
2. Erodable soils	Slope erosion channels were noted. The erosion channels observed were created by surface runoff dislodging and transporting soils and waste particles downslope into the lower slopes of the waste body and into the river 500m down slope on the valley.
3. Seepage	Potential basal seepage downslope to the river northeast of the site.
Construction material	The residual soil down to 2m depth across the test pits is generally moist. It displays some medium expansiveness. These should therefore be noted to constitute problems under conditions of moisture migration.
4. Permeability	The residual soil has been tested to permeability coefficient of $3.5x10^{-9}$ m/s which is impervious enough to meet minimum capping requirements
5. Excavation	**Ease of excavation - Excavatability and Rippability -** As evidenced during test pit excavations, a tractor with a backhoe to rip loose from surface down to 2m and deeper depth should enable easy removal of materials (classified as SOFT to INTERMEDIATE in terms of SABS 1200DA) from surface down to 2m depth or deeper. Notwithstanding the above comments, hard rock (hard and competent dolerite and shale) could be encountered at deeper depths and random depths within the residual soils in the form of core stones. No sidewall collapse was observed during the excavation of the trial pits. However, the sidewalls of deeper excavations, may become unstable. The risk of sidewall collapse will increase with increasing soil moisture content. The risk of collapse will have to be assessed on site during construction and shoring must be implemented if considered necessary.
6. Open-cast or underground mines	There is no evidence of mining activity beneath the study area
7. Undermined ground	There are no undermined areas
8. Instability in areas of soluble rock	The proposed site does not reflect any risk for the formation of sinkholes or subsidence caused by the presence of water-soluble rocks (dolomite or limestone) and no evidence of mining activity beneath the study area has been revealed. The site does not reflect any risk for the formation of sinkholes or subsidence caused by the presence of water-soluble rocks (dolomite or limestone)
9. Steep slopes	The current ~10-20m height slopes are relatively steep and require flattening. Some sections show signs of deep erosion
10. Areas of unstable natural slopes	None observed
11. Areas subject to seismic activity	The probability of a seismic event occurring is low
12. Areas subject to flooding	Due to its topographic location, the landfill is not subject to flooding
13. Application of on-site soils for designed base and capping layers in landfills	There is potentially >4m deeply weathered red clayey silty soil which is appropriate material to use as a capping material over the waste. The base of the landfill has not been lined so the prevention of water ingress has to be done from the top of the waste. Geology underlying the landfill is deep red residual/colluvial soil and underlying shale

4. IMPACT ASSESSMENT

Typical impacts which need to be taken into account as part of the closure of the landfill site are tabulated in the Tables below together with mitigating measures. The identified combined risks can typically be mitigated to a large degree by the implementation of an appropriate and effective Environmental Management Plan (EMP). The mitigation measures should be implemented to avoid or reduce negative impacts during the closure phase.

The potential future developments are only conceptual and thus there was limited information available to facilitate the geotechnical and geohydrological assessment at the time of report compilation. The following assumptions and limitations are stated pertaining to the investigations:

- The current assessment is broad in nature and detailed analyses are to be conducted by the closure engineers.
- It is understood that no investigations had been undertaken at the site prior to the establishment of this landfill and therefore the nature and engineering properties of the subgrade material (in-situ soil and rock below the waste bodies) were unknown until this preliminary investigation.
- No detailed records of the waste dumped during the operational life of the site have been kept and therefore the engineering properties and exact nature of the waste is limited.
- It is recognised internationally that the geotechnical properties of waste (shear strength, potential settlement etc.) in general are difficult to measure accurately. This is related to the heterogeneity of waste and limited research carried out on the subject of geotechnical properties of the landfilled waste.
- A limited number of test pits has been dug, however this is considered sufficient to provide suitable recommendations with regards to conceptual engineering designs and basis for next phases of work.
- Potential dust and air pollution, siltation of adjacent streams/rivers/dams and leachate pollution did not form part of this assessment even though some minor comments in this respect are made.

Table 9: Impact assessment during decommissioning phase.

Activity/Aspect	Potential Impact	Nature	Status	Extent	Duration	Probability	Severity/Beneficial scale		Significance
							Before mitigation	**After mitigation**	
Slope stability	Failure (by landslide) of landfill slopes – slope angles steeper than shear strength of material	Because of quality of waste and cover material composition and quality, external inducing factures (climate, seismic activity) or engineering design	Negative	Local	Short-term	Probable	Moderate	Slight	Medium
Settlement of waste	Subsidence and ponding of water which, in turn, may cause saturation of waste and subsequent slope failures	Saturation of waste and subsequent slope failures.	Negative	Local	Long-term	Highly Probable	Moderate	Slight	Very low
Soil erosion	Exposure of upper capping layer, siltation of water courses, and pollution of water courses and safety of workers/public.	Soil and waste particles will continue to be washed downslope into the lower slopes of the waste body, as well as the surrounding drainage channel situated at the toe of the waste body. The erosion of these slopes will be exacerbated during periods of heavy rainfall.	Negative	Regional	Long term	Probable	Medium	Slight	Medium
Seismic activity	Damage to a building, system, or other entity on the landfill structure.	Side slopes of the landfill may become unstable resulting in local or large-scale slope failures and damage to structures. This may cause exposure of soil and waste which, in turn, may increase soil erosion.	Negative	Regional	Short-term	Improbable	Moderate	Slight	Medium
Closure/capping of waste disposal cells	Uncontrolled leachate generation and build-up of leachate level	Insufficient/inappropriate cover construction resulting in rainwater infiltration, leachate generation and eventually leachate seepage from disposal cells	Negative	Local	Medium term	Probable	Moderately severe	Slight	Medium

Activity/Aspect	Potential Impact	Nature	Status	Extent	Duration	Probability	Severity/Beneficial scale		Significance
							Before mitigation	**After mitigation**	
Treating/disposal of surplus leachate and storm water in the holding dams at final closure	Contamination of ground and surface water resources	Poor leachate management resulting in surplus at closure	Negative	Local	Medium	Probable	Moderately severe	No effect	Medium
Maintenance of storm water control systems	Soil erosion at closed disposal cells	Erosion of cells resulting in collapse and exposure of waste material	Negative	Local	Medium	Probable	Moderately severe	Slight	Medium
Maintenance of capping	Uncontrolled leachate generation	Capping losing its low permeability character resulting in rainwater infiltration and leachate generation	Negative	Local	Medium	Probable	Moderately severe	Slight	Medium
Maintenance of water monitoring systems (boreholes) and surface water and maintaining a sampling and analysis programme after closure according to permit conditions	Quality deterioration of water resources	Poor maintenance and control of groundwater and surface water monitoring points and boreholes, as well as neglecting regular sampling and analyses as stipulated in permit conditions	Negative	Local	Medium	Probable	Moderately severe	Slight	High

Table 10: Proposed mitigating actions during the Closure stage.

Phase	Activity	Impact Description	Proposed Mitigation
Decommissioning	Slope Stability	Failure (by landslide) of landfill slopes – slope angles steeper than shear strength of material	• Maximum slope angle of 1v:3h implemented across the landfill. • Shaping of waste bodies and construction of capping system to avoid infiltration or ponding of water and subsequent saturation of waste; which may influence stability of waste. • Allowing for factors such as interface friction, slope angles and soil/material shear strength during design of capping layer to prevent instability of liner. That is, the liner to be suitably designed. • Implementation of safe slope angles based on seismic risk.
	Soil erosion	Exposure of upper capping layer, siltation of water courses, and pollution of water courses and safety of workers/public	• Maximum slope angle of 1v:3h implemented across the landfill. • Complete vegetative covering of waste bodies (ideally indigenous flora). • Selection of non-erodible and non-dispersive topsoil to avoid erosion. • Creation of sufficient horizontal channels along outer slopes of waste bodies to decrease flow rate of surface runoff and minimise erosion. • Concrete drainage channels surrounding cells to be maintained to avoid clogging and possible overflowing of storm water and leachate resulting in continued erosion along base of waste bodies.
	Seismic Activity	Damage to a building, system, or other entity on the landfill structure.	• Implement safe slope angles
	Settlement of waste	Subsidence and ponding of water which, in turn, may cause saturation of waste and subsequent slope failtures	• By taking into consideration the total predicted magnitude and rate of settlement and related potential adverse effects when designing the elements of the closure and rehabilitation. • Storm water channels situated upon the waste bodies should be designed to be relatively flexible so as to allow for settlement in the long term, as well as to allow for easy maintenance and repairs. • Designing the level crest area to accommodate the estimated settlements such that no low areas are formed causing ponding of storm water. Ponding of storm water increases the risk of saturation of the waste which may accelerate settlement of the waste.
	Closure/capping of the landfill	Uncontrolled leachate generation and seepage, build-up of leachate level	Proper capping of each landfill and regular maintenance of capping according to permit conditions to avoid infiltration of rainwater and thus leachate generation within the waste pile. Installation of leachate level monitoring facility or each cell monitoring point
	Treating/disposal of surplus leachate and storm water in holding dams at final closure	Contamination of ground land surface water resources	Treating and/or disposal of final leachate volumes and draining of holding dams
	Maintenance of storm water control systems	Soil and waste pile erosion after closure	Development and implementation of a storm water management plan as well as the proper maintenance of storm water control systems on site after closure according to permits and regulations issued from time to time by the relevant authorities. Regular inspections by authorities
	Maintenance of water monitoring systems (borehole and surface water) and programme	Quality deterioration of water resources	Regular water quality monitoring according to permit conditions and in compliance to Minimum Requirement documents of DWAF. Reporting of results to authorities on a six-monthly basis

