Stakeholder Participation in Surface Water and Groundwater Quality Management in the Waterberg Area; Limpopo Province, South Africa

SCHOOL OF ANIMAL, PLANT AND ENVIRONMENTAL SCIENCES

A Research Report submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science

LESLEY-ANN JOLENE CORNELIUS
Student no. 1444686

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DECLARATION

I declare that this research project is my own, unaided work. It is being submitted for the Degree of Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

Miss Lesley-Ann Jolene Cornelius

29th day of January 2018 in Johannesburg

ABSTRACT

The aim of this research was to assess the status of water quality in a selected area of the Waterberg over a twenty-year period and to gain insight into the perceptions of stakeholders about water management. The objectives were met through the comparison of historical water quality variable records for various water uses, by measuring the level of stakeholder commitment in water quality measurement and verifying a relationship between the two approaches.

This study focuses on measuring the extent of different stakeholders' involvement in the management and decision-making processes of water quality in the Waterberg region of Limpopo province, which is encouraged by the formulation of South African policies. The specific area of interest is in the north-western part of the Waterberg. There are three distinct settlements, Lephalale, Marapong and Steenbokpan, located in the Lephalale Local Municipality. Close by are major industrial and mining activities from Eskom's Matimba and Medupi power stations, and Exxaro's Grootegeluk Coal Mine.

To address the specific research questions and objectives for this study, two approaches were necessary: A quantitative approach that required surface water and groundwater data from 1995 to 2015, to determine the quality of water, and a qualitative approach that comprised of the distribution of 20 questionnaires in the residential areas, and 15/20 successful pre-selected individual interviews, to assess the different levels of stakeholder participation. Each approach presented its own challenges. For example, the water quality data provided were incomplete, which created limitations in the interpretation and during the questionnaire distribution, time constraints and language preferences, though anticipated amongst different social groups, there was difficulty communicating the concept of the study. Also, during the planning phase of selecting interviewees, there was a lack of interest in the study from environmental consultants, who are vital role players in the environmental status of the area.

The water quality data indicated that pH levels in the surface water sites have remained steady and are not significantly different from one another. The results from the one groundwater site, reveals that there is a significant difference between the pH levels of surface water and groundwater which is to be expected. The results also suggest that the high concentration of ammonium, phosphate and nitrate midstream in the Mokolo River are related to the waste water being discharged mid-stream into the river via a pipeline. The high concentrations of sodium and potassium in the groundwater site are linked to the interaction time with the surrounding geology and the overall EC levels correspond with the fluxes in sodium in the groundwater site

resulting in the significant difference in EC between the surface water and the groundwater sites. No data were available for the midstream site.

The questionnaire results indicate that there's limited stakeholder involvement in water quality management from participants in Steenbokpan and Marapong, which are socio-economically disadvantaged areas, when compared with Lephalale, a more affluent area. In contrast to Lephalale, Marapong and Steenbokpan residents are less educated, have higher unemployment numbers, and have restricted access to water related information, and electricity, water and sanitation services. In the overall area, there is also a 30% unawareness amongst general water users about the topic of water pollution, but again it is mostly from participants in Steenbokpan and Marapong.

The interview results signified a higher level of stakeholder involvement in water quality management from individuals in influential positions. This, however, does not mean that water related issues in the area are adequately addressed. Interviewees revealed that there is a lack of funding, skills, infrastructure, manpower and competence. There is also an apparent inequality with regards to water access to informal settlements, farmers and rural villages. Additionally, there is a high level of dependency on Eskom and Exxaro, rather than the local municipality, to provide its water users with proper water services. The dependency on Eskom and Exxaro is largely due to their high level of influential development. Improvements and maintenance on basic service from these structures to the surrounding communities form part of their off-set programmes to continue major development in the area.

Due to the large difference of the qualitative and quantitative approaches, it was difficult to prove how one supports the other, even though, on its own, both are crucial components in water quality management practices. Even though the water quality data provide more reliable support on the condition of surface- and groundwater in the Waterberg, the social aspect (partially revealed through the subjective view of the general users who completed the questionnaire) is required to determine the community's relationship with water use and to identify management practices through stakeholders responsible for them.

In memory of my loving mother

Malie Cornelius

1951 - 2011

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Last, but not least, all the honour and glory to God for bringing me this far and helping me succeed and most importantly, to my dad, Lesley Harry Cornelius, thank you. Thank you for the sacrifices you have made, for always being in my corner, always believing in me, supporting and loving me all the way, no matter the distance.

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CMA – Catchment Management Agencies

CMS – Catchment Management Strategy

DAgRD for KZN – Department of Agriculture and Rural Development for KwaZulu Natal

DEA – Department of Environmental Affairs

DPMC – Department of Prime Minister and Cabinet

DWA – Department of Water Affairs

DWAF - Department of Water Affairs and Forestry

DWS – Department of Water and Sanitation

EC – Electrical Conductivity

GWP – Global Water Partnership

ICWE – International Conference on Water and Environment

ICWE – International Conference on Water and the Environment

IDP - Integrated Development Plan

LM - Local Municipality

MDG – Millennium Development Goals

MPCA – Minnesota Pollution Control Agency

MSA – Municipal Systems Act

NWA – National Water Act

SAWQG – South African Water Quality Guidelines

SDG – Sustainable Development Goals

TAC – Technical Advisory Committee

TCID – Tissue Culture Infectious Dose

UN - United Nation

UNCED – United Nations Conference on Environment and Development

UNEP – United nations Environmental Programme

WB – World Bank

WBCSD – World Business Council for Sustainable Development

WMA – Water Management Area

WSA - Water Service Act

WSA - Water Service Authority

WSP - Water Service Provider

WUA – Water Usage Associations

WWC – World Water Council

WWF – World Wildlife Fund

Chapter 1: INTRODUCTION

The Waterberg Region (Figure 1) is situated in the Limpopo province of South Africa. This province borders the north of Gauteng, Mpumalanga and North West provinces as well as south-eastern border of Botswana (Moatshe, *et al.*, 2009). Vegetation in the area falls within the savanna biome. This biome is characterised by a continuous grassy ground layer and a woody upper layer. The functioning of this biome relies largely on nutrient and water availability (Scholes & Walker, 1993).

The Waterberg is found at between 1500 – 1800m above sea level. It experiences a semi-arid climate and is characterised by wet seasons that have high inter-annual rainfall variation and dry seasons that are warm and occasionally hot. The area has an annual mean temperature of approximately 20°C and a mean annual rainfall of 421mm. The area is rich in mineral resources such as iron, platinum and coal and it also has an abundance of wildlife (Mucina & Rutherford, 2006).

The Waterberg is an area with an extreme variety of stakeholders who use water for different purposes. The current land use of the Waterberg includes mining, agriculture, game farming and hunting, eco-tourism, conservation and to a lesser extent cattle farming (Claassen, *et al.*, 2010; DEA, 2012). It is host to Matimba power station, and Medupi, which will generate the greatest electrical capacity once fully operational, and is approximately 6km apart from one another. The area also contains one of the biggest coal mines in the country, Grootegeluk, which provides coal to Matimba and the operating section of Medupi Power Stations (Corbett, *et al*., 2008; Moodley, *et al.*, 2014).

This region is the cornerstone of the economic income of the district (DEA, 2012). The rapid increases in development and number of job opportunities in the Waterberg have resulted in the rapid increase in the population and has increased the strenuous impacts on the natural resources (Flood, 2015). The area has a high demand for water and needs an improved water management system. A water management system is only as successful as its management practices. Water management practices refers to the strategies companies and/or organizations have in place to overcome water challenges and to adapt to the needs of its users (Goodrich, 2013).

Figure 1: *The Lephalale local municipality north-west within the Waterberg District in the province of Limpopo, South Africa (Source: www.municipalities.co.za). Lephalale, situated in the Waterberg District, is located in the Mokolo River Catchment Area (refer to* Figure 4*).*

1.1 The use of pH, ions and electrical conductivity (EC) in measuring surface water and groundwater quality

Surface water and groundwater sources have different properties. Surface water forms part of an aquatic environment above ground, which in turn provides a diverse habitat for aquatic life and supplies water to animals and humans (Florescu, *et al.*, 2010). Groundwater is dependent on the geological composition and the amount present is different between extraction and the recharge. Meaning that the water table is dependent on how much water is being removed from the aquifer in balance with how much is being returned. The return is dependent on surface water availability, runoff and infiltration rates (Todd & Mays, 2005). The quality of water refers to the measurement of its condition for a specific use or purpose, based on its chemical, physical and biological properties (DWA, 2003). The quality of different water bodies differs due to anthropogenic activities and natural processes within a region (Dinka, *et al.*, 2015).

Natural processes that may influence surface water and groundwater quality, include the area's geology, vegetation, climate, precipitation and flow conditions, just to name a few (Florescu, *et al.*, 2010). Around the Lephalale area, the greatest impacts from human activity on the quality of water, are the discharge of waste water from the local municipality and nearby industries, agriculture (mainly game farming), mining and urban development. Based on these activities, different sections within the surrounding water bodies would be associated with a higher concentration of major ions than in other parts of a river or aquifer (Dinka, *et al.*, 2015).

For the purpose of this study, pH, selected major ions and electrical conductivity (EC) were the chosen based on a consistent availability of data between 1995 -2015. Ideally sulphate should also have been include in the list of ions due to its relation to coal mining and coal fired power stations in the area. unfortunately, it did not meet the criteria on which the other variables were chosen. The selected variables were used to evaluate water quality form available sample sites in the upper region of the Mokolo River Catchment Area of the Waterberg district. Assessing and monitoring water quality, using these parameters, and others, is a vital part of water planning, protection and management. Especially with the rapid growth in human population and the intense urban, industrial and agricultural development and increased risk of water contamination (Tiwari, 2011; Renn, 2004).

By investigating the changes in the pH, EC and the chosen ions for this study, which were ammonium, phosphate, nitrate, sodium, potassium and calcium, a better understanding of possible natural or anthropogenic sources of those ions, such as soil dust or industrial emissions, is developed. Dust fallout and industrial emissions play a significant role in water quality when it interacts with the compound for an extended period of time. These data (pH, EC and ions) can be used as comparative indicator values against a set of standards, allowing detection of possible exceedances of the threshold set by the South African Water Quality Guidelines of 1996 which may become harmful to human health or ecosystem function (Bruyns, 2015).

Pollution and poor management of water in recent years, which includes wasteful practices, has resulted in the deterioration of the quality of water faster than would have been predicted (DWAb, 2013). Costs have increased for the treatment of water in order to make it potable and agricultural yields have decreased, due to water limitations (DWA, 2003). Therefore, involving different water users and stakeholders in managing the resource, has become very important. Stakeholder involvement can aid in avoiding or minimizing impacts, improving the quality of groundwater and surface water, and possibly ensuring the sustainable use of the resource (Mazvimavi, 2013).

1.2 Stakeholder involvement in water quality management

Stakeholder participation has become a vital part in planning and implementation of development. By combining local and scientific knowledge with collaborative thinking in the decision-making process, mutually agreed-upon solutions for development issues could result

(Choo-In, *et al.*, 2015). For this study, stakeholder participation and the different types of stakeholders were investigated to assess any kind of relationship between them and the quality of surface water and groundwater.

In South Africa, the policies and legal framework for stakeholder consultation and involvement are some of the best in the world, but only on paper. The South African government has put Catchment Management Agencies (CMA), Water Usage Associations (WUA) and Water Management Areas (WMA) in place to mobilize Catchment Management Forums (CMF) to increase stakeholder involvement in water resource management. However, there is little flow of information between community based structures and local, provincial or national governmental systems (Nare, *et al.*, 2011).

Even though water management starts at a national level and forms part of provincial planning, Nare *et al.* (2011) suggests that efficient water user practices start at a municipal level simply because local governmental structures control and fund community level development activities. Municipal responsibility includes basic water services (supply and delivery), sanitation services, waste water treatment and the maintenance of water related infrastructure. As the designated Water Service Authority (WSA) and Water Service Provider (WSP), Lephalale Municipality also has the responsibility to equitably allocate water resources amongst its consumers, regulate access to water supply and sanitation services, and to protect and conserve resources (WSA, 1997).

Besides wasteful behaviour, pollution and poor management of water resources by humans, South Africa, for the greater part is a semi-arid region, which is subject to prolonged droughts and high evaporation rates (Eales, *et al.*, 2005). Thus, managing water quality and availability has become essential. Hirji, *et al.* (2002) predicted that the demand for water in South Africa will not meet the supply by 2025. However, resources required to improve monitoring and managing water quality, such as funding, technical staff, infrastructure and community involvement are lacking (DWAb, 2013) and makes it increasingly difficult to manage the scarce resource.

1.3 Aim

The aim of this research was to assess the status of water quality in a selected area of the Waterberg from 1995-2015 and to gain insight into the perceptions of stakeholders about water management.

1.4 Objectives and key questions

1) To determine the water quality of surface water and groundwater resources in the Waterberg district, by comparing water quality variables from historical records from the last 20 years to the South African Water Quality Standards for domestic, industrial, livestock and irrigation uses.
    - What is the quality of surface water and groundwater in selected areas of the Waterberg district?

2) To identify the level of commitment and competence of stakeholders with regards to managing surface water and groundwater quality in the Waterberg area.
    - What is the nature of stakeholders' participation in the management of surface water and groundwater quality?

3) To determine the relationship between the quality of the water and the level of stakeholder participation.
    - Does stakeholder participation in surface water and groundwater quality management, in the Waterberg district, influence the quality of water in the area and vice versa?

Chapter 2: LITERATURE REVIEW

The purpose of this chapter, is to review the recent literature that is relevant to this study. This chapter is divided into four major sections. The first, focuses on international, national, provincial and regional water policies, legislation and strategies. The second section looks at water services, followed by the third section that looks at different characteristics of surface water and groundwater quality resources. The fourth and final section, focuses on the importance of stakeholder participation and approaches used to assess facts and perceptions, within the decision-making process regarding development and water resource management.

2.1 Water policies, legislation and strategies related to the management practices to ensure the necessary water quality for a variety of uses

Water management practices are strategies organizations and/or companies have in place to overcome water challenges and to adapt to the needs of its users (Goodrich, 2013). Water legislation and policies act as a set of guidelines allowing for law enactment that will improve on resource management practices, now and in the future. The need for legislation is to prevent wasteful behaviour, prevent or reduce water contamination, or provide strategies in cases of water scarcity.

2.1.1) International water policy and strategy requirements

On an international level, challenges that relate to managing freshwater resources was an important topic at the United Nations Conference on Environment and Development that took place in Rio de Janeiro in 1992 (Chéret, 2004). It was preceded by the International Conference on Water and the Environment earlier that year in Dublin (UNEP, 2002). These two conferences fed into the formulation of the Millennium Development Goals (MDGs) and Agenda 21 (TAC, 2000).

The International Conference on Water and the Environment (ICWE) resulted in the development of the four Dublin principles aimed at improving water management with poverty as the focal point.

1. Freshwater resources are vulnerable and restricted. It is also essential in sustaining life, social and economic development, and environmental functioning.

2. The participatory approach should be the basis of water management and infrastructure development. This approach involves users, policy makers and planners at multiple stages of the decision-making process.
3. Women should be more involved in the provision, management and safe guarding of water resources.
4. Water has economic value and should be seen as an economic good (ICWE, 1992).

The International Conference on Water and the Environment (ICWE) emphasised that water is at the centre of sustaining life and important for any human activity to take place. Without reliable access to water, there is no social or economic development. This concept led to the development to the eight Millennium Development Goals (MDGs), with the long term aim of environmental sustainability, economic development and poverty reduction by the year 2015 (TAC, 2000).

The Millennium Development Goals were as follow:

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/Aids, malaria and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development (TAC, 2000).

The time for the MDGs has passed and targets were not fully met. The MDGs were the basis for the negotiation of the 17 new goals called the Sustainable Development Goals (SDGs) to be met by 2030. The new set of goals has three clear focus categories:

- ✓ Human well-being
- ✓ Economic development
- ✓ Biophysical environment

For this study, the important goal is number 6, which ensures availability and sustainable management of water and sanitation for all (UN, 2015).

Goal 6 of the SDGs focuses on improving the participation of local communities in water and sanitation management. It also investigates the implementation of integrated water resource management, ensuring sustainable water withdrawals, improving water quality by reducing pollution, and protecting and restoring all water related ecosystems, while striving to achieve universal and equitable access to safe and affordable drinking water for all (UN, 2015).

2.1.2) National water legislation

The Constitution of the Republic of South Africa (No. 108 of 1996) makes provision for water laws. It states that everyone has the right to have access to sufficient food and water, an environment that is not harmful to their health and well-being and that water resources must be protected for the current and future generations. It also says that the national government is the custodians of groundwater and surface water resources and that the local government has the responsibility of providing municipal water supply and sanitation services (Rebublic of South African Goverment, 1996).

In South Africa, the National Water Act (No. 36 of 1998), provides the legal framework for sustainable management of its resources. The focus of this act is to recognise that water is a precious and scarce resource that belongs to all South African people. The main aim of the South African Water Act, is to manage, control, protect, conserve, use and develop the resource while promoting integrated management of the resource and including the participation of various stakeholders (NWA, 1998).

The National Water Act (No. 36 of 1998) links to goal 6 of the Sustainable Development Goals by making it a corner stone of social and economic development while alleviating poverty. In South Africa, like in many other countries, this has become increasing difficult because many of the existing water resources, especially surface water resources, are significantly altered and over-used due to every day human activities and in a water scarce country the demand for water is greater than the availability. This means that some areas are water stressed and that some people do not have access to potable water (DWAF, 2012).

Sustainability, equity and efficiency are the principles that guide the act in managing, controlling, protecting, conserving, using and developing the resource. To achieve sustainability, equity and efficiency, the resource must be managed in an integrated manner that relates to the hydrological cycle by linking human activities, water resources and the biophysical environment to one another. Integrated water resource management requires co-ordinated planning of land, water and environmental resources while also providing sufficient information about groundwater and surface water resources, while involving planners, individuals and institutions in water related planning and decision-making (DWAF, 2012).

South Africa has 9 different Water Management Areas. The National Water Act (No. 36 of 1998) requires that for each catchment a water strategy is developed called the Catchment Management Strategy (CMS). The strategy has a set of objectives, plans, guidelines and procedures for overall water management. The CMS also takes into account the classification of water resources in the area, has resource quality objectives and makes sure that the water resources meet the requirements of the reserve and international obligations. The reserve refers to the amount of water set aside to provide for basic human needs and to protect and sustain healthy water ecosystems. It has a water allocation plan that is set in accordance with the regional and national plans and it enables public participation in managing the resource in order to take the needs of current users into consideration (DWAF, 2012).

2.1.3) Provincial water strategy

The Municipal Systems Act (No. 32 of 2000) regulates any development planning within local government. Its purpose is to integrate proposals for municipal development and to align its resources and capacity when implementing the plan. The regional area for this study is the Lephalale Local Municipality situated within the Waterberg District and Limpopo Water Management boundaries. The Lephalale Municipality (LM) is the designated Water Service Authority and the Water Service Provider and has a duty to provide water services to a population of 115 746. This area is made up of urban, peri-urban, game farming and rural communities (IDP, 2013).

Rural areas and farms mostly make use of unmonitored, groundwater resources (Respondent-1, 2016). The groundwater supplied by the local municipality to the rural areas is insufficient due to poor flows and unacceptable quality, based on the standard provided by Volume 1 (Domestic Use) and Volume 7 (Aquatic Ecosystems) of the South African Water Quality Guidelines (DWAFa, 1996; DWAFf, 1996). The boreholes that supply water to these areas are owned and operated by the local municipality. The water is pumped and placed in storage reservoirs before it is distributed. However, most farms are situated close to the river and the farmers have drilled and maintain their own boreholes. The high yields produced this close to the river are groundwater interflow and are often of better quality (IDP, 2013).

Water quality in South Africa, as per the Department of Water Affairs (2003), refers to the suitability of the resource's condition for a specific use or purpose, based on its chemical, physical and biological properties. Together with the South African Water Quality Guidelines (DWAF, 1996), it is easier to determine whether a surface- or groundwater source is deteriorating or at an acceptable level for a specific use.

All water for the urban area is from the Mokolo Dam. Exxaro's Grootegeluk Coal Mine built the main supply lines, pump station, balancing dam and purification works. The maintenance and supply chain of the infrastructure is carried out by the Grootgeluk Mine. The township of Marapong receives its water from the municipality supplied by the Mokolo Dam. According to the local municipality's official Integrated Development Plan (IDP) document the municipality is supplied with purified water by Eskom's Matimba power station. The municipality is currently benefitting from the agreement it has with Eskom and Exxaro, but there is a concern about the long-term development needs, maintenance and ownership of the water supply infrastructure (IDP, 2013).

Based on the current infrastructure and water availability in the area, no spare water exists to allocate to any future economic development in the area. This realization led to the Department of Water Affairs allocating R1.8 billion for the Mokolo-Crocodile Water Augmentation Project to address water shortages. The project has two phases; one to expand on the supply from the Mokolo Dam, and two, to transfer water from the Crocodile West River to the Lephalale area (DWA, 2010). The project has been approved despite the already overallocation of the Crocodile West River.

Water access to the rural population in this region is very poor. Many have to walk up to 500m just to gain access to a water point. A third of households in Lephalale municipal area do not have access to piped water on their property. Water losses in the system are also not accurately measured. This information is important for effective and efficient management of the water resources (IDP, 2013).

2.2 Basic water services

Based on the National Water Act (No. 36 of 1998) water has to be divided for basic human needs and enough for ecological reserve for natural ecosystem processes to continue. There are two types of water services that are basic human rights; water supply and sanitation as stated in section 2 (a) of the Water Service Act (No. 108 of 1997). The main objective of the act is to ensure the right to access, sufficient water supply and sanitation services and an environment not harmful to human health or well-being as stated by the constitution.

The Department of Water Affairs and Forestry (2002) defines water supply services as follows: "the abstraction from a water resource, conveyance, treatment, storage and distribution of potable water, water intended to be converted to potable water and water for industrial or other use, where such water is provided by or on behalf of a water services authority, to consumers or other water services providers." Sanitation services includes the collecting, disposing and treating of industrial waste water, as well as human and domestic waste water by the appropriate authority (DWAb, 2013).

2.2.1) Different water uses

There are multiple uses for water resources. They include water for:

1. Drinking
2. Domestic use
3. Industrial use
4. Agriculture – Irrigation
5. Agriculture – Livestock
6. Aquatic Ecosystems
7. Recreational activities (DWAF, 1996).

The assessment of general water resource usage is mostly from the 20th century because earlier records of household and industrial water use are incomplete or non-existent (Flörke, *et al.,* 2013). Water use assessments have shown that irrigation is one of the biggest freshwater withdrawals for human purposes worldwide. Industries use about 20% and municipalities use nearly 10%. In South Africa, 54% of water is used for agriculture and 3% used for mining. Most of the water used for human consumption and industry returns as waste water and requires treatment before it can be reused (WWC, 2010).

According to the World Business Council for Sustainable Development (WBCSD), humans need at least 25l of water per person per day to survive. Of that water, 2l are for drinking and 23l are for domestic purposes. But the average withdrawals per capita for drinking and domestic use vary significantly between developed and developing countries (WBCSD, 2006).

Even though the desired chemical composition of water required for industry is different from drinking or livestock watering, a certain quality of water is essential to produce many products, including electricity. One of the largest uses for water in industry, is for cooling water when producing electrical energy in power stations (WBCSD, 2006). However, the amount of water used in producing electricity depends on the type of fuel and power generating technology used. For example, biodiesel-fuelled power plants use more water than coal, nuclear or wind generated power stations (Giobognoli, 2013). In interest for this study, the Waterberg has an abundance of coal but a shortage of water. Therefore, coal fired power stations with air cooling systems is preferred over most renewable energy options.

While some industries dispose of their waste water into natural fresh water systems, such as rivers and lakes (WBCSD, 2006). Only some of those waste products, such as phosphate and toxic chrome from textile industries and nitrates from fertilizer production, can be broken down and diluted by natural occurring processes, such as the water, phosphorus and nitrogen cycle. Other inorganic, solid or acidic waste e.g acid mine drainage, deteriorates the quality of water and is no longer usable without costly treatments (WBCSD, 2006; Alturkmani, 2010). Therefore, polluting processes, such as coal burning emissions from power stations (Bruyns, 2015) and urban waste water discharge into the Mokolo River, could directly or indirectly alter ion concentrations in the surrounding water courses to a toxic level. These changes may cause major long term negative effects. If unattended, those impacts can be irreversible or very expensive to treat. This is because the ratio between water and the contaminant is to large.

Although food production only makes up a small part of the economic income of the Waterberg, water use through irrigation is the key component for developing countries to produce food (WBCSD, 2006). This statement is supported by *Figure 2* (below) which shows that the greatest amounts of water used for agriculture has occurred in North Africa, Latin America, the Caribbean and South Asia with Sub-Saharan Africa being the exception which uses the lowest amount relative to the other developing regions (WWF, 2017). With a rapidly growing population, more food will be required and more water to grow food. However, food production will be limited if further stress and competition for water resources continues through inefficient irrigation practices and other conflicts involving water allocation (WBCSD, 2006).

