Investigation of the impact of pit latrines on groundwater in Matlerekeng area

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ABSTRACT

South Africa is one of the developing countries in the world which is dominated by rural areas. In such countries supplies of basic services such as water and sanitation facilities are a challenge. As a result, the available water sources become compromised. The Department of Water and Sanitation developed a National Water Resource Strategy (NWRS) to help to address such problems across the country.

The area under study is Matlerekeng which is commonly known as Zuurbekom under EMLM. The area was developed during the apartheid era when town planning schemes where not effective. As a result, the community is scattered which makes the distribution of services costlier and the internal roads are also not properly planned. As a result, the community members use pit latrines for sanitation and abstract water from boreholes for domestic use. Pit latrines are known to be common causes of groundwater pollution in rural areas.

Groundwater pollution is accelerated by different factors such as the type of aquifers, the soil and the topography of the area. The soil nutrients might also contribute to contamination of groundwater. *E. coli* is the most common bacteria found in human excreta. The presence of these bacteria in groundwater in most cases depends on the availability of pit latrines, sewage and agricultural activities.

For the determination of the pollution of groundwater by pit latrines in the Matlerekeng area, samples from domestic boreholes were taken for analysis. The chemical parameters such as nitrate and ammonia together with *E. coli* bacteria were analysed. The samples were collected using specified bottles as per groundwater sampling guideline by Department of Water and Sanitation (WRC, 2007) and taken to accredited laboratories for analysis.

The sampling points were selected randomly in the area depending on availability and use. The results were analysed and compared to the South African National Standard (SANS), 2015 water guidelines for domestic use. In addition, the vulnerability of the aquifer to pollution was also determined.

Key terms: Pollution, groundwater, pit latrines, borehole samples, human waste, water quality parameters, sanitation services.

LIST OF ABBREVIATIONS

ATSDR	Agency for Toxic Substances and Disease Registry
BWA	Borehole Water Association
Cfu	Colony-Forming Unit
EMLM	Ephraim Mogale Local Municipality
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
DWAF	Department of Water Affairs and Forestry
GIS	Geographic Information System
GRIP	Groundwater Assessment Information Project
GPS	Global Positioning System
IDP	Integrated Development Plan
Mg/l	Milligram per Litre
Mm/a	Millimetres per annum
Mm^3/a	Cubic millimetres per annum
NGA	National Groundwater Archive
NWA	National Water Act No 36 of 1998
NWRS	National Water Resource Strategy
PGDS	Provincial Growth and Development Strategy
SABS	South African Bureau of Standards

SANS	South African National Standard
WHO	World Health Organisation
WRC	Water Research Commission
VIP	Ventilated Improved Pit latrines

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CHAPTER 1 INTRODUCTION AND PROBLEM STATEMENT

1.1. Introduction

Fundamental principles of the National Water Act (NWA) No 36 of 1998 were drafted to ensure a sustainable share of water resource whereby the need for present and future allocation is not compromised (DWAF, 1998). It further indicates that the natural resources need to be protected to promote social and economic development through the use of water (DWAF, 1998).

The study area is Matlerekeng, one of the rural villages in the Limpopo Province. Matlerekeng falls under the Ephraim Mogale Local Municipality (EMLM) in Sekhukhune District Municipality. The area under study is still developing and services such as water and sanitation are still a challenge (EMLM, 2011). As a result, communities resort to using available resources for living. In most of the households, communities abstract groundwater through boreholes for domestic use. For sanitation Ventilated Improved Pit (VIP) toilets are used; however, some households still use old-fashioned pit latrines (Templeton *et al.,* 2015).

Odiyo and Makungo (2012) revealed that pit latrines are prone to cause pollution of groundwater especially in areas of shallow aquifers. A study conducted in Limpopo from 1970-1999 revealed that about 42% of boreholes assessed were not suitable for consumption prior to treatment due to high concentrations of nitrates, fluorides and other physicochemical pollutants (Odiyo & Makungo, 2012). The study by Chidavaenzi *et al.* (1997) recommends investigations of groundwater pollution arising from core existing pit latrines and boreholes in the rural areas of the Limpopo province.

Henceforth, the investigation of the geohydrological profile and the geographical set-up of the study area and possible pollution by pit latrines is significant and needs to be undertaken. The determination of pollution will be conducted by the sampling of the groundwater (DWA, 2003) from different domestic boreholes and analysis of samples. A qualitative method will be followed henceforth the result of the study will provide the status of the quality of groundwater in the area.

1.2 Problem statement

The study area falls under local municipal management as most basic services are offered by the municipality. Some of the community members use domestic boreholes as a water source and pit latrines for sanitation purposes (EMLM, 2011). Most of these pit latrines are situated in a corner of their yard less than 70m from the boreholes. The leachate from the pit latrines contains some pathogens and chemicals which might pollute the groundwater.

According to the EMLM (2011) the study area is characterised by sandy soil which is considered permeable and easily allows seeping of pollutants into the groundwater system (DWAF, 2003). The delay in allocation of basic sanitation might accelerate the health threat to the community members using groundwater for drinking purpose. Henceforth the need to understand the geohydrological profile of the area, and to establish potential pollution of the groundwater by use of pit latrines.

1.3 Research aims and objectives

The aim of the research is to investigate the impact of pit latrines on groundwater in the Matlerekeng area and to provide possible solutions. The aim will be achieved through the following objectives:

- to investigate the status of groundwater quality of the area whereby parameters such as nitrate, ammonia and *E. Coli* bacteria will be assessed. Additionally, the sample analysis results will determine the impacts;
- to recommend possible solutions.

1.4 Layout of mini-dissertation

Chapter 1: Introduction – this chapter outlines the background of the study, the purpose and the research objectives.

Chapter 2: Literature review – the work conducted by other authors in relation to the groundwater pollution by pit latrines will be reviewed. Possible solutions will also be assessed.

Chapter 3: Study area - information regarding the study area will be presented.

Chapter 4: Methodology – the method used to collect data will be analysed. The sampling points where the study was done will be presented and maps are attached. The sampling for chemicals and microorganism as well the procedure for collecting water samples, types of bottles used, and preservation methods are presented in this chapter. The South African National Standard SANS 2015 was used to assess the presence of pollutants. Calculating the vulnerability of the groundwater system and protection of boreholes will also be discussed.

Chapter 5: Results – the results of the study will be discussed in this chapter.

Chapter 6: Conclusions and recommendations – a discussion of the entire investigation and the results will follow. Recommendations will be presented.

CHAPTER 2 LITERATURE REVIEW

2.1 Background

After 23 years of democracy, South Africa still has rural areas that are struggling with access to basic services such as potable water supplies and proper sanitation facilities. A study by Dzwairo *et al.* (2006) indicates that larger part of the population living in African rural areas represents approximately 70–80% of the continent’s population. These rural areas are characterised by poverty and lack of services, hence the study by Aheneka and Adeoye (2013), revealed that 24 % of populations in such areas depend on groundwater for survival.

Additionally, pit latrines are considered a common means of ablution in most developing countries in the world (Graham & Polizzotto, 2013). The World Health Organisation (WHO) (2001) estimated that approximately 1.1 billion people around the world use pit latrines as a primary means of sanitation, while 2.4 billion lack access to improved sanitation (Brikkie & Bredeo, 2003). Because of the increasing use of both pit latrines and groundwater resources (Brikkie & Bredeo, 2003) in low income countries, there are concerns that pit latrines may pollute groundwater due to the presence of microbiological and chemical pollutants (DWAF, 2003).

In 2012, Odiyo and Makungo revealed that water pollution is a major threat to the scarce water resources. However, a study by Kiptum and Ndambuki (2012) and Anabella *et al.* (2014), indicates that groundwater is generally of good quality and requires less treatment. Aheneka and Adeoye (2013) recommend the use of water from boreholes only if a proper siting method for construction of pit latrines is employed. Henceforth, factors such as soil type, topography, aquifer type and the distance between the pit latrines and the borehole are considered before installation.

DWAF (2003) recommends that a borehole should be installed as far as possible from activities and environment which can impact negatively on the water quality. Such activities include the location of pit latrines near households’ boreholes. The study by Kiptum and Ndambaki (2012) supported by Dzwairo *et al.* (2006) and Sugden (2006), recommend reasonable distance between the pit latrine and water sources. The longer the distance from water source the more pollutants will die off naturally along the way.

However, bacteria associated with faecal waste could travel in restricted areas through the soil (Sugden, 2006).

2.2. Water supply and sanitation in study area

According to EMLM (2010) Integrated Development Plan (IDP), Ventilated Improved Pit latrines (VIP) toilets were planned to be constructed in each household in Moutse West. Moutse West is the region where Matlerekeng is located. Due to a backlog, the project was carried to the next IDP cycle of 2011-2016. The 2017/2018 IDP indicates that the construction of VIP toilets in the Moutse area has not been completed (EMLM, 2017).

Due to the predominantly rural character of the municipality's area of jurisdiction there is no bulk water provision in most of the villages in Moutse West (EMLM, 2011). Water is provided by means of water tanker trucks and boreholes (EMLM, 2011). It was indicated that the provision of bulk reticulation and cost recovery in Moutse West were to be implemented in 2011/12 according to water sector programme Provincial Growth & Development Strategy (PGDS) targets.

Currently, the Sekhukhune District Municipality is developing a bulk water Master Plan which will assist in investigating the alternative means of providing water services to some areas within the municipality (EMLM, 2017/18). The results showed that groundwater abstraction is the best option for now and it will have continued in to be near future.

2.3.1 Assessment of groundwater vulnerability

According to Dzwairo *et al.* (2006), a hydrogeological condition is considered one of the significant factors which affect the groundwater pollution. In assessing the impact of hydrogeological condition, the ground water vulnerability will be considered whereby the effect in saturated and saturated zone of the ground water will be assess (Babiker *et al.,* 2005). In this study, the DRASTIC method was used whereby factors such as aquifer media, soil media, net recharge, topography, depth of the groundwater, hydraulic conductivity and impact of the vadose zone are considered. In this study the modified version of the DRASTIC method is used as in Lynch *et al.* (1994). The reasoning behind this is that hydraulic conductivity values for fractured groundwater systems are difficult to calculate accurately due to the high variability of this parameter over short distances Lynch *et al.* (1994).

2.3.2 The aquifer media

The type of aquifer also plays important role in determining the pollution of the ground water. The more fractured and the higher the permeability of the rock, the higher the vulnerability (Musekiwa & Majola, 2013).

Allen *et al.* (1987) indicate that the path length, hydraulic conductivity and gradient determines the time available for attenuation process such as sorption, reactivity and dispersion of pollutants in an aquifer. Studies by Graham and Polizzotto (2013), and (Allen *et al.,* 1987) revealed that a fractured aquifer promotes movement of microbial pollutants and determine route which pollutants will take. The larger the grain size, the more the fracture within an aquifer, higher the permeability and the lower the attenuation capacity hence the greater the pollution.

2.4.1 Soil media

Soil medial is the uppermost portion of the vadose zone which is characterised by significant biological activity. It has a significant impact of the amount of recharge which can infiltrate into the ground, and the ability of the pollutant to move vertically into the vadose zone (Allen *et al.,* 1987). The areas where soil layer is thick, the attenuation process of filtration, biodegradation, sorption and volatilisation may be quite significant. The soil texture also determines the permeability of pollutant into the aquifer (Allen *et al.,* 1987).

Sandy soil is highly permeable with low absorption capacity which acts as an effective agent for the movement of pollutants through the sand layer (Musekiwa & Majola, 2013 and DWAF, 2003). Sandy soil is free of clay and silt with soil particles ranging from 1,16mm to 2mm (Allen *et al.,* 1987). Although, sandy soil is highly permeable with a low absorption capacity, it is often able to create conditions that form an effective barrier for the movement of pollutants through the sand layer (DWAF, 2003).

Clay soil is less permeable and as a result reduces the rate of flow (Musekiwa & Majola, 2013) and prevent movement of pollutants. A study by Sugden (2006) indicates that clay soils have the capacity to absorb viruses and prevent their passage to the saturated zone (Sugden, 2006). According to Allen *et al*. (1987), Clay soil has the potential to form cracks when wetting dry-up which as a result increase the permeability hence the filtration of pollutants.