5. MONITORING SYSTEMS

As part of the closure, a monitoring programme is suggested to be in place. Monitoring can be described as the repetitive and continued observation, measurement and evaluation of geohydrological information such as water level and groundwater quality to follow changes over a period of time to assess the efficiency of control measures. In essence, monitoring serves as an early warning system so that any corrective actions required can be taken promptly. The objectives of water quality monitoring will be to:

- comply with the relevant Licence conditions and legislation;
- detect any pollution emanating from the landfill;
- serve as an early warning system, so that any pollution problems that arise can be identified and rectified; and
- quantify any effect that the landfill has on the water regime.

The development of a groundwater monitoring programme will be important for assessing the impacts of the decommissioned Landfill on groundwater and the environment. It is recommended that groundwater monitoring be undertaken in accordance with guidelines set out in the documents Minimum Requirements for Waste Disposal by Landfill (DWAF, 2nd edition, 1998 and draft 3rd edition, 2005a) and the Minimum Requirements for Water Monitoring at Waste Management Facilities (DWAF, 2005b, 3rd edition) issued by the Department of Water Affairs and Forestry, specifications for the monitoring of groundwater at waste disposal facilities. The various aspects of the monitoring are presented in this section, along with relevant recommendations.

Table 11: Recommended scope for monitoring boreholes.

General Waste	No. Holes	Distance (m) from waste site	Monitoring Frequency
Small (<25 tonnes per day)	2-4 (*2 holes already drilled)*	• 20-200 based out ground geophysics outcomes	• Samples from boreholes every 6 months or as specified in the permit • Sample boreholes 1-5km radius initially when problems are expected • Sample surface water as specified in the permit. • Sample monthly for leachate, if any

5.1 **Surface water or run-off monitoring**

Water sources around the landfill within a radius as suggested by the risk assessment must be sampled and water preserved for chemical analysis. To establish a potential pollution baseline, continuous recording of water flow and possible waste run-off (quantities) and quality is necessary. Similarly, rainfall levels at the landfill must be recorded for the past 24 hours at a set time every day. This includes leachate collection and toe seepage.

5.2 **Ground water monitoring**

Currently there 4 boreholes on site, 2 of which it would seem were drilled specifically for monitoring purposes. It is not known if the boreholes have water, intersection depths and volumes thereof.

According to the 3rd edition draft of the Minimum Requirements for Water Monitoring at Waste Management Facilities (2005), between 1-2 boreholes would typically be required for a small general waste site. Each borehole should have a cover (e.g. lockable cap) to prevent it from being polluted and damaged. Boreholes must be kept accessible to allow for continual monitoring of water levels and chemistry of groundwater.

Based on the geohydrological data available from the existing reports and from follow-up ground geophysical survey outcomes, it will be determined if these existing boreholes are located at suitable locations with where fracture zones and zones of deep weathering that may be indicative of groundwater flow and represent potential aquifers have been identified. If so, the boreholes should be used to establish a groundwater monitoring system for the waste site as well as obtaining additional geological and geohydrological information. The survey results will also determine whether new holes need to be drilled or not.

It is recommended that ground geophysical surveys be carried out designed to cover the site surrounding the existing waste site and surrounds as per the airborne geophysics results. Yield tests to determine the aquifer properties and water quality tests should be carried at these existing boreholes as well as those new boreholes which will intersect water.

5.2.1 **Monitoring Frequency**

DWAF (1998b) only prescribes annual water level measurements, but to best understand and monitor the site it is recommended that monthly water level measurements be taken. Boreholes should be sampled bi-annually (i.e. once in summer and once in winter), while groundwater levels should be measured on a monthly basis and accurately recorded. If contamination is picked up then more regular monitoring will be required to determine the source, movement and extent of contamination.

According to the Department of Water Affairs and Forestry (DWAF) (1998b) an assessment of groundwater usage and borehole yields should be undertaken on an annual basis. A detailed hydrocensus should focus on an area within 1 km of the landfill.

Post-closure monitoring is to continue for 30 years following closure of the site, unless otherwise motivated, and authorised by the authorities.

5.2.2 **Sampling Method**

5.2.2.1 Sampling Process

The monitoring boreholes should be assessed whether they are low or high yielding before sampling. Should the monitoring borehole be of low yield and unable to be pumped with a conventional pump (until field parameters stabilize and a sample collected), a bailer (grab) sample can be collected. It is preferable to use a low volume sampling pump though (also known as a bladder pump). For a high yielding borehole, it is recommended that the pump be installed either half a meter above the bottom of the borehole or at the highest yielding water-strike depth. The groundwater should be pumped into a flow-through cell, and an EC and pH probe should be placed into the flow-through cell. The borehole must be pumped until field chemistry parameters stabilise prior to sampling.

5.2.2.2 Sample Collection, Preservation and Submission

Sample bottles must be labelled with the borehole name, site name and date. At the time of sampling field chemistry parameters must be measured and recorded. These include electrical conductivity (EC), oxidation reduction potential (ORP), pH, temperature and dissolved oxygen (DO). Samples must be taken in their correct sampling container and preserved (if necessary) in the correct manner (Table 12) prior to submission to an accredited laboratory for the analysis of selected parameters.

The sample method and preservation must be discussed with the laboratory prior to sampling. The different preservation requirements for the different types of sample are discussed below. This table lists the correct sampling methods and preservation thereof for a range of parameters. The parameters that should be analysed for will be stipulated in the initial permit granted during the application for the closure permit.

5.2.2.3 Groundwater levels

Groundwater level measurements are prescribed for the monitoring boreholes to be drilled as part of the closure. A dip meter can be used to measure the water level below the top of the borehole collar / casing height, however, the height of the collar / casing must also be measured. The water level is then calculated by subtracting the collar/casing height from the water level. All three values must be recorded along with the date and time that the measurement was taken. An interface meter can be used during monitoring to detect the presence of non-aqueous phase liquids (if present). Monthly recording of groundwater levels is recommended.

5.2.2.4 Inorganic analysis

Plastic sample bottles with a plastic cap (with no liner within the cap) can be used for the inorganic sampling. The bottle must be clean and should be rinsed along with the cap prior to sample collection. The sample bottle should be filled entirely to ensure there is no air in the sample. The samples must be put into an ice box immediately following sampling and stored/transported at temperatures of approximately 4°C. No preservation of the sample is generally required if the sample is to be submitted within 6 hours of sampling. If not the minimum sample preservation requirements (DWAF, 1998b) must be adhered to.

5.2.2.5 Microbiological analysis

The microbiological samples must be taken in designated sterilized sample bottles obtained from the microbiological laboratory. Care must be taken not to touch inside the bottle or the bottle lid in any way. The sample bottle must be filled carefully not allowing water to wash over the side of the bottle. The bottle can be filled ¾ of the way and then closed and then refrigerated (at 4°C). The samples must be delivered to the laboratory within 24 hours of the sampling. Ideally the samples should be submitted within 6 hours of sampling.

5.2.3 **Water Quality Variables to be Analyzed**

For first time monitoring, a comprehensive analysis must be undertaken to obtain a baseline of groundwater conditions. Such an analysis should include a complete macro analysis and an analysis for trace elements that can be expected from the site (note that the closure permit for the existing landfill will provide a list of water quality variables to be tested for background monitoring). Once this has been undertaken, an indicator analysis can be continued with for further monitoring. A list (Table 12 below) of these parameters will be available in the permit that that will be applied for. After a comprehensive analysis has been completed, an **indicator analysis** can be continued with, to save on costs. This will still provide enough data to determine whether further action is required. For general waste the "pollution indicators" are COD, Cl, K, NO_3 and NH_4. As a standard, pH, EC, alkalinity and acidity should be analysed.