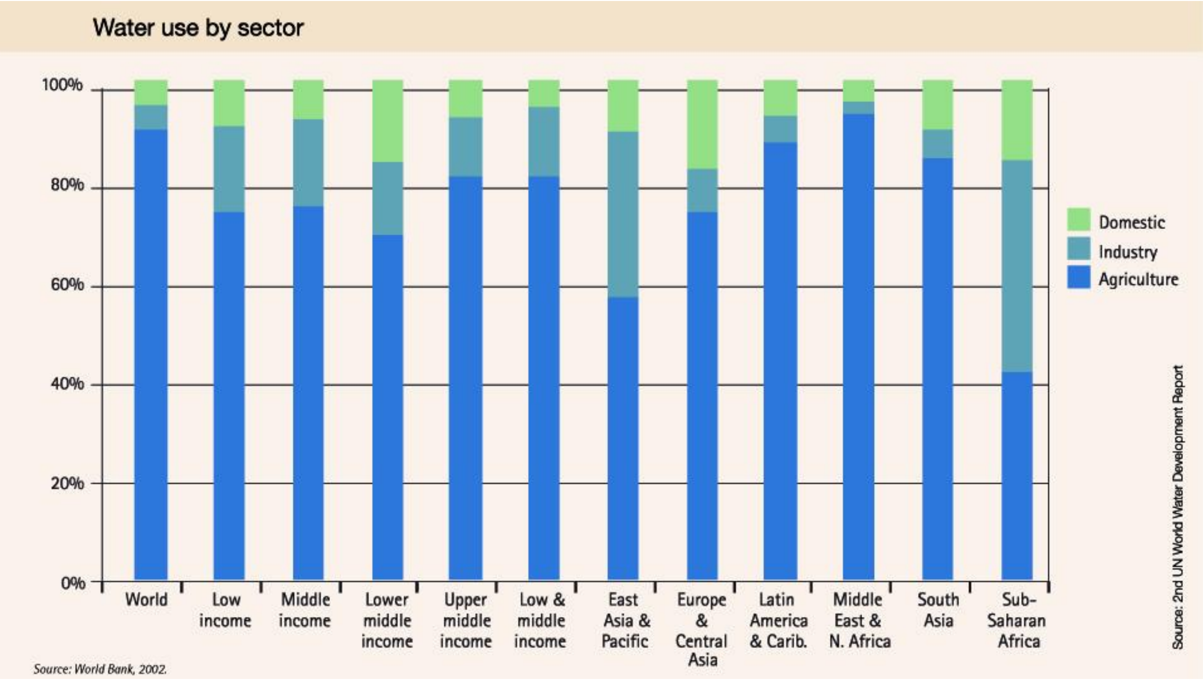

Figure 2: *Domestic, industrial and agricultural uses of water for different income levels and within different continents as provide by the World Bank in 2002 (Source: wwf.panda.org)*

The success of livestock enterprises is dependent on a good water supply. Livestock comprise different species and make use of different sources of water, such as free drinking water and water contained in feed. However, there are certain factors that farmers need to take into consideration when it comes to the composition of water and livestock e.g the geographical location, the quality of water provided, the type and size of the animal, and its diet (Alberta, 2005).

Terrestrial animals can survive without food for long periods of time, but a lack of water can cause death in a matter of hours or days, depending on the animal (DAgRD for KZN, 2016). Even though no data was collected on the specific agricultural activities in the Waterberg region, game farming forms an important part of this area. Therefore, natural occurring surface water and especially groundwater availability play a vital role in the survival of wildlife in an already water scarce area.

Recreational uses of water are usually linked to enjoyment and refreshing of the body and mind. Water related recreational activities come in various forms, such as fishing, swimming and water parks (Atkins, 2017). Water for recreation also has economic value in the form of water-based sport, tourism and leisure (Jennings, 2007). Due to the variety of recreational activities that involve water, each activity may require a different standard of water quality (DWAFb, 1996) and quantity (DWAb, 2013). However, because the Waterberg is a water scarce area, there is no proof of the use of water for recreational purposes, such as swimming pools or water parks.

2.2.2) Basic water supply and sanitation

Mentioned in a previous paragraph, is that every person needs a basic amount of water supply to survive every day. The minimum amount of water per person per day for drinking and domestic use is 25l, but the WSA promises 6000l of potable water per household per day. The basic water supply must be safe to drink and does not involve any health risk. These promises are difficult to keep to those households that get their water directly from a river. The demand in water supply can seldom keep up with the demand that comes with urban and industrial development. Delivering water services to residential populations and industry is an important part of water allocation, but often conflicts with the requirements for agricultural activity and the biophysical environment (DWAb, 2013).

Basic sanitation does not only focus on having a clean and reliable toilet system, but also involves education on personal health and hygiene. Much like the water supply services, a growing population is linked to an increase in sanitation service delivery and waste water management (DWAb, 2013). In South Africa, many who are from underprivileged, socio-economic backgrounds cannot afford or do not have the option of basic sanitation services. Sixteen years ago the country adopted a policy to provide free basic services to everyone, but specifically aims to give the poor first benefit, which included water supply, sanitation, refuse removal and electricity. For sanitation services, this meant providing clean and reliable toilets to all, and improving on existing toilets that are unhygienic, on an already strained budget. By December 2008 the sanitation backlog was estimated at 3 million homes. The aim was to meet, the then MDG sanitation goal, of eliminating the sanitation backlog by 2010 (Still, *et al.*, 2009).

The supply of basic water provision and sanitation services are dependent on water resource infrastructures and financing (TAC, 2000). Provision of these services is not only dependent on the governance and management approaches, but also on the socio-economic status of the people. In South Africa, these facts result in unequal service delivery to the wealthy versus the poor, and to metropolitan areas versus rural areas (Van Vuuren, 2011).

Sadly, assessments done in recent years on South African water supply and sanitation infrastructure, have shown only marginal improvements. The infrastructure has been reported to be of poor quality and unreliable, due to the lack of skill within the water service authorities and providers, neglect of maintenance and the lack of finances required to upgrade current water and sanitation infrastructure (Clifford-Holmes, *et al.*, 2016). Evidence has been provided to show that all levels of governance, concerning water provision, is under stress (Van Vuuren, 2011).

2.2.3) The South African Water Service Authorities

In terms of the Water Service Act (No. 108 of 1997) Chapter 3, Section 11, the Water Service Authority "has a duty to all consumers or potential consumers in its area of jurisdiction to progressively ensure efficient, affordable, economical and sustainable access to water services"

Water service authorities have the constitutional responsibility to equitably allocate water resources amongst its consumers, regulate access to water supply and sanitation services, and to protect and conserve water resources. Consumers must pay a certain tariff for the water supply and sanitation services, based on prescribed norms and standards. If consumers or the water provider fails to comply to the terms and conditions set for these water services, the water service authorities have the right to limit or discontinue the provision of the services (WSA, 1997). In other words, financial stability is a major contributing factor to whether or not a service is provided and the quality thereof.

However, there are those individuals who do not have the option of accesses to or the means to pay for basic water supply and sanitation services. It is therefore also the responsibility of the water service authority to ensure that the trade-offs necessary to meet their mandate are planned, implemented and transparent. This provision is also referred as 'social water' (Nkondo, *et al.*, 2012).

2.2.4) The South African Water Service Provider

A Water Service Provider has a contract with another service provider and/or with a Water Service Authority to be a bulk water service provider or a retail service provider. A bulk service provider, for example Rand Water, sells water or accepts waste water with the purpose of treating it to a certain geographical area. A retail water service provider, for example local municipalities, provides water and collects human waste water from consumers within a specific geographically area (DWAb, 2013).

The water service provider may only provide basic water and sanitation services to a specific area, only if it has the approval of the water service authority to do so. Approval is only granted subject to certain conditions and is only approved for a limited time period. The water service provider also has the responsibility to issue information on the distribution of the water services. This information must be accessible to the consumer, the water service authorities, the relevant province and to the Minister of water and sanitation (WSA, 1997). Sometimes the WSP and WSA are often in the same municipality, which raises the problem of who is the referee to ensure that the other party complies.

When providing water and sanitation services to an area, those services should be monitored and evaluated. How these water services are provided, depends on the local government system that is in place. This includes finances, reporting, skills and knowledge that are available. How these local government systems perform varies between municipalities that serve towns, metropolitan areas, urban settlements, traditional villages and informal settlements (DWS, 2015).

2.3 Contributing factors to the quality of natural water resources

South Africa as a water scarce country is so classified due to its low annual rainfall, which is highly variable and its naturally high evaporation rates (DEA, 2011). With water scarcity comes water shortages. Currently the country's known freshwater resources are already over allocated, which is a clear indication of shortage in water (Hedden & Cilliers, 2014). The lack of sufficient water has highlighted river water quality evaluations as a relevant and pressing issue (Ongley, 1998).

Water misuse, in the form of pollution, wasteful behaviour and poor management, has led to the deterioration of water quality and thus, leads to decreased agricultural yields and an increase in the treatment costs of potable water (DWA, 2003). Due to increased water pollution levels linked to population growth and over consumption, there is also a need for a new system and techniques to assess water quality (Chau, 2006). This is because traditional methods are no longer sufficient in classifying and quantifying environmental effects or providing logic means for dealing with missing data (Lermontov, *et al*., 2009).

2.3.1) Characteristics of surface water and groundwater quality

Surface water is any water that naturally occurs on the earth's ground surface. This includes rivers, wetlands and oceans. Freshwater bodies are naturally fed through rainfall, or other forms of precipitation, and surface water and groundwater interaction. Surface water naturally also loses moisture through evaporation, ground infiltration and/or the use by plants and animals

(Wood, 2017). Surface water sources are susceptible to negative impacts from various human activities (Simeonov, *et al.*, 2003), as well as erosion and changes in precipitation (Akkoyunly & Akiner, 2012). Urban and rural settlements are significantly different. These differences are evident within its socio-economic backgrounds – for example access to basic services. However, both parties are partially responsible for water contamination. But the lack of access to safe water and inadequate sanitation services in rural areas, demands an increase or a change in the efficiency of the processes associated with waste water treatment in aid to improve water quality (Makgoka, 2005).

Groundwater is an important source of fresh water supply and amounts to the largest freshwater source on the planet (Greenburg, 2005). Groundwater in its natural form contains dissolved mineral ions, derived from soil particles, sediments and rocks, as it travels through the pores and fractures in the unsaturated zone and aquifer. It is fed through the infiltration of precipitation, surface water runoff as and/or surface water and groundwater interaction (Harter, 2003).

The non-visible underground movement of groundwater is what makes it unique and results in the chemical reactions it has with its surrounding soil and rocky environment. For example, all groundwater contains salts from underground movements in its distant past and its current location (Todd & Mays, 2005). In South Africa, human activity has historically been depended on surface water supplies, but population growth, droughts and increased surface water pollution, has led to an increase in groundwater usage (Lathamani, *et al.*, 2015). However, with the increased use of the resource, for human activity, there has been a negative impact on the quality and quantity of groundwater resources (Al-Zabet, 2002; Voudouris, 2009).

2.3.2) The water quality standard in South Africa

In 1996, the then known Department of Water Affairs and Forestry (DWAF), developed the South African Water Quality Guidelines. These guidelines serve as an aid to support decision-making related to the standard of water for different uses. Domestic, recreational, industrial, agricultural (for irrigation, livestock and aquaculture) and aquatic system uses, all have different target water quality ranges (see Table 1). The Waterberg region, however, uses water mainly for domestic, industrial, irrigation and livestock purposes, but water for aquatic systems in the area are also a requirement, although not a focus point in this study.

Table 1: *The pH, ions (mg/l) and EC (mS/m) standard, set for different types of water uses as determined by the Water Quality Guidelines of South Africa (DWAF, 1996).*

Water Use	pH	Ammonium	Phosphate	Nitrate	Sodium	Potassium	Calcium	EC
Domestic	6.0 – 9.0	0 – 1.0	X	0 - 6	0 - 100	0 - 50	0 - 32	0 - 70
Recreational	6.5 – 8.5	X	X	X	X	X	X	X
Industrial	7.0 – 8.0	X	X	X	X	X	0 - 50	0 – 250 (depending on category)
Agriculture: Irrigation	6.5 – 8.4	X	X	X	<70	X	X	<40
Agriculture: Livestock	X	<7	X	0 - 100	0 - 2000	X	0 - 1000	X
Agriculture: Aquaculture	6.5 – 9.0	0 – 0.3	0.1	<300	X	X	20 - 100	X
Aquatic Ecosystems (surface water)	6.0 – 8.0	<7	X	X	X	X	X	X

*X = does not have a guideline value available

When looking at water quality regulations, it consists of pollution parameters and statistical summaries about (mostly surface) water bodies that are understandable to scientists. However, this information should also be meaningful to decision makers in the water sector and to water users who want to know about the state of their local water resources (Nasirian, 2007). That is why using a water quality index (WQI) is a practical method to use when observing and representing issues around water contamination (Akkoyunly & Akiner, 2012).

There is not a specific WQI available for the Waterberg. Water quality indices are designed to describe the overall water quality status in one expression. The most commonly used WQI, to assess water for human consumption, is the National Sanitation Foundation Water Quality Index (NSFWQI). This method is based on nine water quality parameters that can assess any water body that is critically polluted:

1. pH
2. Nitrates
3. Biological Oxygen Demand (BOD)
4. Turbidity
5. Temperature
6. Fecal coliform
7. Dissolve oxygen
8. Total solids
9. Total phosphates (Tyagi, *et al.*, 2013).

With multiple water quality issues in the Waterberg, such as the lack of a proper sewage system, failing municipal sewage works and polluted water runoff from mines, industry and agricultural pesticides and fertilizers (WDM, 2016), NSFWQI would be the ideal approach when identifying changes in water quality over a certain area and evaluating the water quality for a particular use. Making NSFWQI one of the most preferred methods to use for complex water related issues (Tyagi, *et al.*, 2013).

Due to the low annual rainfall and scarcity of surface water in the Waterberg, groundwater resources are extremely valued, especially by the farming community and rural traditional villages. However, groundwater quality in the Waterberg is continuously threatened by the impacts associated with opencast mining of the shallow Waterberg coal reserves (Vermeulen & Bester, 2010).

There are two types of groundwater systems located in the coalfields of the Waterberg:

1. The upper Weathered Groundwater System
2. The lower Fractured Groundwater System (Vermeulen & Bester, 2010).

Hodgson and Krantz (1998) describes the weathered aquifer as made up of soil and rock, is between 5 – 15m thick from the surface and is recharged by rainfall. Due to the low rainfall in the area and the insignificant thickness of the aquifer, the weathered zone is low yielding, but the water is of good quality.

The fractured rock below the weathered zone is impermeable and does not allow for water flow. Secondary groundwater movement must take place in fractures, intrusions, joints and cracks in sandstone and quartzite known to the area. Water yield in the fractured aquifer is better than in the weathered aquifer, but the water contains higher salt concentrations due to the long time the water had been in contact with the rock (Hodgson & Vermeulen, 1998).

2.3.3) Chemical water quality properties

Chemical data aids in identifying factors that influence surface water systems and contributes to sound water management practices and solutions for water contamination challenges (Simeonov, *et al.*, 2003). The chemical properties of surface water (and groundwater) are critical factors that can influence human health when used for drinking and domestic purposes. The ions analysed for water used for drinking and domestic purposes are sodium (Na^{+}), iron (Fe^{2+}), chloride (Cl^{-}) and manganese (Mn^{2+}) (Table 2). Industry, irrigation and livestock water have an alternative set of ions that are analysed and at different levels (Table 3) (Zhang, *et al.*, 2012). A reliable monitoring programme that will provide data on surface water quality is important and must involve frequent fresh spatial and temporal sampling. Analysis must be carried out at the correct resolution and sample data stored for historical reanalysis (Simeonov, *et al.*, 2003). The same goes for groundwater borehole sampling.

Table 2: *Ions analysed for water used for drinking, as presented by Mamba* et al. *(2008), and domestic purposes, as presented by the Department of Water Affairs and Forestry (DWAFa, 1996).*

Ions	Drinking (Mamba *et al.*, 2008)	Domestic (DWAF, 1996)
Sodium	0.2mg/l	100mg/l
Iron	0.2mg/l	0.1mg/l
Chloride	0.2mg/l	100mg/l
Manganese	0.01mg/l	0.05mg/l

Table 3: *Ions analysed for water used for industry, irrigation and livestock as presented by the Department of Water Affairs and Forestry (DWAFd, 1996; DWAFe, 1996).*

Constituent	Industrial	Irrigation	Livestock
Sulphate	0 – 30mg/l	-	0 – 1000mg/l
Chloride	0 – 20mg/l	<100mg/l	0 – 4000mg/l (depending on species)
Nitrate	-	-	X
Ammonium	-	X	X
Phosphate	-	X	X
Sodium	X	<70mg/l	X
Potassium	X	-	X
Lead	X	X	0 – 0.1mg/l
Chromium	X	X	0 – 1.0mg/l
Arsenic	-	X	0 – 0.1mg/l
Benzene	-	-	-

*- =ion analysed, but does not have a guideline value available

*X = ion not analysed for specified use

Most of the ions mentioned in *Table 2* and *Table 3* are not used for this study due to limitations of data collection. Due to those limitations, only certain ions will reflect within the results section to water uses for domestic, industrial, livestock watering and irrigation

Chemical and biological reactions in the areas through which the groundwater moves, determines its chemical characteristics. As mentioned before, the geology and soil type have a major influence on ion concentration within the groundwater. Inorganic ions commonly found in groundwater include the following (more than half of the ions mentioned in the list are not used for this study due to data unavailability):

- ✓ Calcium (Ca^{2+})
- ✓ Chloride (Cl^{-})
- ✓ Iron (Fe^{2+})
- ✓ Magnesium (Mg^{2+})
- ✓ Sodium (Na^{+})
- ✓ Manganese (Mn^{2+})
- ✓ Aluminium (Al^{3+})
- ✓ Nitrate (NO_3^{-})
- ✓ Fluoride (F^{-})
- ✓ Ammonium (NH_4^{+})
- ✓ Sulphate (SO_4^{2-})
- ✓ Phosphate (PO_4^{-3})
- ✓ Potassium (K^{+})

Other characteristics that affect both the quality of groundwater and surface water, are the hardness, pH, electrical conductivity (EC) and total dissolved solids (TDS) values. The concentrations of these cations and anions, as well as hardness and TDS, are measured in milligrams per litre (mg/l). EC is measured in milli-Siemens per metre (mS/m) and pH has no specified unit of measure. (Todd & Mays, 2005).

2.3.4) Physical water quality properties

Besides the natural process that feed river systems, there are a variety of inputs that include surface runoff from non-natural sources and discharge from associated water bodies and developments (Schreiber, *et al.*, 2015). Surface water quality is also influenced by sediment loads. These loads may be enriched with nitrogen and phosphorus as a result of surrounding agricultural activities, which in turn results in eutrophication of river systems (Chapman, 1996). The rate and magnitude of the natural process of soil erosion, are influenced by the soil structure and composition, wind speed, amount of precipitation, as well as vegetation cover and topography. Soil erosion contributes up to 60% of soils loaded into surface waters in

Southern Africa (Jordan, *et al.*, 2014). The Waterberg is covered with mostly sandstone, marula trees and tall grass, which aids in lowering the erosion potential. However, other areas are bear and have a 1m thick, top layer made up of medium grains and silty sands, which in increases erosion sensitivity (Paterson & Seabi, 2010).

In the Waterberg district, approximately 1% of the total surface area is covered with rivers and wetlands (IDP, 2013). The area is also made up of various soil types, which means different capacities to buffer the effects of acid deposition on the surface of the soil (Bruyns, 2015). However, in the case of coal, the mineral does not become a problem when it is deposited to the surface, but rather thru its exposure to air and then water. The lithology of the area (Figure 3*)* indicates 26 dominant rock types (DEA, 2010) of which most is sandstone (De Klerk, 2003).

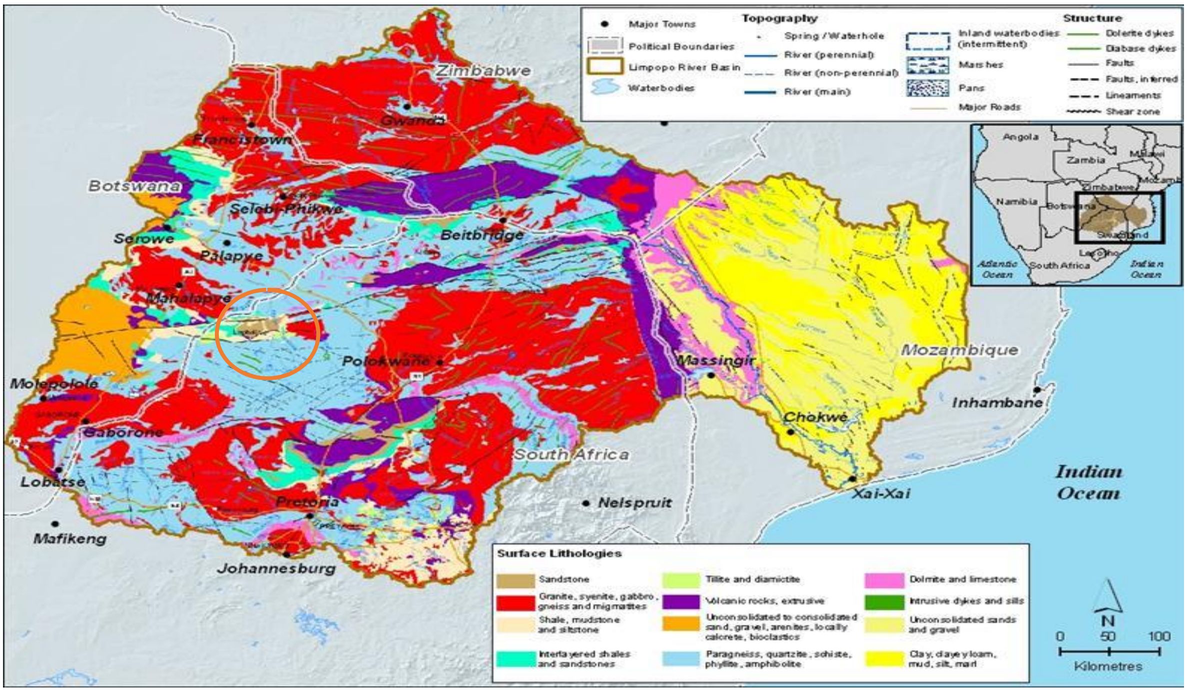

Figure 3: *The lithology of the Limpopo River Basin. The Waterberg area is highlighted with a circle. (Source: www.limpopo.riverawarenesskit.org).*

Transformation of surface land cover by human activities, such as urbanization, deforestation, industrialization and agricultural practices, can increase the rate of erosion (Toy, *et al.*, 2002), which results in sediment transportation during runoff, altering surface water quality as well as drainage (Jordan, *et al.*, 2014).

Groundwater is not openly exposed to external activities such as, industrialization, urbanization, deforestation, agriculture, erosion, wind speed or vegetation cover (Toy, *et al.*, 2002). This makes groundwater less susceptible to pollution and requires little to no treatment, unlike surface water (Aller, *et al.*, 1987). Even Physical properties to focus on during groundwater and surface water analysis are turbidity, temperature, colour, taste and odour (Todd & Mays, 2005).

Temperatures are reported in degrees Celsius (°C) and should be measured in situ. Turbidity measures colloidal matter in water, such as clay, silt, organic matter and microscopic organisms, and it is usually measured spectrophotometrically. Changes in colour are caused by organic matter or minerals. The presence of dissolved organic matter may turn the water different shades of brown whereas algae may turn it green. The colour of mineral availability in water will depend on the minerals and concentrations present. Changes in the odour or taste in water, can only be distinguished against odourless and tasteless water. Unpleasant tastes or smell may be caused by bacteria, mineral matter, dissolved gasses or phenols (Todd & Mays, 2005).

2.3.5) Biological water quality properties

Biological contaminants often severely, negatively impact surface water quality. Contaminated river water, as mentioned before, can jeopardize human health and there are several types of pathogens that can cause gastrointestinal illness with an intake of a small number of cells, namely:

1. viruses
2. bacteria
3. fungi
4. parasites (Allos & Blaser, 2009).

Contaminated surface water does not just threaten potable water, but also impacts recreational activities and crops if irrigated with polluted water (Kistemann, *et al.*, 2002).

Possible transmission routes for the above named pathogens are through drinking untreated, polluted water, ingesting raw edible crops irrigated by contaminated water or swimming in polluted surface water (Donovan *et al.*, 2008; Yonder *et al.*, 2008).

Analysing biological properties of groundwater and surface water quality is important when the water is being used for human consumption or for the irrigation of edible crops. Biological analysis for groundwater mainly involves testing for coliform bacteria. The reason for this being, some coliform organisms in groundwater resources serves as an indication of contact with sewage sources and can be found within human or animal intestines if ingested. Biological analysis for surface water, however, looks at different bacteria, viruses and parasites (Todd & Mays, 2005).

Table 4: *The standard for coliforms, heterotrophic bacteria, coliphages, viruses and protozoan parasites set for domestic and irrigation uses of water as determined by the Water Quality Guidelines of South Africa (DWAFa, 1996; DWAFd, 1996).*

Water Use	Coliform	Heterotrophic Bacteria	Coliphages	Viruses	Protozoan Parasites
Domestic	0 counts/100ml	0 – 100counts/1ml	0 – 1counts/100ml	0 $TCID_{50}$/10l (TCID refers to the tissue culture dose required to cause 50% infection)	0 cysts or oocysts/10l
Irrigation	<10 000 bacterial counts/ml	X	X	X	X

Just because groundwater has low susceptibility to pollution does not mean that it is not at risk. Rural areas, traditional villagers and farming communities, count on groundwater for potable water. (Solley, 1988). However, in some areas the resources have gone unmonitored for decades and agriculture, industrial activities and poor waste water management, threatens both the quality and the quantity of groundwater resources (Baalousha, 2010, Muhammad, *et al.*, 2015).

2.4 The importance of various stakeholder participation

The importance of stakeholder participation is based on the second principle of the Dublin Principles. Stakeholder participation mainly focuses on the involvement of various public groups, individuals, businesses, NGO's and governmental bodies, who are negatively or positively affected, or interested in any ongoing or proposed actions involved in the decision-making process, of local and public social, economic or environmental development (Aloni, *et al.*, 2015).

Any major or minor development project has some level of impact on the surrounding environment and can cause changes to occur in the biophysical environment, such as air pollution or in the quality of surface- and groundwater. Adjustments also occur within the local community's livelihoods, for instance more or less employment opportunities, services of facilities, or their cultural heritage (Mazvimavi, 2013). Stakeholder or public participation presents the opportunity for any and all interested and affected parties to raise their concerns and opinions. It also allows for a platform to create community awareness on mutual public issues as well as having open access to updated information about developments in their area (Townsend, 2007).