Gravel soil normally consists of sand, silt and clay particles, with large-sized particle (Allen et.al, 1987). It particles normally ranges between 2-3mm particle. In most cases, gravel media is found within a fractured zone, may both allow rapid movement and minimal absorption of pollutants (DWAF, 2003).

2.4.2 Net recharge

Precipitation is a primary source of water which eventually infiltrate the surface through to the water table. The net recharge indicates the amount of water per unit area of land which penetrate the ground surface and reaches the water table and horizontally within the aquifer. The net recharge determines the quantity of water available for dispersion and dilution in the vadose zone and in the saturation zone. In areas where an aquifer is unconfined, recharge occurs rapidly, and pollution potential is greater than in areas with confined aquifers.

2.4.3 Topography

Aheneku and Adeoye (2013), indicate that topography plays a role in the distribution of pollutants in groundwater. In areas of low slope there is a greater chance of the pollution infiltrating the aquifer as opposed to areas of high slope Musekiwa and Majola (2013). Topography has a potential for pollutants to run off or remain on the surface in one area long enough to infiltrate into the ground water Allen *et al.* (1987).

In areas where pollutants are cumulative, the greater the infiltration, the higher the pollution potential as associated with slope. Additionally, Allen *et al.* (1987) revealed that topography also influences soil development, and therefore affects the attenuation of water movement. It is also significant for the gradient and direction of flow that often can have an influence on the water table conditions from the general slope of land. The steeper the slope signifies higher rain-water velocity (Allen *et al.* 1987).

A 0-2% slope provides the greatest opportunity for pollutants to infiltrate hence fewer run-offs or pollutants infiltrate the surface. 18% or more percent slope warrants high run-off capacity therefore lesser probability of infiltration with subsequent lower pollution potential (Allen *et al.* 1987.

2.4.4 Hydraulic conductivity of the aquifer

According to Allen *et al.* (1987) the hydraulic conductivity of aquifer transmits water, which in turn, control the rate at which ground water will flow under given hydraulic gradient. The rate at which water flow controls the rate at which pollutants will be moved away from the point at which it enters the aquifer. Hydraulic conductivity is controlled by the amount and interconnection of void spaces within the aquifer which may occur as consequences of intergranular, porosity, fracturing, bedding planes etc. (Allen *et al.,* 1987).

2.4.5 Depth of the groundwater

Depth of the ground water determines the ground water sensitivity (DWAF, 2003) since it represents the distance travel by the pollutant through the unsaturated zone. Allen *et al.* (1987) describe the depth of an aquifer as the depth to the water surface in an unconfined aquifer or to the aquifer where the aquifer is confined. The depth determines distance from surface which pollutants must travel before reaching the aquifer.

It also determines the amount of time during which contact with other surrounding media is maintained. Allen *et al.* (1987) indicated that the depth of the aquifer, provides the maximum opportunity for oxidation by atmospheric oxygen. The greater the attenuation occurs as the depth to the water increases because deep water levels infer longer travel times (Allen *et al*. 1987; Sugden, 2006). Studies by Aheneku and Adeoye (2013), recommend that, to reduce concentration of pollutant reaching ground water pit latrines must be constructed at 2m above the water table.

2.4.6 Unsaturated zone/vadose zone

The unsaturated zone is the first layer of the ground water and is considered the first line of natural defence against pollution of the groundwater (Holden *et al.,* 2005). It is commonly known as a vadose zone. The vadose zone has low water content relative to the saturated zone below the water table (DWAF, 2003). Above the capillary fringe, vadose-zone pore spaces are generally air-filled (Holden *et al*., 2005) with thin water films coating solid particles. Pore spaces become water-filled when rainfall percolates, followed by drainage and gradual drying.

According to Musekiwa and Majola (2013), the vadose zone contains natural organisms which have the ability to break down pollutants into secondary products. However, Allen et al.(1987 indicate that the reduction of pollution in the unsaturated zone is a function of the rate of flow through the unsaturated zone, the type of pollutants, and the capacity of the media to adsorb pollutants or create an effective barrier to the movement of pollutants, e.g. through filtration.

2.4.7 Saturated zone

In the saturated zone, where rapid groundwater movement takes place, dilution and dispersion also take place. Passage of water through aquifers may take years or decades rather than days (DWAF, 2003). In cases of deeper aquifers, in areas where groundwater is extracted for domestic use, an understanding of area recharge, rate of flow and flow direction is important in minimizing and or controlling groundwater pollution (DWAF, 2003). Flow rate below the water table will be increased by pumping because a cone of depression is formed around the pump extraction point (DWAF, 2003).

2.5 Assessment of pollution indicators

2.5.1 Microbiological pollution of groundwater

Faecal coliform bacteria have been used as indicators of pollution caused by humans and other warm-blooded animals (WRC, 2007). These bacteria normally grow in the large intestines (colon) of humans and are present in high numbers in the faeces of humans. They are also present in the waste of other warm-blooded animals such as birds and mammals and may reach water bodies through faecal discharge. According to WRC (2007) guideline, these coliform organisms can ferment lactose at 44.0ºC to 44.5ºC within 48 hours or two days.

Microbiological quality of groundwater in relation to pit latrines applied culture-based assays to measure faecal indicator bacteria such as Escherichia coli (previously known as Bacillus coli), which occur in high concentrations in faeces (Pitkanen *et al.,* 2011) of healthy adults and have epidemiological evidence to support their use as indicators of water quality (WRC, 2007). Dzwairo *et al.* (2006) indicate that communities who consume groundwater where pit latrines are within reach, are at risk of consuming water polluted with faecal coliforms.

2.5.2 Chemical parameters

2.5.2.1 NITRATE

Nitrate is an essential source of nitrogen for plants when nitrogen fertilizers are used to enrich soils. Nitrates may be carried by rain, irrigation and other surface water features through the soil into the groundwater (Templeton *et al.,* 2015). Human and similar waste can also contribute to nitrate pollution of groundwater. Nitrate in water cannot easily be detected because it is odourless, colourless and tasteless. Other sources of nitrate in groundwater are on-site waste water disposal sites, septic tanks, solid waste sites and landfill sites (Templeton *et al.*, 2015)

Templeton *et al.* (2015), mentioned that solid waste is made of urea plus urine and various forms of organic nitrogen in faeces and the biodegradation of the waste within the pit latrines. Graham and Polizzotto (2013) indicate that nitrate has been associated with faecal pollution due to the high concentration of nitrogen in human excreta. However, nitrate can be derived from sources such as plant debris, animal manure, garbage, reposition, livestock pens and soil fertilizers (Templeton *et al.,* 2015).

The study by Kiptum and Ndambuki (2012) shows that concentration of nitrate is in almost all samples from boreholes in both the dry and wet seasons and exceed the limit of 50 mg/l of WHO guideline. Templeton *et al.* (2015), mentioned that nitrate is mobile in the subsurface and it is difficult to remove from a water environment.

High concentrations of nitrates make groundwater unpalatable for human consumption (WRC, 1998). The preferred level of nitrates in groundwater is less than 10 mg/l but concentration above 20 mg/l can cause significant health risk to humans (WRC, 1998). According to Nash and Still (2002), nitrate concentrations in water are reduced by dilution and the natural denitrification processes in the soil. SANS (2015) established specifications for drinking water to regulate the minimum level of pollutants. The level of nitrate allowed in a class 0 water is limited to <6.0 mg/l (SANS, 2015).

2.5.2.2 AMMONIA

Ammonia is produced naturally from decomposition of organic matter, including plants, animals and animal waste (Lingle, 2013). In the environment, ammonia is part of the nitrogen cycle and is produced in soil from bacterial processes. Ammonia is also produced naturally in a human body and in water, soil and air. In human health, ammonia and ammonium ions are vital components of the metabolic process. The human body makes ammonia when the body breaks down foods containing protein into amino acids and ammonia, then converting the ammonia into urea.

The study by Graham and Palizzotto (2013) also used ammonia as an indicator of groundwater pollution by pit latrines. Dzwairo *et al.* (2006), observed only one incident of ammonia >15mg/l in borehole water that was microbiologically polluted by pit latrines. In most studies conducted previously, the concentration of ammonium was found to be below the SANS of 2ml/l. Lewis *et al.* (1980) found 0.2 mg/l and 3 mg/l respectively in two samples.

A study by Dzwairo *et al.* (2006) revealed that ammonia tends to accumulate and persist under anaerobic conditions and high concentrations are likely when the water table intersects the base of the pit latrines.

CHAPTER 3 BACKGROUND OF THE STUDY AREA

3.1 Study area

3.1.1 Location

The study area known as Matlerekeng is located at S 24º 59′ 28,4″; E 029º 04′ 24.3″. The area is situated in the south-western part of the EMLM within the Limpopo Province. Rathoke is approximately 6 km to the north of Matlerekeng. To the east are ward 5 villages. Commercial farming activities are taking place approximately 5 km to the east of the study area. Matlerekeng Village has 697 households with a total of 3832 residents, while Rathoke has 666 households with total population of 3330. Matlerekeng is located adjacent to the N11 with the town of Marble Hall being 25 km to the east of Matlerekeng.

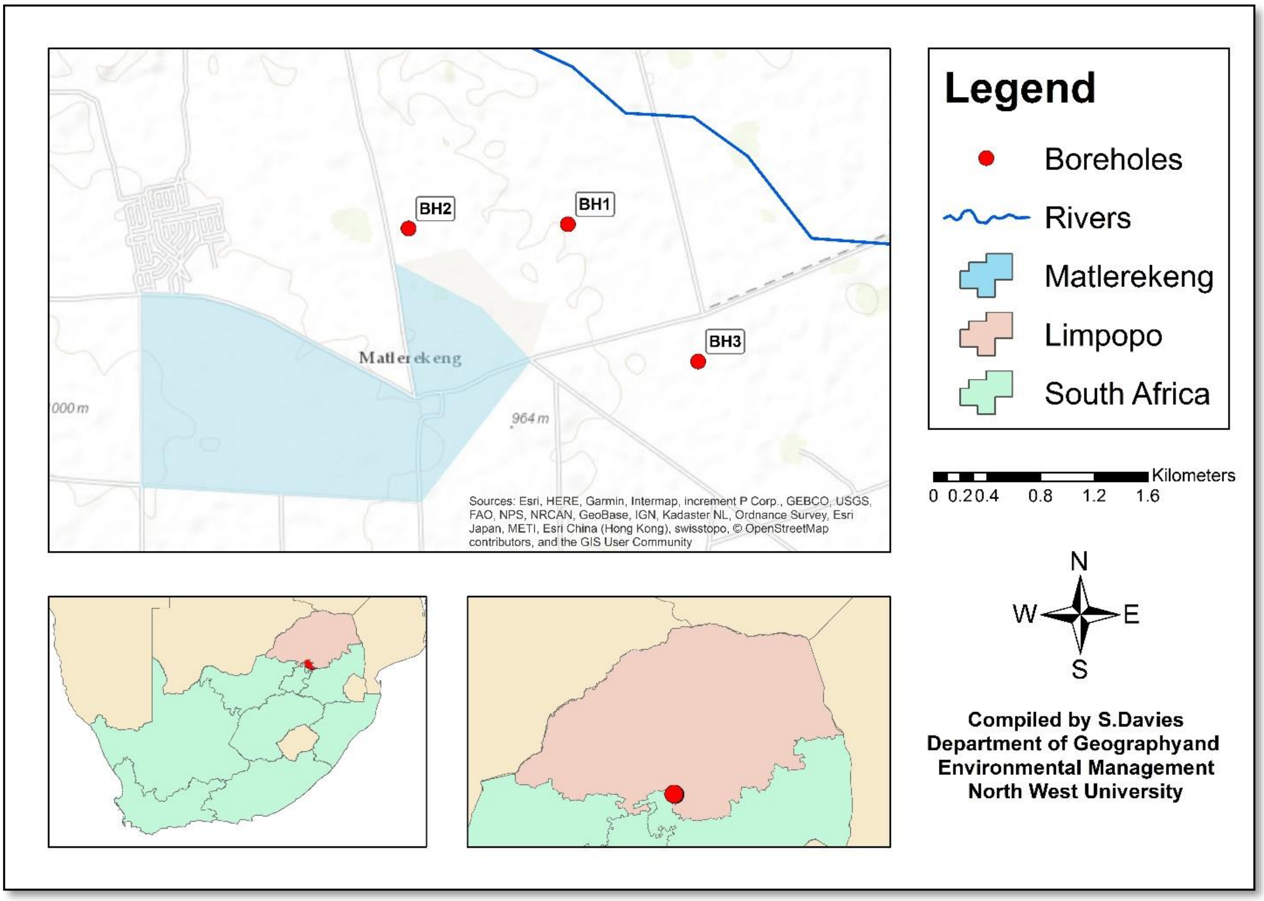

Figure 1: Study area

The most dominant land use in the area is both subsistence and small-scale commercial farming (Photo 1). There are also forestry plantations scattered within the area (Figure 2).