Table 12: Minimum requirements for water sample preservation from DWAF (1998b).

Variable	**Action**
Carbon dioxide	Analyse immediately
Chloride – residual	
pH	
Electrical Conductivity	No additives. Refrigerate. Analyse as soon as reasonably be achieved
Acidity	
Alkalinity	
BOD	
Colour	
Chromium (VI)	
Nitrite	
Silica	
Sulphate	
Boron	Analyse when convenient
Bromide	
Chloride	
Fluoride	
Potassium	
Sodium	
Hardness	Filter in field. Add NHO_3 to pH<2
Metals (general)	
COD	Add H_2SO_4 to pH>2
Grease and oil	
Nitrogen – NH_4	
Nitrogen – NO_3	
Nitrogen-organic	
Phenols	
TOC	
Cyanide	Add NAOH to pH>12
Sulphide	Add 4 drops 2N zinc acetate/100ml
No preservatives are required if the sample is to be analysed within 6hours. Samples should always be stored or transported at temperatures around 6 degrees centigrade	

5.2.4 Data storage and collation

All collected data, field measurements and laboratory results must be captured into an appropriate database for ease of reference and meaningful interpretations and reporting. This must be kept up to date and the data assessed regularly.

5.2.5 Documentation and Record Keeping

The following is a list of documentation that shall be retained with the responsible person in charge of the decommissioned Landfill site and must be made available on request:

- Borehole monitoring results;

- Monthly groundwater levels

5.2.6 Monitoring and Auditing

Quarterly internal environmental audits and annual external audit reports must be conducted. The audits are to verify the projects compliance with the conditions of the Waste Management Licence. In this regard a checklist shall be compiled using the CEMP and the Waste Management Licence and with each audit the compliance can be verified against this.

6. CONCLUSIONS AND RECOMMENDATIONS

Based on the desktop study, site investigations and profiling of eight (8) test pits excavated within the general landfill facility on 3 November 2017 together with results from laboratory tests, the following can be concluded:

- The landfill site is unlicenced and ceased operations in 2010 prior to which it seems it operated for some 30 years by receiving general waste from Stanger and the surrounding areas. The site is currently abandoned and completely covered by alien vegetation and weeds.
- The Geological map of Durban shows the site to be underlain by quaternary alluvium, shale and post Karoo dolerite. A fault north-east to south-west striking fault is located approximately 1.5km north west of the landfill site. The fault is however not expected to play a crucial role in the local hydrogeology of the site.
- The aquifer type is classified as minor aquifer class. Due to the nature of the alluvium expected below the site, the underlying aquifer is expected to be intergranular. The NGA database does not have boreholes in very close proximity to the site but generally show an intergranular and fractured type aquifer. The water strikes are generally deeper than 30mbgl and are likely to be encountered between the two layers of rock. Recharge values range between 75 and 110 mm/annum and the groundwater levels are expected between 31 to 40 mbgl.
- A NE-SW magnetic lineament cuts across the Shakaville site and the area is also surrounded by several NNW-SSE lineaments.
- Eight (8) test pits were excavated (to 2m depth) on site on 3 November 2017. Test pits were dug and ended in residual soil or waste body. Some test pits have exposed light brown to khaki residual shale soils and in some cases brownish residual dolerite soils. An in-situ exposure of khaki brown shale rock was observed on site. Two samples each representing these two distinct soil types were collected. No groundwater or perched leachate tables were encountered within the test pits excavated. The landfill does not have a basal liner.

Laboratory results indicate that in general, the two samples tested comprise the following:

<u>Brownish weathered dolerite</u>

- Gravel (9%), sand (56%), silt (21%) and clay (14%). The soil is therefore described as clayey, silty sand. In terms of the Unified Soil Classification system the soil classifies mainly as a “SC” soil type, these being clayey sand. The Grading Modulus of 1.11 seems to reflect the soils as of fairly fine coarseness nature, as corroborated with the sieving analysis results.
- The plasticity indices (a measure of the plasticity of the clay) recorded show medium values (13) which are indicative of medium activity (lower medium expansiveness) for the soils. These should therefore be noted to constitute some slight problems under conditions of moisture migration.

- Permeability (hydraulic conductivity) tests conducted in the laboratory on disturbed samples indicate values of $2.2x10^{-8}$m/s. This soil is therefore suitable to use as capping material subject to further consolidation at optimum density and moisture content.

<u>Weathered khaki/light brown shale</u>

- Gravel (14%), sand (34%), silt (37%) and clay (14%). The soil is therefore described as sandy silts. In terms of the Unified Soil Classification system the soil classifies mainly as a “CL” soil type, these being clayey sands or silty clays. The Grading Modulus of 0.79 seems to reflect the soils as fairly fine nature, as corroborated with the sieving analysis results.
- The plasticity indices (a measure of the plasticity of the clay) recorded show low values (9) which are indicative of low activity (low expansiveness) for the soils. This should therefore not constitute any problems under conditions of moisture migration.
- Permeability (hydraulic conductivity) tests conducted on disturbed samples in the laboratory indicate values of $4.8x10^{-10}$m/s. This soil is therefore suitable to use as capping material subject to further consolidation at optimum density and moisture content.

The potential risks that could impact the decommissioning of the landfill site comprise soil erosion, slope stability, and settlement of waste and potential surface and ground water pollution.

- The proximity of the landfill to the surrounding river down slope presents a leachate pollution risk to surface water and possibly ground water.
- In spite of the existing vegetation, slope failure due to the slope height and angles is a potential collapse risk, should wet conditions become excessive.
- The site does not reflect any risk for the formation of sinkholes or subsidence caused by the presence of water-soluble rocks (dolomite or limestone) and no evidence of mining activity beneath the site.

In view of the initial objectives set by the client it is believed that during the desk study, site walkover and investigations, it is believed that sufficient information at this stage of the project was obtained to enable a reasonable geotechnical and geohydrological assessment which will provide reasonable and appropriate information for the Conceptual engineering design for the planned decommissioning (closure) and rehabilitation of the landfill site.

6.1 **Further Work**

Additional studies should be carried out to ascertain the potential for pollution originating from the existing waste site. The additional geohydrological work entails further detailed studies of the existing geological and geohydrological information available for the site and the surrounding areas. The aim of the additional geohydrological work for this phase of the investigation will be three-fold:

- Clarify the groundwater flow and the likely migration of a pollution plume around landfill and determine the groundwater conditions to the northwest of the existing site towards the dam and river.
- Establish a more comprehensive groundwater monitoring system around the entire.
- Further determine the geotechnical and geohydrological properties of the soils and underlying bedrock.

The scope of the work (also see Table 13) and associated costs (Table 14) below envisaged is as follows:

6.1.1 **Surveys**

- Undertake detailed topographic surveys to map out the terrain of the site which would ensure accurate detailed closure engineering designs.

6.1.2 **Geotechnical Assessment**

- Review of Desktop and limited preliminary stage data acquired from the work done as documented in this report.
- Further test pit excavations and mapping of identified areas to confirm capping material availability and volumes. Perform in-situ tests such as permeability and DCP's (determine the variation in in-situ stiffness). Sampling and laboratory testing.
- Soil samples from the test pits will be tested for classification, compaction characteristics and strength/stiffness properties. Problem soils, if presents, will be tested to quantify the degree of the problem condition (e.g. collapse potential).
- Compiling a geological/geotechnical map indicating features observed;
- Identifying and assessing significance of potential geotechnical constraints to the proposed development;
- Proposing mitigation measures that could reduce or eliminate the identified constraints; and
- Compiling a report that will be based on the findings of the study

6.1.3 **Geohydrology Assessment**

- A review of all existing groundwater information available to date the baseline status;
- A follow-up detailed hydrocensus within an identified buffer zone;
- Perform follow-up ground geophysics (magnetics, resistivity) from current airborne magnetics data (identify local deep fracture zones and structures which could be water-bearing and act as groundwater aquifers and electrical resistivity (to determine presence of water in the fractures). Results will be the basis for sighting locations of geohydrology monitoring boreholes which will be drilled. Pump testing and borehole equipping. Subcontractors will carry out the work.
- Carry out a rotary percussion-drilling (Monitoring Boreholes) programme to verify the presence of any aquifer(s). Subcontractors will carry out the fieldwork.
- Aquifer Tests - to test the yield, storativity and transmissivity of the aquifer(s). Subcontractors will carry out the fieldwork.
- Hydrochemical sampling and analysis
- The development of a Flow and Mass Transport Models; and Pollution plume simulation.
- Establish a groundwater monitoring system for the site that is based on the information obtained from outcomes of activities as listed above.
- Data analyses of information collected during the field investigations.
- Discuss preliminary findings with other relevant team members during progress meetings.
- Present data on maps and compile a report on each of the three sites.
- Present data at meeting and finalise report.