Even though the importance of stakeholder participation is now fixed into national and international policy, all participatory approaches are different in a geographical and disciplinary sense. According to Reed (2008): "decisions made through stakeholder participation is strongly dependent on the nature of the process leading to them." Therefore, ways of information quality control have been proposed through transdisciplinary knowledge production by integrating scientific and political systems (Hage, *et al.*, 2009).

Published literature often mentioned the use of a 'tool-kit' approach for stakeholder participation. For example: 1) by using utilization-focused-evaluation (UFE) to identify and analyse stakeholders (Bryson, *et al.*, 2011) and 2) a Cabinet Implementation Unit (CIU) tool-kit was developed by the Australian government on who to engage with, how to engage with them and what will be discussed during the engagements with stakeholders (DPMC, 2013).

More recent literature focuses on the need to replace that approach trough the Sustainable Development Goals (UN, 2015). This led to the development of eight principles of best practices to involve stakeholders. These principles were identified by using a social science technique to systematically develop a theory through analysing data. This approach is known as Grounded Theory Analysis. The principles developed through this approach, are as follow:

1. Stakeholder participation needs to be underpinned by a philosophy that emphasises empowerment, equity, trust and learning.
2. Where relevant, stakeholder participation should be considered as early as possible and throughout the process.
3. Relevant stakeholders need to be analysed and represented systematically.
4. Clear objectives for the participatory process need to be agreed among stakeholders at the outset.
5. Methods should be selected and tailored to the decision-making context, considering the objectives, type of participants and appropriate level of engagement.
6. Highly skilled facilitation is essential.
7. Local and scientific knowledge should be integrated.

8. Participation needs to be institutionalised (Reed, 2008).

The following headings used in the next section were derived from the above mentioned principles.

2.4.1) Clear objectives amongst stakeholders

Clear working goals for the participatory group must be set from the beginning (Lynam, *et al.*, 2007). Setting goals aids in identifying boundaries and issues from the stakeholders alongside the developers and it creates a platform on which stakeholder involvement can be analysed (Reed, 2008). However, deciding on a single set of objectives can easily focus only on general surface issues and avoid discussing diversity of opinion and values. The goals that are then ultimately agreed upon, diverts attention from other possible issues (van de Kerkhof, 2006).

Having a difference of opinion during the participatory process, helps recognise that trade-offs are a definite to the decision-making process. Allowing argumentation, rather than just negotiation, explores the diversity of opinions and assumptions that participants have (Dryzek, 2000; Renn, 2004). This deliberate approach is more honest. The deliberate approach is defined by Manuwa (2014) as: "where the collective vision, goals and / or intention(s) of an organization (in most cases, as determined by its leadership) is articulated as broadly and in as much detail as possible, communicated to the actors (i.e. the employees – those responsible for implementation) within that organization in order to realize a given outcome." This quote states that, the deliberate approach is a planned strategy and that the outcome is already predicted.

The deliberate approach makes problem identification and problem solving much easier (Dunn, 1988). By developing the goals through an open dialogue with stakeholders, they are more likely to take ownership of the process and makes building a partnership with them that much easier. Addressing stakeholder needs will motivate them to continuously engage actively (Johnnson *et al*., 2004; Lynam, 2007).

2.4.2) Early consideration of stakeholder participation and throughout project cycle

Stakeholder participation should be considered at the beginning of any given development project. From the development and planning of the concept, during construction, through implementation, to the monitoring phases and evaluation of outcomes. Involving stakeholders in the decision-making process as early as possible is essential if the decisions are to be durable and of high quality (Reed, 2008).

The 'tool box' approach typically only engages with stakeholders at the implementation phase of a project cycle (Estrella & Gaventa, 2000). The 'tool box' approach is a method used to frequently engage with stakeholders. At these engagement sessions, different topics are discussed related to the set project and used as a platform to ask questions, make comments and raise concerns. Unless adaptability is built into project design, the involvement of stakeholders in proposals might be perceived to projects that have already been finalised (i.e copy and paste) and not within the needs and priorities of the participants of the new project (Chess & Purcell, 1999).

2.4.3) Establishing empowerment, equity, trust and learning

Stakeholder participation needs to be adaptive to different and changing circumstances. Emphasis is on the need to empower participants through this process, by ensuring that they are able to influence the decision (Tippett, *et al.*, 2007) and equipping participants with the technical ability to engage effectively (Richards, *et al.*, 2004). This may involve educating participants to develop their knowledge and confidence (Reed, 2008). Also, two-way learning between participants with different perspectives and knowledge, and between research specialists and stakeholders are imperative (Gunderson & Holling, 2002).

Age, gender and socio-economic backgrounds could be a contributing barrier to meaningful engagement. Creating opportunities for different groups to socialize, has proven to enhance trust and relationships between participants (Prell, *et al*., 2007). Thus, allowing for the decision-making process to be fair and valid (Tippett, *et al.*, 2007).

2.4.4) Stakeholder analysis and systematic representation

The process of stakeholder analysis involves identifying aspects of natural and social systems that could possibly be affected by a decision or action, identifies groups and individuals who can affect those systems and to prioritise these groups and individuals when engaging with them in the decision-making process. The analysis process allows for ideas to be drawn from development studies, natural resource management and business management (Reed, 2008).

There is a wide variety of methods available to approach stakeholder analysis:

- Identifying stakeholders
- Differentiating between stakeholders and categorising them
- Investigating relationships between stakeholders

But due to stakeholder participation being a time consuming process, practitioners rarely use all these methods. Their main focus is usually on identifying stakeholders and on occasion categorising them. Stakeholder analysis can, however, be done without participants actively being involved in the process (Bryson *et al*., 2011; Aloni *et al.*, 2015).

2.4.5) Institutionalise stakeholder involvement

The success of stakeholder participation may depend on firmly establishing the participating process as an official part of the final decision-making process. Even though participation is already included into policy, the requirements vary across structures of authority who are responsible for implementing these policies. Limitations experienced with institutionalization, are within the organizational culture of participants. This means that pre-determined decisions are made by higher levels within an organization, before the participation process. Making negotiations difficult for those involved. Therefore, a radical shift needs to take place in the organizational culture of government agencies and other influential institutions (Reed, 2008).

2.4.6) Stakeholder participation challenges

The success of decisions made with the involvement of stakeholders strongly depends on the nature of the process, which is highly unpredictable. Other aspects that makes the participatory process risky to participants, is when stakeholders come to the table with non-negotiable positions, power inequalities in groups, lack of respect between stakeholders, no value for the voluntary investment and time, and when resource availability is limited to execute the participatory process (Reed, 2008).

For developers, the biggest challenges in local communities is illiteracy, government's organizational difference in implementing related policies and the time and effort required to include and address all concerns, complaints and opinions of various stakeholders in the final decision-making process (Schwaibold, 2016). For locals, the issue is mainly that traditional knowledge is still being underestimated. These are all contributing factors that create frustrations and potential conflict (Hage, *et al.,* 2009).

2.4.7) Integration of local and scientific knowledge

Rapid growth in global population coupled with industrial and mining development has resulted in the increase on the demands of water. With it came the complexity of social and economic issues. Engineering solutions to increase water supply were unsustainable. Water management demanded efficiency improvements and a holistic strategy to meet future needs (Claassen, 2013).

Integrated Water Resource Management (IWRM) is a holistic approach that seeks to integrate the management of the physical environment within the broader socio-economic and political framework (Hassing, *et al.*, 2009). Its emphasis is on accurately dividing institutional roles and responsibilities, enabling policies and regulating the environment as a requirement to accurately manage water resources while supporting sustainable social and economic development, despite the transdisciplinary complexities involved in integrations (Claassen, 2013).

In South Africa, the National Water Act (Act 36 of 1998) was developed to manage water at a national and catchment scale. It has specific provisions on how to protect surface water and groundwater resources and establish mechanisms to ensure equitable and efficient water use.

For the purpose of this study, the main approach was on integrating local and scientific knowledge because of the multi-levelled influence on water resources, from various stakeholders in the Waterberg region. By making use of social and scientific knowledge integration, also allows easy adaptability to socio-economic and environmental factors of the area. According to Richards *et al.* (2004), the chosen participatory method should be accommodative to change and to different stages within stakeholder participation, to be effective.

Scientific information and analysis is essential to any participatory process due to the complexity of the decision-making process. However, if not balanced carefully, there is a danger that scientific information may bias decisions. Together with traditional knowledge, scientific knowledge can contribute to a more complete understanding on complex natural processes and systems (Johnson, *et al.*, 2004).

Published literature suggests that, combining local and scientific knowledge, empowers local communities to manage and monitor environmental changes more easily and accurately. By including local knowledge, makes for more detailed information sources and results in sturdy solutions to environmental challenges. It also moves away from the top-down, science-led transfer of the technology paradigm (Reed & Dougill, 2002; Stringer & Reed, 2007; Reed, *et al.*, 2007; Ingram, 2008).

Scientific knowledge ultimately attempts to understand the underlying principles and theory behind observable events. This is referred to as the 'know-why'. Local knowledge is more practical knowledge and this is referred to as the 'know-how' because the knowledge is based on collective experiences of generations of practice and observation (Ingram, 2008). By integrating researchers and local communities with these different understandings, produces more effective and relevant environmental practices and policies. This ultimately suggests that these two approaches to knowledge generation are fundamentally compatible (Reed, 2008).

2.4.7.1 Mode one and mode two knowledge generators

Traditionally, stakeholder involvement was typically one-way and only involved knowledge transfer from knowledge producers (mode-one), in this case, researchers. Recent interest lies in shifting towards a collaborative approach that involves exchanging knowledge between knowledge users, in this case stakeholders, and knowledge producers (mode-two). This allows for the two parties to communicate more frequently and influence each other throughout the research process, while producing information of value at the same time (Reed, 2008).

2.4.8) Conclusion

In conclusion, the main reason why consistent involvement of various stakeholders is important, is because these individuals and organisations are responsible for identifying additional impacts, or adds a more diverse source of values and knowledge, scientific or indigenous, to the process of managing and monitoring an impact. All environmental issues are complex and different. It therefore requires flexibility and transparency when it comes to the decision-making process. In addition to that, the rate at which issues are addressed must be timely and enthusiastically implemented. It has been shown many times that involving stakeholders, enhances the quality of environmental decisions, through considering a wider range of inputs.

Chapter 3: METHODS AND MATERIALS

3.1 Study site

For this study, the area of interest are three distinct settlements with different socio-economic backgrounds located in Lephalale Municipality in the Waterberg region of Limpopo province. Lephalale Local Municipality is situated in the north-western part of the Waterberg region. The census data published by Statistics South Africa (2012), estimated the population of the municipality at 115 768 people. Steenbokpan, Marapong and Lephalale (formally known as Ellisras) were the chosen locations to distribute questionnaires and conduct the interviews.

The Lephalale Local Municipality is the biggest municipality in the Limpopo province with the most activity in the Waterberg region. This is mainly due to the operation of Eskom's 4000 MW power station, Matimba [23°40'6"S 27°36'38"E] and Exxaro's Grootegeluk Coal Mine [23°40′18″S 27°31′44″E]. Also, the recent construction and partial operation of Eskom's Medupi Power Station [23°43'21.72"S 27°40'45.19"E], which will produce 4 800 MW upon completion in 2018, less than 10km away from the main town Lephalale and rapidly increased population figures in the district (ESKOM, 2012).

The water supply for residents, living within urban, peri-urban and rural areas of the Lephalale Municipality, is sourced from the Mokolo Dam. The full capacity of the dam is 146 million cubic meters per year (DWS, 2017) and also supplies water to the ongoing construction of the Medupi power station (Dhemba, 2013), the fully operational Matimba power station, Grootegeluk coal mine and agricultural activities (DWA, 2013). The construction of the pump station, the maintenance of the dam and supply of the water is currently controlled by Exxaro's Grootegeluk Coal Mine. Eskom is a raw water supplier to Lephalale Local Municipality, which is a designated Water Service Provider (WSP), and in turn provides potable water to businesses and households in the Lephalale town and Marapong township areas, with a Blue Drop score of 85% in 2014 (IDP, 2016). However, the Green Drop status is of more interest to environmental water qualit

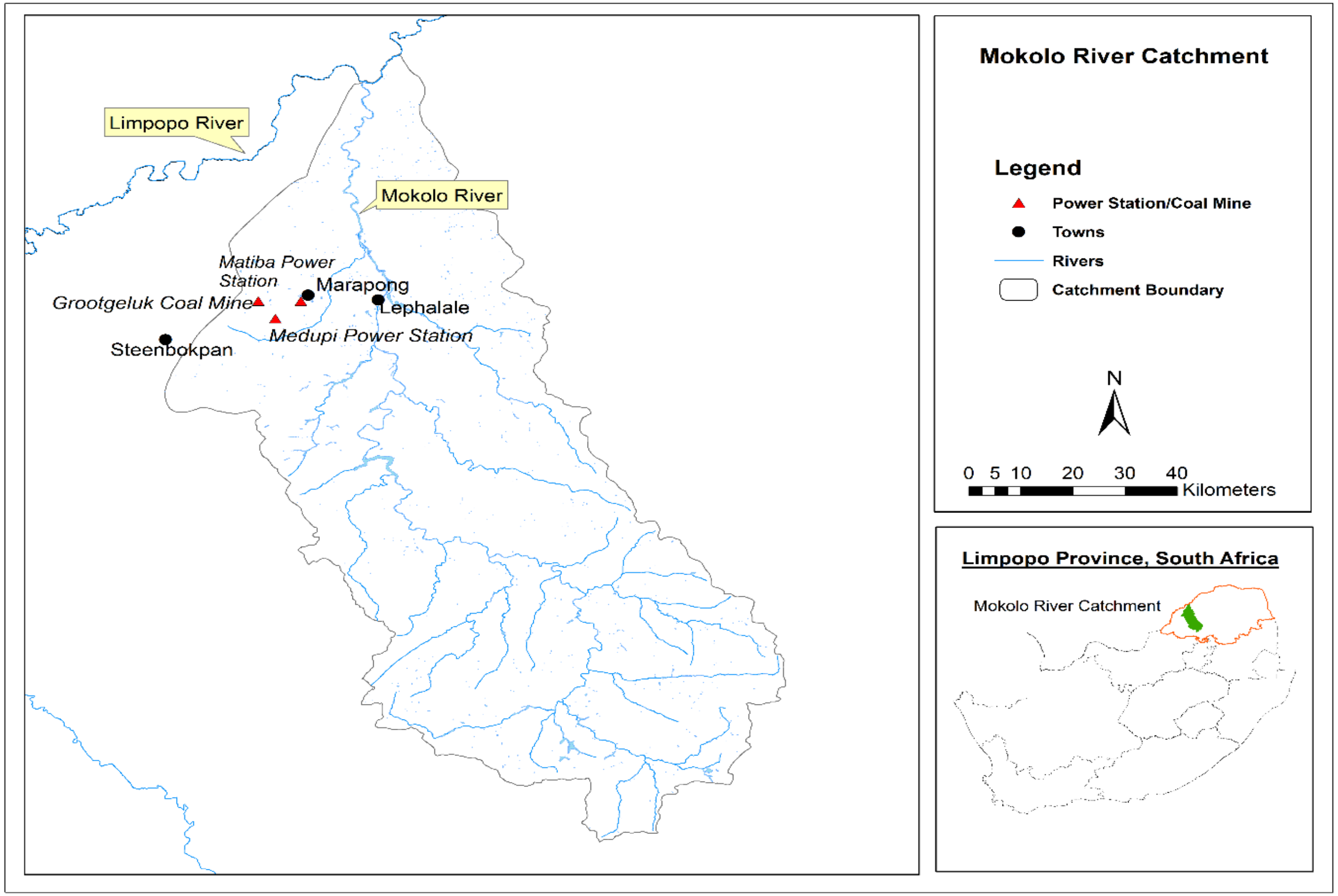

Figure 4: *Major residential, Mining and industrial activities upstream of the Mokolo River Catchment in the Lephalale Municipal area*

The three chosen human settlements, Steenbokpan, Marapong and Lephalale town, are approximately 10 – 40km away from Medupi and Matimba Coal Power Stations and Grootegeluk Coal Mine. Even though these three settlements are within a similar geographic proximity, they were chosen based on their different social and economic backgrounds, which will allow for comparisons based on those characteristics.

3.1.1) The geographical locations of the surface water and groundwater (boreholes) sampling sites

The Mokolo River catchment (see Figure 5a) is only one of the catchments in the Limpopo Water Management Area and is approximately 8 437 km^2 (Prucha & Graham, 2012). Surface water and groundwater sources in the upper reaches of this catchment are exposed to extensive pollution from coal mining activities and the rapid growth of informal settlements (Bruyns, 2015). Groundwater in the Mokolo River catchment, in its natural form, is not suitable for human consumption due to the high salt content in the secondary aquifer (Vermeulen & Bester, 2010).

Three focus areas were chosen for the purpose of this study; upstream, midstream and downstream of the Mokolo River, close to Marapong and Lephalale residential areas. Within each focus area, a surface water sampling site and a groundwater monitoring borehole were chosen to compare the different water sources with one another. The surface water and groundwater data on selected variables for each chosen site were collected and provided by the Department of Water and Sanitation: Resource Quality Services between 1995 and 2015.

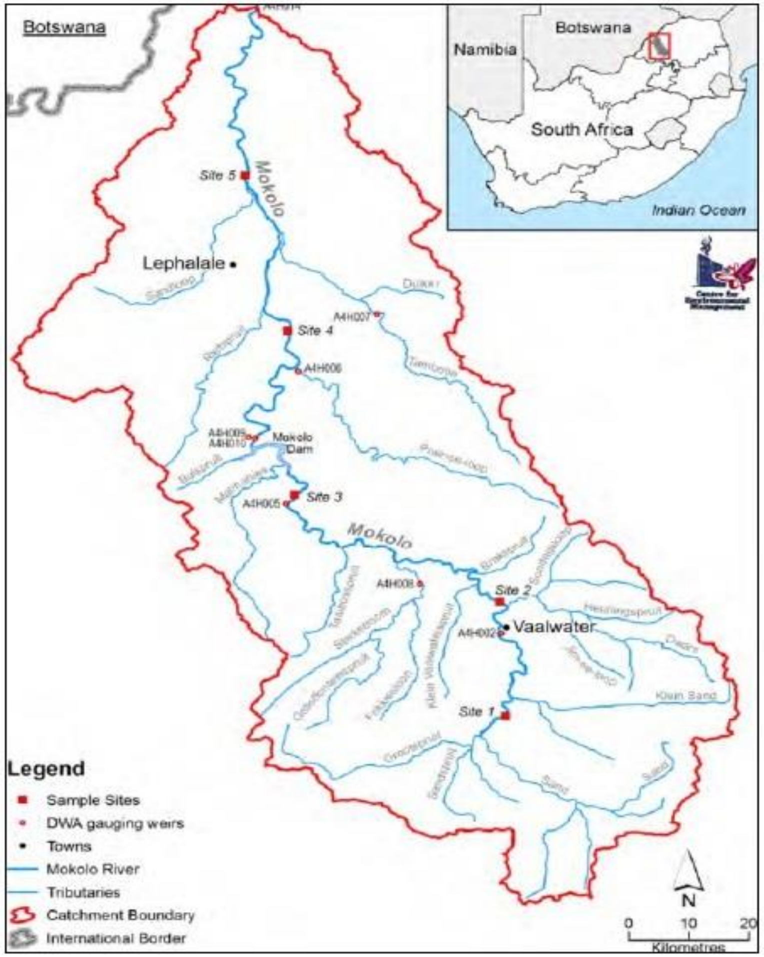

Figure 5: a) *The Mokolo River catchment in the Limpopo Catchment area. The most northern section of the river closest to the Botswana border and Lephalale is the focus area for this study (Source: Prucha* et al.*, 2016)* **b)** *The three sections within the northern part of the river is where the selected Department of Water and Sanitation (DWS) surface water and groundwater monitoring sites are located.*

The first focus area is upstream in the Mokolo River and has a surface water sampling site, called the Moorddrift/Vught (pink pin) site. However, there is no borehole close to this site to compare the quality of groundwater. The second focus area is mid-stream in a tributary of the Mokolo River and is close to the Marapong township. The surface water sampling site in this area is a waste water discharge point (pink pin) into a Mokolo River tributary through a pipeline. The closest groundwater monitoring borehole to that site is the Waterkloof/Ellisras (yellow pin) monitoring borehole. The third and final focus area is downstream in the Mokolo River. The surface water sampling site in this area, is the Ellisras residential area/Rietspruit (pink pin), and the nearby borehole, is the Rietspruit Ellisras/Witkop (yellow pin) monitoring site (see Figure 5b).

3.1.2) Residential site 1: Steenbokpan

The Steenbokpan area [23°45'0"S 27°23'0"E] is known in the area as an informal settlement. Of the questionnaires distributed here, 80% was from Leseding Location and the remaining 20% from surrounding farm/business owners. The settlement is surrounded by rural villages, game farms and lodges. Even though the settlement is a rural development from recent years, it is still referred to as a 'location', a term used by the Apartheid government to describe non-white residential areas. With an estimated population of 600 people, the settlement does not receive any formal services from the local municipality.

3.1.3) Residential site 2: Marapong

Marapong [20°53′36″S 27°4′32″E] is a township founded in 1986 (eNCA, 2014) and a census done in 2011 places the population of Marapong at approximately 13 800 people (StatsSA, 2012). It is closely situated to Eskom's Medupi and Matimba power stations, and to Exxaro's Grootegeluk coal mine. The term 'township' is also from the Apartheid era, which referred to an underdeveloped urban area and was reserved for non-whites as well. The settlement is home to mostly mine and construction workers at the local power stations and coal mines, who travel by bus or taxi to get to and from work (eNCA, 2014).

The township has a combination of formal and informal housing. The formal housing in the area is government built or provided by Eskom or Exxaro. It has electricity, and basic water and sanitation services. The roads in the area are also paved and mostly well maintained. The large and growing informal settlements, however, have poorly maintained gravel roads and lack basic services.

3.1.4) Residential site 3: Lephalale (formerly Ellisras)

The town of Lephalale [23°40′S 27°45′E] is primarily made up of two nodes, Onverwacht and old Ellisras. It is structurally the largest of the three chosen residential sites and home to people with greater socio-economic stability. Established in 1960, the town was renamed, Lephalale, in 2002 by the Limpopo provincial government, joining the two nodes (IDP, 2013). By 2011, census data put the resident count in Lephalale at 13 500 (StatsSA, 2012).

The rapid development in coal mining and energy production industries, has allowed the town to reap major economic benefits. Retail options have increased with the recent opening of the Lephalale Mall, including large chain stores, such as Checkers and Game, and restaurants like Nando’s and McDonald’s (Mantshantsha, 2013). Property owners have benefitted the most due to the extra housing requirements, with rent per month going up four times from what it used to be before major development took place (ibid, 2013).

3.2 Methodology for data sampling

To address question one of the study, a quantitative approach was used by acquiring surface water and groundwater quality data for the selected time period of 1995 to 2015. For this process, a governmental database was used to obtain the data for surface water and groundwater sampling sites upstream, midstream and downstream of the Mokolo River, from existing sampling sites, for various water quality variables. The intent was also to make use of Exxaro’s groundwater quality data for 1995 up until 2015 for comparison, but no response was received from the appropriate authorities or the Grootegeluk mine to a formal request to access the information.

Two qualitative data collection approaches were used to address the second research question of this study. The first data collection method was in the form of questionnaires and the second, interviews which included open- and close-ended questions. In order to obtain information from the surveys and interviews in a legal and ethical manner, a non-medical ethics clearance certificate was required (see *Appendix C*). Separate information sheets and consent forms (see *Appendix A and B*) were provided prior to any questionnaires being distributed or interviews being conducted. All questionnaires and personal interviews were done during a field visit to the Waterberg during 5 – 15 October 2016.

This questionnaire had both qualitative and quantitative data collection components. The use of closed questions in the questionnaire provided evidence which could be analysed statistically, while the semi, open-ended questions strengthened the interpretations by adding a qualitative perspective to it. While the questionnaires were distributed amongst general water users in each residential area by going to public spaces, such as the library, clinic etc., the interviews were conducted with stakeholders at various influential levels, through prior arranged meetings, which added further depth and perspective to the survey results.

3.2.1) Historic water quality data collection process

The surface water and groundwater quality data used in this study were collected and provided by the Department of Water Affairs (DWA): Resource Quality Services from 1995 – 2015 in the Waterberg Area. In total, of the intended six sampling surface water and groundwater sampling sites, only five had data available, but only four had enough data for interpretation. Refer to Table 5 on how data usage was assessed. The four monitoring sites that were used were as follow:

- Surface water – Upstream: Moorddrift/Vught
- Surface water – Midstream: waste water discharge point into the Mokolo River through a pipeline (close to Marapong township)
- Surface water – Downstream: Ellisras residential area/Rietspruit
- Groundwater – Downstream: Rietspruit Ellisras/Witkop

The quantitative water quality data formed a crucial part in the approach to address the first research question. The variables used of the collected data were pH, ammonium, phosphate, nitrate, sodium, potassium, calcium and electrical conductivity (EC). These variables were chosen because they were the most common amongst the chosen sites and because they had the most consistent amount of data available for the chosen time period, but they are also vital when focusing on the quality of water for domestic use, irrigation and industrial purposes known for the Waterberg.