Photo 1: Farming activities

Furthermore, other land uses are the residential areas where in the eastern part there are scattered households and municipal offices, taxi ranks and recreational facilities in the southern part.

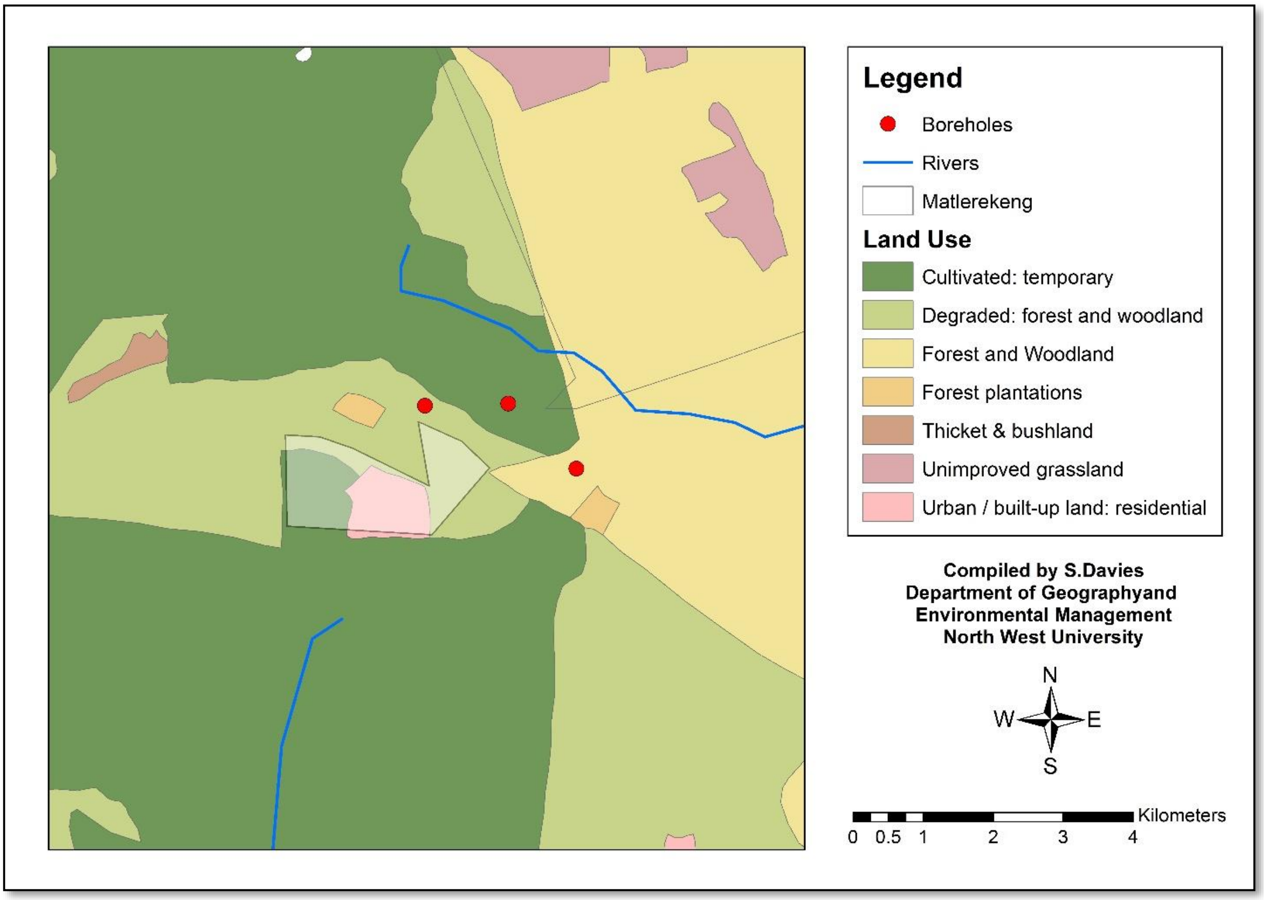

Figure 2: Land use

3.1.2. Topography and drainage

The study area falls on the boundary of two quaternary catchments, namely quaternary catchment B31J in the north and B31H in the south. More information regarding these catchments is documented in Table 1.

Table 1: Information regarding quaternary catchments (Aquiworx, 2014)

Catchment	Size (km^2)	Rainfall (mm/a)	Mean annual runoff (Mm^3/a)	% No flow in rivers	Baseflow (Mm^3/a)	Present ecological status
B31J	1380	552	6	51	0	D[1]
B31H	612	575	15	0	5	D

[1] Moderate levels of widespread impacts – limited but noticeable effect on the environment.

In the northern sections there is non-perennial Droëkloofspruit and the Kareespruit which flow in a southerly direction (Figure 3). To the south-west of the municipal area is the Olifants River which is located on an open floodplain area and to the north, the river is located in a valley surrounded by the Strydpoort Mountains (parallel hills and lowlands). Strips of erosion can be found in the valleys alongside most of the perennial and non-perennial rivers (EMLM, 2011).

The topography within the area is relatively flat. There are some small hills in the vicinity of the area with slopes that vary between 900 and 920 m above sea level.

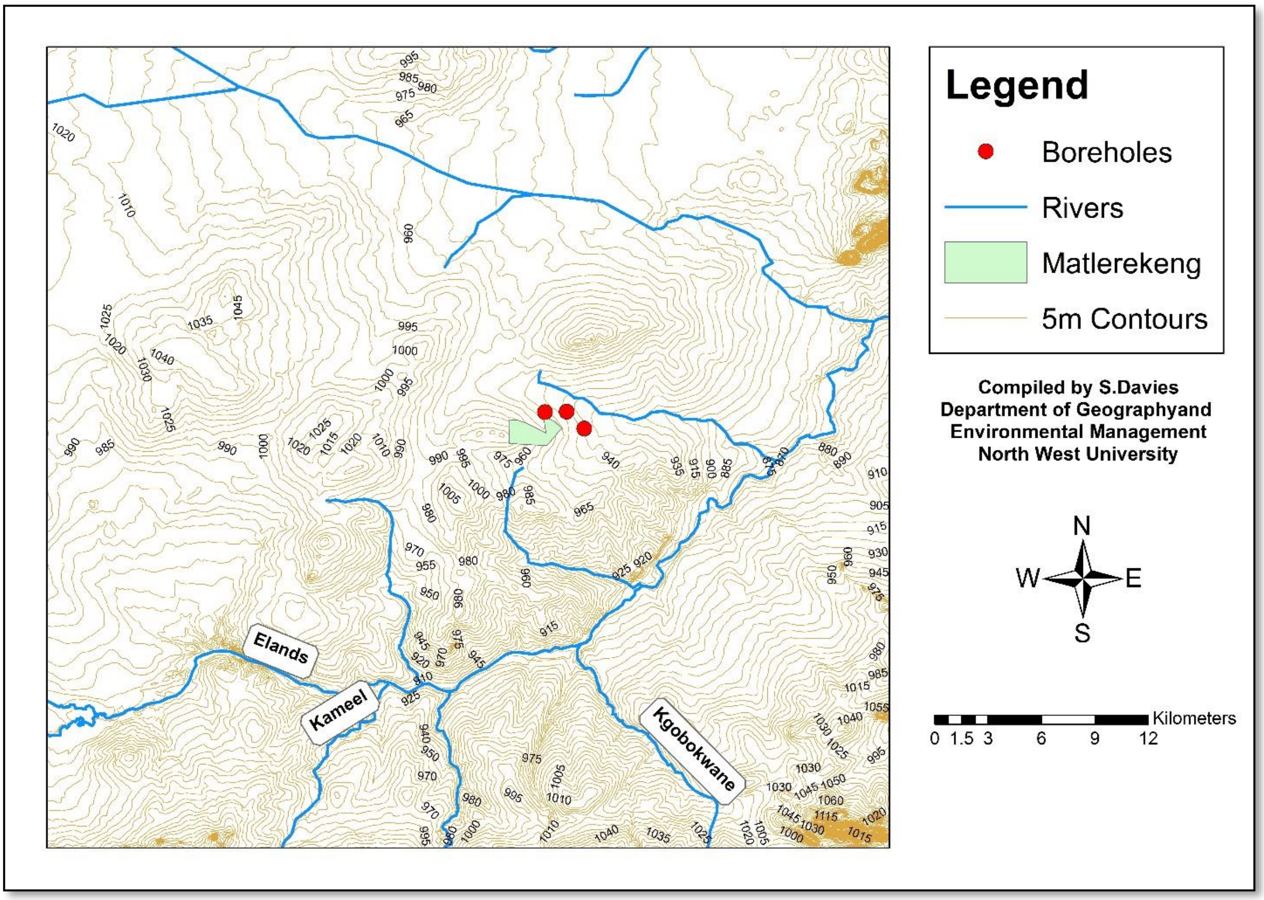

Figure 3: River catchments in the vicinity of the study area

3.1.3. Geology, soil and geohydrology

The geology is that of the Early Proterozoic Transvaal Supergroup, which comprises volcanic and sedimentary rocks, within the youngest constituent of the Bushveld Igneous Complex (Nebo granite of the Lebowa Granite Suite). The Lebowa Granite Suite overlays the Rustenburg Layered Suite. There are two types of granitic rocks namely intrusive and metamorphic which have been grouped together and form the Rashoop Granophyre Suite. This Suite may occur above and/or below the Lebowa Granite Suite. The Lebowa Granite Suite consists of the following: Nebo, Makhutso, Klipkloof, Bobbejaankop and Verena Granites (Johnson *et al*., 2006).