Leading to or as part of the closure the following sequence of events listed in Table 13 below are recommended.

Table 13: Suggested closure sequence of events.

Activity	**Status at the time of the writing of this report**
(i) Obtain information on disposal practices, volumes and type of waste.	This document serves the purpose
(ii) Obtain available information on the topography, stream flow, fountains, dams, geology, existing boreholes, wells and excavations (see Chapter 6 of the Minimum Requirements for Waste Disposal by Landfill).	This document serves the purpose. Desktop and some Preliminary stage data obtained to ensure conclusion of Conceptual designs.
Sample surface and groundwater for chemical analyses to determine the presence of pollutants, if any, at existing points. Obtain information on other human activities that could be affected by the disposal of the waste. Delineate possible pollution plumes at existing waste sites.	Proposed as part of next phase scoped activities
(iii) Perform a risk assessment and decide on the level of the impact study and the monitoring facilities that will be required (see Chapter 5 and Appendix A).	This document serves the purpose
(iv) Perform geophysical investigations to locate groundwater barriers and aquifers (see Chapter 6 of the Minimum Requirements for Waste Disposal by Landfill).	Proposed as part of next phase scoped activities
(v) Drill boreholes at positions as determined by (i), (ii), (iii) and (iv). Record geological and geohydrological information from boreholes. If necessary, perform tests such as hydraulic conductivity, aquifer yield and water quality profiling in boreholes. Study characteristics of rainwater penetration into waste. Install, if required, early warning devices underneath new disposal sites (see Chapter 6).	Proposed as part of next phase scoped activities
(vi) Perform water sampling from holes. Analyse for elements typically found within the natural and waste environments	Proposed as part of next phase scoped activities
(vii) Document data or enter it into the computerized database, Waste Manager, for processing and interpretation. Interpret data, extract tables and graphs, identify and investigate anomalies	Proposed as part of next phase scoped activities
(viii) Present report, database and recommend methods and frequency of sampling to the client. Specify equipment to sample water from boreholes.	Proposed as part of next phase scoped activities & the closure plans
(ix) Include information in the application for a waste management permit in the case of general	Proposed as part of next phase scoped activities
(x) Train on-site personnel in the use of the database, the sampling equipment and in the interpretation of the data. Provide facilities for the client to report to the Department in terms of their permit conditions.	Proposed as part of closure plans

Table 14: Cost estimate (Class 0 +-45% accuracy & level of estimation) for recommended further work.

ACTIVITY	**COST (Rand)**
Land Survey	100,000
Geotechnical Assessment	
• *Site Investigations*	*100,000*
• *Laboratory testing*	*R50,000*
• *Data analyses and final reporting*	*R150,000*
Geohydrological Assessment	
• *Ground geophysics*	*100,000*
• *Detailed Hydrocensus*	*50,000*
• *X2 holes - Percussion Drilling, borehole equipping & supervision*	*300,000*
• *Aquifer testing*	*200,000*
• *Geohydrological modelling (pollution plume simulation, etc)*	*100,000*
• *Water quality analyses*	*50,000*
• *Data Analysis and final reporting*	*150,000*
Sub-total	1,350,000
Contingency 10%	135,000
Vat 14%	189,000
Total	**1,674,000**

7. DISCLAIMER - LIMITATIONS AND USE OF THIS REPORT

This report has been prepared for the exclusive use of the client for specific application to the project discussed and has been prepared in accordance with generally accepted engineering geology practices.

This report has been based on a desktop study followed by a site visit and limited penetrative investigations where sub-surface soils were examined through test pit excavations, soil profiling and laboratory analyses. The nature of geotechnical engineering is such that variations in what is reported here may become evident during construction and it is thus imperative that a Competent Person inspects all excavations to ensure that conditions at variance with those predicted do not occur and to undertake an interpretation of the facts supplied in this report.

Although every effort has been made to ensure the integrity of the data and information on which this report is based, conditions at variance with those encountered during construction may occur and the shortcomings of a limited penetrative investigations should be noted. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered unless the Consultant reviews the changes and either verifies or modifies the conclusions of this report in writing.

8. REFERENCES

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9. APPENDICES

- APPENDIX A – GPS Survey data
- APPENDIX B – Laboratory test results
- APPENDIX C – Criteria and Definitions used in Impact Assessment Tables

APPENDIX A - GPS Survey data

APPENDIX B - Laboratory test results

APPENDIX C - CRITERIA AND DEFINITIONS USED IN IMPACT ASSESSMENT TABLES

Impact Assessment Criteria and Definitions

In order to evaluate the significance of potential impacts, the following criteria and terminology is used to identify and describe the characteristics of each potential impact:

- the ***nature*,** which shall include a description of what causes the effect, what will be affected and how it will be affected;
- the ***status***, which will be described as either a **positive** impact or a **negative** impact.
- the ***extent***, wherein it will be indicated whether the impact will be **local** (limited to the immediate area or site of development) or **regional**;
- the ***duration***, wherein it will be indicated whether the lifetime of the impact will be of a **short duration (0–5 years**), **medium-term (5–15 years**), **long term (> 15 years)** or **permanent;**
- the ***probability***, which shall describe the likelihood of the impact actually occurring, indicated as **improbable** (low likelihood), **probable** (distinct possibility), **highly probable** (most likely), or **definite** (impact will occur regardless of any preventative measures);
- the ***severity/beneficial scale****:* indicating whether the impact will be **very severe/beneficial** (a permanent change which cannot be mitigated/permanent and significant benefit, with no real alternative to achieving this benefit), **severe/beneficial** (long-term impact that could be mitigated/long-term benefit), **moderately severe/beneficial** (medium- to long-term impact that could be mitigated/ medium- to longterm benefit), **slight or have no effect**; and
- the ***significance***, which shall be determined through a synthesis of the characteristics described above and can be assessed as **low**, **medium** or **high**.