Table 5: *The total number of data points available for pH, ions and EC variables, for the four sites used for interpretation from 1995 to 2015.*

Monitoring station number	Type of monitoring site	Monitoring site location	Water quality variables							
			pH	NH_4^+	PO_4^{-3}	NO_3^-	Na^+	K^+	Ca^{2+}	EC
A4H13	Surface water (river)	Moorddrift/Vught	121	121	121	121	106	106	120	121
193407	Surface water (river)	Waste water discharge/Mokolo River	16	1	20	16	1	0	0	0
190201	Surface water (river)	Ellisras residential area/Rietspruit	25	2	9	25	23	20	23	25
ZQMELS1	Groundwater (borehole)	Rietspruit Ellisras/Witkop	29	32	26	0	29	28	30	30

3.2.2) Questionnaire data collection process

The questionnaires were distributed to individuals from households in the informal settlements and urban areas amongst the chosen communities of Steenbokpan, Marapong and Lephalale. These three residential zones have different social and economic backgrounds, which created the initial basis upon which these areas were chosen. The total sample size for the interview was 20. The sample size was mainly chosen based on restricted time frames from site visits and not increased due to the individual-interview factor. Five from Steenbokpan, five from Marapong and ten from Lephalale (due to variety of individuals with different backgrounds in this area). All participants were chosen from libraries, clinics and even at ongoing EIA (Environmental Impact Assessment) meetings in these residential areas. The venues were strategically chosen on how they place the population of each residential area.

The sample group was small enough to work through within a few days, but also large enough to gain a usable amount information on each residential area. Even though the sample size for the questionnaire was small, it is important to keep in mind that it only forms one of three parts of the project. Together the three components provide enough information to address all the research questions.

The questions in the survey were divided into four sections. Section A focused on questions about each participant's personal information and everyday livelihood and section B asked questions on how the resource is used in each of their households. Section C's questions referred to how these different households perceive the quality of water and the last section's questions focused on the participants' basic knowledge and understanding of how the resource is managed in their area and how involved and aware they are of the decision-making process.

3.2.3) Interview data collection process

The second phase of the qualitative method was in the form of interviews with individuals that are in influential or water related management positions in and around the Waterberg area. this process is known as purposive sampling. Interviews were done with Eskom and Exxaro Grootegeluk Coal Mine's environmental officials, concerned cattle and game farmers, principals from educational institutions, committee members from the Water Usage Association and the Waterberg Nature Conservancy, researchers who specialize in water quality related issues, as well as a representative from the local municipality associated with the water treatment works in the district. Of the planned 20 individuals, 15 were successfully interviewed in total. Interviews were in person and voice recorded where permission was given. Where distance and time constraints became an obstacle, interviews were done via Skype, e-mail or per telephone. Five of the twenty planned interviews were unsuccessful due to lack of interest in the study or time constraints.

The interview questions focused on challenges in the different institutions, environmental concerns and water use in the workplace, to measure the level of awareness and involvement of the institutions in water related issues in the Waterberg region. A set of 11 questions was used to serve as a template across all the interviews that were carried out. The outcome of these questions covered skills relating to leadership, training, organizational structure, communication, incentives, measurements, evaluation and teamwork. All these aspects aided in determining different types of uses for the water (domestic, agricultural, industrial, mining or recreational), how each sector contributes to understanding the quality of surface water and groundwater in the area, what the level of participation is in managing the resource from each stakeholder and in gaining indigenous and scientific knowledge, and practices in water quality monitoring in the area.

3.3 Data analyses methodology

All quantitative data for surface water and groundwater quality, as well as quantitative data from the questionnaires, were entered into an Excel 2016 spreadsheet and the recorded interviews were compiled into an essay in a Word document. Within Excel there are various statistical analytical tools (further described in detail in the subsections below) that were used to clean, compartmentalise and produce results from the water quality and questionnaire data.

3.3.1) Analysing water quality variables

To meet objective one, the historic surface water and groundwater quality data provided by the Department of Water and Sanitation (DWS) for the selected monitoring sites, were placed in Excel spreadsheet in such a manner for it to be comparable to the water standards set by the South African Water Quality Guidelines (DWAF, 1996), for water uses known in the Waterberg., However, the Waterkloof/Ellisras borehole, site 357, that was specifically chosen for its close proximity to the surface water (waste water discharge point), site 193407 in Marapong, was not used. The site only had one month's worth of data available for the entire 20-year period, which made it difficult to compare with any of the other variables from the other sites, creating a limitation for further statistical calculations.

From the available data, an average pH value per year was calculated and presented in a cluster column graph with standard error bars, from 1995 to 2015. A basic statistical description (max, min, median, mode, mean and variance) was then done for those values, to describe the range of the data and was used to compare it to mean pH values from a previous water quality study done in the area. The pH data from previous studies acts as a baseline to the pH results revealed in this study. Also, a one-way ANOVA test was applied to the mean pH values to determine whether there were significant differences.

The number of calculated means for the ions and EC, for all sites, were displayed in a table. Where data were available, the means and variances were calculated for all ions and EC values for each site, between 1995 to 2015, and presented within four separate tables, supported by descriptions for each table. In addition, a one-way ANOVA test was applied to the mean EC values to determine significant differences.

3.3.2) Analysing questionnaires

As mentioned before, to meet objective two, a combination of questionnaires and interview data were used. For the interpretation of the questionnaire data, a combination of statistical approaches were used for different sections of the questionnaire:

- Section A: Livelihood Assessment
    1. Tables of demographics (age, gender, marital status and number of household members).
    2. Mean, variance, standard deviation and one-way ANOVA tests to describe differences between the number of people employed and educated.
    3. Multiple tables to describe different types of jobs held across the three respective residential areas, additional employment in household and affordability of a flat screen television to assess the socio-economic status of each residential area.

- Section B: Resource Usage
    1. A table indicating the total number of participants with electricity, water and sanitation in Steenbokpan, Marapong and Lephalale, with calculated means and variances and a cluster graph representing the information.
    2. A table indicating the total number of participants that own a geyser, washing machine, kitchen and/or a swimming pool, with calculated means and variances and a cluster graph to represent the information in percentages.
    3. Numeric table indicating the estimated monthly water and electricity bill for participants across the three different residential areas, as well as a table showing the different sanitation options used in Steenbokpan, Marapong and Lephalale, with calculated means and variances. This information was also presented in a cluster graph using percentages.
    4. A scatter plot was used to display the correlated relationship between the number of participants employed and educated against the number of participants who have electricity, water and sanitation in Steenbokpan, Marapong and Lephalale indicated with an exponential growth pattern.
    5. A table and pie diagram was used to present the number of participants from each chosen residential area that own different types of gardens and don’t have a garden at all.

- Section C: Water Quality Perceptions
    1. A table and pie diagram was used to present the number of participants from each chosen residential area that are aware on the topic of water pollution and the overall unawareness on the topic across all residential areas.
    2. Data indicating the number of uses of a different range of information sources on water pollution by those participants aware of the subject, was presented in a table. Another table presented water quality ratings in the three selected areas using a 1 (poor) to 5 (excellent) rating system accompanied with a cluster graph showing the data in percentages.
    3. A pie diagram showing the difference in opinion in rating (Very high to None) the water contamination in the area from all the participants.
    4. Tables presenting sources of contamination and a combination of answers from participants to question 29b, 29d and 30, on perspectives of the consequences of water contamination in the area, in percentages.

- Section D: Water Management Participation
    1. The percentile method was used to demonstrate the number of participants that have access to three different water sources, shown in a cluster columned graph.
    2. The percentile method was used to show the number of participants that are engaged in water recycling activities in Steenbokpan, Marapong and Lephale, displayed in a pie diagram.
    3. A numeric table to portray the different purification methods and a table to show the main sources of information used on water related issues, in percentages, by participants from the respective residential areas.

3.3.3) Essay report on interviews

The interviews were analysed by critically capturing and discussing the completed interviews and comparing it to available information on the study site, such as past literature, newspaper articles and Integrated Development Plans.

Chapter 4: RESULTS

This chapter is based on results derived from the three main parts of this study; a) historic data on the quality of surface water and groundwater in the Waterberg region, b) the responses from questionnaires distributed amongst individuals selected within public spaces, such as libraries, clinics and schools, from three chosen residential sites within the Waterberg area and c) the responses from individuals interviewed, working in establishments that are water-related or affects how the resource is being managed in the Waterberg.

4.1 Description of the chosen surface water and groundwater monitoring sites

The raw data provided by the Department of Water and Sanitation (DWS): Resource Quality Services (RQS), were from three surface water monitoring sites in the Mokolo River and two groundwater monitoring sites (boreholes) close to Marapong and Lephalale residential areas within the Waterberg district of Limpopo province in South Africa (see Figure 6), between 1995 and 2015.

Figure 6: *The location of the groundwater (yellow) boreholes and surface water (pink) monitoring sites close to the towns of Marapong and Lephalale in the Waterberg.*

The first focus area is upstream in the Mokolo River, where there is a surface water sampling site, called the Moorddrift/Vught site. However, there is no borehole close to this site to compare the quality of groundwater. The second focus area (mid-stream) is close to the

Marapong township. The surface water sampling site in this area is a waste water discharge point into the Mokolo River through a pipeline. The closest groundwater monitoring site (borehole) to that site is the Waterkloof/Ellisras monitoring site. The third focus area is downstream in the Mokolo River. The surface water sampling site in this area, is the Ellisras residential area/Rietspruit, and the nearby borehole, is the Rietspruit Ellisras/Witkop monitoring site (refer to Figure 6).

4.2 The water quality standards of the chosen variables for different uses known to the Waterberg

The water in the Waterberg is mainly used for domestic, industrial and agricultural purposes, more specifically for irrigation and livestock. Each use has a specific water quality standard for pH, ion concentrations and Electrical Conductivity (EC) determined by the South African Water Quality Guidelines of South Africa (refer to Table 1*)*.

The ions analysed for drinking water and water for domestic purposes are sodium (Na^{+}), iron (Fe^{2+}), chloride (Cl^{-}) and manganese (Mn^{2+}) (refer to Table 2). Industry, irrigation and livestock water have an alternative set of ions that are analysed at different concentration levels (refer to Table 3) (Zhang *et al.*, 2012). However, some of the ions mentioned in table two and three are not used for this study due to limitations of the data provided. Due to those limitations, only certain ions will reflect within the results section to water uses known to the Waterberg.

The raw data collected from the Department of Water and Sanitation: RQS, was on a monthly basis and were analysed for changes in the pH, selected ion concentrations and EC. pH is the negative logarithm to the base ten of the hydrogen concentration in a solution and is expressed as follow:

$$\text{pH} = -\,log_{10}[H^{+}]$$

A pH above seven indicates alkalinity and a pH below seven indicates acidity.

The ions chosen for this study are:

- Ammonium (NH_4^{+})
- Phosphate (PO_4^{-3})
- Nitrate (NO_3^{-})
- Sodium (Na^{+})
- Potassium (K^{+})

- Calcium (Ca^{2+})

And were measured in milligrams per litre (mg/l). Electrical conductivity (EC), measures the ability of water to carry an electrical charge and is expressed in milli-Siemens per metre (mS/m).

4.3 Data analysis on the quality of surface water and groundwater sources in the Waterberg area

The data illustrated in this section are from the year 1995 till 2015. Not all surface water sampling sites and boreholes chosen for this study had data available for each month of every year. The available measured data for the pH, selected ions and EC were compared to the same variables in the Water Quality Guidelines of South Africa (DWAF, 1996) to determine whether the quality of water for various uses comply with standards in the Waterberg area.

Table 6: *The total number of sample data available for pH, ions and EC variables, for the respective sites from 1995 to 2015.*

Name of the monitoring station	Type of monitoring site	Monitoring site location	Water quality variables							
			pH	NH_4^+	PO_4^{-3}	NO_3^-	Na^+	K^+	Ca^{2+}	EC
A4H13	Surface water (river)	Moorddrift/Vught	121	121	121	121	106	106	120	121
193407	Surface water (river)	Waste water discharge/Mokolo River	16	1	20	16	1	0	0	0
190201	Surface water (river)	Ellisras residential area/Rietspruit	25	2	9	25	23	20	23	25
ZQMELS1	Groundwater (borehole)	Rietspruit Ellisras/Witkop	29	32	26	0	29	28	30	30
357	Groundwater (borehole)	Waterkloof/Ellisras	1	1	0	0	1	1	1	1

The figures given in Table 6 show that only one site (A4H13) has an extensive data record and the other sites have extremely limited data with values ranging from 0-30 over a 20-year time period. Due to this poor data, only limited interpretations were possible.

The Waterkloof/Ellisras borehole, site 357, was specifically chosen because it is within close proximity to the surface water (waste water discharge point), site 193407, in Marapong. But, the borehole data available for this site were difficult to compare to that of the river site, or any of the other variables from the other sites, because there are only one month's (August 2008) worth of data available for the entire 20-year period (see Table 7). This creates a limitation for further statistical calculations and will not be used.

Table 7: *The quality of groundwater for one month during 2008 from the Waterkloof/Ellisras borehole, monitoring site 357.*

Number of samples (n)	Date	pH	NH_4^+	PO_4^{-3}	NO_3^-	Na^+	K^+	Ca^{2+}	EC
1	Aug-2008	8.94	0.09mg/l	X	X	510.40mg/l	16.40mg/l	86.25mg/l	327.00mS/m

*X = no value available

4.3.1) Changes in pH measured for the surface water and groundwater sources from 1995 to 2015

Previous analysis done by Burne (2015) revealed that the mean pH levels from the Mokolo River had increased from 6.6 to 7.6 between 1988 and 1991. The pH levels measured within those three years fall within the same period Matimba Power Station was commissioned (between 1988 and 1993). Further analysis done by Bruyns (2015) revealed a decrease in the mean pH values in the Mokolo river to 7.51 ± 0.19 between 1999 and 2011. That is a difference of -0.09 units. The comparison between the surface water quality and the operation of Matimba power station suggests a linkage between the water pH and the burning of coal.

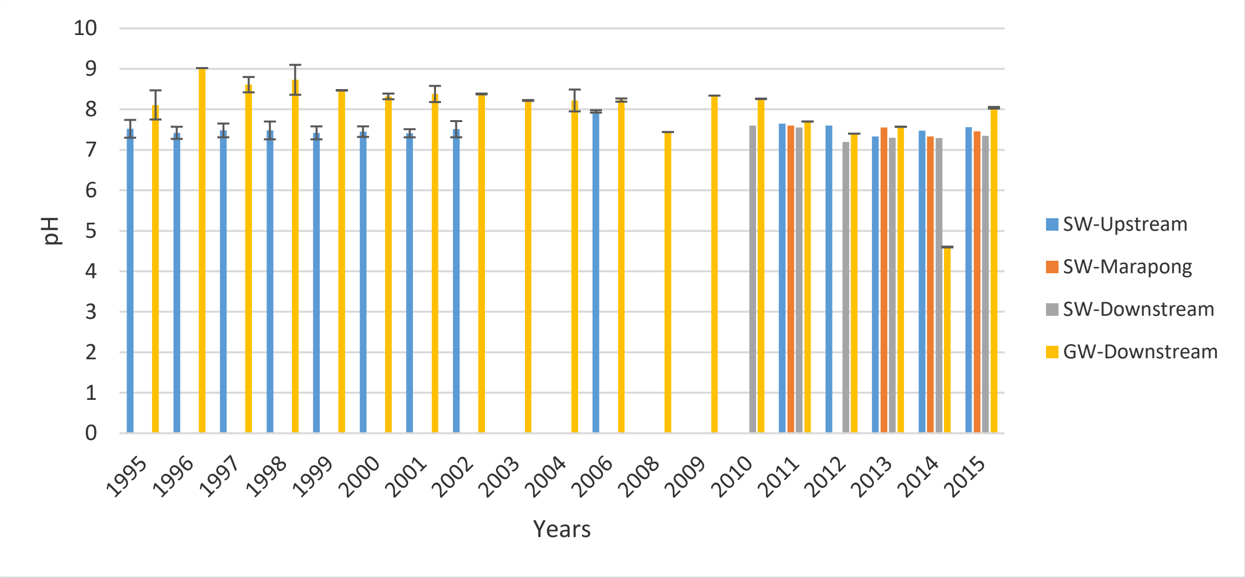

Figure 7: *The annual mean of monthly pH values of the Moorddrift/Vught (SW-Upstream), waste water discharge point (SW-Marapong), Ellisras residential area/Rietspruit (SW-Downstream) and Rietspruit Ellisras/Witkop (GW-Downstream) monitoring sites, measured from 1995 to 2015.*

*SW = Surface water

*GW = Groundwater

The pH values for the surface water upstream site remain between 6 and 8 throughout the period of 1995 till 2015. The downstream groundwater site, for the same period, maintained a slightly higher pH value of between 7 and 9 with an exception of 2014 where the mean pH value was 4.6 ± 0.0001. For the waste water discharge point in Marapong (mid-stream) and downstream surface water sampling sites the pH values remained between 7.3 and 7.6, and 7.2 and 7.6 respectively, from 2011 to 2015. There is no clear difference between the pH levels during that time at both sites.

Table 8: *The difference in pH values in the upper middle and lower sections of the Mokolo River (surface water) between 2011 – 2015, in comparison to the overall pH value of the Mokolo river, 7.51, as found by Bruyns (2015) between 1999 – 2011.*

	Between 2011 - 2015	**+/- Variances**	**Difference**
Moorddrift/Vught (SW-Upstream)	7.52	0.12	+0.01
Waste water discharge point (SW-Marapong)	7.49	0.14	-0.02
Ellisras residential area/Rietspruit (SW-Downstream)	7.38	0.12	-0.13

*+ = increased units

*- = decreased units

In comparison to the pH value, 7.51, measured in the overall Mokolo river between 1999 to 2011 by Bruyns (2015), the upper site in the Mokolo river increased by 0.01 units, the middle site in the Mokolo river decreased with 0.02 units and the lower site in the Mokolo River also decreased, but with 0.13 units between 2011 and 2015.

Table 9: *The statistical description of the pH values measured for the Moorddrift/Vught (SW-Upstream) and Rietspruit Ellisras/Witkop (GW-Downstream) monitoring sites, from 1995 to 2015, and for the waste water discharge point (SW-Marapong) and Ellisras residential area/Rietspruit (SW-Downstream) monitoring sites from 2011 to 2015.*

Statistical Description	SW-Upstream	SW-Midstream/Marapong	SW-Downstream	GW-Downstream
Maximum	7.95	7.60	7.60	9.02
Minimum	7.33	7.33	7.20	4.60
Median	7.48	7.51	7.33	8.23
Mode	7.42	#N/A	#N/A	8.38
Mean	7.52	7.49	7.38	8.00
+/-Variance	0.02	0.01	0.03	0.86

*#N/A = not applicable

An ANOVA test was done on the mean pH values of the selected monitoring sites. The test revealed that the pH values across the different sites were significantly different with an f-score equalled to 2.45. Based on the variances, the surface water pH values are not significantly different from each other, but the groundwater pH value indicates a significant difference to the surface water values and which would explain the high f-score produced by the ANOVA test.

According to the South African Water Quality Guidelines (DWAF, 1996), the pH of natural occurring water is usually between 6 and 9 (see Table 1). Physical properties, such as the geology, and geochemistry of soils and rocks that interact with water, are particular to a certain catchment and affect the pH of the water. The Waterberg is known to be associated with mostly sandstone. Together with quartzite, it forms a fractured, secondary aquifer with high salt concentrations caused by the long interaction with the rock (Hodgson & Vermeulen, 1998). However, ion changes in surface water systems, such as that of sulphate, are more affected by the coal combustion by local power stations, especially rivers downwind of the power stations (Bruyns, 2015).

The production of sulphate over decades of coal combustion by local power stations gives a probable explanation to the higher pH values in the Rietspruit Ellisras/Witkop (GW-

Downstream) borehole, with the exception of the mean pH value of 4.60 in 2014 which is a clear outlier. Biological processes, such as nutrient cycling, and anthropogenic activities, such as household and industrial effluent discharge, can cause increases or decreases in pH levels.

Based on Figure 7 and Table 8, here is no clear difference in the pH levels for the waste water discharge point (SW-Marapong) and the Ellisras residential area/Rietspruit (SW-Downstream) site between 2011 and 2015, and for the Moorddrift/Vught (SW-Upstream) and Rietspruit Ellisras/Witkop (GW-Downstream) sites between 1995 and 2015 (apart from 2014's outlier).

4.3.2) Changes in ions and electrical conductivity (EC) measured for the surface water and groundwater sources from 1995 to 2015

The ions chosen from existing data for the purpose of this study, between 1995 – 2015 from the respective water monitoring sites, were ammonium, phosphate, nitrate, sodium potassium and calcium. These variables were chosen because they were common among the monitoring sites and had the most consistent data available to compare any changes in the ion concentrations, especially from 2011 – 2015. The changes in ion levels in water can be due to natural- or anthropogenic process, such as human effluent, agriculture or industrial activities in the area.

Table 10: *The number of calculated means, for each selected ion and EC, composed of annual values across all sampling sites, from 1995 to 2015.*

Site Description	Ions						
	NH_4^+	PO_4^{-3}	NO_3^-	Na^+	K^+	Ca^{2+}	EC
Moorddrift/Vught (Surface water – Upstream)	14	14	14	13	13	14	14
Waste water discharge point (Surface water – Marapong)	1	4	4	1	0	0	0
Ellisras residential area/Rietspruit (Surface water – Downstream)	1	5	5	5	3	4	5
Rietspruit Ellisras/Witkop (Groundwater – Downstream)	19	17	0	18	18	19	19

The largest number of samples were taken from the surface water upstream site and the downstream borehole. In most cases the sampling was similar across the different ions for both sites, except for nitrate which was not measured for the groundwater site.

Table 11 (a-d): *Mean (mg/l) and variance values for all the selected ions and electrical conductivity (EC) (mS/m), in the* ***a)*** *surface water – upstream,* ***b)*** *surface water – midstream,* ***c)*** *surface water – downstream and* ***d)*** *groundwater downstream sites between 1995 and 2015.*

n		**Ammonium**	**Phosphate**	**Nitrate**	**Sodium**	**Potassium**	**Calcium**	**EC**
1995	**Mean**	0.025	0.013	0.030	6.66	2.55	5.78	9.33
	Variance	0.00	0.00	0.00	0.44	0.15	2.83	1.34
1996	**Mean**	0.021	0.019	0.030	5.51	1.86	4.58	7.89
	Variance	0.00	0.00	0.00	4.31	0.95	5.58	8.92
1997	**Mean**	0.030	0.008	0.025	5.88	0.75	4.69	7.53
	Variance	0.00	0.00	0.00	0.41	0.06	0.70	0.61
1998	**Mean**	0,032	0.013	0.024	7.50	1.11	5.19	9.25
	Variance	0.00	0.00	0.00	0.31	0.13	1.34	0.69
1999	**Mean**	0.033	0.018	0.022	6.62	0.96	4.44	8.36
	Variance	0.001	0.00	0.00	1.13	0.11	0.44	0.87
2000	**Mean**	0.024	0.018	0.094	6.32	0.88	4.36	7.92
	Variance	0.00	0.00	0.020	1.91	0.11	0.58	2.13
2001	**Mean**	0.060	0.028	0.059	6.62	0.73	4.53	8.49
	Variance	0.008	0.00	0.009	1.13	0.09	1.92	0.87
2002	**Mean**	0.029	0.032	0.047	5.40	1.76	3.79	8.77
	Variance	0.00	0.001	0.003	4.34	1.68	2.45	1.23
2006	**Mean**	0.074	0.017	0.280	11.95	0.77	13.20	1.68
	Variance	X	X	X	X	X	X	0
2011	**Mean**	0.025	0.005	0.025	8.84	1.79	3.70	8.40
	Variance	0.00	0.00	0.00	0.44	1.25	0.39	2.10
2012	**Mean**	0.039	0.006	0.025	7.52	2.16	5.62	11.33
	Variance	0.00	0.00	0.00	5.18	0.74	5.62	5.35
2013	**Mean**	0.025	0.005	0.085	6.22	1.22	3.86	8.08
	Variance	0.00	0.00	0.009	1.88	0.45	0.76	0.86
2014	**Mean**	0.047	0.009	0.077	None	None	3.58	10.45
	Variance	0.00	0.00	0.006	N/A	N/A	1.27	3.68
2015	**Mean**	0.107	0.013	0.061	8.68	1.63	3.93	10.50
	Variance	0.038	0.00	0.001	22.18	0.83	1.24	3.43

a) Surface water – upstream site

*N/A = Not applicable

*X = has no variance (one sample only)

*0.00 = values very close to zero but rounded. Therefore, the zero variance are not real

		Ammonium	Phosphate	Nitrate	Sodium	Potassium	Calcium	EC
2011	**Mean**	None	8.90	0.20	178	None	None	None
	Variance	N/A	X	X	X	N/A	N/A	N/A
2013	**Mean**	None	2.67	1.08	None	None	None	None
	Variance	N/A	3.15	0.19	N/A	N/A	N/A	N/A
2014	**Mean**	None	3.49	0.70	None	None	None	None
	Variance	N/A	3.78	0.00	N/A	N/A	N/A	N/A
2015	**Mean**	None	2.92	0.70	None	None	None	None
	Variance	N/A	5.20	0.00	N/A	N/A	N/A	N/A

b) Surface water – mid-stream/Marapong site

*N/A = Not applicable

*X = has no variance

		Ammonium	Phosphate	Nitrate	Sodium	Potassium	Calcium	EC
2010	**Mean**	None	0.02	1.00	4.00	None	None	6.30
	Variance	N/A	X	X	X	N/A	N/A	X
2011	**Mean**	0.40	0.02	0.64	19.75	None	3.63	None
	Variance	2.29	0.00	0.37	70.58	N/A	0.30	N/A
2013	**Mean**	None	1.00	0.90	11.07	1.55	4.37	9.78
	Variance	N/A	X	0.16	41.10	0.34	2.31	11.21
2014	**Mean**	None	0.05	0.70	8.09	1.14	3.41	8.05
	Variance	N/A	0.00	0.00	23.44	0.08	1.79	16.14
2015	**Mean**	None	0.05	0.70	6.70	1.00	3.30	7.30
	Variance	N/A	0.00	0.00	2.32	0.02	0.19	1.57

c) Surface water – downstream site

*N/A = Not applicable

*X = has no variance

		Ammonium	Phosphate	Nitrate	Sodium	Potassium	Calcium	EC
1995	**Mean**	0.52	0.02	None	343.20	4.38	5.85	699.60
	Variance	0.00	0.00	N/A	432.18	0.08	0.13	953304.24
1996	**Mean**	0.55	0.04	None	321.30	4.11	6.30	1450
	Variance	X	X	N/A	X	X	X	X
1997	**Mean**	0.59	0.02	None	333.65	3.33	9.00	162.50
	Variance	0.00	0.00	N/A	3.64	0.08	8.82	4.50
1998	**Mean**	0.61	0.02	None	332.20	3.62	6.60	701.50
	Variance	0.00	0.00	N/A	18.00	0.01	1.28	601704.28
1999	**Mean**	0.08	0.01	None	336.74	3.91	6.67	172
	Variance	X	X	N/A	X	X	X	X
2000	**Mean**	0.30	0.02	None	347.60	3.56	6.17	168.50

	Variance	0.15	X	N/A	X	0.03	2.06	0.50
2001	**Mean**	0.10	0.04	None	301.35	3.77	3.42	164.50
	Variance	0.01	0.00	N/A	731.92	0.11	0.04	4.50
2002	**Mean**	0.02	0.02	None	276.22	3.74	3.53	165
	Variance	0.00	0.00	N/A	2102.13	X	6.23	X
2003	**Mean**	0.02	0.02	None	327.26	3.82	7.85	169
	Variance	0.00	X	N/A	375.39	0.05	0.79	8.00
2004	**Mean**	0.02	0.01	None	333.32	3.82	7.17	167.50
	Variance	0.00	X	N/A	56.64	0.00	0.03	24.50
2006	**Mean**	0.13	0.03	None	322.20	3.79	6.63	168
	Variance	0.02	0.00	N/A	8.77	X	0.47	X
2008	**Mean**	0.06	0.01	None	4.05	1.40	2.97	6.22
	Variance	0.00	0.00	N/A	0.00	0.57	0.64	0.005
2009	**Mean**	0.03	None	None	4.77	1.70	2.44	6.53
	Variance	X	N/A	N/A	X	X	X	X
2010	**Mean**	0.07	None	None	204.00	3.33	4.07	101
	Variance	X	N/A	N/A	X	X	X	X
2011	**Mean**	0.05	0.01	None	8.16	2.50	4.82	9.13
	Variance	X	X	N/A	X	X	X	X
2012	**Mean**	0.05	0.02	None	6.15	2.17	3.63	9.88
	Variance	0.00	0.00	N/A	1.16	0.00	0.14	0.07
2013	**Mean**	0.03	0.01	None	6.00	1.00	5.86	9.10
	Variance	0.00	0.00	N/A	0.11	0.00	4.15	0.12
2014	**Mean**	0.05	0.01	None	None	None	6.27	15.01
	Variance	0.00	0.00	N/A	N/A	N/A	1.88	0.07
2015	**Mean**	0.05	0.01	None	7.62	1.29	4.42	10.13
	Variance	0.00	0.00	N/A	1.03	0.04	2.11	0.16

d) Groundwater – downstream site

*N/A = Not applicable

*X = has no variance

*Table 11(*a-d) illustrates the mean and variance values for all the selected ions, across all the monitoring sites between 1995 and 2015. All standard deviation error bars are customized to cover positive and possible negative values, hence the negative values in some axes. And because some values are difficult to see on the graphs, most referrals are made to Table 11(a-d*).*

4.3.2.1) Interpretation of ammonium data

The ammonium levels indicated in Table 11(a-d) changed throughout, but never went above 0.6mg/l. With the exception of the maximum level recorded for ammonium was 87mg/l. This value was associated with the mid-stream site (the waste water discharge point close to Marapong) in 2011. This is far above the acceptable levels based on the standard values set by the South African Water Quality Guidelines, for domestic (DWAFa, 1996) and livestock (DWAFe, 1996) uses and can have direct health consequences. Therefore, this value was not included in the graph because it is a clear outlier. However, it does indicate an incident that caused a drastic increase in ammonium levels.