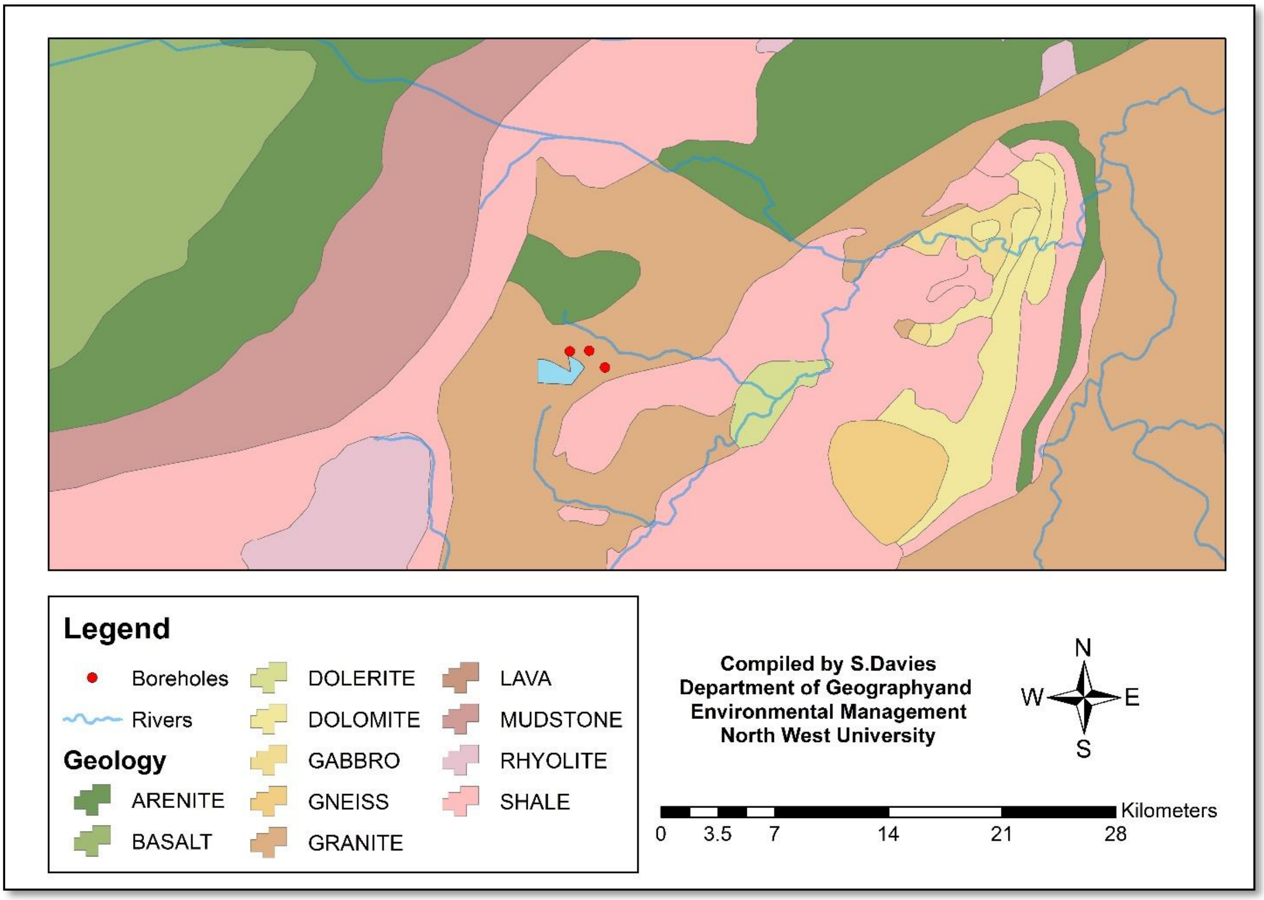

Figure 4: Geological map

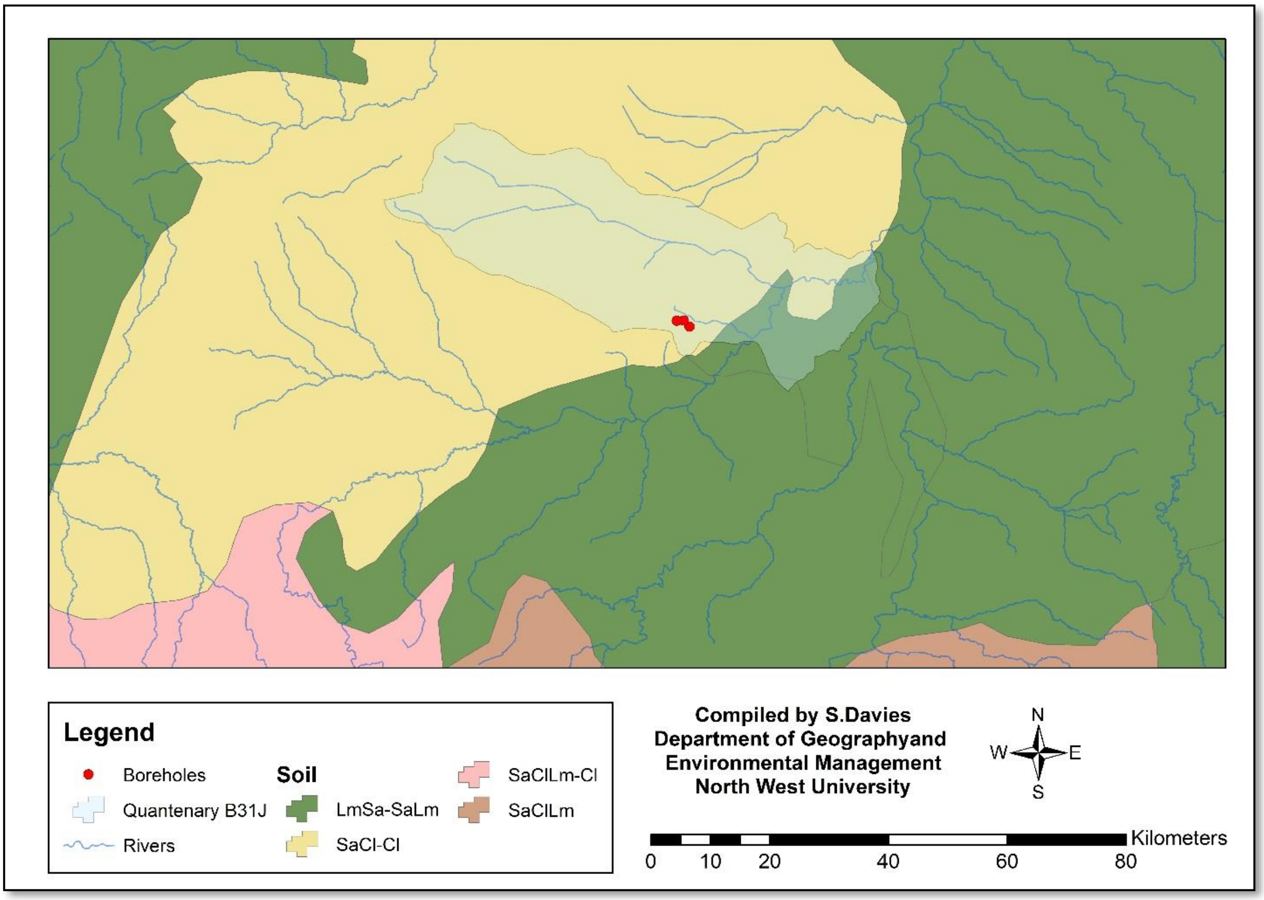

Figure 5: Soils

Additionally, the area under study is characterised by shallow to moderately deep sandy-clay-clay soils (

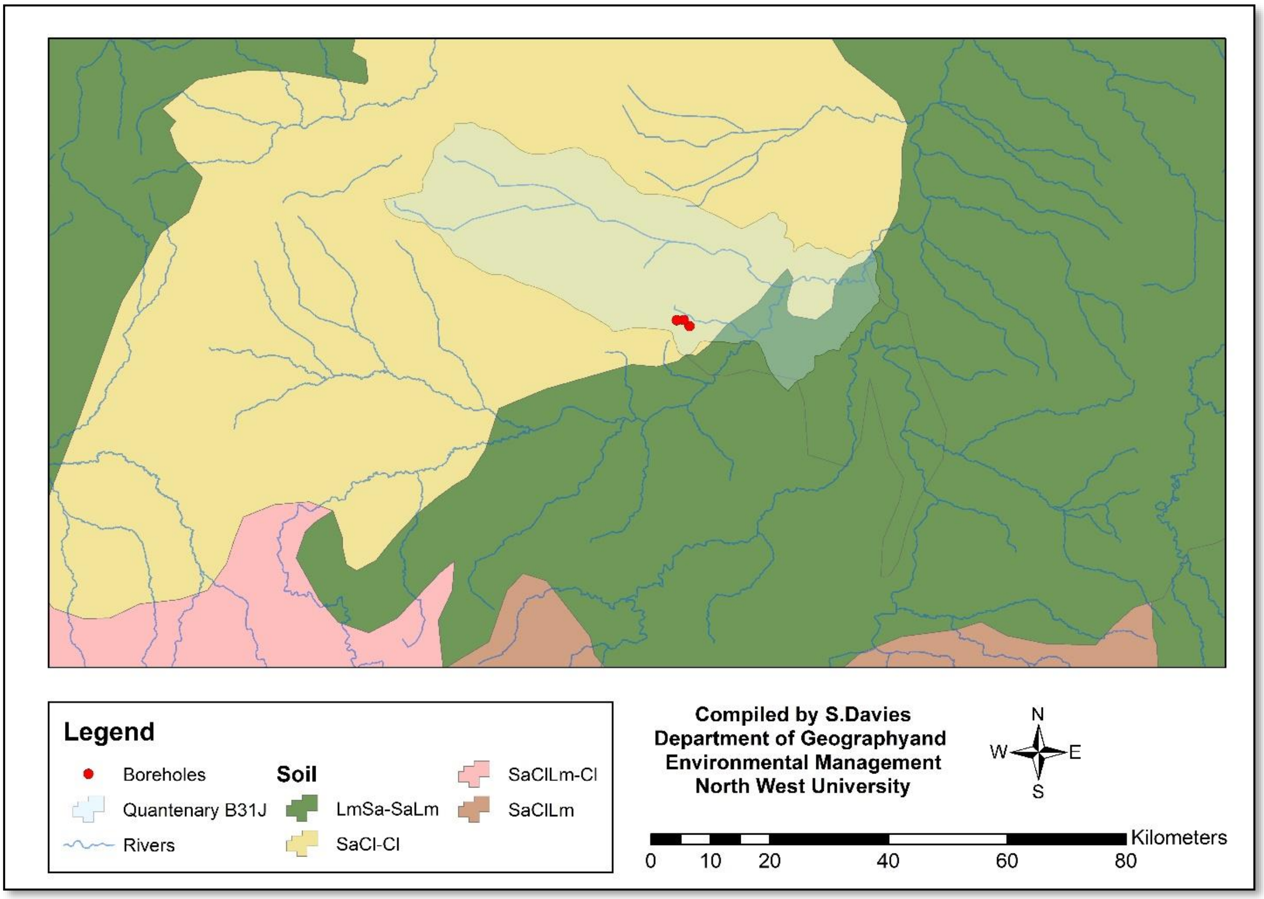

Figure 5) on flat and undulating terrain overlying the granitic rocks. The area has a moderate potential for agriculture hence there are a number of small scale agricultural activities in the area.

Underlying the study area is a fractured/weathered aquifer, with a water level of approximately 8 m below ground level. The groundwater is used for local water supply.

3.1.4. Vegetation cover

Firewood collection is practised on a huge scale. Improper practices of agricultural activities also contribute to vegetation clearing caused by overgrazing and veld fires as a result, so the area that is left is prone to soil erosion either by wind or heavy rainfall. Most of the available vegetation is indigenous plants such as acacia, thorn bush and various grass species (Photo 2).

Photo 2: Typical vegetation

Figure 6 indicates the vegetation occurring in the area is classified as mixed Bushveld which consists of a mixture of grasslands and trees.

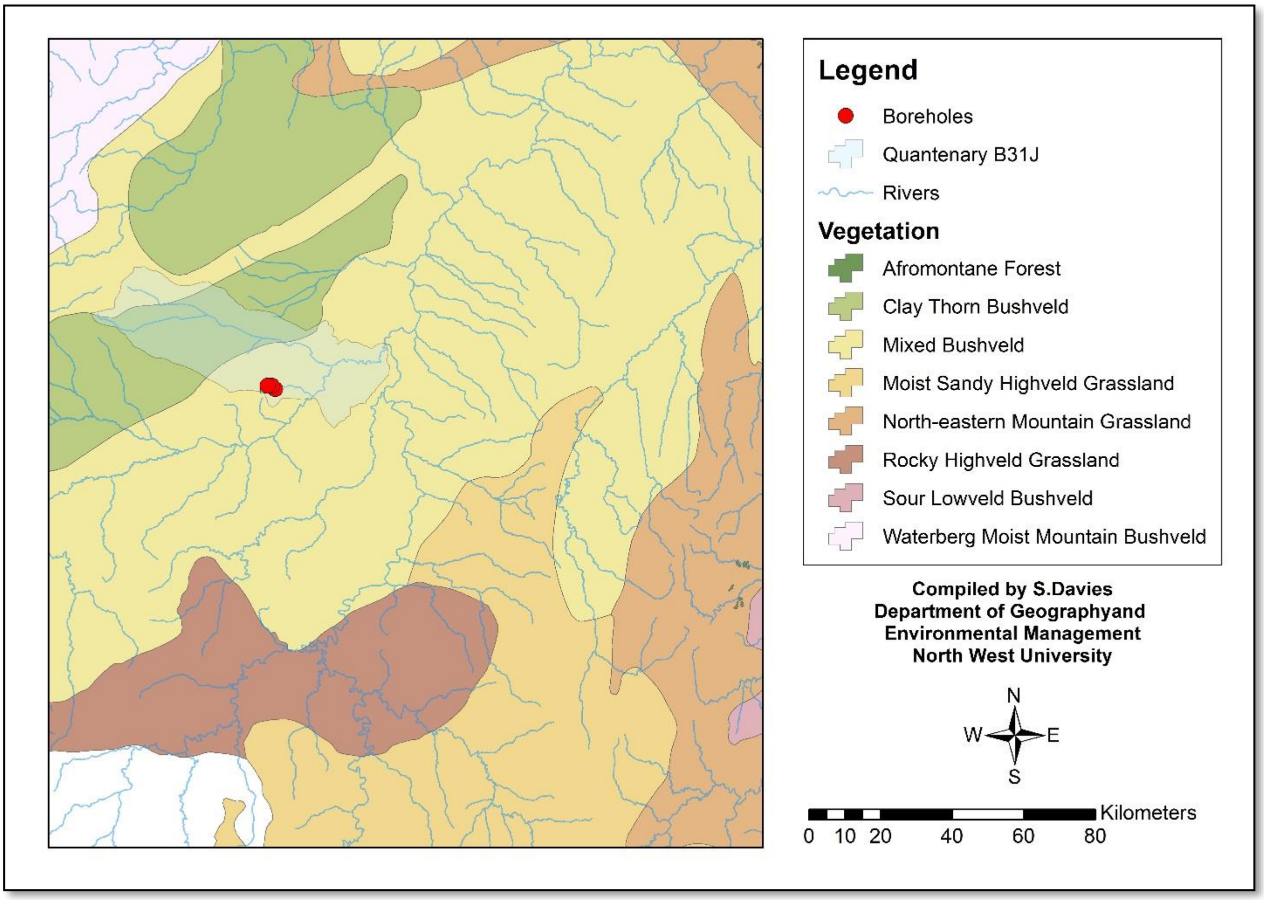

Figure 6: Vegetation map

The evapotranspiration was obtained for the study area from Aquiworx (2014) and is shown Figure 7. The evapotranspiration is the highest in January with an average of 178 mm/month and the lowest in June with an average of 70 mm/month.