Shakaville GPS survey data

Landfill ID	Latitude (S)	Longitude (E)	Elevation (m)	Waypoint Name	ns4:CreationTime	Description
Shakaville	-27,58253203	32,03361799	93,315399	SBH1	2017-11-01T14:25:48Z	Borehole
Shakaville	-29,33110197	31,30287303	29,572372	SBOR1	2017-11-03T09:49:28Z	Borehole
Shakaville	-29,33111798	31,30287898	27,652058	SBOR2	2017-11-03T09:50:07Z	Borehole
Shakaville	-29,32871698	31,301344	48,495068	SBOR3	2017-11-03T10:45:36Z	Borehole
Shakaville	-29,32868497	31,30136001	48,804131	SBOR4	2017-11-03T10:46:15Z	Borehole
Shakaville	-29,32923599	31,30417197	30,351221	SBOR5	2017-11-03T11:06:07Z	Borehole
Shakaville	-29,32934102	31,30200097	44,555218	SHAKALANDFILL	2017-11-01T14:28:15Z	
Shakaville	-29,32903499	31,30309498	26,509834	SPIPELINE	2017-11-03T10:58:20Z	Pipeline across landfill
Shakaville	-29,33133599	31,30213802	18,563374	SPIPELINE2	2017-11-03T11:25:48Z	Pipeline across landfill
Shakaville	-29,331064	31,30303999	28,764296	SSEW	2017-11-03T09:53:09Z	Sewage manhole
Shakaville	-29,32906701	31,30087696	37,646526	SSEWLEAK	2017-11-03T12:03:19Z	Sewage manhole leak into river
Shakaville	-29,33118302	31,30265702	27,853365	SSHALE	2017-11-03T09:48:14Z	Shale rock outcrop
Shakaville	-29,32857298	31,30119103	49,259014	SSP1	2017-11-03T10:48:54Z	Landfill survey point
Shakaville	-29,32902602	31,30360099	25,994629	SSP10	2017-11-03T11:00:17Z	Landfill survey point
Shakaville	-29,32905402	31,30409704	24,41993	SSP11	2017-11-03T11:02:07Z	Landfill survey point
Shakaville	-29,32909702	31,30428898	24,544283	SSP12	2017-11-03T11:02:54Z	Landfill survey point
Shakaville	-29,32923599	31,30432402	32,64682	SSP13	2017-11-03T11:04:46Z	Landfill survey point
Shakaville	-29,32944898	31,30429803	31,567865	SSP15	2017-11-03T11:07:51Z	Landfill survey point
Shakaville	-29,329957	31,30475502	30,933056	SSP17	2017-11-03T11:09:36Z	Landfill survey point
Shakaville	-29,330373	31,30435302	30,791414	SSP18	2017-11-03T11:11:57Z	Landfill survey point
Shakaville	-29,33003101	31,30385396	35,948395	SSP19	2017-11-03T11:13:25Z	Landfill survey point
Shakaville	-29,32848497	31,30143603	44,342735	SSP2	2017-11-03T10:49:37Z	Landfill survey point
Shakaville	-29,32978199	31,303357	38,671268	SSP20	2017-11-03T11:14:25Z	Landfill survey point
Shakaville	-29,33016798	31,30315399	39,641922	SSP21	2017-11-03T11:15:31Z	Landfill survey point
Shakaville	-29,330748	31,30301502	36,280743	SSP24	2017-11-03T11:17:31Z	Landfill survey point
Shakaville	-29,33093199	31,30309003	32,287922	SSP25	2017-11-03T11:18:26Z	Landfill survey point
Shakaville	-29,33094498	31,30286104	33,067356	SSP27	2017-11-03T11:19:09Z	Landfill survey point
Shakaville	-29,33111002	31,30317704	25,695246	SSP28	2017-11-03T11:20:25Z	Landfill survey point
Shakaville	-29,33127204	31,30332003	21,127718	SSP29	2017-11-03T11:21:09Z	Landfill survey point
Shakaville	-29,32824198	31,30156503	36,023781	SSP3	2017-11-03T10:50:28Z	Landfill survey point
Shakaville	-29,33142602	31,30343	19,498177	SSP30	2017-11-03T11:21:41Z	Landfill survey point
Shakaville	-29,33165199	31,30351298	18,573463	SSP31	2017-11-03T11:22:25Z	Landfill survey point
Shakaville	-29,33137396	31,302307	21,655598	SSP32	2017-11-03T11:25:16Z	Landfill survey point
Shakaville	-29,33131898	31,30201899	16,443989	SSP33	2017-11-03T11:26:39Z	Landfill survey point
Shakaville	-29,33066703	31,30239601	35,406521	SSP34	2017-11-03T11:29:33Z	Landfill survey point
Shakaville	-29,33109803	31,30270002	29,380739	SSP35	2017-11-03T11:31:57Z	Landfill survey point
Shakaville	-29,33082604	31,30286196	33,812965	SSP36	2017-11-03T11:32:59Z	Landfill survey point
Shakaville	-29,33080902	31,30148599	16,94062	SSP37	2017-11-03T11:37:42Z	Landfill survey point

Shakaville GPS survey data

Shakaville	-29,33060601	31,30159998	26,84511	SSP38	2017-11-03T11:38:36Z	Landfill survey point
Shakaville	-29,32818096	31,30177902	29,18329	SSP4	2017-11-03T10:51:05Z	Landfill survey point
Shakaville	-29,330488	31,30178204	32,559101	SSP40	2017-11-03T11:39:27Z	Landfill survey point
Shakaville	-29,32979004	31,30130997	32,364819	SSP41	2017-11-03T11:42:25Z	Landfill survey point
Shakaville	-29,32963899	31,30152203	38,386013	SSP42	2017-11-03T11:43:47Z	Landfill survey point
Shakaville	-29,32931797	31,30187198	42,42767	SSP44	2017-11-03T11:44:47Z	Landfill survey point
Shakaville	-29,32948301	31,30388296	35,525211	SSP47	2017-11-03T11:48:32Z	Landfill survey point
Shakaville	-29,329381	31,30376201	34,285725	SSP48	2017-11-03T11:49:09Z	Landfill survey point
Shakaville	-29,329309	31,30331199	35,863811	SSP49	2017-11-03T11:50:08Z	Landfill survey point
Shakaville	-29,32852202	31,30208697	29,934334	SSP5	2017-11-03T10:52:22Z	Landfill survey point
Shakaville	-29,32927304	31,30303999	36,717503	SSP50	2017-11-03T11:51:04Z	Landfill survey point
Shakaville	-29,32931202	31,30243398	39,61314	SSP51	2017-11-03T11:52:37Z	Landfill survey point
Shakaville	-29,32914899	31,30215696	42,930065	SSP52	2017-11-03T11:53:26Z	Landfill survey point
Shakaville	-29,32901203	31,301934	44,575356	SSP53	2017-11-03T11:54:01Z	Landfill survey point
Shakaville	-29,32888504	31,301675	42,584724	SSP54	2017-11-03T11:54:38Z	Landfill survey point
Shakaville	-29,32871397	31,30156796	43,34866	SSP55	2017-11-03T11:55:07Z	Landfill survey point
Shakaville	-29,32860802	31,300985	46,604015	SSP56	2017-11-03T11:57:30Z	Landfill survey point
Shakaville	-29,32880399	31,30063397	41,837887	SSP57	2017-11-03T11:58:31Z	Landfill survey point
Shakaville	-29,32882201	31,30041403	40,249886	SSP58	2017-11-03T11:59:05Z	Landfill survey point
Shakaville	-29,32888898	31,30240498	29,113863	SSP6	2017-11-03T10:53:38Z	Landfill survey point
Shakaville	-29,32913197	31,30087201	35,775429	SSP60	2017-11-03T12:01:59Z	Landfill survey point
Shakaville	-29,32914999	31,30121802	38,088799	SSP61	2017-11-03T12:04:34Z	Landfill survey point
Shakaville	-29,32895604	31,30144198	44,581547	SSP63	2017-11-03T12:05:16Z	Landfill survey point
Shakaville	-29,329008	31,30260497	28,596386	SSP7	2017-11-03T10:54:39Z	Landfill survey point
Shakaville	-29,32911303	31,30274302	27,188845	SSP8	2017-11-03T10:56:26Z	Landfill survey point
Shakaville	-29,32901898	31,300467	39,923111	STARROADCROSS	2017-11-03T11:59:44Z	
Shakaville	-29,3301	31,3026	44	STP1	2017-11-03T08:17:17Z	Test pit
Shakaville	-29,3296	31,3023	44	STP2	2017-11-03T08:31:03Z	Test pit
Shakaville	-29,3296	31,3026	44	STP3	2017-11-03T09:00:52Z	Test pit
Shakaville	-29,3302	31,3031	40	STP4	2017-11-03T09:25:26Z	Test pit
Shakaville	-29,3302	31,3023	37	STP5	2017-11-03T09:40:16Z	Test pit
Shakaville	-29,3308	31,3023	34	STP6	2017-11-03T10:05:18Z	Test pit
Shakaville	-29,3311	31,3028	29	STP7	2017-11-03T10:14:00Z	Test pit
Shakaville	-29,329063	31,301727	45	STP8		Test pit

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Civilab
Civil Engineering Testing Laboratories

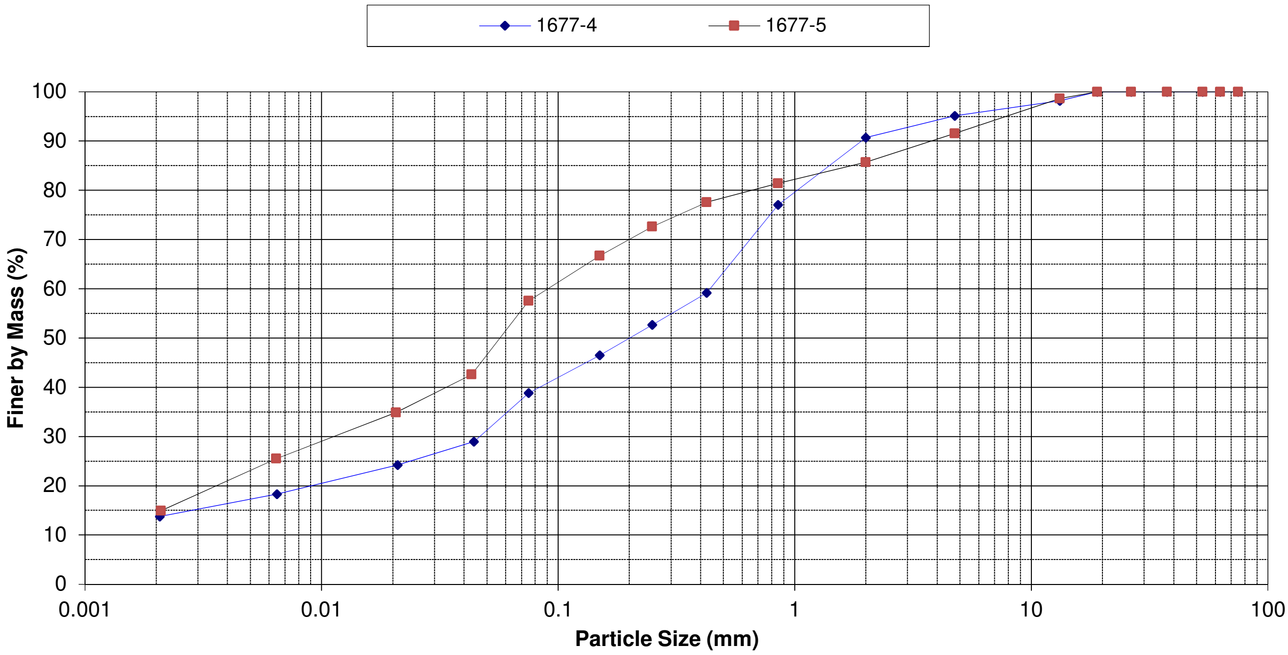
Foundation Indicator Test Data

Project	North Arrow Consulting - Glad Africa		
Project No.	2017-H-1677	Date	21 November 2017

Sample No.	1677-4	1677-5	
Field Ref. No.	SSTP3001	SSTP8001	
Depth	1-2m	0.7-1.4m	
Sieve size	%Passing	% Passing	% Passing
75.00	100	100	
63.00	100	100	
53.00	100	100	
37.50	100	100	
26.50	100	100	
19.00	100	100	
13.20	98	99	
4.75	95	91	
2.00	91	86	
0.85	77	81	
0.425	59	78	
0.25	53	73	
0.15	46	67	
0.075	39	58	
0.04	28	42	
0.02	24	34	
0.006	18	25	
0.002	14	14	

Sample No.	1677-4	1677-5	
%Gravel	9	14	
%Sand	56	34	
%Silt	21	37	
%Clay	14	14	
NMC %	Not Tested	Not Tested	
Liquid Limit	48	29	
Plasticity Index	23	12	
Linear Shrink.	10.5	6.5	
Overall P.I.	13	9	
Grading Modulus	1.11	0.79	
H.R.B.	A-7-6 (4)	A-6 (5)	
Unified	SC	CL	
Weston swell (%) at 1 kPa			

Analysis as per method D422 of ASTM of 1985
The results reported relate only to the samples tested.
Documents may only be reproduced or published in their full context.



Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse
	Silt			Sand			Gravel		

Remarks:

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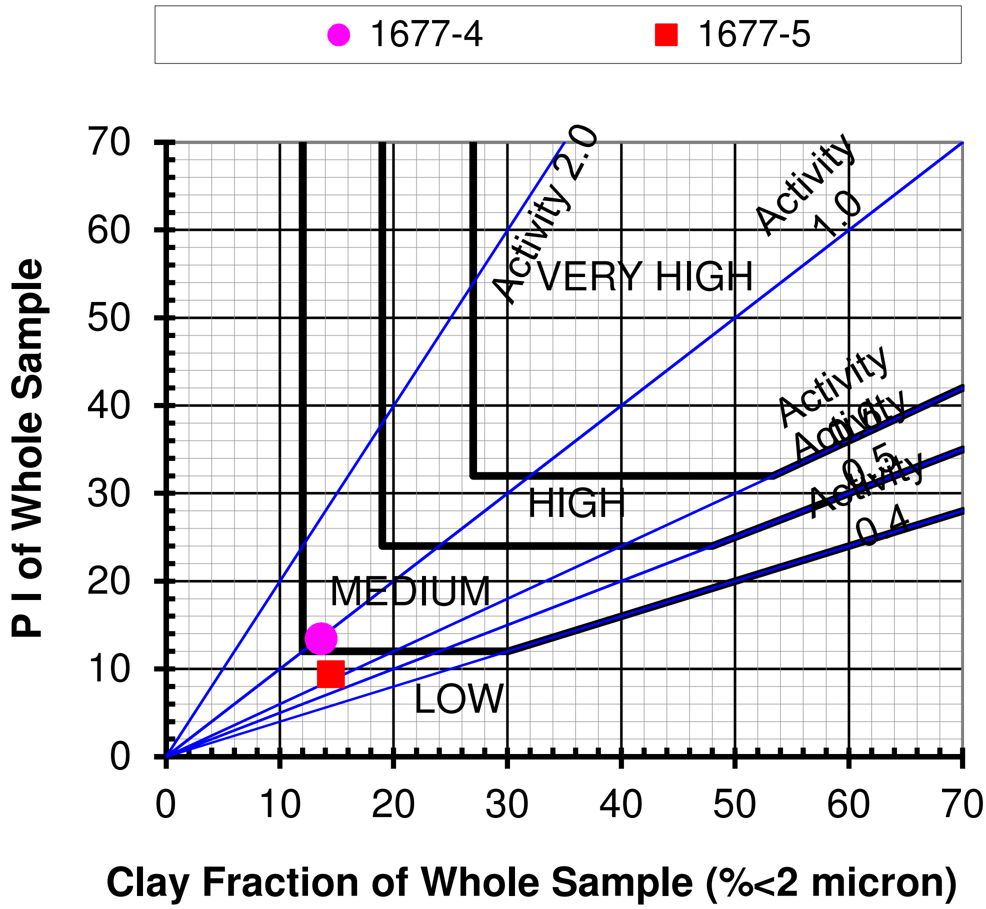
Activity Diagram After D H van der Merwe



Plotted Values:

Sample	Clay Frac	PI
1677-4	13.6	13.4
1677-5	14.5	9.4

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Civilab

Civil Engineering Testing Laboratories

Flexible Wall Constant Head Permeability Test Results

PROJECT:	Gladafrika	DATE : 24/11/2017
PROJECT No.:	2017-B-2665	

Field Sample Number	Sample Depth in metres	Moisture Content (%)		Dry Density (Kg/m³)	Co-efficient of Permeability (m/s)		
		Before Test	After Test		Range Minimum	Range Maximum	Average
SSTP3001	1.0-2.0	8.4	14.4	2004	1.8E-08	2.7E-08	**2.2E-08**
SSTP8001	0.7-1.4	11.3	16.9	1902	4.6E-10	4.9E-10	**4.8E-10**

REMARKS : Disturbed Sample
Effective cell pressure of 100 kPa
Pressure Difference = 20 kPa

Curriculum Vitae (CV) of Clement T. Rikhotso

BSc (Hons) UCT; PMD (GIBS); Pr.Sci.Nat; fGSSA; aSAIMM; aSAIEG

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SYNOPSIS:

Clement Rikhotso is a practicing geologist who has 23 years relevant mining industry experience primarily in the diamonds sector. He has operated in grassroots and brownfields exploration projects across the mine value chain in diverse countries and cultures (Canada, Russia, Angola, Botswana, South Africa). His contribution has led to some of these projects becoming profitable mines or life of mine extensions for the benefit of the shareholders. He has accumulated immense business, project management, drilling, mineral processing & recovery, laboratory, technical geosciences (mineral resources management) and senior leadership experience, in positions held with the De Beers Group of Companies, a member of Anglo American Plc.

He is experienced in operations management of exploration and resource evaluation projects involving multiple disciplines and areas of work. He is a Competent Person as contemplated within the SAMREC Code, with a proven track record of compiling acceptable reports on the technical aspects of a project. He also has a strong knowledge of safety, health, environment and community requirements, associated risks and control measures, particularly in sensitive areas of exploration activity. Other experience acquired from 1990 to 1993 is in gold, base metals and coal. He has previously served as an Executive Director of four De Beers Companies in South Africa, Botswana and Angola. Clement holds a Programme for Management Development (PMD) certificate from GIBS (University of Pretoria) and a BSc Honours Geology (UCT) degree with an Engineering Geology thesis. He is a registered professional (Pr. Sci. Nat Reg. no: 400111/05), a Fellow of the GSSA and Associate of the SAIMM and SAIEG, all in good standing.

Below is a summary of his credentials comprising practical Board, business, technical and senior management experience and exposure:

- Multi-jurisdiction Executive Board memberships, technical and senior leadership participation - critical inputs into project delivery and business custodianship.
- Project Management – Geological Discipline Lead application within multi-disciplinary capital projects through all stages (from Concept to Feasibility). Proven track record and ability to plan, co-ordinate, execute and deliver work programmes.
- Procurement of services (in particular drilling services) – tender technical scoping, specifications, costing (BOQ's), adjudication, award and contract management.
- Capital expenditure (Capex) and operating expenditure (Opex) budget accountability.
- People leadership – Development, coaching/mentoring and empowering of effective teams to deliver on set objectives.
- Implementation of strategic imperatives. Organisation change management.
- Mineral Resources Management - Mineral resources due diligence, assurance and audits.
- Stakeholder and relationships management.

PROFESSIONAL MEMBERSHIP

- South African Council for Natural and Scientific Professions (SACNASP) – Pr Sci Nat (Reg. no: 400111/05).
- Fellow of the Geological Society of South Africa (GSSA).
- Associate of the South African Institute of Mining and Metallurgy (SAIMM).
- Associate of the South African Institute for Engineering & Environmental Geologists (SAIEG).

BSc (Hons) UCT; PMD (GIBS); Pr.Sci.Nat; fGSSA; aSAIMM; aSAIEG

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KEY ACCOMPLISHMENTS

- 2014 - Led a restructure (as per RSA Labour Relations Act Sec. 189) of the De Beers Exploration Laboratory Services business.
- 2014 – Member of technical due diligence teams to review Rio Tinto's Bunder kimberlite diamond project in India and Perigrine's Chidliak project on Canada's Baffin Island.
- 2011-2012 - Accountability for the delivery of the Angola Mulepe-1 diamond resource evaluation capital project (~US$35M) supported by a Conceptual Study. A potential Tier 3 mine.
- 2005-2006 - Lead a team of geoscientists (geology/geotechnical, plant operators, logistics) and several contractors to evaluate (cost of US$30m over 2 years) and deliver an Indicated Resource for AK06 kimberlite which was the basis for further Conceptual Study and later a Feasibility Study decision. Project has since been divested out to Lucara Diamonds Plc. Now a profitable operating Karowe Mine in Botswana.
- 2004-2005 – Venetia Diamond Mine large diameter drilling project (~R200 million capital cost) to evaluate potential resources below current open pit mining. Major underground capital project currently underway based on this initial work.
- 1998-2000 - Leadership and technical management of Cullinan (formerly Premier) Diamond Mine C-Cut Block underground resource extension project. R30 million capital project expenditure.
- 1997 – Part of a Technical due diligence team which reviewed the River Ranch diamond mine in Zimbabwe for a potential acquisition transaction.
- 1996-1998 – Junior Technical Assistant to three respective Consulting Geologists and Senior Technical Assistants, responsible for Anglo/De Beers Group's diamond exploration and mine geosciences.

KEY LEADERSHIP ROLES (2007 to Feb 2016)

- 2007-Feb 2016, a member of De Beers Exploration senior leadership team reporting to the Head of De Beers Exploration who reports to the De Beers Technical Director.
- Coach and mentor Junior staff across several disciplines.
- Executive Director of De Beers Angola Prospecting Ltd, De Beers Centenary Angola Properties Ltd (Angola), De Beers Group Services (DBGS) Pty Ltd (South Africa) and De Beers Holdings Botswana (Pty) Ltd (Botswana).
- Chairman of De Beers Group Exploration RSA Employment Equity and Skills Development Committee and De Beers Group Exploration RSA Safety and Health Committee.
- De Beers Exploration-South Africa representative (Geology sub-committee) in the South African Minerals Education Trust Fund (METF).
- Member of the De Beers Diamond Product Security and Mineral Resource Management Peer Groups.
- Annual by-invitation-only attendance of the De Beers Group Strategic Leadership Conference (SLC).

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PROFESSIONAL EXPERIENCE (1994-Current)

ORGANISATION	POSITION	PERIOD FROM -TO		KEY PERFORMANCE AREAS AND ACHIEVEMENTS
North Arrow Holdings (Pty) Ltd	Founding Managing Director	May 2016	Current	Lead, manage, co-ordinate and optimise the business of Consulting and Advisory Services to the mineral resources and built-environment sectors
De Beers Exploration, Johannesburg	Senior Advanced Projects and Laboratories Manager - reporting to De Beers Head of Exploration (F Band). Patterson EL Band (or Towers Watson Level 5/14) position/grade since 2007	February 2012	February 2016	• Accountable for the delivery of De Beers kimberlite resource capital projects, which is the basis for determining economic mining viability. • Consultancy services to the Mining Divisions of De Beers such as Debswana (Botswana), De Beers Consolidated Mines (RSA) and De Beers Canada Mining. • Senior Management accountability for Safety and Health with objective for zero harm. • Oct 2013-Feb 2016: Additional management and leadership accountability for De Beers Exploration Laboratories (indicator mineral sorting, analytical, microdiamond and microdiamond recovery). • Feb-Oct 2012 - Technical Assurance (and acting General Manager/Operations Manager roles) role at De Beers Angola Prospecting, Lunda NE project deposit and resource evaluation work programmes (people, drilling, DMS treatment, diamond recovery (on-site & off-site) and chain of custody, portfolio management & reporting). Based out of Angola, Lucapa (Lunda NE province) exploration base camp. • Part of Diamond Control (DCT) and product security reviews as lead by Group Security specialists • Involvement in Job roles/profile design and grading committees. • Business coaching and mentoring of peer and subordinate professionals and general staff. • Change and diversity management. • Capex and Opex management.
De Beers Group Exploration, Johannesburg	Manager Advanced Projects, reporting to De Beers Head of Exploration Extensive travels to all exploration ventures in Angola, Botswana, India, Canada, Russia, DRC	2007	Feb 2012	• Accountable for the delivery of kimberlite resource capital projects, which is the basis for determining economic mining viability. • Responsibility for executing geotechnical and geohydrological projects and collecting information and data on behalf of engineering specialists. Siting for water wells using geophysical methods, drilling, yield/pump testing, and borehole equipping for the Mulepe community resettlement project at Lucapa town • Maintain close integration with the different exploration ventures to ensure accountability in moving new discoveries and brownfields kimberlite clusters from deposit through to resource levels and beyond. • Technical and general leadership for the kimberlite evaluation. Talent tracking and deployment of potential evaluation project managers. • Responsibility for the critical role of maintaining close liaison with Engineering and Mineral Resource

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ORGANISATION	POSITION	PERIOD FROM -TO		KEY PERFORMANCE AREAS AND ACHIEVEMENTS
				estimators to ensure constant integration as projects progress further. • Oversee the core disciplines of drilling and DMS treatment, which are key to the delivery of resource projects. Sapiential involvement in Diamond recovery facilities (micro and macrodiamond recovery) • Capex and Opex management.
De Beers Botswana Prospecting (Debot), Gaborone, Botswana	Senior Project Manager AK06 Resource Delivery Project	2005	2006	• Lead a team of geoscientists (geology and geotechnical) to evaluate (cost of US$30m over 2 years) and deliver an Indicated Resource which was the basis for further Conceptual and Feasibility Studies. Project has since been divested out to Lucara Diamonds Plc. Now a profitable operating Karowe Mine. • Supervision of geotechnical and geohydrological (e.g. siting using geophysical methods, drilling, pump testing, and borehole equipping, borehole dewatering) works.
De Beers Venetia Diamond Mine, Musina Limpopo Province, RSA	Project Manager-LDD, Resource Extension Project (REP)	2004	2005	• Start-up (LDD drilling, sample treatment, recovery) sampling programme (~R200 million capital cost) to evaluate potential resources below current open pit mining. Major underground capital project currently underway based on this initial work. • Drill contract negotiations, award and management. Recruit, train and manage a team of geologists and plant operators. • Review of geotechnical core logging data for design purposes. • Exposure to open pit mine planning, mining/grade control and ore processing & diamond recovery – reporting to Technical Services Manager (Survey, Geotechnical, MRM).
De Beers Canada Exploration Inc., Yellowknife (NWT) & Toronto (Ontario), Canada	Evaluation Project Manager	2001	2004	• Best Practice review of drilling, sampling and treatment methods and techniques for continual improvement. • Project Management (people, camp, teams, SHEQ) in the arctic regions. • Input into Strategic Business Planning. • 2001 Gahcho Kue 24-inch drilling programme – Database Management, Final drill report compilation, diamond results analysis. Evaluation Data handover to resource estimators. • Involvement in 24-inch large diameter drill evaluation and geotechnical logging programmes at Fort A La Corne, Attawapiskat and Gahcho Kue (now at mine construction stage). • Supervision of geotechnical drilling studies and geohydrological drilling (mine dewatering and exploration and development of potable water wells for camp sites).
DBCM Premier Mine C-Cut Feasibility Study Project, Cullinan,	Project Geologist, C-Cut resource evaluation reporting to the Feasibility	1998	2000	• Leadership and technical management of underground C-Cut Block resource evaluation using a 12-inch large diameter drill, 3 contract diamond core drills and a DMS treatment plant & off-site diamond