The minimum overall ammonium mean value was 0.018mg/L ± 0.004 and is associated with the Rietspruit Ellisras/Witkop (groundwater – downstream) borehole in 2004. Leading to the assumption that groundwater resources in the area are safe for a range of uses in its natural state. However, the ammonium concentrations in the groundwater-downstream site decreased from between 0.3mg/l and 0.6mg/l during 1995 to 2000. Ammonium levels remained steady between 0.018mg/l and 0.13mg/l from 2001 to 2015.

The ammonium levels in the surface water – upstream site, were low and ranged between 0.024mg/l to 0.11mg/l with no significant difference between the values based on the variances seen in Table 11a. The surface water – downstream site only had data available for ammonium in 2011, with a mean value of 0.4mg/l ± 2.29. Due to the poor availability of ammonium data on this site, it was difficult to come to an overall conclusion for this ion, for this site, during the selected period.

4.3.2.2) Interpretation of phosphate data

The maximum overall phosphate value was 8.9mg/l and was derived from measured data that were available between 2011 and 2015, from the midstream surface water site (the waste water discharge point close to Marapong). This high level of phosphate would suggest possible sewage. Otherwise, the site maintained phosphate levels between 2mg/l and 4mg/l. The minimum mean value for phosphate was recorded at the upstream surface water site in 2011 and 2013 (see Table 11) at 0.005mg/l. Further mean values ranged between 0.008mg/l and 0.032mg/l with no significant difference between the values. The surface water - downstream site had phosphate concentrations ranging between 0.02mg/l and 0.05mg/l from 2010 to 2015. The groundwater – downstream site's phosphate levels ranged between 0.01mg/l and 0.04mg/l from 1995 to 2015.

There are no standard values available for phosphate in the South African Water Quality Guidelines for any of the major uses of water in the area. Therefore, the guide cannot be used as a reference to measure the level of phosphate acceptability in the surface water and groundwater resources. However, of the four sites, the waste water discharge point had abnormally high levels of phosphate, just like ammonium. This could indicate a possible alteration of the water body's natural state, between the upstream and downstream sites, by a natural or anthropogenic activity, such as discharging waste water into the river. Changes in the phosphate levels can be picked up in the downstream sites. These changes are noticeable by the slight increases in phosphate, in comparison to that of the surface water upstream site.

4.3.2.3) Interpretation of nitrate data

There were no nitrate data available for the Rietspruit/Witkop borehole. Thus, there were no nitrate data available for the groundwater source to be compared to that of the surface water sites. Again, the maximum mean nitrate value, of 1.08mg/l ± 0.44, was associated with the midstream surface water site (the waste water discharge point close to Marapong) in 2013. Leading to the assumption that there is a link between this site and ammonium, phosphate and nitrate levels. Further nitrate levels for this site ranged between 0.2mg/l and 0.7mg/l.

The overall minimum mean value for nitrate was measured wat the surface water upstream site in 2000 at 0.02mg/l. For the other years, within the selected period, the nitrate levels at this site ranged between 0.022mg/l and 0.28mg/l (see Table 11a). At the downstream surface water monitoring site, the measured levels for nitrate were between 0.64mg/l and 1mg/l. Using the SAWQG, the nitrate concentrations do not exceed the acceptable standard for domestic and livestock uses. There are, however, no standard values available for industrial (DWAFc, 1996) and irrigation (DWAFd, 1996) purposes in the SAWQG.

4.3.2.4) Interpretation of sodium data

Sodium levels are extremely high at the groundwater – downstream site with an overall maximum mean value recorded at 347.60mg/l in 2000 (see Table 11d). The high sodium concentrations could be linked to the interaction and structure of the fractured, sandstone aquifer known to the Waterberg. According to Hodgson and Vermeulen (1998), water produced in this zone contains high salt concentrations due to prolonged contact with the rock. Further sodium mean values at this site, vary between 276.22mg/l and 347.6mg/l from 1995 to 2006, with highly significant differences between the values. Between 2008 and 2015, the sodium levels drop drastically to between 4.05mg/l and 8.16mg/l, except for 2010 which had a recorded sodium level of 204mg/l. The large drop in sodium would suggest the occurrence of a major influential event sometime between 2006 and 2008.

The range for sodium levels for the surface water – upstream site was between 5.18mg/l and 11.95mg/l, from 1995 to 2015. There was only one measured value for the midstream surface water site (the waste water discharge point close to Marapong) which was 178mg/l in 2011. This is not enough information to determine whether the sodium level here is linked to the high concentrations in ammonium, phosphate and nitrate at this site. Recorded sodium values for the surface water – downstream site varied between 4mg/l and 19.75mg/l from 2010 to 2015.

4.3.2.5) Interpretation of potassium data

There is no potassium data available for the midstream surface water site (the waste water discharge point close to Marapong). The highest overall mean value for potassium was 4.38mg/l, measured at the groundwater – downstream site in 1995 (*see Table 14d*). Like sodium, the presence of potassium in groundwater, increases with its interaction time in the ground. However, potassium is common in top soil with clay particles (MPCA, 1999), which are not in abundance in the Waterberg. Other values associated with this site vary between 1.29mg/l and 3.90mg/l, during the selected time period.

The minimum overall mean value measured for potassium was 0.73mg/l at the upstream surface water site in 2001 (*see Table 14a*). The range of the remaining values, for this site, were between 0.74mg/l and 2.55mg/l, with some difference between the values based on the variances. The surface water – downstream site only had data available for potassium from 2013 to 2015, of which the mean values varied between 1mg/l and 1.55mg/l. Per the SAWQG, none of the monitoring sites exceed the potassium standard acceptable for domestic purposes. There are no standard values available in the guide for potassium for any of the other major uses in the area.

4.3.2.6) Interpretation of calcium data

There were no data available for calcium at the midstream surface water site (the waste water discharge point close to Marapong). The Maximum overall value for the remaining sites was 13.20mg/l, occurring at the upstream surface water site in 2006. Further values at this site varied between 3.58mg/l and 5.78mg/l for the other year between 1995 and 2015 *(see Table 14a).*

The minimum value for calcium was recorded at the groundwater – downstream site at 2.44mg/l in 2009. Other calcium values measured between 1995 and 2015 varied from 2.97mg/l to 9.0mg/l, with a low to high significant difference between values based on the variances *(*see Table 11d*).*

The surface water – downstream site only had calcium data available between 2011 to 2015. The mean values ranged from 3.30mg/l to 4.37mg/l with significant differences between the values (see Table 11c). None of the sites exceed the acceptable standard for calcium set by the SAWQG for domestic (DWAFa, 1996), industrial (DWAFc, 1996) and livestock (DWAFe, 1996) uses. There is no calcium standard value available in the guide for irrigation purposes.

4.3.2.7) Interpretation of electrical conductivity (EC) data

As mentioned before, electrical conductivity (EC) is dependent on charge of the total ions dissolved in the water. Per the South African Water Quality Guidelines of 1996, most organic compounds do not dissociate into ions, dissolve in water and consequently do not affect the EC levels. Inorganic compounds, such as nitrate, sodium, potassium and calcium, all carry an electrical charge.

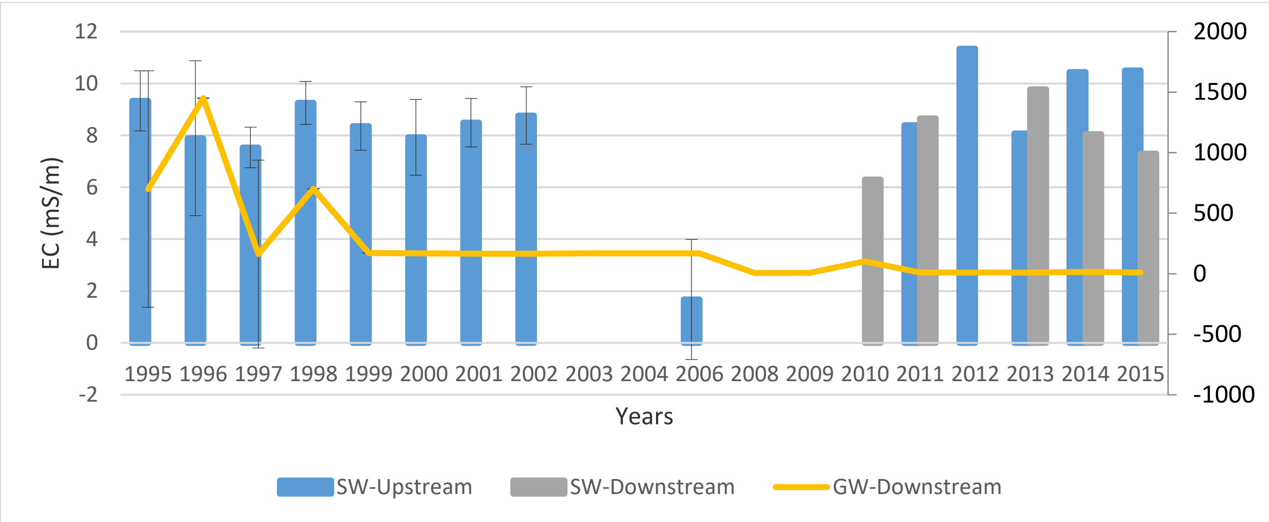

Figure 8: *The annual mean Electrical Conductivity (EC) values of the Moorddrift/Vught (SW-Upstream), Ellisras residential area/Rietspruit (SW-Downstream) and Rietspruit Ellisras/Witkop (GW-Downstream) monitoring sites, measured from 1995 to 2015. The standard deviation error bars are customized to cover positive and possible negative values, hence the negative values on the y-axes.*

Figure 8 **s**hows that there were no data available on EC for the midstream surface water site (the waste water discharge point close to Marapong). There were also data missing for the surface – upstream site from 2003 to 2004, and 2008 to 2010. The maximum mean value for EC for this was 11.33mS/m in 2012. Other values, from the selected period, varied from 1.68mS/m to 10.45mS/m with significant differences between the values. Of the data available for the surface water – downstream site, from 2010 to 2015, the maximum mean value for EC reached were 16.14mS/m in 2014 (see Table 11a-c).

The EC levels in the groundwater downstream site (see Table 11d) were significantly different from any of the surface water sites. The maximum EC value for this site was 1450mS/m in 1996. The EC levels remain high (between 162.50mS/m and 701.50mS/m) from 1995 to 2006. From 2008 to 2015 the EC levels decrease drastically to between 6.22mS/m to 15.01mS/m, apart from 101mS/m in 2010. This pattern coincides with sodium concentrations for the same time period and site.

Table 12: *A comparison of the Electrical Conductivity (EC) values for the four respective monitoring sites between 1995 – 2010 and between 2011 – 2015.*

Monitoring site	Between 1995 – 2010	Between 2011 - 2015	Difference
Moorddrift/Vught (SW-Upstream)	7.69mS/m ± 0.64	9.75mS/m ± 2.05	+2.06mS/m
Ellisras residential area/Rietspruit (SW-Downstream)	6.30mS/m (for 2010 only)	8.44mS/m ± 1.74	+2.14mS/m
Rietspruit Ellisras/Witkop (GW-Downstream)	307.28mS/m ± 153538.59	10.65mS/m ± 6.15	-296.63mS/m

*+ = increased units

*- = decreased units

An ANOVA test was done in Microsoft Excel on the mean EC values between the selected monitoring sites. The test revealed that the mean EC values across the respective sites were significantly different with an f-score equalled to 3.65. The large variance value indicates the very high increase of in EC levels at the GW-downstream site.

4.3.2.8) Conclusion

Based on the provided data, ammonium, phosphate and nitrate concentrations reached the reached the highest measurements at the midstream surface water site (waste water discharge point close to Marapong). Indicating that these three ions are mostly affected by sewege within this section of the Mokolo River. The maximum recorded value for ammonium at this site, is far above the acceptable standard set by the SAWQG for domestic and livestock uses. The maximum levels reached for nitrate are well within the standards of the SAWQG, for all uses known to the Waterberg area, but there aren't any values available in the guide for phosphate.

Sodium levels were at its highest in the groundwater – downstream site, between 1995 to 2006. Between 2008 and 2015, the sodium levels decreased significantly, with the exception of 2010. This information would suggest an event happening sometime, between 2006 land 2008, with major influences on the groundwater sodium levels. The EC levels, at the groundwater site, followed the exact same pattern as that of sodium, from 1995 to 2015. This is not unexpected because sodium levels are directly related to EC. This would suggest that sodium has the most effect on the EC. And even though the waste water discharge into the mid-section of the river, increased ammonium and phosphate levels in this site, it was difficult to determine the effects of these increases on EC levels due to the lack of data. In the case of available data for potassium and calcium, for all sites, both ions do not exceed the standards set by the SAWQG for domestic uses (DWAFa, 1996).

4.4 The interpretation of completed questionnaires

This section of the results focuses on the analysis of the responses of the questionnaires distributed to local people from three settlements within the Waterberg area. A total of 20 questionnaires were randomly distributed to individuals who were all above 18 years of age and residing within the area; five people from Steenbokpan (site 1), five from Marapong (site 2) and 10 from Lephalale (site 3). The number of questionnaires distributed differ because of the difference in size and population of each settlement. The purpose of this section is to present and interpret the completed questionnaires. The questionnaire, itself, was divided into four different sections. Each section had a specific theme with several questions addressing that theme and which each individual had the option of answering.

4.4.1) Section A: Livelihood Assessment

The goal of the following set of questions is to gain personal information of each participant, their livelihood and to define the socio-economic background of the respective residential areas. Socio-economic circumstance is a major factor that influences the general use of water by individuals.

1. How old are you?
2. What is your gender?
3. What is your marital status?
4. How many members are in your household?
5. Where do you live?
6. Are you employed?
7. If you are employed, what type of work do you do?
8. Do you have any educational qualification?
9. If yes, which of the following qualifications do you hold?
10. Are any other people in your household employed?

11. If you were to buy a flat screen television, without taking a loan, would you be able to afford it?

Table 13: *Personal information about the 20 participants from the three selected residential sites.*

	Age	Gender	Marital status	Number of household members
Steenbokpan				
1	18	Male	Single	2
2	30	Female	Single	3
3	39	Male	Single	3
4	60	Male	Married	2
5	21	Female	Single	6
Marapong				
1	31	Female	Single	3
2	37	Female	Single	3
3	56	Male	Married	8
4	24	Male	Single	7
5	31	Female	Married	7
Lephalale				
1	46	Male	Married	4
2	42	Female	Married	3
3	35	Male	Married	4
4	41	Male	Cohabitating	Did not indicate
5	57	Female	Married	Did not indicate
6	27	Female	Single	3
7	38	Male	Single	Did not indicate
8	27	Female	Married	3
9	40	Female	Married	5
10	24	Male	Single	2

The first section of the questionnaire (see Table 13) revealed that within the selected sample size, the ages ranged from 18 to 60, of which half were male and the other half female. The marital status of all the participants indicated that nine are married, ten are single and one individual is cohabiting. The number of household members, varied between two to seven across the different residential areas. In Steenbokpan, one out of every five people are married and of those who are single, share a single abode with up to six other people. Marapong is not much different, two out of five people are married and household numbers vary between three and eight. In and around the larger town of Lephalale, more than half of the participants are married with an average household number of three.

Table 14: *Number of employed and educated individuals in Steenbokpan, Marapong and Lephalale and the number of different types of education across the three respective residential areas with a statistical description of the data using the one-way ANOVA test.*

Location	Number employed	Number educated	Types of education	Number of individuals
Steenbokpan	1	4	**High School**	12
Marapong	4	5	**Diploma**	5
Lephalale	9	10	**Trade**	1
			Tertiary	1
Total	14	19		19
Mean	4.67	6.33		4.75
Variance	16.44	10.34		26.92
Standard Deviation	4.05	3.22		5.19

The number of individuals employed and educated in Steenbokpan, Marapong, Lephalale are shown in Table 14 as well as the various qualifications held by these individuals. The aim of the data displayed in the table, was to compare the number of employed individuals with the number of educated individuals. The one-way ANOVA test was used to describe whether there is a significant difference between the number of people who are educated and who are employed, based on their qualifications, across the different sites. The test revealed am F-score of 0.14 revealing no significant differences between the mean values. Also, the different types of educational qualifications (see Table 14) would suggest that the higher the qualification, the fewer the number of people who have attained that level.

Table 15: *The distribution of the different types of educational qualifications held by the participants from the three selected residential locations.*

Location	High School	Diploma	Trade	Tertiary	None
Steenbokpan	X			X	X
Marapong	X				
Lephalale	X	X	X		

Table 16: *The job description of each of the participants from Steenbokpan, Marapong and Lephalale.*

Individuals	Steenbokpan	Marapong	Lephalale
1	Unemployed	Unemployed	Administrator
2	Entrepreneur	Cleaner	Bookkeeper
3	Unemployed	Security guard	Educator

4	Unemployed	Company representative	Housekeeper
5	Unemployed	Chef	Branch co-ordinator
6			Manager
7			Unemployed
8			Manager
9			Senior supervisor
10			Unemployed

In Steenbokpan (see Table 16) the number of individuals employed are low and the majority of people who are educated, only have a high school education. One participant has no education and another holds a tertiary degree and is a business owner in the area. The situation in Marapong is similar to that of Steenbokpan. The highest level of education is high school. The difference, however, is that 80% of these individuals are employed, but hold four different types of positions, which may require limited skills. Of the participants in Lephalale, everyone has some form of education, which varies from high school to trades, with most holding a diploma. Of these selected individuals, 90% are employed. Job descriptions from individuals in this area vary between administrator, educator, manager, supervisor and bookkeeper.

Table 17: *A financial reflection of the households from Steenbokpan, Marapong and Lephalale.*

Location	Additional individuals employed in household (question 10)	Afford a flat screen TV (question 11)
Steenbokpan	2/5	2/5
Marapong	3/5	3/5
Lephalale	8/10	7/10

Lephalale is (see Table 17) the area with the largest number of households that has more than one person per household that is employed, which would suggest a second form of income. Based on question 11, 70% of individuals in Lephalale believe that they can afford to own a flat screen television. In Steenbokpan, only 40% of households have more than one person that is employed and believe that they can afford a flat screen television. The number of individuals in Marapong who have more than one person employed in their household, is the same as those who believe they can afford a flat screen. The data in Table 17 would suggest that the ability to afford a flat screen go hand-in-hand with multiple incomes per household.

In conclusion, section A would suggest that Steenbokpan residents are seemingly of a lower socio-economic status than those in Marapong and Lephalale.

4.4.2) Section B: Resource Usage

By establishing socio-economic background from the questions in Section A, Section B aims to determine if the participants have access to water resources and how they are utilized. If so, a link can be maid between an individual's socio-economic background and how they use the resource.

12. Do you have any electricity in your house?
13. If yes, how much is your monthly electricity bill?
14. Do you have running water in your house that is connected to a sewage system?
15. If yes, what is your monthly water bill?
16. Does your house have a geyser?
17. Does your house have a kitchen?
18. Does your house have a bath or a shower?
19. Is your toilet situated inside or outside your house?
20. Do you own a washing machine?
21. Do you have a swimming pool?
22. Do you have a home garden?
23. If yes, how would you describe your garden?

Table 18: *The percentage of participants from each residential area that have access to electricity, water and sanitation services, with added mean and variance values.*

	Electricity	**Water**	**Sanitation**
Steenbokpan	20%	20%	20%
Marapong	60%	80%	60%
Lephalale	100%	90%	80%
Overall	70%	70%	60%
Mean	4.67	4.67	4.00
Variance	3.44	2.51	2.36

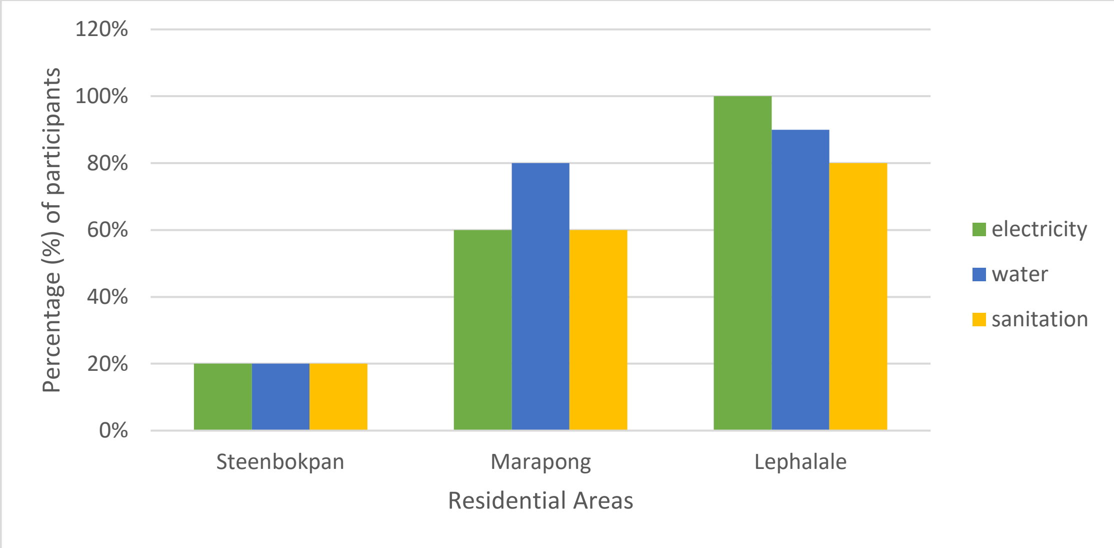

Figure 9: *The number of participants interviewed with electrical, water and sanitation service delivery in Lephalale, Marapong and Steenbokpan.*

Indicated in Figure 9 (above), there is a clear pattern of having access to running water, proper sanitation facilities and electricity, with the greatest access in Lephalale, then Marapong and then Steenbokpan. Table 18 shows within the means and variances that there is no significant different between the values of the different services, however there is a major significance in how these services are spread amongst the three residential areas. Section B of the questionnaire revealed that accessibility to electricity and potable water in each locality goes hand-in-hand with its socio-economic status, which was established in Section A (refer to Table 18 and Figure 9).