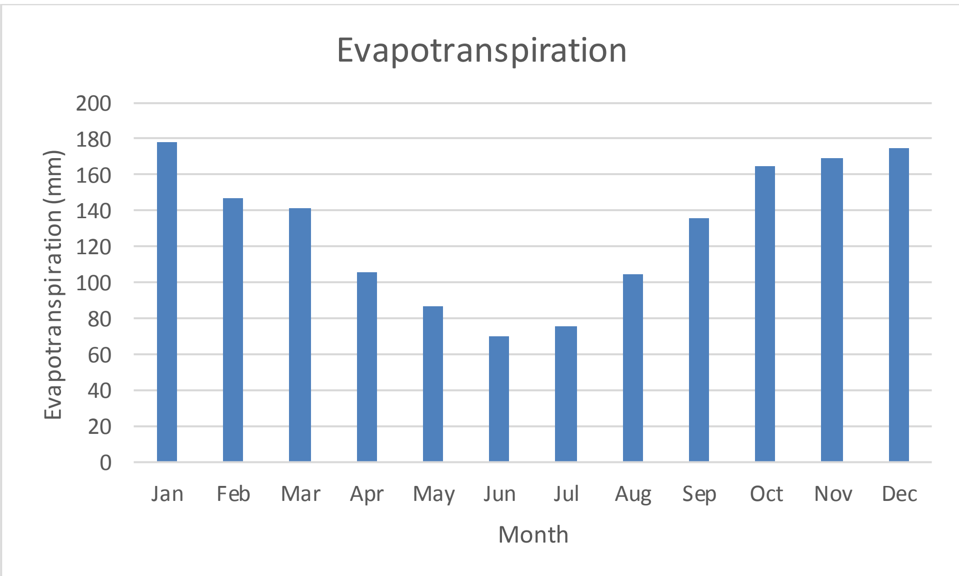

Figure 7: Evapotranspiration

3.1.5. Climate

The average maximum summer temperatures vary between 30 – 34ºC and the average minimum summer temperatures of 18 – 22ºC. The winter maximum temperatures vary from 22 – 26ºC with an average minimum temperature of 5 – 10ºC (IWMI, 2008).

The study area falls within the summer rainfall area. According to Water Resources (2012) the average rainfall for the study area is approximately 450 mm. The maximum rainfall normally occurs in December while the least rainfall occurs in July as shown in Figure 8.

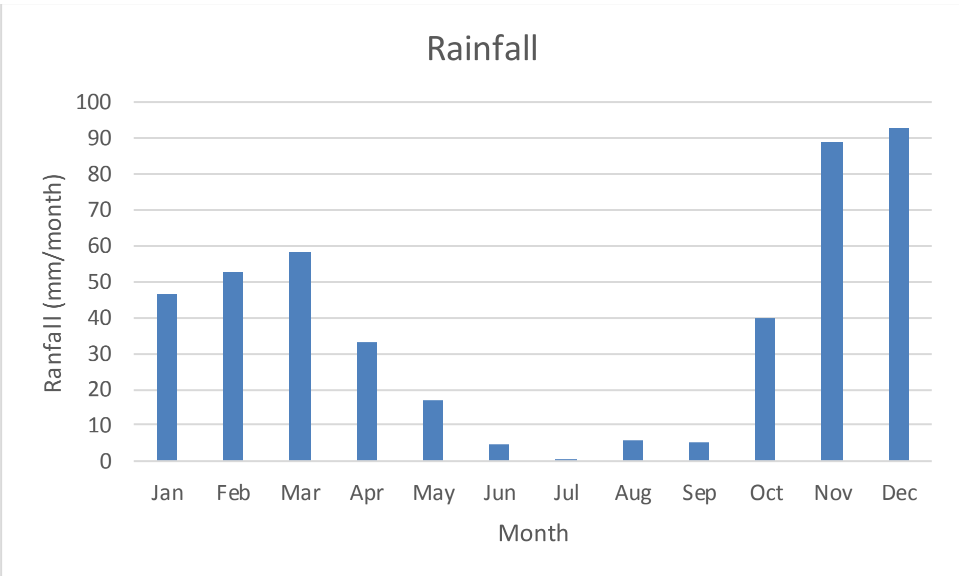

Figure 8: Annual rainfall

CHAPTER 4 METHODOLOGY

4.1. Research design

4.1.1. Data source

Data were collected through the following:

(a) **Observation**

A site visit to the study area was undertaken on 11 July 2018 and 10 September 2018. The aim was to gather information about the area and to map the sites to be sampled. Pictures of the locality, vegetation, soil and sampled boreholes were taken. The coordinates for all sampling points were taken using the Global Positioning System (GPS).

(b) **Desktop study**

A desktop study was conducted to gather all available information about the area. The Grip-Limpopo and National Groundwater Archive (NGA) databases (DWS, 2017) were used to gather information on the groundwater monitoring data and location of the boreholes. The Geographic Information System (GIS) was used to gather the information loaded on the system about the area. This information was about the drainage, topography and geology of the area.

Published journals containing articles regarding groundwater pollution by pit latrines were studied. In addition to these methods used to determine the vulnerability of the aquifer were also investigated. The groundwater vulnerability was determined using the DRASTIC approach taking into account (Aller *et al.,* 1987):

- Depth to groundwater (D) – determines the maximum distance contaminants travel before reaching the aquifer;
- Net recharge (R) – the amount of water that is able to travel from the ground surface to the water table;
- Aquifer (A) – the composition of the aquifer material;

- Soil media (S) – the uppermost portion of the unsaturated zone;
- Topography (T) – the slope of the ground surface;
- Impact of vadose zone (I) – the type of material presents between the bottom of the soil zone and water table; and
- Hydraulic conductivity of the aquifer (C) – indicates the aquifer's ability to allow for the flow of water to occur.

Literature was also obtained regarding the protection of boreholes. Zones of protection can be used to protect boreholes, namely the radius of influence of a borehole and the borehole protection zone for on-site sanitation.

4.1.2. Data-collection technique

(a) Observation

The site was physically visited to conduct visual assessment of the area and to map the area using Garmin Global Positioning Satellite. In mapping the area, points were selected whereby coordinates of the area were taken to be able to gather some information from the desktop about the geohydrology of the area and the current land use which might influence the water quality of the area.

(b) Desktop study

Information about the area from different sources such as IDP (EMLM, 2011) for local municipalities was used. Ground and surface water quality monitoring data from DWS was also considered. However according to the data retrieved from this website, no information on the water quality of the area under study was available. Borehole locations and groundwater levels were available. It was only monitoring points with coordinates, but no work done. Most of the monitored boreholes were reported not to be in a good state (refer to Annexure 1). Information about the geology and hydrology from the desktop study was used.

4.1.3 Data Analysis and Interpretation

- **Observation –** pictures taken were used as part of the report and were not altered**.** Notes about the area and source such as legislation, water pollution journals and environmental dictionaries were used.
- **Desktop study –** the geology, locality, vegetation and drainage map were used to assess the natural environment of the area and the changes made by human activities which contribute to the groundwater pollution. EMLM IDP (2011) was used to gather basic information of geology of the area. In addition, the radius of influence and the protection zones for the three boreholes under investigation were calculated.

4.2 Sampling techniques

4.2.1 Sample-collection technique

Sampling from water quality monitoring boreholes

The samples were planned to be collected from DWS water quality monitoring boreholes in the area. Information about the boreholes was gathered from grip Limpopo website attached in Annexure 1. The boreholes found were not in a good condition to be sampled and some could not be accessible. Most of them were vandalised while some were dry (Photo 3). The information in Annexure 1 indicate that no sampling was done previously in these monitoring points.

 

Photo 3: Dry and vandalised water quality monitoring boreholes

Sampling from domestic boreholes

Domestic boreholes were used to assess the water quality on site because of the status of the water quality monitoring borehole in the area as presented above. Because domestic boreholes are rare in the area under study, only four were identified. This is because the area is characterised by a low income community and only few households can afford to install the water boreholes.

Factors such as topography, soil and geology could not be considered, the monitoring point were selected based on its availability. The boreholes sampled were three, the fourth borehole could not be sampled because the water is pumped from underground and stored into the tank for some time before use.

Chemical parameters such as nitrate and ammonia were assessed (Nash & Still, 2002). Faecal coliform bacteria (WRC, 2007) with specific focus on *E. coli* were also assessed. Samples were taken during the spring season therefore no excess liquid flows could influence the concentration of pollutants in the groundwater.

4.2.2. Sampling site

- Sampling point 1: S 24º 58′ 34,4″; E 029º 03′ 47,4″ where the distance from the pit latrine is 34m.
- Sampling point 2: S 24º 58′ 33,4″; E 029º 04′ 25,9″ with distance from the pit latrine is 25m
- Sampling point 3: S 24º 59′ 03,5″; E 029º 03′ 57,4″ with distance from the pit latrine is 44m (Figure 1).

All pit latrines were constructed using the old method whereby no concrete slab was placed to prevent the pollution of groundwater (Van Ryneveld & Fourie, 1997) by faecal waste leachate (refer to Photo 4).

Photo 4: Old pit latrine with no concrete slab

In all sampling points, the distances between pit latrines and boreholes were found to be less than 50m. Still and Nash indicated the recommended distance of 30m between pit latrine and borehole. Additionally, the water was found at 8 m below ground level during the dry season. The water level was measured at the household number 4; however, no samples were collected because at this borehole (Photo 5), the water is pumped into the elevated tank for storage before it could be released through to the tap.

Photo 5: Borehole where water level was measured

Additionally, water could not be extracted from this borehole because the water is used for drinking purposes and the bailer could not fit together with extraction pipe (Photo 5).

Photo 6 is the sampling point 3 where the borehole is pumped using the generator.

Photo 6: Enclosed borehole where water level cannot be measured

4.2.3 Sampling procedure

The samples were collected once during spring season on 10 September 2018.

- The sample for microbiological pollutants were collected using sterilised one litre (1L) whirlpack plastic bags provided by the Laboratory, while for chemical nutrients 1L plastic bottles were used;
- The samples were taken from three boreholes used for domestic purposes by individual households. The sampling points were selected randomly looking at the current use of boreholes in the area;
- Since the aim is to analyse the groundwater pollution by pit latrines, the distance between them was also checked using the manual measuring wheel;
- Before the sample could be collected, the water from the borehole was pumped out for about 3 - 5 minutes as per the WRC (2007), groundwater sampling guideline (refer to Photo 7).

Photo 7: Water pumped directly from the underground using generator

4.2.3.1 Sampling for Ammonia and Nitrate

The sample bottles used to sample for ammonia and nitrate are plastic as per the requirements of WRC (2007). The bottles and caps were new, therefore they were rinsed three times with water from the borehole. Thereafter the sample was taken directly from the pipe using sampling bottles.