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ORGANISATION	POSITION	PERIOD FROM -TO		KEY PERFORMANCE AREAS AND ACHIEVEMENTS
Pretoria, RSA	Study Project Manager			recovery. R30 million project expenditure. • Geological database development, maintenance for geological modelling and ore resource estimation. • Supervision of geotechnical drilling and core logging for shaft sinking and infrastructure location and design purposes • Contractor co-ordination of geohydrological (mine dewatering) projects • Logging of top and sub-surface soil profiles for proposed shaft sinking purposes. • Routine and technical reporting to Project stakeholders and sponsors. • Exposure to underground block cave mine rock mechanics/engineering, planning, engineering, survey, mining, geology/grade control and ore processing (Red Ticket).
Anglo American Diamond Services Division (DSD) - Office of Diamond Consulting Geologists, Johannesburg, RSA	Junior Technical Assistant	1996	1998	• Assist (together with the Senior Technical Assistant) three De Beers Diamond Consulting Geologists in the management of worldwide diamond exploration activities. • Review of worldwide exploration projects and strategy. • Preparation of quarterly and annual reports. • Collation of annual worldwide exploration budgets (US$150 million). • General office management including re-archiving of worldwide exploration records. • Stakeholder relationships and management.
De Beers South Africa Exploration, Kimberley, RSA	Field exploration geologist	1995	1996	• Indicator mineral sampling, ground geophysical surveys and general prospecting for kimberlites in Limpopo (Lephalale, Thabazimbi, Musina, Modimolle areas), Northwest and Northern Cape Provinces. • 8-inch percussion and reverse circulation drilling of geochemical and geophysical exploration targets. • Soil profiling and centre line siting for geotechnical trench/excavation and sampling purposes at Venetia Mine Krone Endora alluvial mining project • Groundwater drilling supervision, yield testing and monitoring. • Geophysics - Ground gravity and aeromagnetic follow-up surveys. • Organisation of prospecting camp moves and logistics.
De Beers South Africa Exploration, Centurion Pretoria, RSA	Contract geologist	1994	1995	
Vocational jobs at Anglogold, Anglo American Prospecting Services (AAPS) Anglo Coal, De Beers Exploration		1990	1993	• Base metals exploration – geochemical soil sampling and ground geophysics • Underground gold and coal mining grade control (Red Ticket), core logging, sampling and 3D model generation • Reconnaissance soil sampling for diamonds

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KNOWLEDGE, CAPABILITY AND SKILLS SET

√ Safety and Health
  - Accountable and responsible SHEQ Practices, Safety and Health Risk Management Programmes & Systems

√ Business, strategy and tactics
  - Sound business acumen, entrepreneurial and continuous improvement mindset.
  - Sound understanding of supply chain, procurement, management of contracts/contractors and general project management.
  - Financial management (capex and opex budgets) and Internal audit exposure.
  - Management of JV's and relationships.
  - Exposure to complex decision-making, strong communications and multi-stakeholder management environments.

√ Leadership, Management and People
  - Passionate and self-motivated about exploration and mining and culture of high performance to deliver results.
  - Networking and collaboration. Organization change and design.
  - Experience in people capability models (mental processing ability, social processing skills, technical skills)
  - Diversity awareness (and company business imperatives) and ability to adapt and effectively work in different cultures and challenging environments.
  - Design of technical competencies and skills (and career paths) for earth geoscientists.

√ Geosciences
  - Development and implementation of technical operating and compliance/assurance frameworks.
  - Management of exploration (activities and outputs) from early stage to advanced stages (resource evaluation) and mining.
  - Moderate working experience in mine operations - mine geology, metallurgy (mineral processing and recovery), survey, engineering, mine planning and production. Mine value chain optimisation.
  - Application of - mineral systems principles, sampling theory and methods, geostatistics, geology, databases, geophysics, GIS, geochemistry, geological mapping, core logging, 3D geological and geo-metallurgical modelling, resource estimation techniques, project management principles
  - Technical due diligence, assurance and audits – drills, treatment plants and diamond recovery.
  - Exposure to mineral economics and financial valuation of mineral projects.
  - Interpretation and dissemination of geoscientific data.
  - Drilling strategies and methodologies. Operational drilling services procurement (technical scopes, BOQ's, adjudication, appointment) and contract management.
  - Experience and exposure in multi-disciplinary mine development projects.
  - Competent Person ("CP"), Compliance and reporting of results as contemplated within international Codes (JORC, SAMREC, NI43-101) and/or listing requirements

BSc (Hons) UCT; PMD (GIBS); Pr.Sci.Nat; fGSSA; aSAIMM; aSAIEG

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√ Engineering Geology

- Stages and levels of Geotechnical Investigations.
- Site Investigation Code of Practice – The Geotechnical Division of SAICE.
- Standard Specifications for Subsurface Geotechnical Investigations.
- Guides to Infrastructure Delivery and Procurement.
- Site investigations - soil profiling, geotechnical logging and laboratory testing.
- Hydrogeology – hydrocensus, water exploration, well development, equipping and water testing programmes. Dewatering programmes.

EDUCATION AND QUALIFICATIONS

QUALIFICATIONS	INSTITUTION	DATE
Certificate: Technical and financial evaluation of mineral projects	Imperial College London	2013
Directorship training (in-house) - Companies Act/King 1-3/Duties of Directors	Institute of Directors (IOD), South Africa	2007-2010
Certificate: Programme for Management Development (PMD)	Gorgon Institute of Business Science (GIBS), South Africa	2001
BSc (Honours) Geology Honours Thesis title: Effects of structure and mineralogy on the shear strength characteristics of residual soils in the Cape Peninsula and some South African soils	University of Cape Town, South Africa	1990-1993

BIOGRAPHIC DETAILS

Date of Birth : 19 November 1972

Languages : English, Afrikaans, XiTsonga (home language), IsiZulu, SeSotho, Portuguese (very basic, incomplete formal lessons)

Health : In good health, mentally and physically fit

Personal Mastery : Getting things done right, humility, team contribution, leadership by example - inspire, coach/mentor, pursuit of excellence.

Mobility : Highly mobile and flexible

REFERENCES

Upon request

edtea
Department :
Economic Development, Tourism and Environmental Affairs
PROVINCE OF KWAZULU-NATAL

Details of specialist and declaration of interest

in terms of the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008), and the Environmental Impact Assessment Regulations, 2014

Reference number:	DC29/0025/2017
Project title:	*Basic Assessment for the proposed Decommissioning (Closure) of the Shakaville Landfill, KwaDukuza Local Municipality, KwaZulu Natal Province*

Specialist:	Clement Rikhotso		
Name of company:	North Arrow Consulting and Advisory Services (Pty) Ltd		
Postal address:	Postnet Suite 319 P/Bag x121 Halfway House		
Postal code:	1865	Cell:	0833068328
Telephone:	011 318 0417	Fax:	
E-mail:	clement.rikhotso@northarrowholdings.co.za		
Qualifications:	Bsc (Hons)		
Professional affiliations:	Pr.Sci.Nat; fGSSA; aSAIMM; aSAIEG		
Expertise:	Engineering Geosciences (Geotechnical, Geohydrology), Drilling, Mineral Resources Management		

EAP:	Nyaladzi Nleya		
Name of company:	GA Environment (Pty) Ltd		
Postal address:	P.O Box 6723, Halfway House		
Postal code:	1685	Cell:	0761479451
Telephone:	011 312 2537	Fax:	27 11 805 1950
E-mail:	environment@gaenvironment.com /nyaladzin@gaenvironment.com		

Declaration by the specialist

I, Clement Talani Rikhotso, declare that --

- I act as the independent specialist in this application;
- I do not have and will not have any vested interest (either business, financial, personal or other) in the undertaking of the proposed activity, other than remuneration for work performed in terms of the EIA Regulations, 2014;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Waste Act and NEMA, regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Waste Act and NEMA, regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I am aware that a person is guilty of an offence in terms of Regulation 48 (1) of the EIA Regulations, 2014, if that person provides incorrect or misleading information. A person who is convicted of an offence in terms of subregulation 48(1) (a)-(e) is liable to the penalties as contemplated in section 49B(1) of the National Environmental Management Act, 1998 (Act 107 of 1998).

Signature of the specialist

North Arrow Consulting and Advisory Services (Pty) Ltd

Name of company

09 January 2018

Date