Table 19: *The total number of participants from each residential area that have access to electricity, water and sanitation services, with added mean and variance values.*

	Geyser	Washing Machine	Kitchen	Swimming Pool
Steenbokpan	1	1	1	0
Marapong	2	2	3	0
Lephalale	9	5	9	0
Total	12	8	13	0
Mean	4.00	2.67	4.33	0
Variance	3.45	1.24	2.89	0

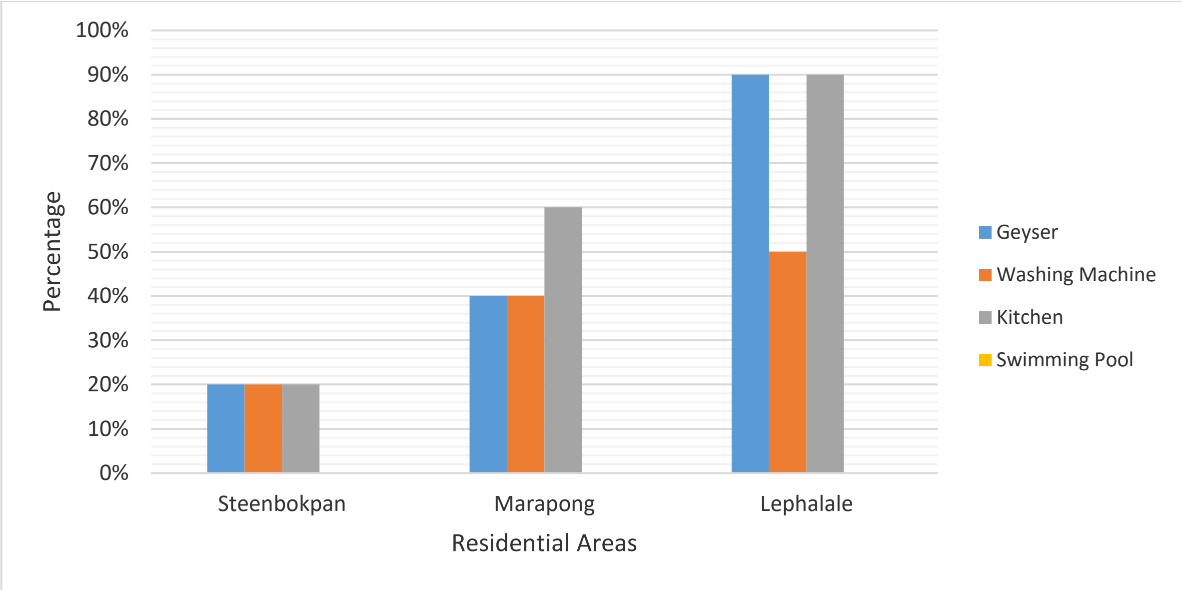

Figure 10: *The percentage of participants interviewed from each chosen residential area that have that have electrical appliances, kitchens and swimming pools.*

Table 20: *An estimate of monthly water and electricity bills indicated by the participants from the selected residential areas.*

Location	Water bill	Number of participants	Electricity bill	Number of participants
Steenbokpan	**between R50 - R300**	1	**>R350**	1
	>R300	1		
	No running water	3	**No electricity**	4
Marapong	**between R50 - R300**	2	**between R250 - R350**	1
	>R300	2	**>R350**	2
	No running water	1	**No electricity**	2
Lephalale	**between R50 - R300**	3	**between R100 - R350**	6
	>R300	4	**>R350**	3
	Unknown	2	**Unknown**	1
	No running water	1	**No electricity**	0

Table 21: *The total number of participants from each residential area that have access to different types of personal hygiene options, with added mean and variance values.*

	Bath	Shower	Bucket	Both shower and bath	Toilet inside
Steenbokpan	1	0	4	0	1
Marapong	0	2	2	1	3
Lephalale	4	3	0	3	8
Total	5	5	7	4	12
Mean	1.67	1.67	2.00	1.33	4.00
Variance	2.17	1.19	1.33	1.58	2.36

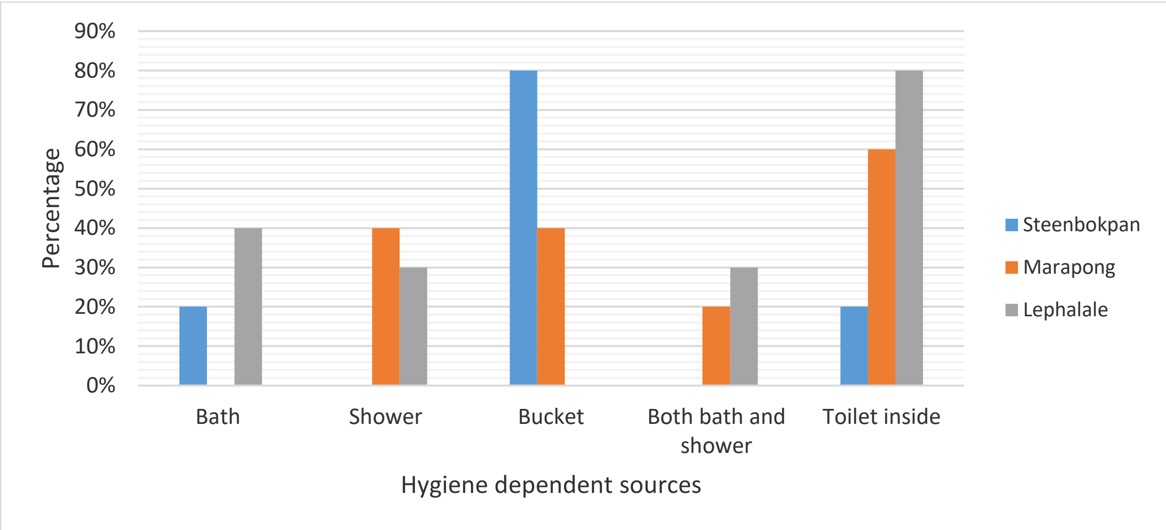

Figure 11: *The percentage of participants with access to different sources of hygiene in the sample group from the respective areas of Steenbokpan, Marapong and Lephalale.*

Other economic status indicators for each area, were the ownership of a geyser, washing machine and swimming pool, whether there is a toilet inside or outside the establishment, the monthly water and electricity bills, whether there is a kitchen in the house or if a shower, bath or bucket system is used for personal hygiene.

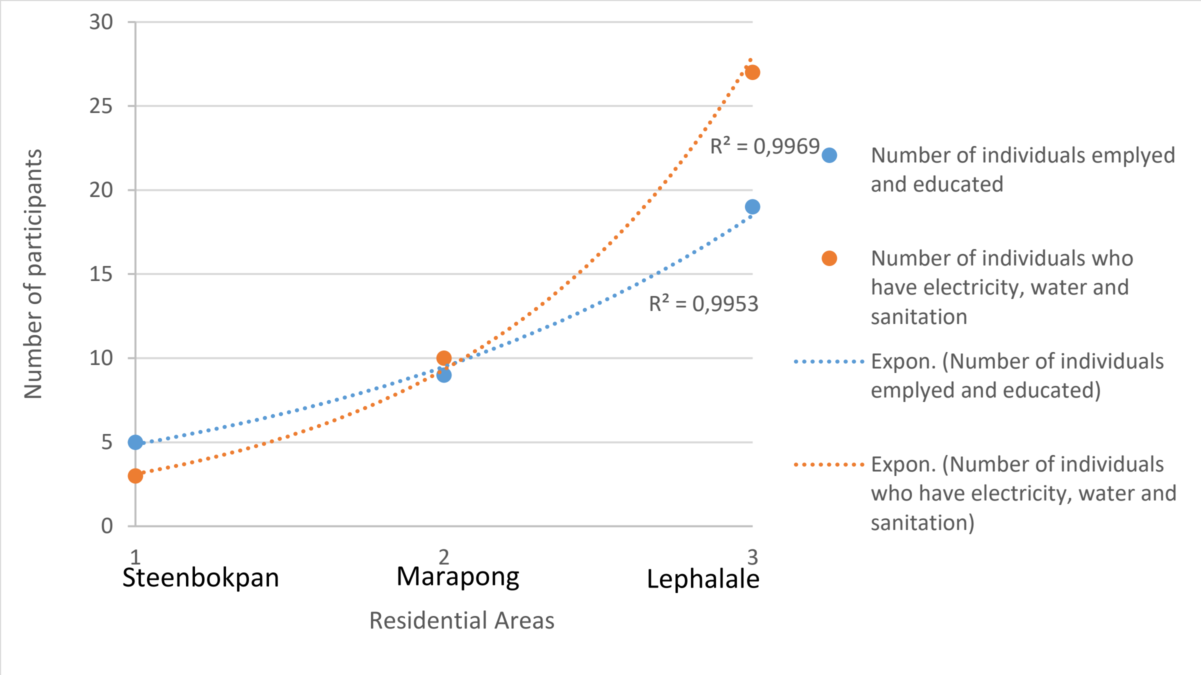

Figure 12: *The correlated relationship between the number of participants employed and educated against the number of participants who have electricity, water and sanitation in Steenbokpan, Marapong and Lephalale indicated with an exponential growth pattern.*

Figure 12 (above) shows that Steenbokpan, which has the lowest number of individuals employed and with the lowest number of individuals educated, shows that it is an informal settlement without electricity, running water and the luxury of a kitchen, geyser or washing machine. The residents that live here mainly make use of outside, non-flushable toilets and a bucket for personal washing (see Figure 12). The data are different for residents living in Lephalale. Here, there is better access electricity and running water. All three study sites have exponentially correlated relationships between employed and educated participants, and having electricity and basic service delivery (see Figure 13) with a correlation coefficient of 0.99, indicating a strong positive relationship. This makes owning a geyser and washing machine (see Figure 11*)* and having access to running water (see Figure 10), showers and baths (see Figure 12) more probable, but with the trade-off of an increase in monthly water and electricity bills (see Table 20). No individuals in any of the residential areas have swimming pools (see Figure 11), even though the Waterberg region can become extremely hot.

Table 22: *The total number of participants from each residential area that own different types of gardens and don't have a garden at all.*

	Vegetable garden	Fruit and Flower garden	Combination garden	No garden
Steenbokpan	1	1	0	3
Marapong	1	1	0	3
Lephalale	0	3	2	5

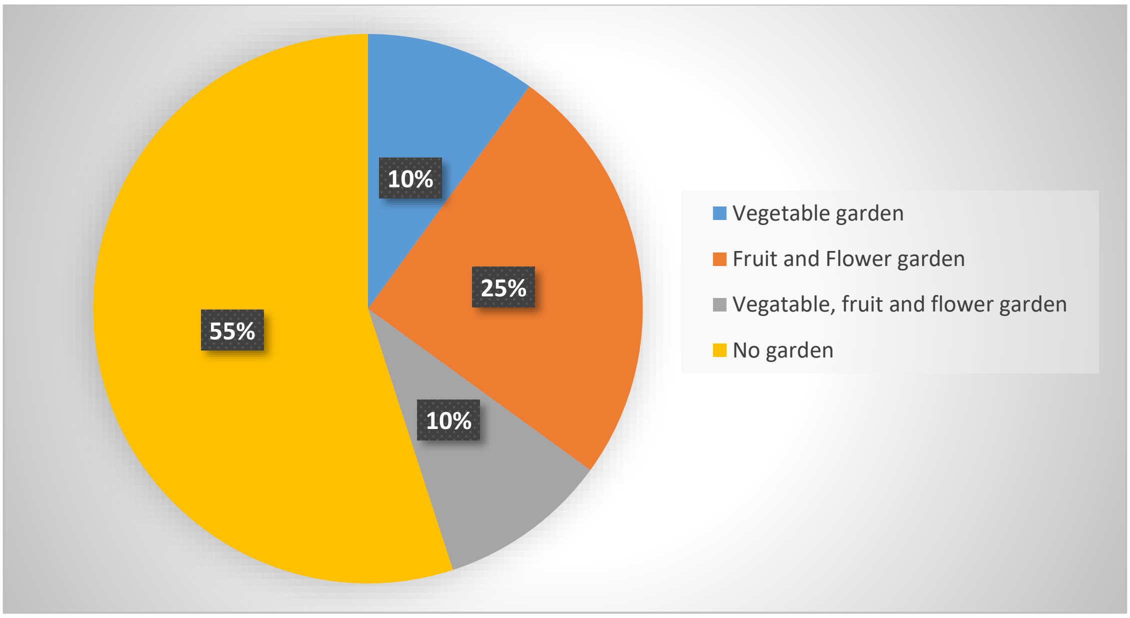

Figure 13: *The ownership of different types of gardens amongst the participants from all three selected communities.*

Additionally, the option of having a food or flower garden seems to be a personal choice (see Figure 14), rather than being associated with any of the social or economic indicators. There was no significant difference in the ownership of gardens across the different locations. More than half of the participants indicated that they do not have a garden.

4.4.3) Section C: Water Quality Perceptions

This list of questions again links to the questions asked in Section A. This section tests the knowledge level each participant has on water quality. This knowledge is influenced by level of education, local knowledge and/or observing the surrounding environment.

24. *Have you heard of water pollution before?*
25. *If yes, indicate below where you have heard of water pollution before.*
26. *How would you describe the water quality that you and your household uses on a day to day basis, rating the water quality on a scale from 1 to 5? (1 being poor and 5 being excellent)*

27. *Do you think the water is polluted in your area?*
28. *If yes, how would you tell that it is polluted? (please tick more than one choice if necessary)*
29. *If yes to question number 27:*
    a) *How would you rate the level of pollution in your area?*
    b) *Do you think that the pollution in your area affects your health negatively?*
    c) *What do you think mostly contributes to water pollution in the Waterberg district? (Rate from 1 to 5. 1 being most influential and 5 being least influential)*
    d) *Do you think your household contributes to water pollution in your area?*
30. *Are you and your household aware of ways to save water and improve water quality?*
31. *If yes, please give one example?*

Table 23: *The number of participants aware and unaware of the general term 'water pollution in the three respective areas.*

Location	Aware	Unaware
Steenbokpan	80%	20%
Marapong	40%	60%
Lephalale	80%	20%

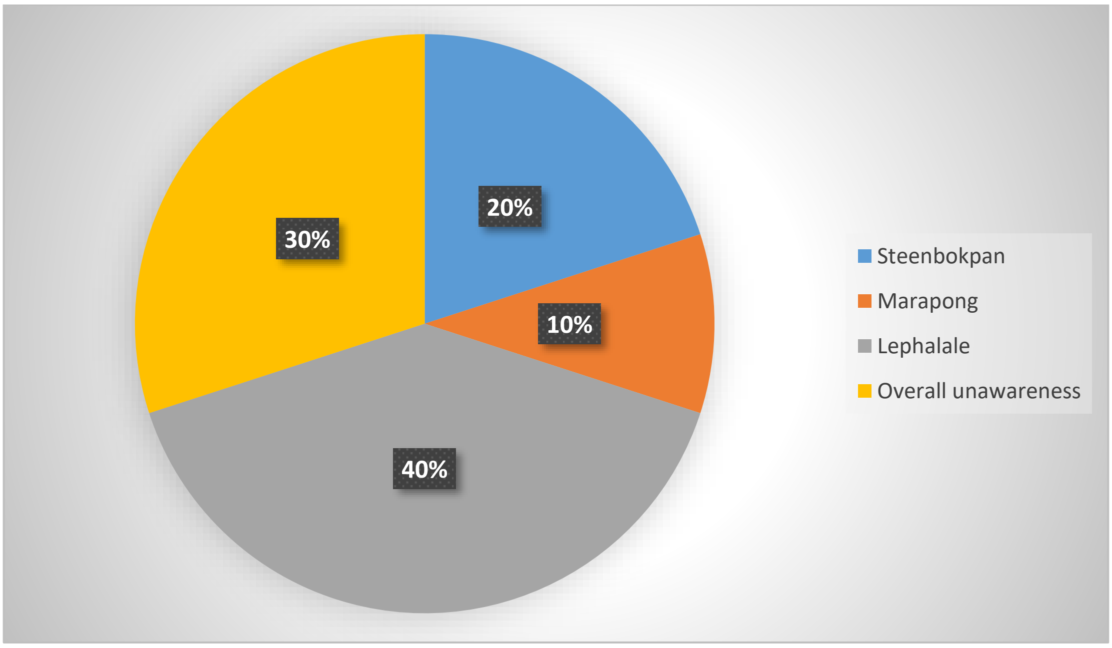

Figure 14: *The percentage of participants who are aware on the topic of water pollution in general, from Steenbokpan, Marapong and Lephalale, and the percentage of participants who are overall unaware.*

Of the total sample group, 70% of the participants indicated that they know what the term water pollution means in general while 30% of the participants do not identify with the term at all (see Figure 15). Of the 14/20 individuals who are aware of the term water pollution (Figure 15), 28.56% are from Steenbokpan, 14.30% from Marapong and the remaining 57.14% are from Lephalale. Of the overall six participants, from the respective areas, who indicated that they are unaware of the term, half (50%) of these individuals are from the vast community of Marapong, 33.33% from Lephalale and 16.67& from Steenbokpan.

Table 24: *The number of uses of a different range of information sources on water pollution by those participants aware of the subject.*

	News	**Internet**	**School**	**Work**	**College**	**Pamphlets**	**Other**
Steenbokpan	xx	x	x				x
Marapong	x			x	x	x	
Lephalale	xxxxx	xxx	x		x	x	xxx
Total	8	4	2	1	2	2	4

*x = used information source

Table 25: *Water quality rating (1 = poor, 5 = excellent) by participants of the three selected areas.*

	1	**2**	**3**	**4**	**5**	**Unsure**
Steenbokpan	40%	40%		20%		
Marapong			20%	20%	40%	20%
Lephalale			50%	30%	20%	

On a scale from one to five (see Table 25), one being poor and five being excellent, the majority of the participants rated the water that they use daily between three and five indicating that most of them believe that the water is of good quality. Each participant also had a different opinion on a) the quality of water that they use every day, b) the level of water pollution in the region, c) if water contamination can affect their health, d) who the biggest contributors to water pollution are and e) whether they believe that the water in their area is polluted.

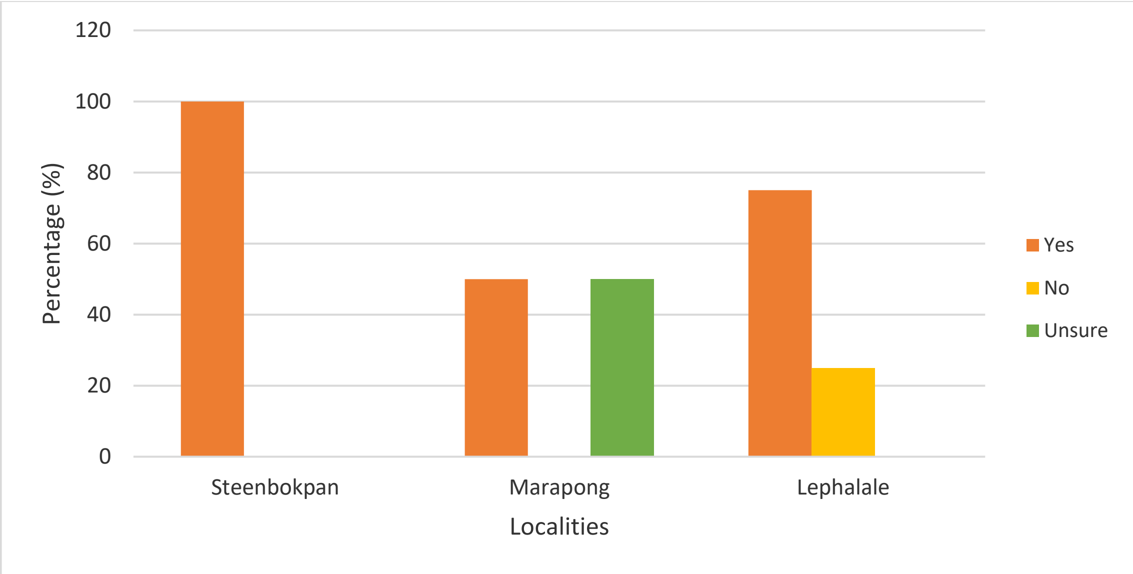

Figure 15: *The percentage of those participants from the three respective locations who are educated on water pollution, who are informed about whether water contamination does take place in their immediate surroundings.*

Question 27 could only be answered, if the answer was yes to question 24. Of those individuals who are knowledgeable on the topic of water pollution, there is a difference in opinion as to whether the water in their immediate area is contaminated. Seen in Figure 16, all Steenbokpan's residents believe that their water is contaminated. In Marapong, 50% says yes and 50% are unsure. While in Lephalale, 75% say yes and the other 25% say no. Lack of knowledge concerning water quality could be linked to the lack of formal education, experienced by the people in Steenbokpan and Marapong (refer to Table 14 and Table 15).

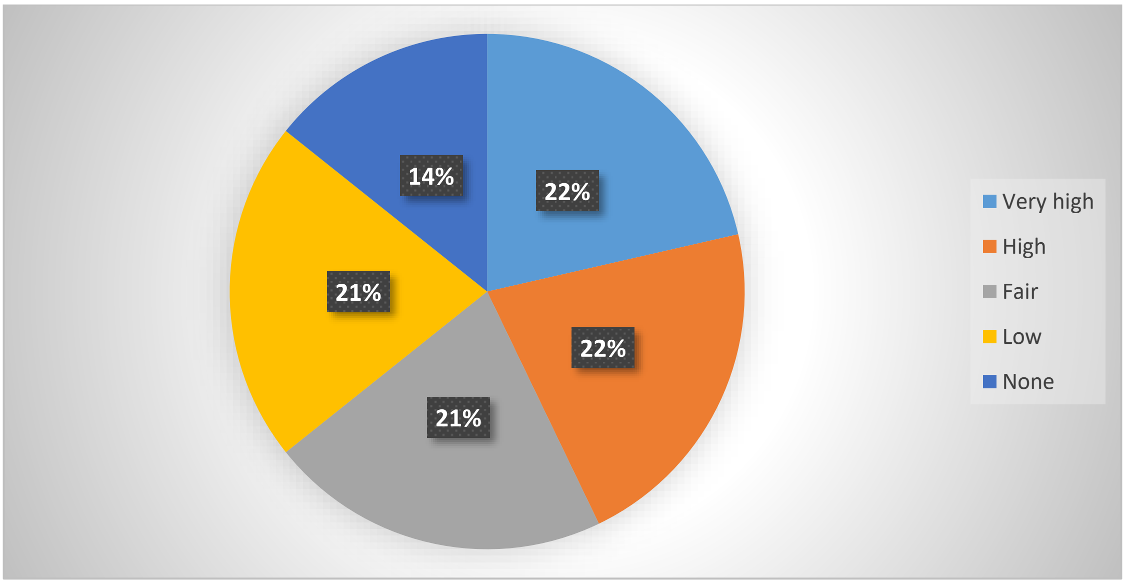

Figure 16: *Difference in opinion in rating (Very high to None) the water contamination in the area from the participants of the three respective residential settlements.*

Seen in *Table 4.23* and *Figure 4.12* is that there are also differences in opinions amongst participants on how the pollution level is rated in the area, in comparison to how they rate the quality of water that they use day-to-day. For this a different rating system was used (very high to none). A participant could only have an opinion on this if he/she answered that they knew what water pollution is and whether they think that it appears in the Waterberg area (refer to *Table 4.21* and *Figure 4.10*). *Figure 4.12* reveals that 44% of the overall participants from the respective residential areas, rate the level of contamination of water in their area as very high to high. 42% of the participants rated water contamination in their area between fair and low. The remaining 14% refers the participants to who believe that there is no water pollution in the area. However, this answer may be contradictive if the same 14% of participants indicated water contamination contributors in question 29c.

Table 26: *Percentage differences in indices of water contamination.*

	Smell	Taste	Colour	Other	Combination	Unsure
Steenbokpan	20%	80%				
Marapong	20%		20%			60%
Lephalale		10%	10%	10%	30%	40%

Residents that took part in the questionnaire from Steenbokpan determined polluted water mostly through taste and Marapong, through colour or smell, but most of them were unsure. Participants from Lephalale indicated that they can tell by the taste, colour or a combination of the senses, while some said that they just have a ‘feeling’ that the water is contaminated, but a large overall percentage are also unsure.

Table 27: *Sources of water contamination in the area.*

	Households	Power stations	Mines	Municipality	Natural causes	Combination	Unsure
Steenbokpan	40%		20%		20%	20%	
Marapong		40%					60%
Lephalale		30%	10%	20%		20%	20%

In Table 27, Steenbokpan residents largely blame local water pollution on household waste, while others blame it on a combination of household wastes, power stations, mines as well as on natural causes. Participants from Marapong who are aware of water contamination in their area, mostly hold power stations accountable for local contamination. This is understandable because this residential area is closest to Eskom's Medupi and Matimba power stations compared to the other residential areas. However, 60% of the individuals in Marapong indicated that they are unsure of any sources of contamination. Locals from Lephalale held several sources accountable for the large portion of pollution that exists in the area, which mostly includes the municipality, mines and power stations.

Table 28: *Percentages to a combination of answers from participants to question 29b, 29d and 30, on perspectives of the consequences of water contamination in the area.*

Location	Agree that pollution affects health negatively	Agree that households contribute to water pollution	Aware of ways to improve and save household water
Steenbokpan	60%	80%	60%
Marapong	20%	40%	60%
Lephalale	20%	0%	70%

There are different opinions, from citizens in Steenbokpan, Marapong and Lephalale, on the affects and contributions of water contamination in the area and how to improve on the quality used every day. Based on question 29d, no one from Lephalale believe that their household waste contributes to their surrounding water pollution levels. But, the opposite is true for individuals from Steenbokpan and Marapong. Answers to question 29b also reveal conflicting opinions as to whether the pollution level in their area can affect human health negatively, 60% of Steenbokpan residents say yes, while only 20% of Marapong and Lephalale residents agree with this statement. Question 30 revealed an almost even distribution of awareness amongst all participants on ways to save and improve on daily water uses.