The WRC guide requires the sample to be preserved in a situation whereby samples could not be analysed on-site. In following the aforesaid procedure, the samples were then kept in cooler box after sampling until they reached the laboratory. Sampling bottles were marked as per the sampling point, date and time of sample collection e.g. BH1-11/09-13:10. The samples were kept for a short period of less than 48 hours before the sample could be analysed (WRC, 2007). The samples were tested from 11 to 13 September 2018.

4.2.3.2. Sampling microbiological pollutants

The WRC (2007) sampling guidelines require the use of glass or plastic bottle sterilised for 15 minutes in autoclave. The laboratory provided 1L sterilised Whirl Pac bags/bottles for sampling. When collecting the water samples, the bags were opened, put under the discharge pipe while holding the bag with strips to avoid tampering with the quality of water. Before sealing the bag, air escaped and then the bag was sealed, folded and strips used to tie it. Touching of the inner part of the bag was avoided always. The sample time and date were noted in the sampling bottle. The filled bottles were stored on ice (4ºC) and in darkness (WRC, 2007). The samples were kept in a cooler box at less than 4ºC until taken to the laboratory.

The WRC groundwater sampling guide (2007) recommends that a sample must be plated out in the laboratory within 6 hours, but within 24 hours is quite acceptable. The maximum holding time for obtaining realistic results is 48 hours. The samples were analysed within 48 hours. The samples were collected on 10 September 2018 where the first one was taken at 13H10, second one at 13H35 and the last one at 14H04. The samples were taken to the laboratory on 11 September 2018 (morning). The report from the laboratory indicates that samples were analysed on 11 September 2018.

4.3 Analysis of results

The results of the analyses are compared to the SANS (2015) guidelines and presented in Chapter 5.

CHAPTER 5: RESULTS

5.1. Data analysis and interpretation

Data analysis is conducted by comparing the sample results with the SANS (2015)**.** The specification also presents the classification of water which can be used for domestic purposes. The classes are defined as follows:

Class 0: is regarded as ideal water and is closely comparable to the current international standard for water quality.

Class 1: this class is considered acceptable for lifetime consumption

Class 2: the class represents a minimum acceptable quality drinking water for various maxima.

5.1.1. Ammonia analysis

The results of the ammonia analysis are documented in Table 2.

Table 2: Sample results for Ammonia as N in mg/l

Sampling point	NH4 (mg/l)	N(mg/l)	Upper limit and ranges	
			Class 0	Class 1
BH1	<0.1	<0.10	<0.2	0.2 – 1.0
BH2	<0.1	<0.10		
BH3	<0.1	<0.10		

According to sample analysis results, in all the samples collected from boreholes 1, 2 and 3 no ammonia content was found. The results show the amount to be less than 0.1 mg/l which can be regarded as zero when compared to the upper limit of less than 0.2 mg/l for the class 0 and between 0.2 and 1.0 mg/l for class 1 water use for domestic purposes.

According to the Agency for Toxic Substances and Disease Registry (ATSDR), 2004 fact sheets ammonia is a corrosive. The main toxic effects are irritation of the skin, eyes, respiratory tract, mouth, and digestive tract.

5.1.2 Nitrate/Nitrite analysis

Table 3: Sample results for Nitrate/Nitrite as N in mg/l

Sampling point	NO_3 (mg/l)	N(mg/l)	Upper limit and ranges			
			Class 0 (Ideal)	Class I (acceptable)	Class II (max. allowable)	Class II water max. allowable consumption period
BH1	51,1	11.5	<6.0	6.0 -10.0	<10.0-20.0	7 years
BH2	48.3	10.9				
BH3	115.0	26.0				

According to the SANS (2015) guideline, the nitrate is measured as N in milligram per litre (mg/l). The samples analysis shows all samples from three boreholes exceeding this limit as shown in Table 4. The analysis of results is done as follows:

(i) House number 1 (BH1) analysis results

In borehole sample collected from house 1, the nitrate content is 11.5 mg/l which exceeds the limits for class 0 and acceptable limit for class 1; however, it falls under class II whereby the maximum allowable consumption period is seven years.

(ii) House number 2 (BH2) analysis results

In sampling point 2, the concentration of Nitrate is 10.9 mg/l which exceeds the SANS (2015) limit of less than 6 mg/l for class 0. When compared to Class I, the sample analysis reveals that the Nitrate content is slightly above the acceptable limit.

(iii) House number 3 (BH2) analysis results

Analysis of samples collected from house no 3 indicates that the nitrate content of 26 mg/l. This content is above the required limit of less than 6 mg/l for class 0 and the accepted level of 6-10 mg/l for class 1. Furthermore, it also exceeds the class II limit with allowable maximum range from 10 to 20 mg/l for a period of seven years (SANS, 2015)

Nitrate can cause chronic tiredness. In some cases, cyanosis and can cause difficulty in breathing in bottle-fed babies (WRC, 1998).

Microbiological analysis

The microbiological results are documented in Table 4.

Table 4: Sample results for E. coli as cfu/100ml

Sampling point	E. coli Counts	Risk	Unit	Standard Limit
BH1	Non- detected	**Acute health -1**	**Count per 100ml**	**Not detected**
BH2	3 Cfu/100ml			
BH3	10 Cfu/100ml			

The sample analysis was done using the reference method SANS (2015). The unit used to measure the concentration of E. coli is count of colonies forming unit (Cfu) in 100ml of water sample.

(i) *E. coli* analysis in House number 1 (BH1)

In borehole 1, no E. coli bacteria was detected in the water sample. The water from this borehole meets the required standard whereby quality of drinking water must be clear of E. coli bacteria.

(ii) *E. coli* analysis in House number 2 (BH2)

The results of sample from house number 2 indicate a total of 3 *E. coli* bacteria present in the water sample. The standard limit is zero detection of the *E. coli* bacteria in drinking water (SANS, 2015).

(iii) *E. coli* analysis in House number 3 (BH3)

The total number of bacterial content detected in sampling point in house number 3 is 10 per cfu/100ml. This *E. coli* count exceeds the required limit of SANS (2015) guideline for drinking water.

E. coli are made up of large groups of bacteria. Most strains are harmless. However, there are some that can cause diarrhoea. Other strains can cause diseases such as urinary tract infections, respiratory illness and pneumonia (ATSDR, 2004).

5.3 Discussions

5.3.1 Ammonia

The analysis for all samples collected from boreholes in three households shows a zero concentration of Ammonia, although, the Ammonia is associated with bacteria, sewage and animal waste pollution. In groundwater, ammonia can undergo nitrification processes whereby oxidation reaction will convert it into nitrate (WRC, 2007). Ammonia concentrations below 0,2mg/l occur naturally in groundwater (Lingle, 2013). The concentration of less than 1.0 mg/l of ammonia in sampled water proves the absence of interference of anthropogenic activities which might be a direct source of ammonia (e.g. fertilizers in the environment in the study area (WRC, 2007).

5.3.2 Nitrate

The analysis results from borehole 1 indicate the concentration of 11.5mg/l of nitrate. The SANS (2015) allows a maximum limit of 20mg/l for class II for use over a period of not more than seven years. This concentration exceeded the limit for class 0, which is considered ideal for use without treatment and the acceptable level of between 6 and 10 mg/l. Factors which might contribute to this concentration are as follows:

- Nitrate is a primary source of nitrogen and according to Nash and Still (2002) its concentration in ground water is less than 2 mg/l. Henceforth, the concentration above 2 mg/l is considered nitrate pollution in groundwater;
- Population density such as number of occupants and clustering of pit latrines in the proximity of the borehole, and atmospheric deposition of air bone nitrogen compound also has an effect.
- Biogeochemical processes that control water and rock interaction in groundwater might affect the concentration of nitrate (DWAF, 2003). The soil nutrients enriched might also accelerate the nitrate content in the groundwater.
- In associating nitrate with faecal waste pollution, the measured distance of 34m between the pit latrines and borehole might have a direct impact on the drinking water in this household. This is due to nitrogen generated by biodegradation of human waste in the pit latrines (Templeton *et al*., 2015).

In sample point 2, the ammonia concentration is 10.9 which falls under the requirements limit of class II (SANS, 2015). The pit latrine in this household was constructed using the old method with no concrete slab. The distance between the pit latrine and the borehole is 25 m and the borehole was sunk in 2017. Only a few people use the pit latrine, however, as in the vicinity there are two more pit latrines. The soil type in this household is fine sand which allows the movement of chemicals into the groundwater.

The nitrate result in sampling point 3 indicates an amount of 26.0 mg/l, which exceeds the maximum limit for class II (SANS, 2015). In most cases, pit latrines are situated in an area topographically higher than the boreholes. The distance between pit latrine and borehole is 44m and the soil is more silty/sandy. The permeability of the soil also accelerates the rate of movement of pollutants in the unsaturated zone.

5.3.3 E. coli

The presence of *E. coli* bacteria was also sampled and analysed in the three households. The results for sampling point 1 indicate no detection of *E. coli* bacteria. This might be because the borehole was installed recently and the distance between the pit latrines and borehole is only 34 m. Since the concentration of *E. coli* is associated with human excretion, the distance plays major role whereby the pathogen can die in between the cracks and the soil before reaching the aquifers (Sudgen, 2006). The sample was taken during the dry season and as result less liquid is available to create liquid pressure into the saturated zone of the subsoil.

Since the flow is less, most of the pathogens remain in the pit latrines. Results from sampling points 2 indicate total counts of 3 cfu/100 of *E. coli* bacteria. This suggests possible pollution of groundwater by *E. coli* as it exceeds the limit of zero count (SANS, 2015). This might have been influenced by the type of the pit latrines and other available pit latrines in the proximity. In the household 3, sample analysis results indicate the *E. coli* count of 10 cfu/100. Since the samples were collected during the dry season, it is possible that some pathogens take time to travel to the water source hence it was detected 44m away from the pit latrine.

5.4 Groundwater vulnerability

According to Lynch *et al.* (1994) the groundwater vulnerability can be calculated as:

Groundwater vulnerability = $D_rD_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_rI_w + C_rC_w$

Where (Lynch *et al.* 1994):

r = Rating

w = Weight

D = Depth to groundwater

R = Recharge

A = Aquifer media

S = Soil Media

T = Topography (% slope)

I = Impact on the vadose zone

D_w = 5

R_w = 4

A_w = 3

S_w = 2

T_w = 1

I_w = 5

Lynch *et al.* (1994) also provide rating values for depth to groundwater, recharge, aquifer media, soil media, topography and impact on the vadose zone as documented in Annexure 2. The rating values assigned are documented in Table 5.

Table 5: Ratings assigned for groundwater vulnerability calculation

Item	Description	Rating
Depth to groundwater	Measured – approximately 8 m	7
Recharge	14 mm Aquiworx (2014)	6
Aquifer media	Fractured and weathered (See Figure 4 and Figure 5)	3
Soil media	Sandy clayey clay (See Figure 5)	5
Topography (%slope)	Area relatively flat (See Figure 3)	10
Impact on the vadose zone	Granite (see Figure 4)	6

The vulnerability rating is calculated as 118 which according to Lynch *et al.* (1994) implies that the aquifer is most susceptible to pollution.

5.5 Radius of influence and protection zones

The radius of influence (r_e) can be defined as the maximum distance at which drawdowns can still be detected for a certain borehole or in other words the maximum extent of the cone of depression. According to Parsons and Wentzel (2007) it can be calculated as:

$$r_e = 1.5\sqrt{\frac{Tt}{S}}$$

Where

T = Transmissivity

S = Storativity

t = Time

Protection zones can be placed around boreholes to make sure that on site sanitation will not have an impact on the boreholes. The protection zones can be calculated taking Table 6 into account.

Table 6: Protection zones (Parsons & Wentzel, 2007)

Risk	Protection zone
High or very high risk of microbial pollution	2 times fracture radius
Low risk for microbial pollution	1 times fracture radius
No risk for microbial pollution	0.5 times fracture radius
High risk for N for infants	2 times fracture radius
Low risk for N for infants	1 times fracture radius
No risk for N for infants	0.5 times radius

If the fracture information is not available the following equation can be used (Parsons & Wentzel, 2007):

$$Fracture_{radius} = 0.28T + 53$$

In the following calculations a transmissivity of 10 m^2/d and a storativity of 0.001 (Dennis and Dennis, 2012) were used. The radius of influence for the three boreholes under investigation is presented in Figure 9. The radius of influence is a conservative approach as it protects a large area surrounding the boreholes. The radius of influence for the boreholes in the study area is calculated for pumping one day, one month and a year. The results are documented in Figure 9, Figure 10 and Figure 11.

The protection zones for high or very high risk of microbial pollution or high risk for nitrates for infants is shown Figure 13.

Figure 9: Radius of influence for 1 day of pumping

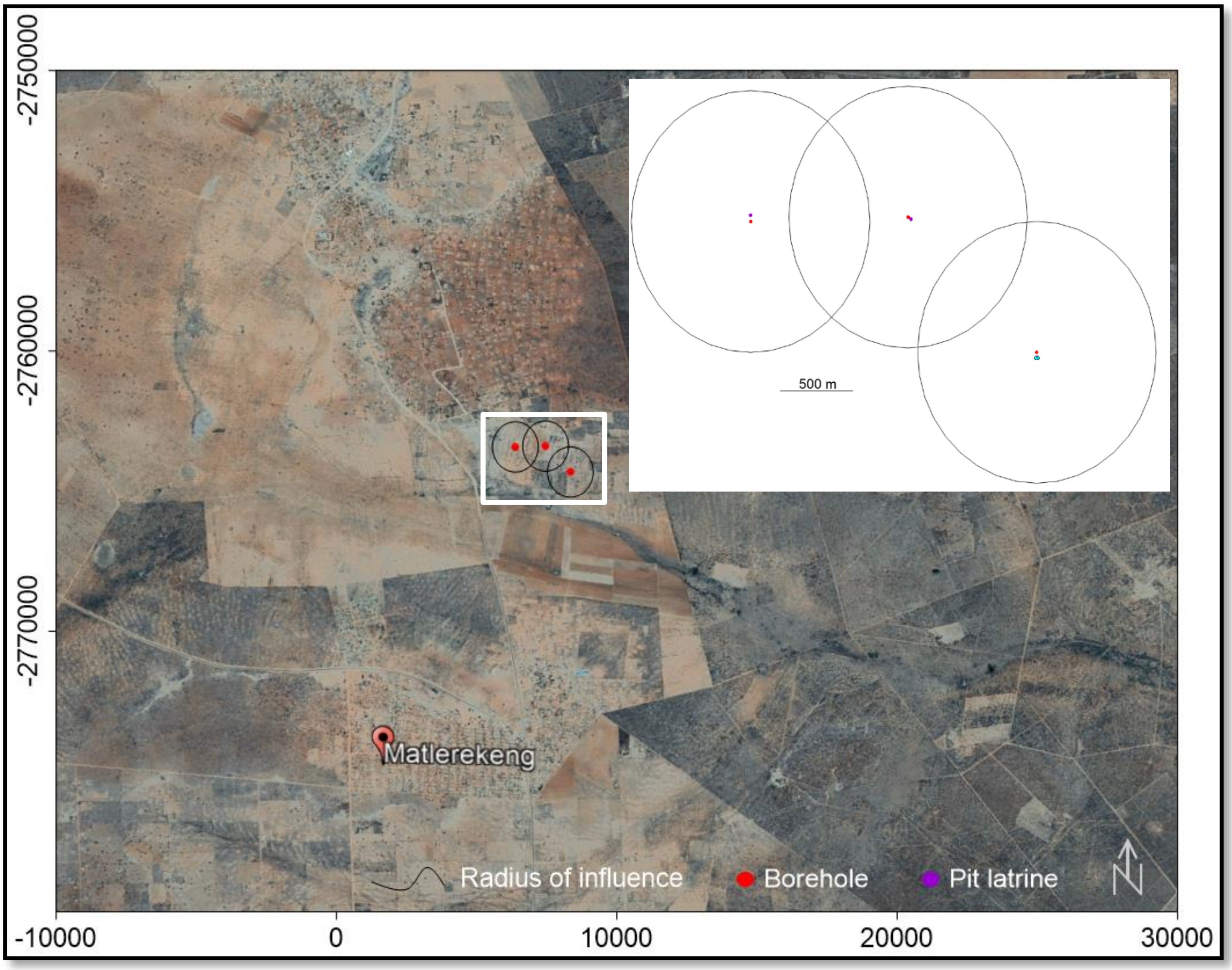

Figure 10: Radius of influence for 30 days of pumping

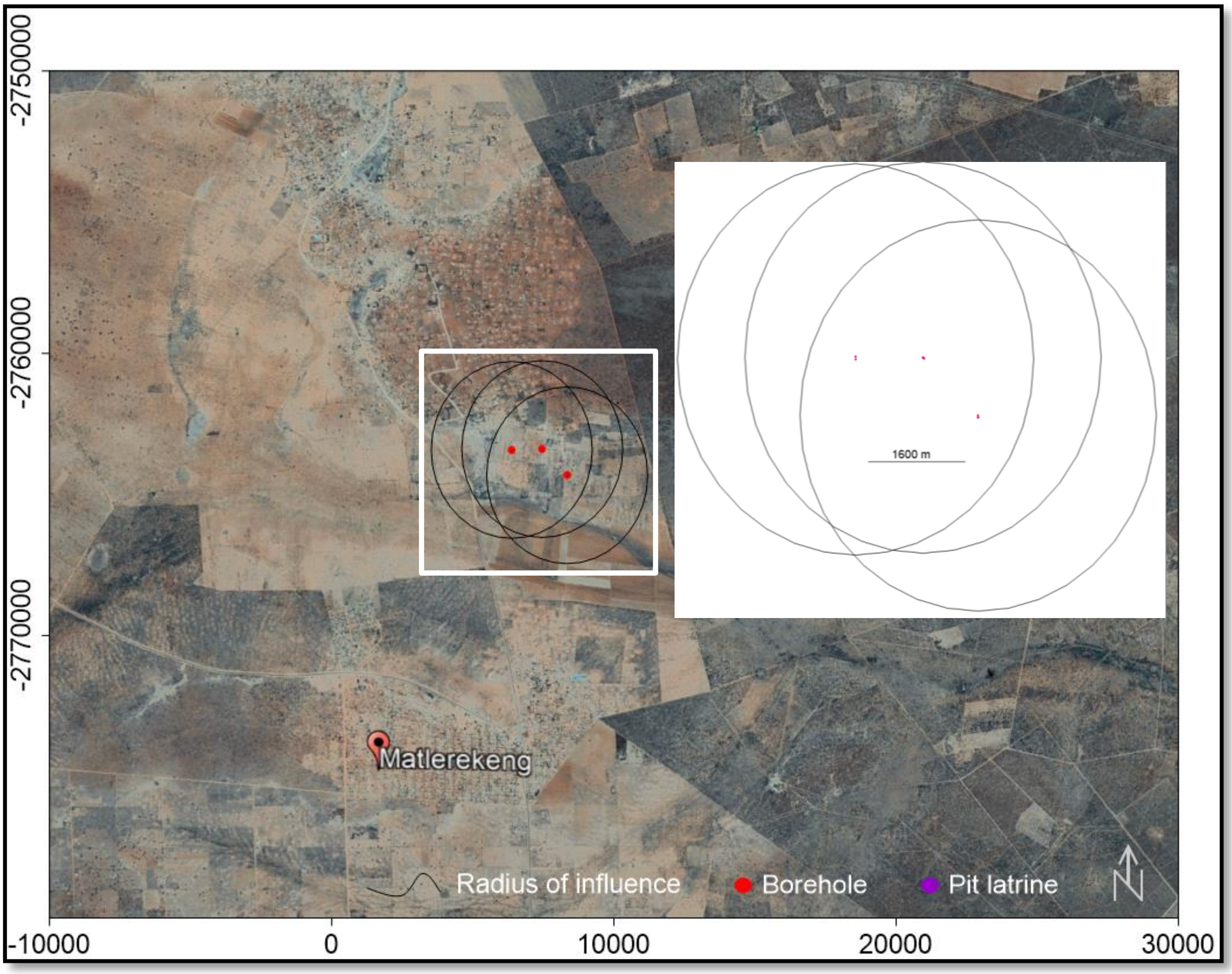

Figure 11: Radius of influence for 1 year of pumping

Figure 12: Protection zones for high or very high risk of microbial pollution or high risk for nitrates for infants

The radius of influence for one day is 150 m, for a month it is 800 m and for a year it is 3140 m. The protection zones for high or very high risk of microbial pollution or high risk for nitrates for infants is 112 m using the method presented in Table 6.

CHAPTER 6 CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSION

The landscape of the study area is made up of low hills in the western part and low lying in the eastern side. The area is characterised by sandy, loamy soil with different particle sizes. All these soil categories make the groundwater resource of the area prone to pathogens and chemical pollution.

In House no 3 which is situated in the middle of the village, both chemical and biological pollutants were found to exceed the specified limit of the SANS (2015) for drinking water. The water is above the required limit for ideal class 0 water for both parameters. Consumption of water with a high nitrate content might result in blue baby syndrome. In all sampling points nitrate is of high concern as it predicts possible faecal pollution of groundwater by pit latrines in the area under study daily.

Additionally, *E. coli* is one of pathogens produced by faecal waste and is transported through the ground by leachate produced from pit latrines and because of its size it can reach unrestricted areas, hence it was detected at a distance of more than 25m from the source. Consumption of water with *E. coli* content can result in water borne diseases which might lead to death. The overall assessment of the sample results for both Nitrate and *E. coli* suggests that continuous use of pit latrines might put the water from the aquifer under pollution threat and its consumption will threaten the health and well-being of the users.

Although Ammonia forms part of the determination of pollution by human waste, in this study no concentration was detected. Nitrate and *E. coli* content which is above the required limit of SANS (2015) indicates that pollution of groundwater by pit latrines in Matlerekeng area is probable.

The groundwater vulnerability rating indicates that the aquifer in the study area is most susceptible to pollution. Furthermore, the radius of influence between the water and pollution source for all sampling points is short. Henceforth, the required conservative protection zone (DWAF, 2004) is greater than 25m. This will help to protect the boreholes from pollution.

6.2. RECOMMENDATIONS

The results of the study indicate the pollution of groundwater by use pit latrines in Matlerekeng village. The pollution could be recurring or continuing due to a lack of service delivery therefore more study is required to determine the extent of pollution of groundwater the area. According to the EMLM (2017) the pace of allocation of basic services in the area is a concern therefore, it is anticipated that groundwater resource will continue to be affected.

As a result, it is recommended that further investigation be conducted in the area to establish possibilities of continuous consumption of polluted water by the community. This can be done assessing the total number of households abstracting groundwater for domestic purpose. Since the use of pit latrines is common in the area, more households which have pit latrines and constructed them using old method should be identified.

The villages in the proximity should be incorporated in the study to gather comprehensive information about the area. Other influences such as agriculture and waste disposal should also be investigated to assess the extent of its contribution to groundwater pollution. In most of the households, pit latrines were constructed without consideration of their effect of it in groundwater. Consequently, the construction method can be used to determine possibilities of seeping of leachate from the pit latrine into the aquifer.

Factors such as geology and hydrogeological profile of the area need further investigation. The slope and drainage pattern will assist in determining the water flow direction of the area. Additionally, more water quality parameters and physical characteristics of ground water should also be investigated. DWS water quality data need to be updated and it can be used to assess the extent of groundwater pollution in the area. A limitation of the study was that only three boreholes were used and additional boreholes would increase the confidence in the results of the study.

BIBLIOGRAPHY

Ahaneku, I.E. & Adeye, P.A. 2013. Impact of Pit Latrines on ground water quality of Foko slum, Ibadan, Southern Nigeria. *British Journal of applied Science and Technology*, 4(3). Retrieved from www.science.domain.org, Date of access: 21 June 2016.

Aller, L., Lehr, J.H., Petty, R. 1987. DRASTIC: A standardized system for evaluating ground water pollution potential using hydrogeologic settings: NWWA/EPA Series, EPA-600/2-87-035

Anabella F, Martin, ST Eugenia, A. & Alberto F. 2014. Assessment, Monitoring and Protection of Groundwater Pollution in Urban Areas -Cordoba City – Argentina. *European Scientific Journal*. Retrieved from http//.www.eujournal.org/index.php/article/view/2910. Date of access: 31 January 2017.

Aquiworx. 2014. Centre for Water Sciences and Management. Retrieved from http://www.aquiworx.co.za. Date of access: 18 November 2018.

Agency for Toxic Substances and Disease Registry. 2004. Public Health Statement for Ammonia. Retrieved from https://www.atsdr.cdc.gov. Date of access: 19 November 2018.

Babiker, I.S., Mohamed, A.A., Thiyama, T., Kato, K. 2005. A GIS-based DRASTIC model for assessing aquifer vulnerability in Kakamigahara Heights, Gifu Prefecture, central Japan. *Science of the Total Environment* 345 (127 – 140). On line Journal. Available at: http:/www.sciencedirect.com.

Brikkie, F. & Bredeo, M. 2003. Linking technology choice with operation and maintenance in the context of community water supply and sanitation, *A Reference Document for Planners and Project Staff.* Retrieved from http://www.who.int/water_sanitation_health/hygiene/om/linkingchap8.pdf. Date of access: 7 November 2018.

Borehole Water Association. 2018. Borehole Water Journal on line, Volume 115. Retrieved from http://www.bwa.co.za, borehole water journal. Date of access: 7 November 2018.

Chidavaenzi, M., Jere, M. & Bradley, M. 1997. Pit latrines effluent infiltration into groundwater. Water and Sanitation for all: Partnerships and Innovations 23rd WEDC Conference, Durban, SA. (pp 59-62) Retrieved from http//:www.edc.iboro.ac.uk/resources/conference. Date of access: 22 June 2016.

Dennis, I. & Dennis, S.R. 2012. Climate change vulnerability index for South African aquifers. *Water SA*, 38(3): 417 – 426.

Dzwairo, B. Hoko, Z., Love, D. & Guzha, E. 2006. Assessment of Impact of Pit latrines on ground water quality in rural areas: *Case study from Marondera District, Zimbabwe*: Retrieved from www.sciencedirect.com. Date of access: 21 June 2016.

Ephraim Mogale Local Municipality. 2010. Integrated Development Plan for 2010. Marble Hall, South Africa.

Ephraim Mogale Local Municipality. 2011. Integrated Development Plan for 2011-2016. Marble Hall, South Africa.

Ephraim Mogale Local Municipality. 2017. Integrated Development Plan for 2017/2018. Marble Hall, South Africa.

Graham, J.P. & Polizotto, M.L. 2013. Pit latrines and their Impact on Ground Water quality. Systematic review: *Environmental Health Perspective,* 121(5):521-523. Retrieved from http://www.hrsc.himmelfarb.gwu.edu.

Google Earth. 2018. Matlerekeng Area. AfriGIS (Pty) Ltd. Image © 2018 Digital Globe.

IWMI. 2008. Baseline Report: Olifants River Basin in South Africa. A contribution to the Challenge Program Project 17: Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin. Pretoria.

Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. 2006. The Geology of South Africa. Geological Society of South Africa, Council for Geoscience, Pretoria.

Kiptum, C.K. & Ndambaki, J.M. 2012. Well Water Contamination by Pit latrines: A case Study of Langas. *International Journal of water resource and Environmental Engineering*, 4(2):36. Retrieved from http//www.academicjournal.org/IJWEE. Date of access: 21 June 2016

Musekiwa C and Majola K. 2013. Groundwater Vulnerability Map for South Africa. South African Journal of Geomatics. Volume 2/2 (2013). Retrieved from http//.www.ajol.infor/index.php/sajg/article/download/. Date of access: 05/02/2019.

Lewis, J.W., Foster, S.D. & Draser, B.S. 1980. The risk of groundwater pollution by on-site sanitation in developing countries: A literature review. International Reference Centre for Wastes Disposal (IRCWD) Report No. 01/82. Retrieved from http//www.Ircwash.org>default>files. Date of access: 2 November 2018.

Lingle, D. 2013. Origin of high level of Ammonium in Groundwater, Ottawa Country, Michigan. Western Michigan University (MSc thesis).

Lynch, S.D., Reynders, A.G. & Schulze, R.E. 1994. Preparing input data for a national-scale groundwater vulnerability map of Southern Africa. *Water SA* 20:239 – 246

Nash, S.R. & Still, D.A. 2002. Groundwater Pollution due to Pit Latrines located in a Sandy Aquifer. A Case Study from Maputaland Water Institute of Southern Africa: Biennial Conference, Durban, May 2002. Retrieved from http//www.sswm.info, Date of access: 5 May 2017

Odiyo, J.O. & Makungo, R. 2012. Water Pollution problems and management in rural areas of Limpopo Province, South Africa. WIT transaction on Ecology and the Environment, 164:135-145 Retrieved from http//www.witpress.com/. Date of access 22 June 2016.

Parsons, R. & Wentzel, J. 2007. Groundwater Resource Directed Measures Manual. Project K5/1427, Water Research Commission, Pretoria.

Pitkänen T, Karinen P, Miettinen IT, Lettojärvi H, Heikkilä A, Maunula R, Aula VH, Vepsäläinen A, Nousiainen L, Pelkonen S and Heinonen-Tanski H. 2011. Microbial contamination of groundwater at small community water supply in Finland. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3357741/. Date of access: 4 November 2018.

Saayman I.C, Beekman H.E, Adams S, Campbell R.B, Conrad J, Fey M.V, Jovanovic N, Thomas A, and Usher B.H. 2007. Assessment of Aquifer Vulnerability in South Africa. WRC Report No. 1432/1/07**.** Water Research Commission, Pretoria.

South African National Standards. 2015. Drinking water Part 1. Microbiological, physical, aesthetic and chemical determinants. SABS, Standard division. (SANS 241-1)

South Africa. Department of Water and Sanitation. 2013. National Water Resource Strategy. Pretoria.

South Africa. 1998. Department of Water Affairs and Forestry. National Water Act, 1998 (Act No 36 of 1998). (Proclamation No. 1091) Government Gazette, 19182:2, 26 Aug 1998. Pretoria.

South Africa. 2017. Department of Water and Sanitation. Groundwater Resource Information Project. Retrieved from www.griplimpopo.co.za. Date of access 7 May 2017.

South Africa. Department of Water and Forestry. 2003. A protocol to manage the potential of groundwater contamination from on-site sanitation. 2nd Edition. Pretoria.

South Africa. Department of Water and Forestry. 2004. Guideline on protecting groundwater from contamination. Toolkit for water service. No.3.4. Pretoria

Sugden, S. 2006. The Microbiological Contamination of Water Supplies. Well factsheet, Retrieved from https://www.lboro.ac.uk/research/wedc/well/water-supply/ws-factsheets/microbiological-contamination/. Date of access: 06 April 2017.

Templeton, M., Hammoud, A.S., Butler, A.P., Braun, L. Foucher, Grossmann, J., Boukari, M., Faye, S. & Jourda, J.P. 2015. Nitrate pollution of groundwater by pit latrines in developing countries, 2(2):303-310. Retrieved from http// www.aimspress.com._Date of access: 5 May 2017.

Van Ryneveld, M. & Fourie A.B.B. 1997. A Strategy for evaluating the environmental impact of on-site sanitation system, 23(4). Retrieved from https://www.ircwash.org. Date of access: 5 May 2017.

Water Research Commission. 1998. Quality of Domestic Water Supplies, Assessment guide. Volume 1, 2nd Edition, TT 101/98.

Water Research Commission. 2007. Ground Water Sampling: Comprehensive guide for sampling method, WRC Report No TT 303/07. South Africa.

Water Resources. 2012. Water Resources Database. Retrieved from: http://waterresourceswr2012.co.za/. Date of access: 5 May 2017.

World Health Organisation. 2001. Nitrate and nitrite in drinking-water. Retrieved from: http://www.who.int/water_sanitation_health/dwq/chemicals/nitratenitrite2ndadd.pdf. Date of access: 5 May 2017.

ANNEXURES

Annexure 1. GRIP Limpopo sampling points data

Farm Num	Province	District M	Local Mun	Settlemer	Settlemer	Alternativ	Longitude	Latitude [	Borehole	Waterleve	Water lev	Depth to	Discharge	Duty cycle	Daily Abst	Equipmen	Power	Quality	Comment
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.04681	-24.9806	0	0	0	0	0	0	0	Handpum	Hand	-	"TO TEST"
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.05378	-24.9842	0	0	0	0	0	0	0	Handpum	Hand	-	"TO TEST"
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.06329	-24.9828	0	0	0	0	0	0	0	"No equip	"No powe	-	BLOCKED
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.0626	-24.9819	117.44	8.88	2011-10-2	100	0.07	24	6.05	"Submers	"Electric n	"CLASS 3"	TESTED
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.06132	-24.9807	0	8.65	2011-11-1	0	0	0	0	"No equip	"No powe	-	"TO TEST"
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.06173	-24.9823	45.6	7.8	2011-11-1	0	0	0	0	"Submers	"Electric n	-	"TO TEST"
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.05921	-24.9848	0	0	0	0	0	0	0	"No equip	"No powe	-	BLOCKED
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.04897	-24.977	0	0	0	0	0	0	0	"Momo-ty	Diesel	-	"TO TEST"
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.05384	-24.9885	0	0	0	0	0	0	0	Handpum	Hand	-	"TO TEST"
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.0626	-24.9864	0	0	0	0	0	0	0	Handpum	Hand	-	"TO TEST"
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.06213	-24.9848	5.57	0	0	0	0	0	0	"Submers	"Electric n	-	BLOCKED
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.06243	-24.9856	6.03	5.91	2008-11-1	0	0	0	0	"No equip	"No powe	-	BLOCKED
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.06669	-24.9891	36.32	6.68	2010-01-1	30	0.6	24	51.84	"Submers	"Electric n	"CLASS 4"	TESTED
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.07753	-24.9744	0	0	0	0	0	0	0	"No equip	"No powe	-	BLOCKED
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.05857	-24.983	230	8.95	2008-08-0	120	0.1	4	1.44	"No equip	"No powe	"CLASS 4"	"PUMP SUCTION"
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.05872	-24.9838	137	0	0	0	0	0	0	"No equip	"No powe	-	DRY-DRILL
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.05919	-24.9815	137	0	0	0	0	0	0	"No equip	"No powe	-	DRY-DRILL
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.0591	-24.9819	137	0	0	0	0	0	0	"No equip	"No powe	-	DRY-DRILL
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.05584	-24.9806	141	11.15	2008-10-1	36	0.4	24	34.56	"No equip	"No powe	"CLASS 3"	TESTED
LPJS001	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.06343	-24.9928	67.81	8.57	2011-04-0	60	0.04	24	3.46	"No equip	"No powe	"CLASS 3"	TESTED
LPKS730	Limpopo	"Greater S	"Greater M	Zamenkor	2214	-	29.06212	-24.9817	79.27	6.31	2011-10-2	0	0.1	2	0.72	"No equip	"No powe	-	"PUMP SUCTION"

Annexure 2. Ratings values determined by Lynch *et al.* (1994)

Depth to groundwater (D_R)	
Range (m)	***Rating***
0 – 5	10
5 - 15	7
15 – 30	3
>30	1
Aquifer media	
Range	***Rating***
Dolomite	10
Inter-granular	8
Fractured	6
Fractured and weathered	3
Net recharge (R_R)	
Range	***Rating***
0 – 5	1
5 – 10	3
10 – 50	6
50 – 100	8
>100	9
Soil media (S_s)	
Range	***Rating***

Sand	8 – 10
Shrinking and/or aggregated clay	7 – 8
Loamy clay	6 – 7
Sandy clay loam and loam	5 – 6
Silty clay loam, sandy clay and silty loam	4 – 5
Clay loam and silty clay	3 – 4
Topography	
Range (% slope)	***Rating***
0 – 2	10
2 – 6	9
6 – 12	5
12 – 18	3
>18	1
Impact of the vadose zone	
Range	***Rating***
Gneiss, Namaqua metamorphic rocks	3
Ventersdorp, Pretoria, Griqualand West, Malmesbury, van Rynsdorp, Uitenhage, Bokkeveld, Basalt	4
Karoo (southern)	5
Table Mountain, Witteberg, Granite, Natal, Witwatersrand, Rooiberg Greenstone, Dominion, Jozini	6
Dolomite	9
Beach sands and Kalahari	10

Declaration

This is to declare that I, Annette L Combrink, accredited language editor and translator of the South African Translators' Institute, have language-edited the dissertation by

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