4.4.4) Section D: Water Management Participation

The goal of the final section of the questionnaire was to assess the level of engagement of local stakeholders in how water is managed and governed in the area. Also, to evaluate the current interaction that general users have with water. The previous sections create a pathway of choices and circumstances that effect the current interaction each participant has with water.

32. *How does your household get the water that they use?*
33. *Does your household reuse bath, laundry or dish water?*
34. *Which household methods do you use if and when you purify water?*
35. *How do you get information about water related issues?*

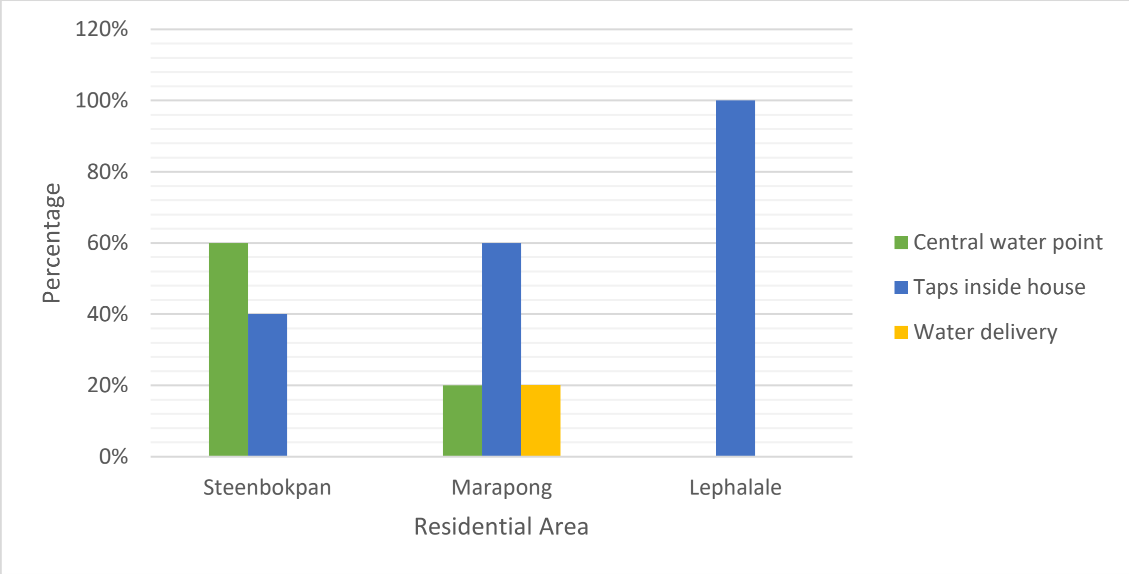

Figure 17: *The percentage of participants, from the respective areas, accessing water from three different sources.*

Figure 17 shows that a 100% of households in Lephalale and 60% of households in Marapong have water taps inside their house. Whereas 60% of Steendbokpan households share a central water point with several other households. Also, seen in this figure, is that Marapong was the only area where residents indicated that they still rely on water being delivered to them. Again, the lack of functional water infrastructure is also linked to the socio-economic disadvantaged areas.

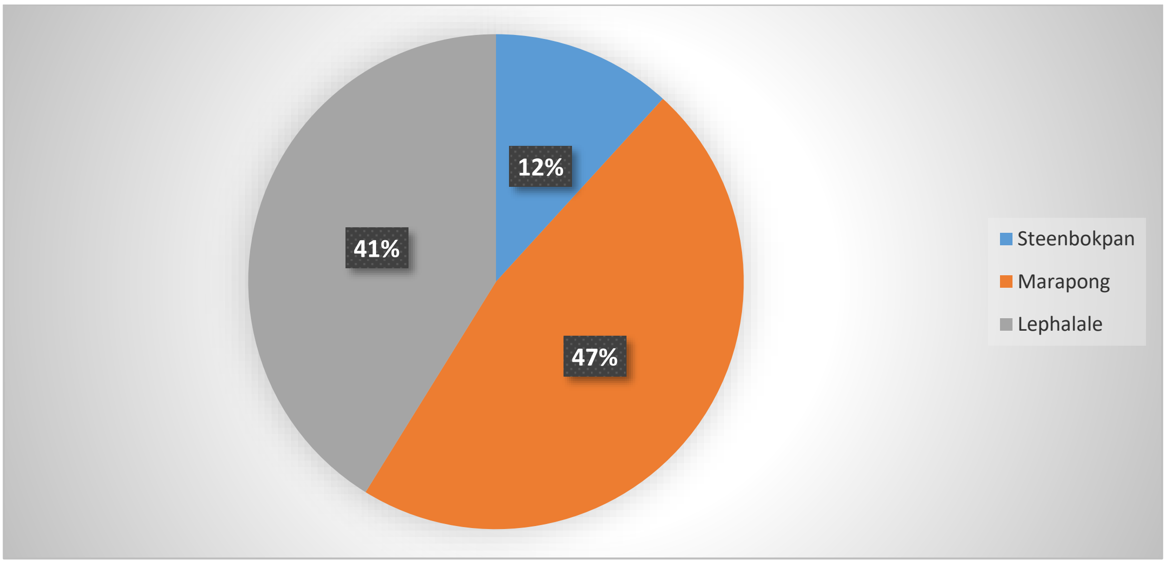

Figure 18: *The percentage of participants that are engaged in water recycling in Steenbokpan, Marapong and Lephalale.*

Answers to question 33 revealed that of those who participate in water reuse activities, 47% of them are from Marapong and 41 % in Lephalale, with very little water reuse in Steenbokpan (see Figure 18). Possible reasons for the high percentages of water recycling in Marapong and Lephalale could be associated with the fact that most participants from these locations have running water and are better informed on how to save water. Whereas, established throughout the questionnaire, in Steenbokpan there is a lack of basic services, access to resources and low employment levels.

Table 29: *Methods used for water purification by participant in each of the three selected residential areas.*

	Boil	Bleach	Buy bottled water	Filter systems	Combination	Other	None
Steenbokpan	1		1			1	2
Marapong	3						2
Lephalale	4	1		2	2		1

Question 34 (see Table 29) revealed that 75% of the selected sample size still make use of water purification methods. The most common method being used for water purification is boiling water. 40% of the overall participants still use this method. This could be due to the affordability of this option. Filter systems are more popular amongst residents from Lephalale, as well as using several different purification methods, probably due to the technical information being available and their higher socio-economic status allowing for the purchasing and maintenance of filters and the ability to afford more options. Water boiling is the most popular method used in the disadvantaged settlement of Steenbokpan (see Table 29), due to costs and access to information. Other methods used by Steenbokpan and Marapong residents involve buying bottled water and using chloride tablets. 25% of all participants do not use any purification methods.

Table 30: *The main sources of information used by the locals on water related issues.*

	School	Municipality	Neighbours	Work	Other	None
Steenbokpan	40%	20%	20%		20%	
Marapong		80%		20%		
Lephalale		60%		10%	20%	10%

Lastly, this section revealed that most participants rely on the local municipality to provide information on water related issues, even though some of these individuals hold the municipality accountable for the local water contamination. Other major sources of water related information are received through work and neighbours. One individual specified that his only source of information is the local water usage association as he is a member. While another individual indicated that he does not receive any information at all. Both are from Lephalale. Even though social media was not a provided option in the questionnaire, none of the participants specified that they use it as a source of information. In Steenbokpan, not many of the participants are employed and cannot rely on their jobs for information and therefore mainly depend on information received from nearby schools and local newspapers. These alternative sources might affect the quality of the information and could prove to be reliable or unreliable.

4.4.5) Conclusion

From the information gathered through the questionnaires, residents are well aware of the fact that the Waterberg region is a water scarce area. Furthermore, this section shows the importance of the socio-economic background of the area in terms of resource availability, access to basic services and the quality of information received with regards to local water related challenges. Still, it is important to keep in mind that the questionnaire was only completed by 20 individuals in the general community of Steenbokpan, Marapong and Lephalale. The next section presents the opinions of society members that are in positions of power and influence, by the use of interviews.

4.5 The interpretation of successful interviews

This section of the results focuses on the analysis of 15 out of 20 successful interviews that were conducted for this study. The other five interviews were unsuccessful due to lack of interest in the study or time constraints. Of the 15 successful responses, some are in influential positions related to water management and others are research experts in the field of water quality. 12 of the 15 interviews were done in person, while others were done via Skype, telephone or email, where distance and time were issues. The purpose of the personal interviews was to assess whether their perceptions differ from the perceptions of the residents who completed the questionnaires. The information gathered was divided into three common themes: 1) issues raised on waste water management, 2) inequality in accessing sufficient water services and water of acceptable quality based on its chemical, physical and biological properties for different uses and 3) addressing the shortage of water through the Magol-Crocodile Water Augmentation Project (MCWAP).

Table 31: *A list of the interviewed participants and their role within their company or organization. (permission was granted from 13 out of 15 interviewees to use their names in this report).*

NUMBER	PARTICIPANTS	COMPANY/ ORGANIZATION	POSITION
1.	Elana Greyling	Farming Association	Representative
2.	Jacques Snyman	Socio-Economic Development Company	Forum Co-ordinator
3.	Astrid Basson	Democratic Alliance	Council member
4.	Christopher Mamabolo	Eskom (Matimba)	Environmental Manager
5.	Simon Nkoe	Lephalale Local Municipality (Water Resource Department)	Institutional Social Development Officer
6.	Makoma Lekalakala	Earth Life Africa	Senior Programme Officer
7.	Fanie Greyling	Private Hospital	Maintenance
8.	Mariana de Villiers	Local Tourism	Freelancer
9.	Leoni Kruger	Magol Post	Editor
10.	Michela Marcatelli	Social Science Department at a European University	PhD Student
11.	Interviewee 1	ABET Academy	Principal
12.	Interviewee 2	Coal Mine	Environmentalist
13.	Nils Meiring	Ellisras High School	Deputy Principal
14.	Richard Wadley	Waterberg Nature Conservation	Board Member
15.	Dr Paul Oberholster	CSIR	Limnologist

The 15 individuals interviewed, represented people in positions of power and influence across the three respective communities, including local municipal officials, heads of educational institutes, research specialists, environmentalists, a local journalist, an Eskom representative, a community council member and various other individuals that are involved in community development and environmental organizations.

The focus of the questions that were asked, was to create an overall picture of how water resources are being managed, by having the following statements in mind:

- To assess the effectiveness of the water management practices with regards to overcoming water challenges and adapting to user needs.
- To identify the struggles that various structures face with regards to their involvement in the decision-making process involving water management and the broader areas of development.
- To determine how big developers and government bodies are challenged when attempting to improve the water management system.

The purpose was to compare the information provided from the participants who completed the questionnaires, with the information from the interviews and to establish any similarities and/or differences.

4.5.1) Issues raised on waste water management

It is important to keep in mind that water treatment from a dam and a waste water treatment plant are two separate processes, usually managed by government in the form of local municipalities, whom are the Water Service Providers. Dam water is natural, unused, unsavoured surface water and is usually located close to mountainous areas. A dam provides a source of drinking water and must be treated for that purpose, but the level of treatment depends on the dam water quality (UNEP, 2001). Whereas waste water treatment involves chemical, physical and biological processes to remove pollutants from household and industrial sewage.

In the Lephalale area, Eskom has taken over the processing of potable water for the Mokolo Dam for residents in the urban area. Thus, the water used daily, in this area, now holds a Blue Drop status. This is a certification process where the Department of Water Affairs does a water performance assessment on the quality of drinking water against the national standard for a fixed time period. The waste water treatment works on the other hand, measured by the Green Drop initiative, are assessed based on the operational services of a treatment system and is managed by the local municipality (3 SMedia, 2012). Lephalale received the second lowest Green Drop ratings in the Waterberg district for waste water processing.

Over the period of data collection for this study, many complaints from town locals, visitors and the farmers along the Mokolo River, mentioned sewage leakages and waste water overflows into the river. The general excuse from the municipality's Social Development Officer given as to why the problem has not be resolved, is because of the lack of funding. According to a local journalist at the Magol Post newspaper, and a socio-economic development forum co-ordinator, waste water spills have been a problem for years. Some experts and an elected ward representative, agree that a lack of funding is a contributing factor, but that a lack of skills, knowledge, manpower and competence is mostly to blame. The Institutional Social Development Officer does, however, state that the matter is being attended to by entering an agreement with the Biokarabelo mine to assist in refurbishing the treatment system. But, this is a long-term solution and no short-term solution was mentioned.

4.5.2) Inequality in accessing sufficient water services and water quality

In the opinion of various researchers that have visited the area, e.g a PhD social science student from Europe and a limnologist, working at the CSIR in Stellenbosch, agree that the biggest concern in this area was the apparent inequality associated with water access, for both domestic and industrial uses. Also mentioned was how the quality of water, for drinking and domestic purposes, varied with socio-economic status. As a social scientist, the greatest challenge for this PhD student was gaining access to those individuals who were most affected by water inequality, which were the poor rural villages and game farmers.

With the possibility of increased developments in the area, farmers are concerned that the quality of the water source is being threatened. According to Elana Greyling, a representative from a local farming association states that they are highly dependent on groundwater resources, through the use of boreholes. Farmers and villagers directly alongside rivers, especially downstream in the Mokolo River, pump directly from the river, and are probably more exposed to the dangers of potentially contaminated water from upstream human activity. Direct use of water from the river has not undergone any treatment process and therefore its users do not know which contaminants it may contain. Also, this extraction method is not monitored and may lead to the misuse of water.

The chosen ions for this study did not indicate any level of groundwater contamination that would be harmful for human consumption and the high sodium concentrations that were found at the downstream groundwater site, are known to the Waterberg region based on its geological composition. As mentioned by one of the respondents (who chooses not to be linked to any specific information), groundwater resources in the area have also gone unmonitored for decades, which prevents credible extraction amounts for sustainable development to be calculated, of which is a requirement for mining and power station operations.

These concerns were rigorously expressed by the representative of the local farming association. Her biggest worry is that some of the local organizations are not heard or recognized in the decision-making processes concerning development in the area. “We have a lot of concerns and fears and terrifying nightmares regarding the industrialization of our area.” were the direct words of this farm owner in the Steenbokpan area. For these farmers, leaving an inheritance for their children is their main priority. To ensure their survival, in an already water scarce area, farmers are highly dependent on rainwater, and groundwater resources are highly valued. Thus, the proposed development of coal mines and power stations nearby, poses a major threat to their way of living. However, some experts say that any further development is currently “on hold” because the water that is available is already fully allocated.

Staff members who hold a water resource management role, within Lephalale Municipality, agree that accessing water is a problem and creates water limitations. The lack of funding to improve the local water supply system and to implement initiatives, are some of the biggest hurdles the water department faces, when having to provide water services to its consumers. Again, the challenge of providing informal settlements and rural villages with potable water, was an ongoing and frequently raised issue. According to council member, Astrid Basson, the quality of naturally occurring, untreated surface water does not meet the published standard for potable water. The same belief is amongst interviewees, that industries and residents in Lephalele town, were receiving better quality water than those people and developments in lower socio-economic areas.

However, per the Institutional Social Development Officer, all communities are equally knowledgeable about water scarcity, but not everyone, mostly in town, receives water services or uses the resource with the same amount of thought. This statement was supported when interviewing the deputy principal of Ellisras High School, who had no complaints or worries with water services to the school and praised the willingness of the municipality to assist when needed. The situation is somewhat different for an individual in a similar position at an educational institute in Marapong. The difficulty is not that the institution does not have enough water, but that little support is received about water awareness and other water related educational topics. Information received is not timely and issues cannot be addressed by the community.

The Institutional Social Development Officer stated that the water service department does have the relevant skills necessary to deal with upcoming water challenges. Of the eight interviewees to who this question was directed to, 75% disagreed with this statement. There were some claims that the department is functional and that they assist with any concerns that the community might have related to water, but Elana Greyling from the farming association would strongly disagree with these sentiments as well as Makoma Lekalakala from Earth Life Africa. The only representatives to believe this claim will be those within the municipality and industries in town that benefit from timely water service delivery.

4.5.3) Addressing the shortage of water through the Magol-Crocodile Water Augmentation Project (MCWAP)

Reading done prior to conducting interviews and the distributing of questionnaires, provided knowledge that the Waterberg region is a water scarce area where there is a rapid increase in urbanization and industrialization due to the presence of coal. The Magol-Crocodile Water Augmentation Project (MCWAP), phase one and two, has been developed and implemented to address the issue on water shortage in the area.

Phase one of the project is already completed. The first phase of the project involved addressing the outdated water infrastructure, which was incapable of carrying the capacity required by increasing urbanization and industrialization in the area. According to the socio-economic development forum co-ordinator, this process involved the upgrade of the current water distribution system. This was done by enlarging the pipes that draw water from the Mokolo dam into the water treatment plant and increasing the flow. The biggest setback during the upgrade was, that the town of Lephalale experienced challenges related to adequate provision of water to its users. This meant that not enough water was available for everyone in town and that water shedding, which involved temporary restrictions for certain uses of water, and rotated water cuts at different times in different areas, were implemented. Phase one increased the flow rate of the water from the river into the dam and should not be confused with more water being available in the dam.

The Magol-Crocodile Water Augmentation Project (phase 2) involves the installation of a 250km pipe line from the Crocodile River to Lephalale. Water will be extracted from the Hartebeespoort Dam scheme. This stage of the project is projected to deliver between 75milion and a 100milion cubic litres per year. This water will allow for the further development of industry, as well as the community, in the coming years. Users in this area are currently paying a very cheap price for water (between R6.00 and R9.00 per cubic litre), but because of the costs associated with the distance the water has to travel and treating the effluent water of MCWAP (phase 2), the price will increase threefold to between R22.00 and R29.00 per cubic litre. The project is yet to be implemented and will take roughly three years to complete.

The DA council member confirmed the information stated above, but was concerned and worried about the social struggles associated with water provision for all the residents in the area. There was little local involvement from general users in the planning of MCWAP (phase 2). This was confirmed by the interviews which estimated that about 80% of the residents are unaware of the increase in water prices upon completion of the project. Another of her concerns is the low level of attention given to the water needs of local rural villagers and dwellers of informal settlements. This is a challenge because most of the individuals in these areas are unemployed and will not be able to afford these services. Therefore, additional funding needs to be sought.

4.5.4) Conclusion

From the information gathered from the interviews, all positive commentary related to water services and water quality, of which the local municipality are responsible for in this region, would come from those delivering the service and those receiving good service delivery. Another observation made from the interview data, are that the difference in water service delivery are related to a settlement's geographical location and socio-economic background. This supports the assumption that bad service delivery is associated with those individuals who feel neglected and underserved by their responsible water service provider and authority and good service delivery is associated with those who are in influential and financial sound positions.

It would also seem that the designated water service provider and authority, Lephalale Municipality, are too dependent on the assistance of Eskom and Exxaro to improve on water service, supply and infrastructure challenges. And even though it is proven that development in the area has the ability to improve on socio-economic status of underprivileged communities, the stress on the biophysical environment and its resources, especially water, are not being considered enough.

Chapter 5: DISCUSSION

The following discussion is based on two approaches that were necessary for this study. The first was the quantitative approach to the study that required surface water and groundwater quality data from 1995 to 2015. The second was a qualitative approach comprised of two components namely, semi-random questionnaire distribution and pre-selected individual interviews. Even though each section of the different approaches is discussed individually based on the results produced, the reviewed literature related to the study shows how the two approaches can possibly be linked and how information gained in one can be used in another.

5.1 Historic surface water and groundwater quality

5.1.1) Surface water and groundwater quality data challenges

The raw water quality data as provided by DWA: RQS presented itself as a challenge in the interpretation thereof. The monitoring sites were pre-selected to fulfil objective one of the study, but data provided by the Department of Water and Sanitation (DWS): Resource Quality Services (RQS) created limitations in the interpretation due to gaps and incomplete data sets. Two of the biggest challenges were that there was no upstream groundwater monitoring site (borehole) close to the upstream surface water monitoring site, and that data from the mid - stream groundwater site (borehole) could not be used because it only had one month's worth of data available for the entire 20-year period. Both cases made data comparisons with any of the other variables from the other sites impossible.

To address these limitations, the intention was to also make use of Exxaro's groundwater quality data, from the Grootegeluk Coal Mine, for 1995 up until 2015 for comparison, but no response was received from the appropriate authorities from the mine to many formal requests to access the information. As a result, the selection of the water data used, were based on common data being available across all sites and for the years between 1995 and 2015 (refer to Table 5). Only available data based on these criteria could be used for the water quality interpretation of the Waterberg, for the selected time period.

5.1.2) A discussion of pH, selected ions and electrical conductivity (EC) in surface water and groundwater quality in the Waterberg region between 1995 and 2015

The water quality standard provided by the SAWQG was used to determine whether the surface water and groundwater in the Waterberg is deteriorating or at an acceptable level for domestic, industrial and agricultural uses known to the area. Water quality in South Africa, as per the Department of Water Affairs (2003), refers to the measurement of the resource's condition for a specific use or purpose, based on its chemical, physical and biological properties. The water quality variables focused on, for the purpose of this study, were pH, ammonium, phosphate, nitrate, sodium, potassium, calcium and electrical conductivity (EC).

5.1.2.1 Changes in pH

When the upstream, mid-stream and downstream surface water pH data were compared to pH values from similar studies done by Burne (2015) and Bruyns (2015) it was revealed that between 1988 and 1991 the pH levels in the Mokolo River increased by one unit (from 6.6 to 7.6) around the same time Matimba power station was commissioned. This suggesting that coal combustion by local power stations, especially rivers downwind of the power stations, had an influence on the pH levels of surface water bodies, possibly due to the co-deposition of the alkaline fly ash (Burne, 2015). Analyses done by Bruyns (2015) revealed a decrease of 0.09 units (from 7.6 to 7.51) in the pH levels in the Mokolo River between 1999 and 2011. Thus, suggesting that from 1989 to 1998 the pH levels in the river remained steady. Results from this study did not reveal significant differences within the three different monitoring points chosen in the Mokolo River between 2011 – 2015, in comparison to Bruyns (2015) overall value for the river (refer to Table 8).

However, the pH values across the different surface water and groundwater monitoring sites were significantly different. Between the three surface water sites, the pH values vary between 7.20 and 7.95. These values balance between neutral and slight alkalinity. The groundwater site, however, has an extreme maximum value (9.02) and a mean pH value of 8.00. The high pH values in the downstream groundwater monitoring site may be associated with the high salt concentrations found in the fractured rock aquifer known to the Waterberg (Hodgson & Vermeulen, 1998). The different soil types in the area allows for the presence of carbonates that aids as a buffer in the effects of acid deposition on the surface and thereby maintaining neutral pH levels. The Waterberg's geology is mostly associated with sandstone, and together with quartzite, it forms a fractured, secondary aquifer with high salt concentrations caused by the long interaction with the rock (ibid, 1998) accumulating carbonates.

It is paramount for the pH levels in the Mokolo River Catchment to withstand sudden changes from anthropogenic impacts to avoid a shift in the water quality towards an undesirable state of high acidity (De Klerk, *et al*., 2016). While carbonates assist as a buffer against acid deposits, too much from coal mining could increase the alkalinity of water systems. In other words, it is crucial for pH to remain as neutral as possible to avoid treatment processes and remain usable.

5.1.2.2 Changes in selected ions

Different natural or anthropogenic activities have different effects on the natural state of surface water or groundwater reservoirs in the Waterberg area (Dinka, *et al.*, 2015). For this study, limited water quality variables were chosen to focus on between 1995 and 2015 due to restrictions from the available data (as mentioned throughout various chapters of the study).

Out of the surface water sites it is evident that the physical, chemical and biological characteristics are most likely affected by sewage discharge. Surface water sources are more susceptible to negative impacts from various associated land use activities, erosion (Simeonov, *et al.*, 2003) and natural activities, such as changes in precipitation (Akkoyunly & Akiner, 2012). Due to the nature of the data provided, the chemical properties of the surface water and groundwater were the focal point. Chemical data aids in identifying factors that influence surface water and groundwater systems and contributes to sound water management practices and solutions for water contamination challenges (Simeonov, *et al.*, 2003). However, the chemical data used in this study does not fully allow for sound conclusions to be drawn and to aid in water management practices due to the limited information it provides.

The mid-stream site is the closest to Marapong and Lephalale where most anthropogenic activities in this area take place. This leads to the site being associated with the waste water from surrounding urban and industrial uses to be discharged into a tributary of the Mokolo River. Thus, resulting in the increase of ammonium, phosphate and nitrate in this section of the river. Built on the boundaries of incomplete data, the conclusion is made that the water upstream in the Mokolo River are relatively unchanged, once again using the SAWQG as a reference to do so. This would lead to the assumption that, due to the lack of human activity upstream of the Mokolo River, the water quality here is less exposed to change when compared with increased human activities downstream of the Mokolo River.

Based on the maximum values of ammonium, phosphate and nitrate, and using the South African Water Quality Standard, only imperfect conclusions can be drawn. The greatest ammonium value exceeds the acceptable water quality standard and poses a health risk towards domestic and livestock uses. Even though the nitrate levels are the highest mid-stream, then in the other two sites, it is still within an acceptable range based on the water quality standard values. However, there is no standard values available for phosphate in the SAWQG that relate to the major water uses of the study area.

Of the phosphate and nitrate values that were available for the downstream surface water site, there are clear indications that the values are slightly higher than the upstream site and relatively lower than that of the mid-stream site. Due to the lack of activity downstream it is safe to suggest that the waste water discharged into the mid-section of the Mokolo River, has diluted downstream. It seemed premature to assume the cause of changes in ammonium, if any, in the downstream site, due to the poor availability data.

Sodium only had one very high measured value for the mid-stream surface water site (178mg/l), which does not provide enough information to determine whether or not the sodium level here is linked to the high concentrations in ammonium, phosphate and nitrate at this site. Again, the sodium levels downstream area significantly lower than the one available reading for the mid-stream site, but higher than the values calculated at the upstream site. Both of which are within the acceptable standard of the SAWQG for domestic (DWAFa, 1996), irrigation (DWAFd, 1996) and livestock (DWAFe, 1996) uses. It is therefore also safe to assume that the lack of human activity downstream allows for dilution of chemicals, containing sodium, discharged upstream in the river.

No suppositions could be made on the state of potassium or calcium in the mid-stream site because there were no data available. The values of these two variables related to the upstream surface water site are expected to be linked to the natural condition of surface water bodies in the area. Again, due to the lack of data available for potassium and calcium for the downstream site and the repeated challenge to make total use of the SAWQG as a reference, no assumptions were made.

Because there was only one groundwater monitoring borehole (downstream) that had data available to be used, it was not possible to compare the chosen variables at this site to the groundwater conditions of the upstream and midstream focus areas. It was, however, possible to determine whether the selected variables at this singular groundwater site were within acceptable standards of the SAWQG of 1996 for the domestic, industrial and agricultural (irrigation and livestock) uses in the area, and to compare the surface water and groundwater quality conditions of the downstream sites to one another. Yet, it was still not enough information to come to an overall conclusion on the groundwater conditions in the area or to determine whether the changes in the surface water quality directly or indirectly result in changes in the groundwater quality.

In comparison to the surface water sites, ammonium and phosphate levels associated with the groundwater site were relatively low over the 20-year period, but there were no nitrate results available. The high groundwater sodium and potassium values are related to the interaction time with the geology. Sodium levels are linked to the structure of the fractured, sandstone aquifer known to the Waterberg. As per Hodgson and Vermeulen (1998), water produced in this zone contains high salt concentrations due to prolonged contact with the rock and potassium is common in top soil with clay particles (MPCA, 1999). The only variable that differs to the other trends of the groundwater site, is calcium, which shows the lowest value between 1995 and 2015. Based on these results groundwater resources in the area are safe for livestock use in its natural state, but based on the sodium levels, it is not safe for domestic or irrigation purposes in its natural state.

5.1.2.3 Changes in electrical conductivity (EC)

The electrical conductivity (EC) of water is dependent on the total substances that dissolved oxygen in surface water and groundwater reservoirs in the area. Organic compounds dissolve in water and consequently contribute on the EC levels. Inorganic compounds, such as nitrate, sodium, potassium and calcium, also carry an electrical charge and effect the overall EC of the water (DWAFa, 1996). This literature is supported by the changes in EC levels that correspond with the alterations of sodium in the groundwater monitoring site downstream of the Mokolo River. It is, however, difficult to prove that the statement is true for the surface water monitoring sites in the area, due to inconsistencies in EC data for the upstream and downstream surface water sites, and no EC data being available for the midstream surface water site.0…

The EC levels in the groundwater downstream site (see Table 11d) were significantly different from any of the surface water sites, however this is to be expected based on the difference in geology. Table 12 refers to fluxes in the EC over the 20-year period in the upstream and downstream surface water monitoring sites and reveals minor changes in these sites. However, the high increase rate in EC levels at the groundwater site, supports the initial statement that the EC levels correspond to inorganic compounds, such as sodium and calcium (major constituents) and, nitrate and potassium (secondary constituents), that all carry electrical charges that primarily controls the charge level of EC (Harter, 2003). But based on the changes in EC patterns, sodium carries the most influential charge associated with the rock type of the fractured aquifer known to this area. However, some dissolved solids originate from river water or precipitation that recharges the aquifer (ibid, 2003). There are two ways to measure salts in surface water and groundwater, by conductivity meter and evaporation and weighing. From the EC value, the Total Dissolved Solids (TDS) can indirectly be calculated and vice versa. The conversion from one to the other does not change or determine the suitability of the water for drinking, agriculture, industrial or mining uses. The higher the TDS or EC value, the less recommended it becomes for any of the above mentioned uses.

The use of these results for water management purposes is not suggested, due to inadequate availability of data for the chosen surface water and groundwater sites, but referals could be made based on the used literature. The SAWQG cannot be used to its full capacity due to gaps and incomplete data and the results produced only provided a superficial overview of the water conditions of the area. However, it can be concluded from literature used in this study that pollutants from anthropogenic activities can transport high concentrations of nitrogen and phosphorus containing nutrients, can control trophic conditions of freshwater and lead to eutrophication (Heathwaite, 1995; Oberholster, *et al.*, 2008). These changes in ion concentrations typically include the application of fertilizers from agriculture, coal mining, informal settlements and game ranching associated with the Waterberg, and are known to increase nutrients and pollutants in water systems and severely impact water quality (Sams & Beer, 2000; Tiwary, 2001; Smet & Ward, 2005). The enrichment of nutrients and pollutants from these upstream activities, could have severe environmental impacts on the Mokolo Dam and surrounding aquatic i, and should be monitored carefully (Oberholster, *et al.*, 2012; De Klerk, *et al*., 2016).

5.2 An overview of stakeholder involvement in water quality management in the Waterberg area via individual questionnaires and individual interviews

5.2.1) Challenges associated with the questionnaires and interviews

Time constraints, language preferences for different social groups and deciding on a sample size were the major challenges encountered prior to the distribution of the questionnaires. Thus, planning ahead and being prepared played a vital role with regards to field visits. Section A of the questionnaire, reveals a vast difference in the socio-economic backgrounds of Lephalale, Marapong and Steenbokpan, creating the foundation on which the unequal distribution of basic services and needs, such as water and electricity, are built. This allowed for more in depth interpretation of different stakeholders' involvement in water quality management.

With regards to the interviews, major challenges involved the lack of interest in the study from vital role players, such as environmental consultants, with significant background information on water quality of the area. This left a gap in information from an important contributor in environmental well-being. Also, time constraints and distance was an issue when setting up interviews with selected individuals. This problem was addressed by making use of other forms of communication such as Skype, telephone and email correspondence.

5.2.2) Stakeholders' perspective of water quality management in the Waterberg region

The questionnaire and interview approaches allowed for stakeholder involvement in the area to be viewed from two different aspects. The interview results displayed knowledge from a more educated and scientific background of how water quality is managed in the Waterberg, versus the local knowledge exhibited through the questionnaire. Making use of these two different knowledge bases allows for frequent communication and a platform to influence each other, while producing information of value at the same time (Reed, 2008).

Due to the multi-levelled influences on the water resources in the area from various stakeholders, looking at integrating scientific and local knowledge is important. Through integration of the two knowledge groups, bias is eliminated in the decision-making process by solely depending on scientific knowledge and enriches the understanding of elaborate natural and socio-economic systems through the use of local knowledge (Johnson, *et al*., 2004).

The results from the questionnaire indicates that there is limited stakeholder participation in water quality management from residents in Steenbokpan and Marapong. The questionnaire revealed that the disadvantaged socio-economic statuses, lack of knowledge and restricted access to information in these areas, are contributing factors towards the individuals' limited involvement. It is therefore safe to say that employment and education levels plays a vital role (refer to Table 14) and are linked to the access of electrical, water and sanitation services (refer to Table 18) and amenities associated with it. Illiteracy and undermining traditional knowledge are proven to be major obstacles in, moving towards environmental integration during decision-making (Schwaibold, 2016; Hage, *et al*., 2009). The results show a gap amongst general water users' involvement and their socio-economic status. Thus, providing the need for stakeholder involvement to adapt to different circumstances and enable empowerment, equity, trust and learning at different levels of education, employment and financial and influential positions (Tippett, *et al*., 2007).

Based on the questionnaire, the participants from Lephalale are more probable to afford high quality services and amenities, but with the trade-off of an increase in monthly water and electricity bills (refer to Table 20). Although obvious, these results suggest that those who are at a financial advantage have more options than those who are not. As a result, financial advantage leads to having better water and sanitation services. And because basic water provision and sanitation services are dependent on infrastructure and financing (TAC, 2000), those from underprivileged, socio-economic backgrounds are still unable to afford basic services (Still, *et al.*, 2009).

As for how this links to objective two; being socio-economic disadvantaged may lead to poor service delivery and being socio-economic advantaged can lead to better service delivery and place an individual in a better position to be heard. However, neither one of these positions guarantee stakeholder involvement if, for the socio-economic disadvantaged, those services are being improved or, for the socio-economic advantaged, those same services are being threatened.

With regards to water quality perceptions and the management thereof, there are a variety of opinions from all participants. There is a 30% overall unawareness of the topic of water pollution in this area (refer to Figure 15) which it mostly from participants in Steenbokpan and Marapong. For a second time, this can be related to the lack of knowledge and access to information sources in these two areas. Of those that are aware of water pollution in the area, have different opinions on how polluted the water is (refer to Figure 17*)*, how to indicate water pollution (refer to Table 26) and which activities they think can contribute to the pollution. (refer to Table 27). Once more, participants in Lephalale seem to be more informed on water pollution and have access to several different purification methods and purchase more technologically advanced methods, such as filter systems. Whereas residents from Steenokpan and Marapong rely on more dated and cheaper methods, such as boiling water or adding bleach to water.

Similar studies within southern African countries have found that smaller communities are more concerned with the physical parameters of water than the biological and base their knowledge of water quality on the taste, colour and odour perceptions of water (Nare, *et al.*, 2011). This seems to be the case for selected residential areas for this study as well (refer to Table 26). Based on traditional knowledge and present physical properties, they are able to determine whether their households contribute to water pollution, if the level of pollution can affect human health and come up with appropriate interventions on how to improve and save water, like recycling bath and laundry water (derived from questionnaire).

By making use of local knowledge in managing water resources in the area, can lead to the community empowerment. Past literature from recent years show that by including local knowledge, generates more detailed information sources and results in sustainable solutions to environmental challenges (Reed and Dougill, 2002; Stringer and Reed, 2007; Reed, *et al.*, 2007). Indicating that by providing adequate services and access to information is not only dependent on the governance and management approaches, but also on the socio-economic status of the general users. However, in South Africa, it is a fact that unequal service delivery exists in the wealthy versus the poor, and in metropolitan areas versus rural areas (Van Vuuren, 2011). This is revealed in Section B of the questionnaire, that there is a clear difference in the accessibility and availability of basic services in Steenbokpan, Marapong and Lephalale.

Information from the interviews indicated concerns and challenges from institutes and individuals who are responsible for managing and maintaining water quality, infrastructure and water services in the area. Lack of funding, skills, infrastructure and the apparent inequality associated with water access to informal settlements and rural villages, seem to be major challenges in this area. As the appointed water service authority and provider, the Lephalale Local Municipality is constitutionally responsible for sufficient water supply and sanitation services to all water consumers as stated in Section 2(a) of the Water Service Act (No. 108 of 1997). Past assessments on South African water supply and sanitation infrastructure, have shown only marginal improvements. The infrastructure has been reported to be of poor quality and unreliable, due to the lack of skill within the water service authorities and providers, neglect of maintenance and the lack of finances required to upgrade current water and sanitation infrastructure. Evidence has been provided to show that all levels of governance, concerning water provision, are under stress (Van Vuuren, 2011).

Providing linkage to literature, the interviews have revealed the following (purely based on the experience and opinions of the respondents):

1. Water quality and availability, for drinking and domestic purposes, vary between socio-economic statuses. The socio-economic disadvantaged, from informal settlement,

townships and rural villages have the poorest service delivery, in comparison to socio-economic advantaged individuals in urban areas have better service delivery (also referring to questionnaire results).

2. Groundwater sources, mostly used by farmers and rural villages, are threatened by the proposed increase of industrial and mining development.
3. The current water supply infrastructure has difficulty keeping up with urban expansion.
4. The man power is lacking and competency of the responsible authority is underperforming with regards to water quality management and maintenance.

Based on the results from the interviews, some of these concerns are in the process of being addressed while others are claimed to have been addressed. Delivering water services to residential populations and industry is an important part of water allocation, but often conflicts with the requirements for agricultural activity and the biophysical environment (DWAb, 2013).

As per the interviewees and their specialities, the local municipality is highly dependent on their relationship with Eskom and Exxaro to provide clean, drinkable water to its users and to maintain water supply infrastructures, which alleviates some liability from the local municipality, but supplying raw water remains the responsibility of the national government. It is also mentioned that the waste water management is not sufficient, when the assistance of Eskom and Exxaro are not present. It is alarming, as it is the water service authority and provider's responsibility to collect, dispose and treat domestic and industrial waste water (DWAb, 2013). Yet, it is evident in the low Green Drop rating awarded for waste water processing from the Department of Water Affairs, that sanitation services in this area are non-satisfactory.

The Magol-Crocodile Water Augmentation Project (MCWAP) phase one and two provides solutions to certain components of above mentioned issues. The first phase of MCWAP involved addressing the outdated water infrastructures. The upgraded system is able to carry the capacity necessary for the current urban, industrial and mining activity in the area (IDP, 2013). This was done through pipe enlargements to increase the flow of water. The aim of phase two of the project is to address water shortage in the area. Due to the fact that the available water in the area is already fully allocated, MCWAP phase two will involve extraction from the Hartebeespoort Dam scheme and the installation of a 250km pipe from the Crocodile River to Lephalale, with the expected water delivery amount of between 75milion and a 100milion cubic litres per year. The biggest concern with this phase of the project, is the costs associated with it and how increased costs will affect residents, from informal settlements and rural villages, that are already unable to pay the current water price.

5.3 Linking stakeholder involvement to water quality management in the Waterberg

Due to the two approaches taken to address the study, it was difficult to show how one approach supports the other, even though on their own, both are crucial components in water quality management practices. Human beings also behave both rationally and irrationally, therefore it is impossible to expect the participants involved in the questionnaire to not be subjective in their opinions on water quality and how it is managed. Subjectivisms is especially clear within the difference in the socio-economic backgrounds in the residential areas from which the participants were chosen.

Human activities, such as agriculture, industrial, mining and domestic uses for water are responsible for alteration of the natural state of water bodies in the area. Therefore, the social aspect in water quality management is unavoidable and determining the community's relationship with water has become a requirement to improve on water management practices. Relying solely on water quality data from surface water and groundwater quality monitoring is no longer sufficient to monitor, manage and control water quality.

Together with the scientific factual knowledge provided by the water quality data, social-scientific knowledge ultimately attempts to understand the underlying principles and theory behind observable events. In this case, the results from the interviews contribute to those factors. Local knowledge is more practical knowledge because the knowledge is based on collective experiences of generations of practice and observation (Ingram, 2008) as demonstrated within the questionnaire results. By integrating researchers and local communities with these different understandings, produces more effective and relevant environmental practices and policies. This ultimately suggests that these two approaches to knowledge generation are fundamentally compatible (Reed, 2008). Gained through this study is demonstrated that it creates a platform for environmental decision-making by involving stakeholders in water quality management, together with statistical evidence from water quality variables, through considering a wider range of inputs. Even though no specific solutions were identified, but major issues were bought to light and should be considered in future decision-making processes.

5.4 Recommendations

5.4.1 Related to the study:

- ✓ Making use of more than one data collection source, if possible, to provide long-term surface water and groundwater quality data sets. Data sets should preferably be complete and reliable to allow for the option of more variables to be chosen for water quality interpretation.
- ✓ Make use of more than one water quality standard guideline that relates to water uses similar to that of the Waterberg and its water scarcity, for example SANS 241-1:2015.
- ✓ Increase the sample size for participants chosen to complete the questionnaires. In order to do so, more time and planning will be required with regards to distributing the questionnaires.

5.4.2 Related to the study area:

- ✓ Skills and knowledge development amongst the local socio-disadvantaged communities of Marapong and Steenbokpan. This could result in making more use of local labour, instead of importing labour, when development takes place in the area.
- ✓ In the long-term, more funds should be made available for the specific use of ensuring equal availability and accessibility of water and sanitation services to farmers, informal settlements and rural villages around Lephalale.
- ✓ Due to the fact that the area is a water scarce area, most farms, informal settlements and rural villages make use of groundwater. Therefore, more resources should be invested in monitoring groundwater in this specific area.
- ✓ Not only should all stakeholders increase their involvement in water quality management, but the different types of stakeholders (general users, NGO's, Government ect.) should strengthen their relationship with one another.

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APPENDICES

APPENDIX A: Questionnaire documentation

University of the Witwatersrand

Richard Ward

1 Jan Smuts Ave

Braamfontein

Johannesburg

2000

www.wits.ac.za

September 2016

<u>Participation Information Sheet: Questionnaire</u>

Dear Sir/Madam

My name is Lesley-Ann Cornelius. I am 25 years old and originally from a small town on the west coast by the name of Vredendal. I hold an undergraduate and honours degree in Environmental and Water Sciences from the University of the Western Cape. I am currently a Master's student at the University of the Witwatersrand, doing my MSc in Environmental Science.

My current project is titled: *Stakeholder Participation in Surface Water and Groundwater Quality Management; Waterberg Region, Limpopo Province, South Africa.* My supervisor for this project is Professor Mary Scholes. This study focuses on measuring the level of participation from various stakeholders, with regards to surface water and groundwater quality management, in the Waterberg area. The water quality data is from the last 20 years collected by the Department of Water Affairs (DWA) and/or USGS. The data will then be positively correlated to the level of participation from stakeholders in the area, which will be measured through questionnaires and individual interviews.

I will be traveling to the Waterberg to distribute 15 – 20 questionnaires (depending on time) to various households in Marapong, Steenbokpan and Lephalale. Households selected and agreed to meet with me have the option of filling out a questionnaire on their own or go through it with them. Whichever way is most comfortable for them. No consent from will be given to those individuals who choose to answer the questions on their own. Them freely handing it over will deem as informal consent.

One questionnaire should take approximately 30min to 45min to complete. All individuals completing a questionnaire must be over 18. No individual is obligated to answer all the questions and is free to withdraw themselves from the study, at any time, without any penalty. Please keep in mind that participation to this project is voluntary and that all answers to the questions are anonymous. All individual names (if any given) will be kept confidential and will be concealed in any public forum.

For any further queries or questions please feel free to contact myself or my supervisor:

- Miss Lesley-Ann Cornelius

Cell phone number: 0731081041

E-mail address: 1444686@students.wits.ac.za

- Prof Mary Scholes

Office number: 011 717 1157/6407

E-mail address: Mary.Scholes@wits.ac.za

With kind regards,

Lesley-Ann Cornelius

Participant Consent Form for Questionnaire

I give consent for the following:

1. I acknowledge that I was invited to participate in the research project conducted by Miss Lesley-Ann Cornelius from the University of the Witwatersrand and I understand my role in the study.
2. I understand that this project is voluntary.
3. I am aware of time required to fill out the questionnaire.
4. I understand that the researcher will not identify me or my family by name in any reports using information obtained from this questionnaire.
5. I understand that the reason for the study is to understand what people think their role is in the quality of water in their environment.
6. I am aware that my answers will be anonymous and kept confidential.

-----------------------------------	--------------------------------------
Participant's signature	Date

QUESTIONNAIRE

Section A: Livelihood Assessment

1. How old are you?

   ____

2. What is your gender?

Male	Female

3. What is your relationship status?

Single	Married	Divorced	Cohabitating

4. How many members are in your household?

   ____

5. Where do you live?

Lephalale	Marapong	Steenbokpan

6. Are you employed?

Yes	No

7. If you are employed, what type of work do you do?

   ____

8. Do you have any educational qualification?

Yes	No

9. If yes, which of the following qualifications do you hold?

Primary school	High school	Diploma	Trade	Tertiary education

10. Are any other people in your household employed?

    ____

11. If you were to buy a flat screen television, without taking a loan, will you be able to afford it?

Yes	No

Section B: Resource Usage

12. Do you have any electricity in your house?

Yes	No

13. If yes, how much is your monthly electricity bill?

Less than R100	Between R100-R200	Between R250-R350	More than R350

14. Do you have running water in your house that is connected to a sewage system?

Yes	No

15. If yes, what is your monthly water bill?

Less than R50	Between R50-R100	Between R100-R300	More than R300

16. Does your house have a geyser?

Yes	No

17. Does your house have a kitchen?

Yes	No

18. Does your house have a bath or a shower?

Bath	Shower	Other (please specify)

19. Is your toilet situated inside or outside your house?

Inside	Outside

20. Do you own a washing machine?

Yes	No

21. Do you have a swimming pool?

Yes	No

22. Do you have a home garden?

Yes	No

23. If yes, how would you describe your garden? (please tick more than one if necessary)

vegetable	fruit	Flowers

Section C: Water Quality Perception

24. Have you heard of water pollution before?

Yes	No

25. If yes, indicate below where you have heard of water pollution before:

News	Internet	Friend	College	Water awareness pamphlet	Other (please specify)

26. How would you describe the water that you and your household uses on a day to day basis on a scale from 1 to 5? (1 being poor and 5 being excellent)

1	2	3	4	5

27. Do you think the water is polluted in your area?

Yes	No

28. If yes, how would you tell that it is polluted? (please tick more than one if necessary)

Smell	Colour	Taste

29. If yes to question number 25:
    a) How would you rate the level of pollution in your area?

Very high	High	Fair	Low

    b) Do you think that the pollution in your area affects your health negatively?

Yes	No

c) What do you think mostly contributes to water pollution in the Waterberg district? (Rate from 1 to 5. 1 being most influential and 5 being least influential)

Mines	Farms	Households	Nature Reserves	Power Stations

d) Do you think your household contributes to water pollution in your area?

Yes	No

30. Are you and your household aware of ways to safe and improve water quality?

Yes	No

31. If yes, please give one example?

____

Section D: Water Management participation

32. How does your household get the water that they use?

House taps	Buckets fetched from a central water point	Water deliveries

33. Does your household reuse bath, laundry or dish water?

Yes	No

34. Which household methods do you use if and you purify water? (choose more than one if necessary)

Bleach	Boil	Other (please specify)

35. How do you get information about water related issues?

Neighbours	School	Church	Work	Municipality

APPENDIX B: Interview documentation

University of the Witwatersrand

Richard Ward

1 Jan Smuts Ave

Braamfontein

Johannesburg

2000

www.wits.ac.za

September 2016

Participation Information Sheet: Individual Interview

Dear Sir/Madam

My name is Lesley-Ann Cornelius. I am 25 years old and originally from a small town on the west coast by the name of Vredendal. I hold an undergraduate and honours degree in Environmental and Water Sciences from the University of the Western Cape. I am currently a Master's student at the University of the Witwatersrand, doing my MSc in Environmental Science.

My current project is titled: *Stakeholder Participation in Surface Water and Groundwater Quality Management; Waterberg Region, Limpopo Province, South Africa.* My supervisor for this project is Professor Mary Scholes. This study focuses on measuring the level of participation from various stakeholders, with regards to surface water and groundwater quality management, in the Waterberg area. The water quality data is from the last 20 years collected by the Department of Water Affairs (DWA) and/or USGS. The data will then be positively correlated to the level of participation from stakeholders in the area, which will be measured through questionnaires and individual interviews.

I will be traveling to the Waterberg to the 10 to 15 individuals who I have been chosen from various sectors and agreed to meet with me at a time, date and location most comfortable for them. Other meetings may be set to be done via Skype where distance or time may become an obstacle. Therefore, permission letters from companies to approve site meetings will not be required.

One interview should take 45min to an hour. All interviews are set to be audio recorded. If an interviewee does not want to be recorded, but still wants to take part they are free to indicate so on the consent form provided. Also, permission to be quoted or not, and the use of their company name can also be indicated on the same form. The interviewee is not obligated to answer all the questions and is free to withdraw themselves from the study, at any time, without any penalty. Please keep in mind that participation to this project is voluntary and that all answers to the questions are anonymous. All individual names will be kept confidential and will be concealed in any public forum.

For any further queries or questions please feel free to contact myself or my supervisor:

- Miss Lesley-Ann Cornelius

Cell phone number: 0731081041

E-mail address: 1444686@students.wits.ac.za

- Prof Mary Scholes

Office number: 011 717 1157/6407

E-mail address: Mary.Scholes@wits.ac.za

With kind regards,

Lesley-Ann Cornelius

Participant Consent Form for Individual Interview

I give consent for the following:

1. I acknowledge that I was invited to participate in the research project conducted by Miss Lesley-Ann Cornelius from the University of the Witwatersrand and I understand my role in the study.
2. I understand that this project is voluntary.
3. I am aware of time required to fill out the questionnaire.
4. I understand that the researcher will not identify me in any reports using information obtained from this interview.
5. I understand that the reason for the study is to understand my work sector's role is in the quality of water in their environment.
6. I am aware that my answers will be anonymous and kept confidential.
7. I allow myself to be audio recorded:

Yes	No

8. I give consent for the company name to be used within the findings of this study:

Yes	No

9. I give consent that I may be quoted within this study:

Yes	No

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Participant's signature Date

INTERVIEW QUESTIONS

1) What is the main aim of the company/organization? (What does it do?)
2) What is your role within the company/organization?
3) What are possible challenges that the company/organization might face going into the future?
4) Do environmental challenges, such as air pollution, water scarcity and energy shortage, feature in the future thinking of the company/organization?
5) What is the company/organization doing about pressing issues regarding water scarcity and changes in water quality?
6) Do you think your company has a role in altering water quality in the area?
7) Does the company/organization have any framework for a development plan when it comes to water challenges (especially ones that they could be responsible for)?
8) Does the company/organization have any finances in place to implement such a plan?
9) What alternative methods or measurements does the company/organization have in case of water shortage to ensure 'business as usual'?
10) Is the company/organization part of any research development programmes with regards to water awareness and education?
11) Is there a water policy documentation to fit the company/organization's water needs and how is it being implemented?

APPENDIX C: Ethics clearance certificate

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

R14/49 Cornelius

cc: Supervisor : Professor M Scholes

PROTOCOL NUMBER: H16106/08

CLEARANCE CERTIFICATE

PROJECT TITLE	Stakeholder participation in surface water and groundwater quality management; Waterberg Region, Limpopo province, South Africa
INVESTIGATOR(S)	Ms L A Cornelius
SCHOOUDEPARTMENT	APES/
DATE CONSIDERED	24 June 2016
DECISION OF THE COMMITTEE	Approved unconditionally
EXPIRY DATE	15 August 2019

DATE 16 August 2016

CHAIRPERSON J Knight

(Professor J Knight)

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10005, 10th Floor, Senate House,
University.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

LA Cornelius

Signature

17 August 2016

Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES