Stakeholder perceptions of raw water quality and its management in Fetakgomo and Maruleng municipalities of Limpopo Province

by

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DECLARATION

I, Namakando Namakando, declare that this dissertation, which I hereby submit for the degree of MSc. Environmental Economics at the University of Pretoria, is my work and has not been previously submitted by me for a degree at any tertiary institution.

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DATE: April 2020

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ABSTRACT

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This study applied the Q methodology to investigate stakeholders' perceptions about the most important ecosystem services provided by the Olifants River, and the management strategies that could potentially improve the river's raw water quality. This is because deteriorating water quality is an issue of concern amongst the different stakeholders who, directly or indirectly, derive utility from the Olifants River. The river is an important source of raw water and other ecosystem services used for environmental, domestic and commercial purposes to support wildlife, households and drive production in South Africa. As a public good, the Olifants River is of interest to both private and public stakeholders with different interests in the resource, some of which may be conflicting. Since stakeholder perceptions influence environmental outcomes, the need to account for stakeholder perceptions is an important step to integrate and coordinate efforts to improve the management of raw water. Using 27 statements and 14 stakeholders drawn from Maruleng and Fetakgomo municipalities of Limpopo Province, the results show that stakeholders held three distinct viewpoints about the most important ecosystem services produced by the Olifants River: ecosystem services that are sources of employment-creation; ecosystem services that provide direct goods/services; and a mixed/holistic perspective that placed importance on all categories of ecosystem services. Using 31 statements and 16 stakeholders drawn from Maruleng and Fetakgomo municipalities, the results showed that stakeholders held four distinct perspectives about solutions to improve water quality: polluters must be made accountable through monitoring and enforcement of regulations; more organisation and coordination is needed in water quality

management; innovation, and creativity in water resources the management through capacity building; and major changes have to be made in how things are currently done. The policy implications for the study findings are that the results can be used to: (a) inform policy about integrated water resource management; and (b) help in designing non-market valuation studies of the Olifants River that include outcomes that are most meaningful to stakeholders.

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LIST OF ABBREVIATIONS AND ACRONYMS

ARC	Agricultural Research Council
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
ESA	Ecosystem Services Approach
ESS	Ecosystem Services
FAO	Food and Agriculture Organisation of the United Nations
GAP	Good Agricultural Practices
IDP	Integrated Development Plan
IWRM	Integrated Water Resources Management
MEA	Millennium Ecosystem Assessment
NWRS	National Water Resource Strategy
SA GAP	South African Good Agricultural Practices
SANBI	South Africa National Biodiversity Institute
SANParks	South African National Parks
STATSSA	Statistics South Africa
WHO	World Health Organization
WQI	Water Quality Index
WRC	Water Research Commission
WRI	World Resources Institute
WWAP	World Water Assessment Programme

CHAPTER ONE : INTRODUCTION

1.1 Background

Throughout the world, water is arguably the most important natural resource, supporting life itself as well as the activities that make life possible (Ashton et al., 2001). As the famous adage goes, “water is life”, meaning that life as we know it would be very different without water, if not non-existent (Gleick, 1998). This is because most cultural, social, economic and environmental processes cannot take place in its absence as water resources are an important input in agriculture, industry and general livelihood improvement through the ecosystem goods and services they provide (Barrow, 2016; Vedeld et al., 2016; Zhang et al., 2017). Unfortunately, global water resources including oceans, lakes, rivers and wetlands continue to experience degradation in water quality (Strokal et al., 2019), which affects their ability to provide ecosystem services at the desired level, to the extent that if the current rate of degradation continues, 45% of the global Gross Domestic Product (GDP) and 52% of the world population will be negatively impacted by the year 2050 (WWAP, 2019).

Similar to the global trend, an integral part of South Africa’s national wealth is constituted by its water resources (McKinley, 2003). The South African government acknowledges that water is an important ingredient to achieving growth and development as reflected in the Constitution, that guarantees the right to water for all the country’s citizens (Nikki Funke et al., 2007). This is in addition to other pieces of legislation that seek to protect water resources on behalf of all citizens. For example, the National Water Act (Act 36 of 1998) is one important piece of legislation whose purpose is to achieve sustainable management of the water resources. The National Water Act of 1998 dictates that water should be protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner for the benefit of all persons (Kahinda et al., 2007). In addition to that, the National Water Resource Strategy (NWRS) was also enacted to serve as the primary framework to guide the sustainable management of water across all sectors by focusing on the role of water in supporting the growth of the economy (Maharaj & Pietersen, 2004). These efforts have been aimed at protecting the country’s water resources and improving the state of water quality in South Africa.

One of the water resources of particular importance to South Africa is the Olifants River. In addition to being a major source of raw water for commercial and domestic use, this river provides multiple social and economic benefits spanning a range of uses in agriculture, industry, mining, ecotourism, municipal use, commercial forestry, environmental use, domestic use, *inter alia* (Nieuwoudt et al., 2004). The waters of the Olifants River and its tributaries provide ecosystem services and goods in the form of irrigation water for farms, water for domestic use, waste water treatment works, mining, recreation and ecological support. These water-derived ecosystem services provide benefits that improve the quality of life for humans, plants and the environment at large. In addition to direct provision of water, the Olifants River is a source of food (e.g. fish), raw materials (e.g. wood), regulating services (e.g. prevention of floods), habitat for a wide variety of life forms and enabling other human activities such as tourism (Biggs et al., 2017). Therefore, the significance of raw water quality as far as the Olifants River is concerned cannot be overemphasised. However, in spite of its significance to the economy, the Olifants River is labelled the most polluted water management area in the country (Kyei & Hassan, 2019), a situation that puts a strain on it being a major provider of ecosystem services to many of its stakeholders who have competing, and sometimes conflicting, interests.

In addition, South Africa ranks amongst the 40 driest countries, and yet its economic development is closely linked to the level of water security in both quantity and quality (Meissner et al., 2018). South Africa is a water-stressed country, meaning that there isn't enough water to go around, to the extent that water resources like the Olifants River can be found to be fully allocated (Lévite et al., 2003; Pollard & Du Toit, 2011; Reig et al., 2013). The presence of so many users with conflicting interests is likely to make the management of the Olifants a challenge, because the efficient and equitable allocation of water resources ought necessarily to involve important trade-offs between different users who are competing for the same water resource (Farolfi et al., 2008).

Transboundary problems of water resource management are also a major issue, because the Olifants river catchment runs through several countries, namely South Africa, Mozambique, Zimbabwe, and Botswana. As the Olifants River is among the most stressed rivers in terms of both water quality and quantity (Morokong et al., 2016), tensions over water use are likely to increase as water pollution soars and demand for quality water increases. Just like the Olifants River, a large number of waterbodies on the African continent are shared between countries, which may differ in terms of their social, economic, and political environment, as well as in the level of need for water resources. The differing needs also means differing priority areas for the countries involved, with concomitant conflict and problems in management. To avoid transboundary conflict, a country's water management strategies has to be in sync with those of its neighbours (Fox & Sneddon, 2007).

In order to contribute to these sustainable management efforts, this research was set as an attempt to determine the perceptions of the different stakeholders associated with the Olifants river to elicit their views about the state of ecosystem service provision, which is of relevance to environmental economics, as it renders validity to stated preference non-market valuation methods by making it possible to identify ecosystem goods and services to be valued (Armatas et al., 2014). Secondly, the results from this study make it possible to design choice experiments to ascertain the trade-offs stakeholders are willing to make as far as Olifants River ecosystem services and goods are concerned (Farolfi et al., 2008). Furthermore, the outcomes recorded here will enable an environmental analyst to make non-market valuation assessments of the Olifants River that include outcomes that are most meaningful to stakeholders (Alpizar et al., 2001). Additionally, the study will investigate problems of raw water quality and how it is managed, in order to contribute to the body of knowledge important for policy direction that will result in better management of water and improvement of water quality.

This research will show the importance of knowing stakeholders' perspectives and how this knowledge will be able to contribute to better management of water quality, restoration of ecosystem services, and how the results of this study are an important prerequisite in non-market valuation of ecosystem goods and services provided by the Olifants River.

1.2 Problem statement

The Olifants River is of strategic importance to South Africa, but its importance is highly dependent on the quality of its waters (Pollard and Du Toit, 2011). This notwithstanding, the Olifants River is one of the most polluted rivers in southern Africa, its pollution having been attributed to originate from many different anthropogenic factors (Dabrowski & de Klerk, 2013; Kyei & Hassan, 2019), which include domestic waste, untreated sewerage discharge, acid mine drainage, extensive irrigated agriculture, among others.

The decrease in water quality in the Olifants River has the potential to negatively impact different sectors of the economy. Hence, there is need for sustainable management of this natural resource in order to ensure the raw water is clean and fit for use. However, the many different types of users and stakeholders involved in the use of the river presents a complex problem in dealing with water pollution because the different stakeholders may have conflicting interests, different marginal values of the ecosystem services, and different choice sets in making trade-offs about which attributes of water quality or ecosystem services they regard as more important (Farolfi et al., 2008). Consequently, the concept of Integrated Water Resources Management (IWRM) offers the most effective approach to the management of a water resource, because it seeks to understand how different users gain utility from the use of the water (Hooper, 2011). The concept of Integrated Water Resources Management (IWRM) was birthed from the premise that management of the water sector has tended to be fragmented, uncoordinated, and stakeholders are siloed.

There is therefore a need to understand the different users' perspectives about water quality management, since this will help in designing solutions and policies that address the needs of the different types of water users. The results of this study can also help to design non-market valuation studies that include outcomes that are more meaningful to stakeholders.

The water resources in the country are under pressure due to increased demand for water in industrial, agricultural and domestic uses (N. Funke et al., 2007b). Consequently, water pollution levels have continued to rise despite extensive legislation formulated to ensure sustainable use of the water. Hence, there is need for an integrated approach to ensure sustainable management. The lack of known perceptions from different stakeholders has prevented policymakers from incorporating those viewpoints into the different conservation interventions that have previously failed, or that have not yielded the desired impact because they did not take into account that stakeholders experience water opportunities and challenges differently (Meissner et al., 2018). Also, a lack of known perceptions about valued ecosystem goods and services has made researchers unable to identify attributes of the Olifants River for non-market valuation which requires a clear understanding of a stakeholder's perceptions (Armatas et al., 2014). Non-market valuation methods would make it possible to estimate the impacts of changes in the Olifants River to the welfare of the stakeholders, which has hitherto not been undertaken. Thus, knowing these perceptions could be an important missing link in raw water quality management and improvement of raw water quality in the Olifants River.

Noting the above, this research proposed to understand the perspectives of the different stakeholders regarding the use and management of the raw water quality in the Olifants River by getting views from stakeholders in Maruleng and Fetakgomo municipalities in Limpopo Province, South Africa. It is against this background that this study aimed to determine stakeholders' perceptions in order to suggest the possible strategies for the sustainable co-management of the Olifants River by all users involved, and provide attributes for stated preference non-market valuation.

1.3 Study objectives

1.3.1 Main objective

The main objective of the study was to investigate stakeholders' perceptions about: (a) the relative importance of ecosystem services derived from the Olifants River; (b) the levels of ecosystems services provision and their relations to current raw water quality status; and (c) the solutions to restore the quality of raw water and the provision of ecosystem services by the Olifants River.

1.3.2 Specific objectives

The objectives of the study are:

1. to identify stakeholders affecting and/or affected by water quality in the Olifants River basin;
2. to understand what ecosystem services derived from the Olifants river are regarded as the most important by stakeholders;
3. to investigate the perceptions about the status of the ecosystem services provided by the Olifants River; and
4. to investigate stakeholders' views regarding the best solutions/policies to restore ecosystem services and solve the problems of water quality in the Olifants River.

1.4 Research questions

This research will seek to answer the following questions:

(i.) Who are the stakeholders that are affecting or are affected by the quality of water of the Olifants River?

(ii.) What ecosystem services do stakeholders derive from the Olifants River?

(iii.) What ecosystem services do stakeholders rank as most important?

(iv.) What is the state of ecosystem service provision by the Olifants River?

(v.) What do stakeholders regard as the solutions to improve water quality in the Olifants?

(vi.) What views are common and what views are divergent among the stakeholders as far as improving water quality in the Olifants River is concerned?

CHAPTER TWO : CONTEXTUAL BACKGROUND

This chapter contextualises existing discourse on raw water quality and its management in the Olifants River. First, the key terms will be defined and put into the context of this research. Then, the state of the water quality in the Olifants River will be discussed. The types of pollutants causing decreased raw water quality will be identified. Also, the roles played by stakeholders will be highlighted, as well as the impact of stakeholders' activities on the quality of raw water in the Olifants River. Further to this, research that has been published regarding the impacts of pollution on the activities of stakeholders will be explored. An analysis of the economic importance of the Olifants River will be given. Finally, the economic, social, environmental and biological impacts of decreased water quality will be explained.

2.1 Definition of key terms:

Raw water: Raw water refers to water that has not been treated. It is water taken straight from the environment such as groundwater, rivers, lakes, or aquifers (Cho & Yun, 2011; Weyer et al., 2006). Raw water is usually unsafe for human consumption and has to be treated or purified to make it fit for drinking. The raw water in South African rivers remains the major source of municipal water, water for irrigation, and water for industrial use (Dzwairo et al., 2012).

Water quality: There exists a level of complexity in defining water quality. According to Dzwairo et al. (2012), evaluating water quality involves the use of a water quality index (WQI), of which many indices have been developed. The quality of water is assessed based on its physical, biological and chemical characteristics (Chapman et al., 1996; Tian et al., 2019). In the context of this research, the South African government defined water quality as water being fit for use for a specific purpose. Therefore, there are different water quality guidelines depending on whether the water is being used for domestic, recreation, industrial, irrigation, livestock or aquatics (DAFF, 1996). Deciding on whether water is fit for use for the particular purpose is determined qualitatively and quantitatively by its physical appearance, odour and the substances dissolved or suspended in the water and how the use of that water impacts on human health or the integrity of the ecosystem. It follows that water can be considered to be of good quality for one purpose and not so good for another. This approach is in concordance with the definition by Codd (2000) that water quality refers to the ability of water to be usable for various activities. Codd (2000) went further to classify the different types in which water quality can be compromised by increased concentration of the following compounds in the water: suspended solids (particulate matter), organic matter, eutrophication, nitrates from fertilisers, pesticides, herbicides, industrial waste, dissolved acids, dissolved heavy metals, salinity, and pathogens such as bacteria, protozoa, and viruses.

Perceptions: Existing literature defines perceptions as a socially constructed reality, in the sense that people mentally construct views about a particular topic based on their experiences (Meissner et al., 2018). Some studies have highlighted the significance of perceptions in water quality. For example, Prouty and Zhang (2016), in their study on people's perceptions of the quality of drinking water in Uganda, found that the perceptions of people affected the choices of how the user treats the water. Similarly, Chapman et al. (1996) concluded that it is only when the public perceives water resources to be polluted that they take the necessary remedial measures to control the pollution. Thus, the important role played by stakeholders' perceptions of water quality need not be downplayed.

Stakeholder: A stakeholder refers to anyone who has an interest in a particular transaction, or who is affected by the actions of other parties in the transaction (Garvare & Johansson, 2010), therefore harbouring a natural right to participate in the decision making regarding the activities in that transaction. In the sustainable management of water resources, modern studies have found that the role of stakeholders cannot be overemphasised (Franzén et al., 2015), because water management is complex, demanding a participatory approach.

2.2 Contextual review

This section described the issue of raw water quality in the Olifants River, detailing why it is a research topic of interest. Over several decades, there has been increased global concern about the state of water resources (Karr & Dudley, 1981; Wang et al., 2009), which has in turn led to the birth of several pieces of legislation to curb further deterioration of water resources in different countries across the world. Due to severe water pollution and other confounding factors, more than two-thirds of the global population (about four billion people) are threatened by water scarcity at some point annually (Mekonnen & Hoekstra, 2016). For this reason, the demand for water quality is a global phenomenon. Consequently, several researchers across the world have done research in water quality issues in different countries, using different research methods and considering different sets of variables (Suthers et al., 2019).

Owing to its economic importance, the Olifants River is a resource of interest among several researchers. Thus, there is research that has been conducted pertaining to different aspects of the water resources in the Olifants River. This section will unpack what other researchers have found with regards to issues of raw water quality and the Olifants River in general. The review of literature in this section will be organised under the following themes:

(i.) The state of water quality in the Olifants River
(ii.) Types of pollutants in the Olifants River
(iii.) The economic importance of the Olifants River
(iv.) Impacts of water pollution in the Olifants River
(v.) Institutional efforts to improve water quality in the Olifants River

2.2.1 The state of water quality in the Olifants River

The role of the water from the Olifants River in domestic use, mining, power generation, sewage treatment, fishing, recreation, among several other uses, has led to the Olifants River being recognised as one of the most important water resources in South Africa (Dabrowski & de Klerk, 2013). Most of these studies have highlighted the high levels of pollution in the waters of the Olifants river. Villiers and Mkwelo (2009) have described the Olifants River as one of the most threatened river systems in South Africa, due to the declining population of fish, crocodiles and other aquatic life which has been attributed to the increasing levels of pollution in the river basin in general. Other studies have also shown evidence that there is decreasing population of aquatic life in the Olifants River due to habitat alteration and decline in the quality of water in the river (Ashton, 2010). A case in point was the death of several fish and Nile crocodiles that were found close to the point where the Olifants River flows into Mozambique in the Kruger National Park in the years 2008, 2009, and 2010 (Lane et al., 2013; Osthoff et al., 2010). Samples collected from the carcasses by several researchers attributed the death of the Nile crocodiles to Pansteatitis (Ashton, 2010; Genthe et al., 2018; Lane et al., 2013; Osthoff et al., 2010) which was traced back to pollution in the River. According to Osthoff et al. (2010), “It was suspected that the source of oxidised fat that causes Pansteatitis in the crocodiles is dead fish (that crocodiles consumed), which may have succumbed to pollutants in the water."

Apart from ecological concerns, other studies also documented evidence to call for human health concerns. Studies that took water samples from the Olifants River found the presence of various human health-threatening substances, such heavy metals, acids, radioactive compounds, sulphates, faecal matter, domestic waste, phosphorous and nitrogen, whose exposure to humans living in communities around the river poses risks of skin diseases, nerve damage, diarrhoeal diseases, and cancer (Genthe et al., 2018).

2.2.2 Types of pollutants in the Olifants River

Apart from noting that the Olifants River was polluted and the state of water quality was threatened, some researchers went further to determine the actual pollutants in the river. Dabrowski and de Klerk (2013) conducted a routine sampling of raw water along the Olifants River to test the concentration of nutrients and heavy metals which they related to land use activities such as mining, industry, wastewater treatment and agriculture. They found that nutrient concentrations were relatively high, a condition likely to support a dense plant population, which can lead to the death of aquatic animals by depriving them of oxygen. The high level of nutrients was emanating from sewage discharge from wastewater treatment works and run-off fertilisers from irrigation farms. Nutrient-enriched water bodies are susceptible to the mass growth of toxic aquatic vegetation which is a health risk to humans and aquatic life alike, which reduced water resources available for drinking, irrigation and leisure activities (Codd, 2000). Other pollutants found by Dabrowski and de Klerk (2013) included sulphates, as well as dissolved salts and metals, especially near mining sites. The concentration found was usually higher than the threshold concentrations set out in the South African water quality guidelines (Department of Water Affairs and Forestry (DWAF), 1996).

The findings above are in accord with the findings by Genthe et al. (2018), who found the presence of metals and metalloids in samples of water collected from the Olifants River. The concentration of these pollutants was reported to exceed the World Health Organization (WHO) guidelines for safe levels of intake by humans. The metals and metalloids found in the water samples were selenium, nickel, molybdenum, arsenic, antimony, cadmium, mercury, chromium, among others. The source of these contaminants was attributed to industrial waste and mining effluent. Similarly, a study by De Klerk (2016), which looked at water quality variables in the Olifants River, found a high concentration of sulphates and acids, along with several other dissolved metals, as found by previous studies, confirming the presence of these types of pollutants. As noted by other researchers, these pollutants were closely attributed to be emanating from different land use activities, where different sectors of water users were contributing particular types of pollutants into the river system according to their different land use activities.

Human influence in water quality cannot be ignored. Through various activities, such as mining, irrigation, domestic use, dam construction, etcetera, the natural flow of water is diverted, or pollutants are introduced into the stream, thus, reducing the quality of water in the river. Most pollution has been attributed to human activity. For example, mining waste discharged into the river, run-off of pesticides, and fertilizers. These actions lead to a reduction in species diversity, increased turbidity, eutrophication, and added particulate matter.

Other studies found the main contaminants to be sewage waste, acid mine water, industrial refuse, herbicides, insecticides, and several diarrhoeal pathogens (Dabrowski & de Klerk, 2013; Genthe et al., 2018; Kotze et al., 1999)

2.2.3 The economic importance of the Olifants river

Due to the universal close-knit association between water quality and economic development (Antman, 2016; Barrow, 2016; Rockström & Falkenmark, 2015), several studies have been instituted to determine the economic value of water resources in several parts of the world. In the South African context, a number of research projects sponsored by the Water Research Commission (WRC) aimed at determining the value of water in different sectors of the economy have been carried out (Beatrice Conradie, 2002; BI Conradie & Hoag, 2004; Plan et al., 1998). In their paper *The value of water in the South African economy: Some implications*, Nieuwoudt et al. (2004) reviewed these studies and their findings. It is of importance to note that they were able to determine monetary values of the marginal benefit of water resources to supporting income-generating activities, job creation, municipal water supply, commercial forestry, agriculture, and other environmental uses of water. These findings have high implications when determining the impacts of water pollution on the economy, the way in which scarce water resources ought to be allocated amongst different competing sectors of the economy, or justifying the amount of resources invested in water quality improvement programmes.

Other valuation methods to determine the economic value of a natural resource such as the Olifants River have also been used (Costanza et al., 1997; De Groot et al., 2002; Millennium Ecosystem Assessment, 2005), and there is a range of literature on the valuation of ecological systems. Notable among these is a study by Costanza et al. (1997), who used both market and non-market valuation methods to estimate the economic value of ecosystem services. In a similar fashion, the total economic value of the Olifants River basin can be estimated on the basis of total goods and services that the raw water in the river basin provides to different stakeholders. These goods and services would be categorised into use and non-use values. Some use values include water for drinking, irrigation, energy production in thermal power plants, aquaculture, flood management, recreation, and touristic activities (Padedda et al., 2017). Non-use values are somewhat abstract or intangible, and would include benefits such as environmental aesthetics, or the moral decision for natural ecosystems be conserved and protected (Hein et al., 2006). They are benefits, nonetheless, for which stakeholders derive some level of utility and therefore place a value on the resource. However, this research was also interested in determining how stakeholders value changes in ecosystem services attributes.

To place the economic importance of the Olifants River into perspective, the table below (Table 2.1) shows the different sectors where water is used in South Africa, where water resources in South Africa can be seen to be an integral part of supporting agriculture and industry, accounting for more than 70% of water use requirements.

Table 2.1: Water use in South Africa (Source: FAO, 2013)

Water use activity	Percentage
Agricultural use	60
Environmental use	2.5
Urban and domestic use	27
Industrial use	10.5

The table above is in agreement with studies claiming that water resources are among the most important ecological assets, as they provide more ecosystem goods and services per unit area than any other ecosystem (Langan et al., 2019). The importance of water resources transcends economic benefit, to include social and cultural goods and services (Barbier et al., 1997; Mitsch et al., 2015;

Mitsch & Gosselink, 2000). By extension, the importance of the Olifants River to the social, economic, and cultural aspects of the stakeholders' livelihoods cannot be overemphasised. Thus, the marginal cost to South African society of water pollution in the Olifants River is extremely high (W. J. De Lange et al., 2012). In a study by De Lange et al. (2012), it was found that decreased water quality led to the reduction in Value of Marginal Product (VMP) in crops, increasing the burden of disease in humans, and resulting in other indirect costs associated with water pollution. This impact is substantial considering that irrigation agriculture contributes about 30% to total agricultural output, which in turn supports approximately 250,000 smallholder farmers, 30,000 commercial farmers, 120,000 permanent employees and numerous seasonal workers employed in irrigation agriculture (FAO, 2013). Furthermore, other studies have shown that many South African rural communities depended on fish harvested from the local water bodies for food (Jooste et al., 2015).

2.2.4 Impacts of water pollution in the Olifants river

The impact of poor water quality on humans and animals has been the subject of many studies. Genthe et al. (2018) tested water samples from sites along the Olifants River, where several households collected their water for domestic use, including water for drinking, and watering their vegetable gardens. The study examined human exposure to metals and metalloids via drinking contaminated water and consumption of vegetables watered by river water. It was found that the collected water and vegetable samples contained disease-causing compounds. The health risks ranged from diarrhoeal diseases, skin lesions, nerve damage, to cancer-causing metals. The study also found that vegetables watered by river water had accumulated said metals.

Considering that there was a correlation between water resources and economic development (Miao et al., 2009), decreased water quality therefore constrained further economic development. In addition to being water stressed, water pollution further confounded the water security of the country (Cumming et al., 2017). For example, South Africa was put in the position of having to import water from neighbouring countries in order to meet the local demand for quality water for electricity generation (Blignaut & Van Heerden, 2009). This placed inordinate strain on the national treasury in the form of foreign exchange resources that would have been used in other sectors of the economy but were being channelled towards importation of water. Among other factors, this could contribute to the rise in the price of electricity, which further affected the manufacturing sector by raising the cost of production (Gulati et al., 2013).

Research showed that the agricultural sector remained the largest user of raw water in South Africa (Reinders et al., 2013). Similarly, the greatest proportion of the Olifants River water was used for agricultural irrigation purposes (Gyamfi et al., 2016a). Researchers have reported that approximately 60% of the raw water from the Olifants River was used on irrigation, thus this represents a substantial amount of potential negative impacts of water pollution in the Olifants River on irrigated agriculture (De Klerk, 2016; Reinders et al., 2013). Gulati et al. (2013) also brought out a connection between poor water quality and decreased economic productivity by farmers. They argued that decreased water quality affected agricultural productivity by reducing crop yields, destroying crops, or leading to poor yields. As a consequence, farmers found it hard to meet standards for certification to penetrate lucrative export markets such as the European Union market.

The massive deaths of wildlife along the Olifants River due to bioaccumulation of metals were also another indication of the severity of water pollution problems, and their potential impact on humans, wildlife, and the greater ecosystem as a whole, because water pollution limited aquatic resources' ability to survive and reproduce (South African National Biodiversity Institute (SANBI), 2014).

Another problem associated with water pollution in the Olifants River was that mines, industries, water boards and other water users had to invest in more expensive processes to pump, filter, or treat the water so that it is usable (McCarthy, 2011).

2.2.5 Institutional efforts to improve water quality

Given the high social cost of water pollution, the efforts and benefits of investing in processes to restore ecosystem services by combating water pollution are highly warranted. In South Africa, several approaches have been implemented to manage water resources and improve water quality as the constitution states that water resources must be protected and used sustainably (M. De Lange et al., 2005).

Several researchers have made mention of institutional efforts by government to ensure that the Olifants River was managed in a way that was beneficial economically, socially, environmentally, and physically (Department of Water and Sanitation (DWS), 2016). The Integrated Water Resource Management (IWRM) approach, for example, despite its difficulties to be implemented effectively, has been shown to be a more effective approach to deal with some of the many inefficiencies in water governance (Biswas, 2004; N. Funke et al., 2007a; Turton et al., 2007). Even though IWRM emphasises the need for water management solutions to be borne collectively by all types of stakeholders (scientists and non-scientists alike), there are still some trade-offs to be made. Some researchers have acknowledged the lack of scientific knowledge among regular stakeholders in dealing with issues of water management, but they have shown that scientists alone have failed to provide all the answers in water quality decisions (Burroughs, 1999). Hence, active stakeholder involvement is increasingly being implemented in water management projects around the world in order to strike the IWRM balance (Edelenbos et al., 2011).

Consequently, several institutions have been mandated to ensure that the goal of water protection and sustainable utilisation was achieved. As more research has put forth evidence to show that coordinated efforts in water management is the best approach, so has the governance structure of water resources management begun to embrace the inclusion of various stakeholders in water management (M. De Lange et al., 2005). The following table highlights the various scientific, institutional and social processes aimed at the improvement of the ecosystem infrastructure of the water resources in South Africa.

Table 2.2: Water resources management institutions in South Africa (Source: FAO, 2013)

Name of institution	Type	Sectors	Activities
Directorate of Water and Irrigation Development (Formerly Directorate Irrigation Engineering: Department of Agriculture (DA)	Government institution	Irrigation	
Department of Water and Sanitation (Formerly Department of Water Affairs and Forestry)	Government institution	Irrigation, Municipalities, Natural resources, wastewater	Infrastructure development, Operation and maintenance Licensing and allocation, Policy and strategy
Water Research Commission (WRC)	University/Research institution	Irrigation, Municipalities, Natural resources	Research
Agricultural Research Council: Institute for Soil, Climate and Water (ARC-ISCW)	University/Research institution	Agriculture, Environment, Irrigation	Research, Training and extension
ARC: Institute for Agricultural Engineering (ARC-IAE)	University/Research institution	Agriculture, Environment, Irrigation	Research, Training and extension
Directorate of Water and Irrigation Development (DWID)	Government institution	Agriculture, Irrigation	Infrastructure development, Operation and maintenance, Policy and strategy
South African Irrigation Institute (SABI)	Non-governmental organisation	Irrigation	Policy and strategy, Research
South African National Committee of the International Commission on Irrigation and Drainage (SANCID)	Non-governmental organisation	Irrigation	Operation and maintenance
Orange/Senqu River Basin Commission	River basin organisation	Transboundary water	Infrastructure development, Licensing and allocation, Operation and maintenance, Policy and strategy
Limpopo Watercourse Commission (LIMCOM)	River basin organisation	Transboundary water	Infrastructure development, Licensing and allocation, Operation and maintenance, Policy and strategy
Komati River Basin Water Authority	River basin organisation	Transboundary water	Infrastructure development, Licensing and allocation, Operation and maintenance, Policy and strategy

CHAPTER THREE : LITERATURE REVIEW

3.1 Introduction

This chapter focused on reviewing existing literature from the works of previous researchers and authors regarding the topic of perceptions, raw water quality, and ecosystem service provision. The chapter also reviewed the methods that had been used to elicit perceptions about raw water quality, water quality in general, or perceptions about other topics. The theoretical approach employed by previous researchers was also unpacked and the debate ensuing from these approaches was discussed extensively. This chapter also highlighted a review of the methodology employed in this research, and why it was a suitable fit to answer the research questions brought forward by this research. Consequently, a gap in research was identified and this chapter illustrated how this study intended to close on that gap through the methods and theoretical approach proposed in this study.

This literature review was organised according to the following subtopics:

a. Perceptions: Alternative definitions
b. The study of perceptions: why it is important
    - Perceptions in environmental research
    - Perceptions in water quality studies
    - Perceptions about raw water quality
c. Studying perceptions: The methodologies
d. Literature review of Q methodology
e. Ecosystem goods and services provision
f. Knowledge gap to be filled by this study

3.2. Study of perceptions: Alternative definitions

Perceptions in this study referred to viewpoints about a particular topic of interest (Meissner et al., 2018). They are composed of personal beliefs, perspectives and meanings. As such, they are usually diverse and are subjective in nature because they are based on an individual's personal, social, cultural and economic experiences (Pereira et al., 2016). Some studies have provided alternative ways to define perceptions. For example, Yarar and Orth (2018) defined perceptions as structured beliefs of laypeople or "lay theories" for the reason that these theories tend to be different from scientific theories, which are factual and based on scientific evidence. Lay theories are subjective, influenced by societal norms and individual experiences, and sometimes may be ambiguous due to their subjective nature (Yarar & Orth, 2018). Other researchers have referred to these sets of perceptions as 'worldview', 'discourse' or 'attitudes' (Barry & Proops, 1999; Ruth M Cross, 2005). These descriptions of perceptions highlight the subjective nature of perceptions.

Similar to other studies, Pereira et al. (2016) contextualised the idea of perceptions as "goals and values". In that study, Pereira et al. (2016) sought to determine how the diversity of farmers' goals and values influenced intra-individual differences in behaviour. The findings were that goals and values were key in influencing the decisions of the individual farmers. The perceptions sought to be determined in the perception studies were an overall combination of views, which were based on different factors and experiences (Yarar & Orth, 2018). Therefore, perceptions are a collection of ideas or points of view.

There was enough evidence to show that the collection of individual viewpoints were key determinants of interaction and behaviour (Pereira et al., 2016; Yarar & Orth, 2018). Through research, it was possible to know the collection of perceptions or values, viewpoints, lay theories, goals, and values of individuals, which may aid policymakers to design the most successful interventions (Yarar & Orth, 2018).

3.3. The study of perceptions: why it is important

The concept of 'perceptions' was the starting point for this study. Generally, there has been a lot of research done around the issue of perceptions (Fairweather & Swaffield, 2000; Hutson et al., 2010; Prouty & Zhang, 2016; Woldetsadik et al., 2018; Živojinović & Wolfslehner, 2015). Different studies have used different methods to elicit perceptions. The most common method for studying perceptions has been via survey, by using standard questionnaires or Likert scales (Carr et al., 2011; Hu et al., 2011; Whelton et al., 2015). Perceptions were elicited by asking respondents to state their opinion about a particular topic or to state how/why they agreed with a particular topic of interest. The results are then determined by quantitative or qualitative methods of analysis.

The interest by researchers to elicit perceptions came about because numerous studies have proved that perceptions held by individuals were very important in determining how individuals constructed their own reality about a particular topic. In business, for example, it was found that consumer demand for goods and services was dependent on the consumers' perceptions of the products' attributes (Lin & Milon, 1993) and significantly affected an individual's quality perceptions about the product (Menkhaus et al., 1993). In agricultural adoption studies too, it was found that farmer adoption of climate smart agriculture was significantly influenced by their perceptions, and those technologies perceived as 'good' have had positive effects on adoption rates and productivity (Buadi et al., 2013; Kalinda et al., 2014). Therefore, the study of perceptions about a particular topic should be of interest to the analysts and policy makers.

3.3.1 Perceptions in environmental research

Particularly in environmental research, individual perceptions are a key component of any conservation efforts because studies have shown that perceptions determined outcomes (Keeler et al., 2012). Researchers have highlighted the importance of perceptions in environmental conservation and sustainable management of natural resources (Zabala et al., 2018). In these studies, it was found that social values and views held by individuals, to a very large extent, determined the success or failure of conservation interventions. Zabala et al. (2018), for example, found that natural resource management efforts depended on whether stakeholders' perceptions were taken into consideration, and whether proposed interventions were perceived as acceptable by the stakeholders. It was found that conservation interventions in the management of natural resources tended to yield positive results when stakeholders' perceptions were taken into consideration. In this way, stakeholders felt that the intervention was acceptable, thus they deemed the interventions useful. This is similar to what Hooper (2011) and Focht (2002) reported about how policy interventions in environmental research tended to yield unlikely outcomes given the value conflicts presented by the many number of stakeholders involved in the use of the natural resources. This, therefore, presented a case for the importance of taking into account the conflicts, controversies and uncertainties presented by multiple users through the subjectivities held in their perceptions.

3.3.2 Perceptions in water quality studies

In water quality studies, water users' perceptions have been shown to be a great determinant of how users interacted with the water. Interaction with water included drinking, storage, purification, disposal and other uses for the water. For example, after a chemical contamination of the Elk River in West Virginia, a survey was conducted among residents and it was found that the majority of the households refused to resume normal water use activities of the river due to water quality concerns even after the contamination was flushed (Whelton et al., 2015). This showed that the perceived quality of the water in the river was more important than the actual quality of the water in the river. This was also similar to the findings by Hu et al. (2011), who likewise found that the likelihood of people using bottled water as an alternative to tap or ground water was higher if they had a negative perception about tap water or ground water quality. These findings by Hu et al. (2011) disregarded whether the water was actually not of good quality, that is, participants were making judgements based on perception alone. In a similar manner, these findings were in concordance with those of de França Doria (2009), who reported that the most important aspect of how users interact with the water was based on their perceptions about the quality of that water, thus dissatisfaction with the quality of tap water encouraged water users to seek alternative sources of water. It is of importance to note that there are studies that have focused on investigating the factors that influence perceptions of water quality (Canter et al., 1992; de França Doria, 2009; Po et al., 2003), which was beyond the scope of this study; although it was also important to note that such studies have focused on the quality of tap and bottled water rather than raw water as was the focus of this study.

3.3.3 Perceptions about raw water quality

Although many researchers have focused their water quality perception studies on the quality of drinking water, some researchers, such as Carr et al. (2011), also did some studies on raw water quality specifically. For example, they conducted a study on perceptions of raw water quality among irrigation farmers, where they found that farmers' perceptions of raw water quality were related to their capacity to control raw water quality and manage the different challenges that came up, because of using poor raw water quality for irrigation. The challenges that were associated with raw water included salinity, causing damage to the irrigation pipes, and causing growth challenges for the crops. Those farmers who had the capacity to mitigate these challenges had a more positive perception of the raw water quality. Other studies also focused on perspectives of water quality in the river with regards to recreational activities, where it was found that users were willing to pay more for recreational activities if they perceived the raw water to be of good quality (Moser, 1984; Um et al., 2002). Most of these studies also concluded that the perceptions about raw water quality were not necessarily connected to the actual quality of the raw water (Carr et al., 2011; Moser, 1984; Um et al., 2002).

3.4 Studying perceptions: The methodologies

There are different methods that researchers have used to study subjectivities and perceptions of individuals or groups of people. Some methods were quantitative, others were qualitative, while other methods were a hybrid of both approaches. Most studies used a questionnaire-based survey to collect the data, but the methods of analysing the data differed. As an example, Den Hartog and De Hoogh (2009) studied the perceptions of ethical leader behaviour by letting subordinates rate their leaders' behaviour. In that study, data was gathered using a questionnaire-based survey, and the analysis was done by determining whether the particular leader's behaviour was rated as fair or otherwise. Similarly, Ogg et al. (2017) used a survey to determine parents' perception of their child's risk of life-threatening food induced anaphylaxis. The perceptions were determined using a score.

However, Fortunato et al. (2018) critiqued the use of survey methods to determine perception by highlighting some of the weaknesses of such a method. Fortunato et al. (2018) suggested that taking averages in a survey had a tendency to aggregate different kinds of respondents in a uniform manner. For example, the perceptions of respondents who were more knowledgeable about a particular topic were assumed to be uniform with the perception of those respondents who were less knowledgeable about the topic. Another drawback was that for the results to be comparable between space or time, it would have to be assumed that the samples were similar (Fortunato et al., 2018; Wu & Leung, 2017).

Some of the methods that have been used in a number of water quality studies have involved household surveys, using questionnaires that asked respondents to gauge the quality of water via a Likert scale or a binary response (Carr et al., 2011; Hu et al., 2011; Whelton et al., 2015). The Likert scale is a rating method originating from the work of Likert (Likert, 2016), whereby respondents were required to rate a particular item on a numbered scale whose numbers corresponded to qualitative attributes such as "not important – very important" or "strongly disagree – strongly agree". The shortcomings of this method are that it does not allow respondents to make trade-offs between items, since each item is rated independently of other items. Thus, it was possible for individuals to say they strongly agreed with every item on the list of items to be ranked (Billiet & McClendon, 2000). Secondly, the rankings were highly subjective for inter-individual comparisons to be carried out meaningfully. It has also been reported by some researchers that the Likert scale may suffer biases (Steenkamp & Ter Hofstede, 2002).

Other methods such as the best-worst scaling technique have also been used to study perceptions. In this technique, respondents were presented with a number of items and asked to state which one they considered the best and worst (Kiritchenko & Mohammad, 2017). For example, Sever and Verbič (2019) used the best-worst technique to assess the recreational value of a nature park by users. However, this technique presents several challenges, such as the difficulty in maintaining consistency between and within the respondents (Kiritchenko & Mohammad, 2017).

While there was no completely effective way to measure perceptions accurately (R. M. Cross, 2004), several options were available and some options were more effective than others depending on the research objectives. Carr et al. (2011) used a semi-structured interview schedule to get the perceptions of raw water quality among irrigation farmers in Jordan. However, this method made it hard for them to standardise the data collection procedure and do the analysis (Foddy & Foddy, 1994) because the farmers' responses were open-ended. The advantage with this procedure was that it enabled the researchers to collect responses that were not restricted by the categories that are imposed on the interviewees by use of a structured questionnaire. This data collection procedure took advantage of the benefits of a purely qualitative study (Baltagi, 2008). Hu et al. (2011) took on a different approach by making use of a panel dataset to collect consumers' perceptions of water quality in the United States. Their approach was a purely quantitative study, which may have lacked the depth of a qualitative study (Foddy & Foddy, 1994).

The Likert scale is one of the most popular methods to measure attitudes, because it does not just require a simple yes/no answer, but allowes for the degree of opinion to be measured (Allen & Seaman, 2007). Even though it makes it possible to transform qualitative subjects into quantitative analysis by making the assumption that attitudes can be measured, it was flawed by assuming that the intensity of perceptions was linear (Allen & Seaman, 2007). The semantic differential scale is also another method that has been used as an alternative to the Likert scale. Typically, the semantic differential scale is a rank-order bipolar rating scale using adjectival opposites such as "agree" to "disagree". This is a fairly simple method, but has been critiqued for its failure to account for differences across respondents (Al-Hindawe, 1996).

3.5 Literature review of Q methodology

In order to account for the shortcomings of the other methods of investigating perceptions, the Q methodology was proposed for this study. When it comes to understanding stakeholders' perspectives, several researchers have recommended Q methodology as an effective option (Havlíková, 2016) for reasons such as its ability to combine the attributes of qualitative and quantitative approaches (Peritore, 1989) making it superior to standard survey techniques. Also, Q methodology is not interested in population statistics but perceptions, without concentrating on the proportion of people holding a particular perspective but aiming to report how those perspectives are held as a whole (Smith et al., 1995). Therefore, Q methodology was considered appropriate to bring out the perspectives held by stakeholders in the Olifants River.

Q methodology is a semi-qualitative research technique used to study subjective viewpoints of different people on a given topic (Carmenta et al., 2017). It was a method developed by William Stephenson in 1935 as a means to study participants' subjective opinions regarding a particular issue (Stephenson, 1953). In this method, correlations and patterns across individuals are uncovered through an inverted factor analysis of their viewpoints, which are expressed through a rank-order of given statements about a selected topic (Yarar & Orth, 2018). The statements to be arranged are a representative of possible opinions about the issue at hand, which were obtained from conducting open-ended interviews with participants or gathered from other valid sources. Participants then arrange the statements in a pre-designed quasi-normal distribution. This arrangement was designed to bring out how participants rank a statement relative to other statements (Carmenta et al., 2017). The goal is to determine participants' social perspectives regarding the particular topic at hand. The detailed procedure and underlying theory were explained in detail in the chapter on methods and procedures.

Q methodology has been used to reveal social perspectives in several fields of study such as nutrition (Yarar & Orth, 2018), governance (Durning, 1999; Klijn et al., 2016; Lobinger & Brantner, 2016), medicine (Chiu et al., 2019; Huang et al., 2016) and psychology (Balloo et al., 2018; Masaryk et al., 2019), among others. Despite having its origins in psychology and medicine, Q methodology has gone on to be a useful tool in conducting studies in unrelated fields such as tourism, animal rights, and animal intelligence, in addition to environment and ecology (Webler et al., 2009).

Thus, Q methodology has become a popular tool by means of which to reveal social perspectives as a pre-requisite to conducting valuation studies or any conservation interventions (Forrester et al., 2015). One of the most popular ways that Q methodology has been used in environmental studies was to reveal the perceptions held over the management of a particular natural resource, as the case with managing natural resources was that there are always many users and stakeholders who may hold different views about how the resource ought to be managed or the best approach to solve an environmental problem such as deforestation (Addams & Proops, 2000; Carmenta et al., 2017). Kafetzis et al. (2010) concluded that any efforts to improve water management must be able to capture different views among stakeholders. Thus, Q methodology presented an effective approach to capture the views about ecosystem services and management of raw water quality in the Olifants River. Kafetzis et al. (2010) further presented evidence that involvement of stakeholders in management efforts resulted in better dissemination, use of information, and greater motivation for public involvement. This is what the use of Q-methodology for this research hopes to achieve.

However, Newman and Ramlo (2010) noted that one of the major weaknesses of Q methodology was that the criteria used for grouping people ought to make logical and theoretical sense, and be in tandem with the objectives of the study. It means that the researcher has to ensure that the characteristics of respondents recruited can best answer the research question at hand in order to achieve the purpose of the study.

3.6 Ecosystem goods and services provision

Ecosystem services have been defined as the direct and indirect benefits derived from a natural resource for the sustenance and fulfilment of human life (Postel et al., 2012). It is important to identify and quantify ecosystem services, because failure to do so resulted in placing an implicit value of zero on the particular ecosystem service (Loomis et al., 2000), which is highly flawed, because a resource such as the Olifants River was responsible for the provision of a multitude of ecosystem services, which are highly valued by the different stakeholders (Biggs et al., 2017).

The Ecosystem Services Approach (ESA) is a tool that has been used in many studies to take into account the full range of benefits that humans derived from their interaction with natural resources (Anzaldua et al., 2018). The following table briefly illustrates the four different types of ecosystem services that would ideally be provided by a freshwater ecosystem (Millennium Ecosystem Assessment, 2005).

Table 3.1: ESS provided by a river (Source: Millennium Ecosystem Assessment (2005))

Provisioning services	Regulatory services	Cultural services	Supporting services
Water for consumptive and non-consumptive use, aquatic organisms for food and non-food uses	Maintenance of water quality, buffering, and flood control	Recreation, tourism and existence values	Ecosystem resilience

However, it is important to note the importance of water quality in ecosystem service provision. According to the findings by Keeler et al. (2012), they established how changes in water quality affected the valuation of ecosystem service provision of the resource because changes in water quality affected the state of ecosystem goods and service provision. The flow chart below illustrates how human activities can lead to changes in value of ecosystem services:

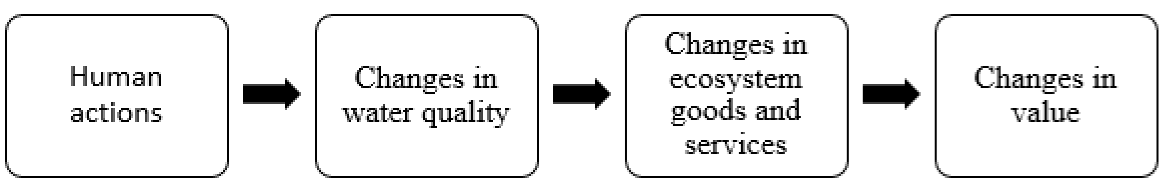

Figure 3.1: Linking water quality to valuation of ecosystem goods and services (Source: Keeler et al., 2012)

In a similar manner, the use of the Olifants River for domestic and commercial purposes has led to changes in the quality of the raw water, which has in turn changed the structure of ecosystem goods and services provision. Consequently, it is expected that there are changes in utility values of the goods and services derived from the Olifants River. Biggs et al. (2017) cited several cases when the Olifants River was threatened by pollution or low flow, and it was a major concern for the river management authorities. Therefore, it is imperative to put in measures aimed at reducing human actions that lead to deterioration of water quality. Ecosystem service rehabilitation and restoration of water resources has been shown to raise the economic value of the resource (Loomis et al., 2000).

3.7 Knowledge gap to be filled by this study

Due to the significance of the Olifants basin to the socioeconomic wellbeing of South Africa, and most importantly to the wellbeing of those living near it, a great deal of interdisciplinary research has already been conducted. Researchers have conducted research into water quality, biodiversity, agriculture, land-use activities, and environmental valuation (Ashton, 2010; Biggs et al., 2017; Dabrowski & de Klerk, 2013; Farolfi et al., 2008; Genthe et al., 2018; Gyamfi et al., 2016b; Kyei & Hassan, 2019).

However, it is of importance to note that the bulk of the research conducted on the Olifants River has focused on pollution vis-a-vis types of contaminants, point sources, sites of pollution, and effects of pollution on the ecology of the river (Dabrowski & de Klerk, 2013; Genthe et al., 2018), as opposed to documenting the social processes involved in the management of the water resource. This means that many of these studies have ignored the socioeconomic dimension of the management of water quality (Ashton, 2010; Farolfi et al., 2008). Consequently, there was little research that had focused on understanding the contributions of the stakeholders on the management of water quality in the Olifants basin.

This study aimed to fill that lacuna by seeking to understand the social perspectives of the different stakeholders, the role they played in the management of the catchment area and their perceptions on the management of the raw water in the Olifants. The research also sought to understand which of the ecosystem services were considered important by the stakeholders. Understanding the views of the stakeholders is likely to present a dimension hitherto ignored, especially that some authors have attributed the pollution in the Olifants River as an issue that could be solved by strengthening institutions and coordination among stakeholders (Muller, 2008). Yet, research showed a strong evidence that the success of environmental management interventions was highly dependent on whether stakeholders perceived the interventions as acceptable or not (Kafetzis et al., 2010).

Furthermore, even though several researchers globally have used Q methodology in studies about perceptions in the management of natural resources (Fairweather & Swaffield, 2000; Hutson et al., 2010; Vaas et al., 2019; Venables et al., 2009), there was a dearth of literature available on the use of Q methodology in studies about raw water quality. A gap found in this research was that Q methodology has not been used before to elicit stakeholders' perceptions about raw water quality, nor were there any published papers that aimed to study the stakeholders' perceptions of raw water quality and its management in the Olifants River catchment.

There was also a gap found in the identification of important ecosystem goods and services provided by the Olifants River so as to enable analysts to determine the actual changes in value that have been a result of the decreased raw water quality of the River. This research sought to answer the core question: "what are the ecosystem goods and services that should be used in non-market valuation methods to determine marginal changes in value of the Olifants River as a result of decreased raw water quality?"

Based on the arguments presented above in support of Q methodology as an effective tool to study perceptions, this study proposed to use this methodology to elicit stakeholders' perceptions about water quality in the Olifants.

The findings in this study thus have profound implications. As Zabala et al. (2018) put it, "understanding perspectives is at the heart of a wide range of conservation questions and problems". Therefore, understanding perceptions of the stakeholders in the Olifants River provided a very useful tool to understand problems and suggest solutions from the perspective of the stakeholders. The results also presented the attributes needed to conduct choice experiments and other non-market valuation techniques to determine changes in value.

CHAPTER FOUR : METHODS AND PROCEDURES

This chapter explains in detail the methods and procedures used to achieve the objectives of this study. It highlights how stakeholder analysis was conducted, the process of site selection, and the detailed steps of how the Q-methodology was employed in the study.

4.1 Study site selection

The criteria for selection of the study locations was that they needed to be close to the Olifants River (point source) and close to the national borders (because the study sought to capture transboundary issues arising from the use a shared natural resource), and at increasing distance from major sources of pollution (mainly in the upper-catchment area). Thus, the study sites were purposively selected as the two municipalities of Maruleng and Fetakgomo (Figure 4-1).

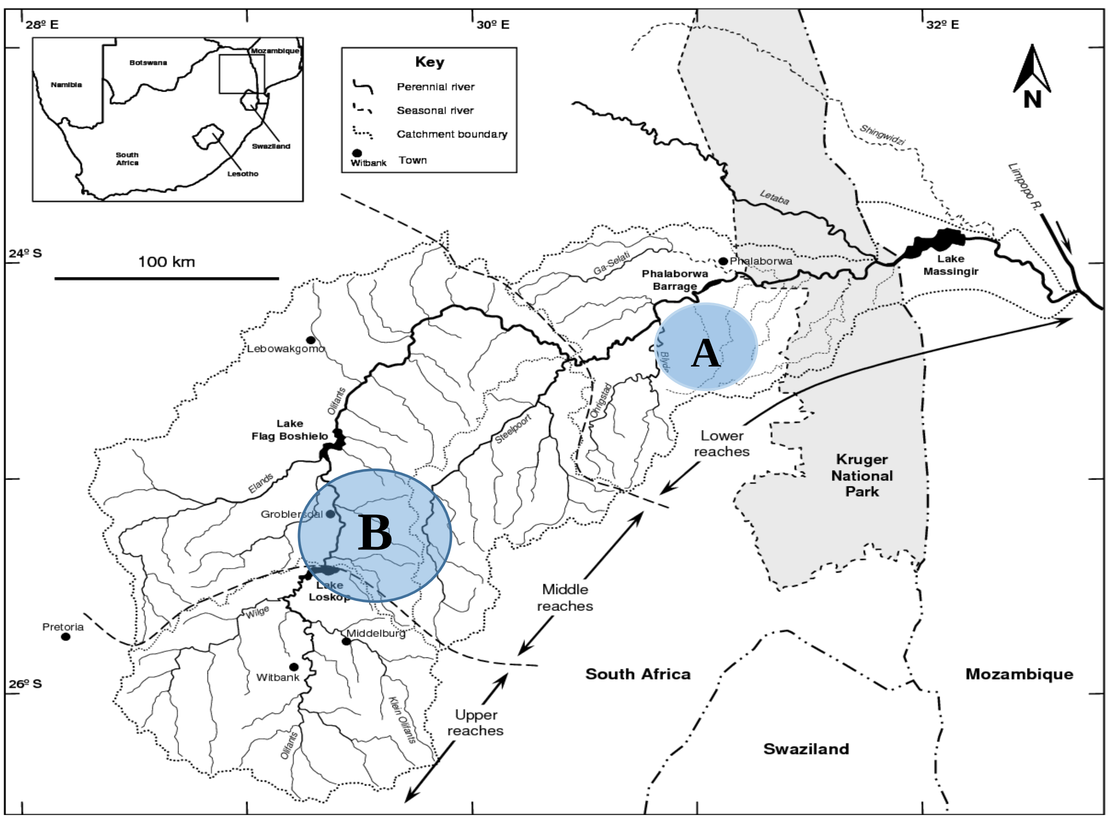

Figure 4.1: Map showing approximate location of study areas: A=Maruleng, B=Fetakgomo. Adapted from Ashton (2010)

The Olifants River catchment is located in the Limpopo River basin which constitutes an international drainage basin shared by Botswana, Mozambique, South Africa, and Zimbabwe, covering an area of approximately 54,000 km^2 (Gyamfi et al., 2016b; McCartney et al., 2004). The main river in the catchment is the Olifants River. The Olifants River has its source in the town of Breyten in Mpumalanga Province, and it then flows through Emalahleni and Middelburg, cutting through the Strydpoort and Drakensberg mountains. It finally flows through the Kruger National Park, before flowing into Mozambique. The full length of the Olifants River from the source to its mouth in the Indian Ocean is approximately 954.9 km (DAFF, 2008). Along its path, the waters of the Olifants River have to meet competing demands from mining activity, irrigation for commercial farms, residential development, industrial use, and maintaining ecological balance. It is estimated that a total of 389,918 people live in the Olifants river catchment (Morokong et al., 2016)

4.1.1 Maruleng Municipality

Maruleng Municipality is the smallest municipality in Mopani District, with a population of approximately 94,857 people, of which 97% are located in rural areas (STATSSA, 2019). In terms of access to water, STATSSA reports that 33% of the population get their water from a local water scheme, 18.1% from boreholes, 28.3% from a river or stream, while 11.3% get their water from a pool, dam, or stagnant water source. The dominant economic activity in Maruleng is commercial agriculture (Mbabvu, 2017; Shokane & Masoga, 2018) The map below shows the position of Maruleng local municipality in Mopani District.

Figure 4.2: Map of Mopani District (Source: www.municipalities.co.za, accessed 17-09-2019)

4.1.2 Fetakgomo Municipality

Fetakgomo Municipality was established in the year 2000. It is located in Greater Sekhukhune district of Limpopo Province. Fetakgomo is a rural municipality with an approximated population of 335, 676 (StatsSA, 2019). Access to municipality services is low as 133,106 households do not have access to water from the municipality (Sebei, 2014). Only 9.5% of the population have access to piped water inside the homes. According to data from STATSSA (2019), a good proportion of the population get their water from boreholes (16.5%) and rivers or streams (16.9%). The municipality is located close to the Olifants River, therefore many households collect their water from the river and its tributaries cc(Radingoana et al., 2019). The following map shows the location of Fetakgomo Municipality in Sekhukhune District.

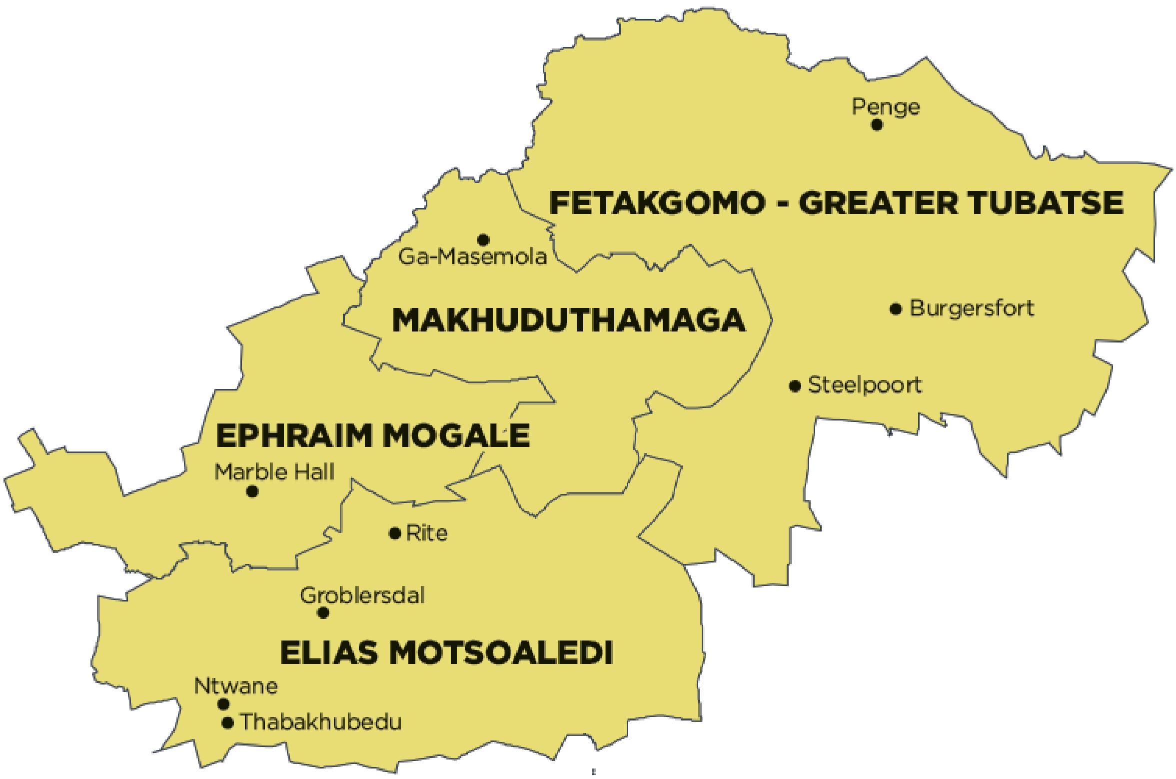

Figure 4.3: Map of Sekhukhune District (Source: www.municipalities.co.za, accessed 17-09-2019)

4.2 Q Methodology procedure

This study used a Q methodological approach to elicit stakeholders' perceptions about important ecosystem services and the management of raw water quality in the Olifants River. In addition to using the Q methodology to analyse subjective viewpoints, this study also collected demographic data from respondents by way of a survey questionnaire. It is important to note that Q methodology is not so much interested in linking perspectives with other demographic variables, but looks to understand the participant's own internal frame of reference (Cairns, 2012). Therefore, demographic data was collected mainly as a way to understand the demographic composition of the participants.

The data collection process of the Q methodology followed the following typical five-step procedure (Yarar & Orth, 2018) as illustrated in the chart below.

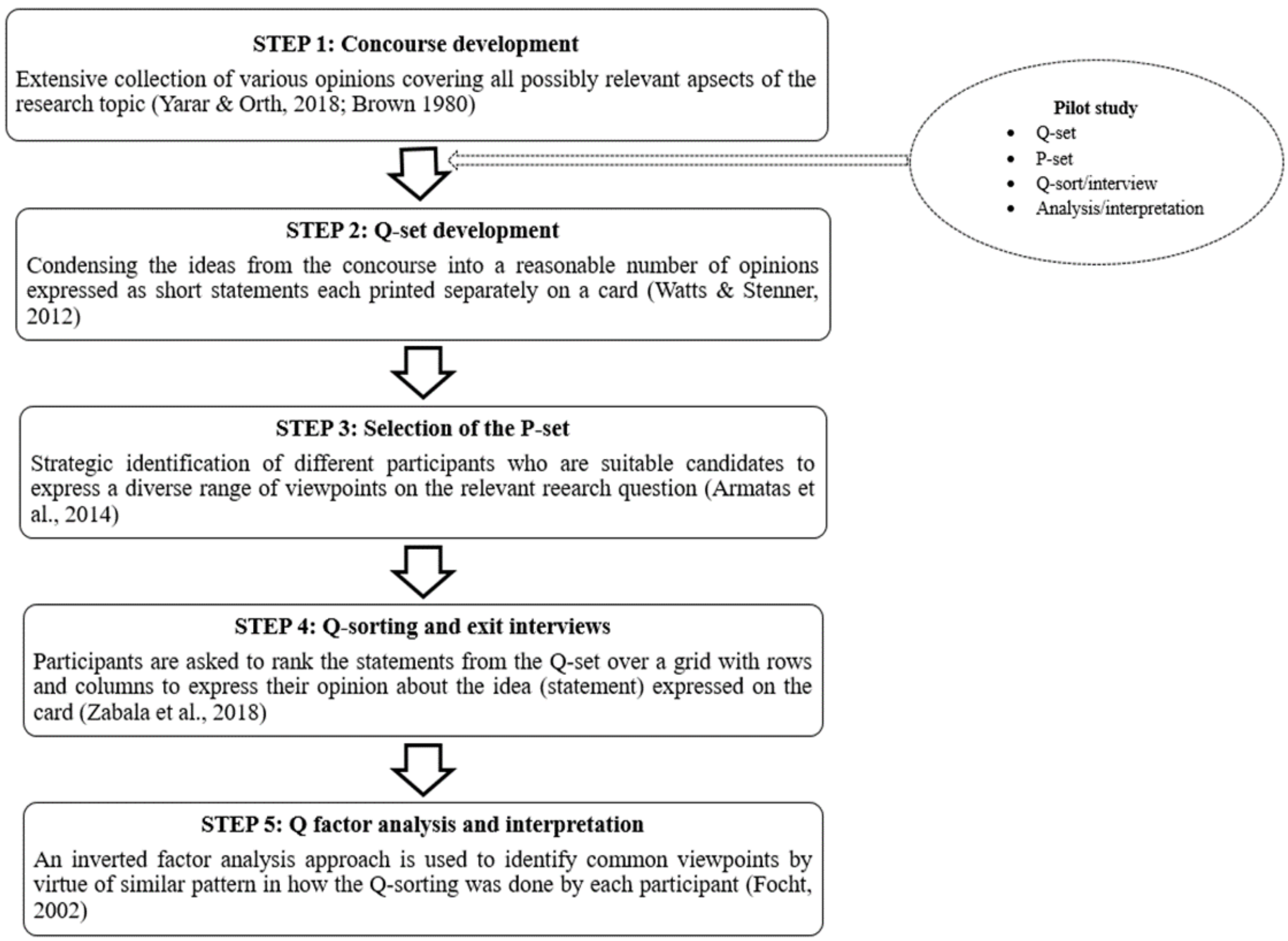

Figure 4.4: Q methodology procedure

This study followed the principles outlined in the typical Q study procedure outlined above, with slight modifications and adaptations to suit the objectives of this study by employing a pilot study after the concourse development. The pilot study also used the Q methodology (see Appendix I on details about pilot study). The details of how each stage shown in the above chart was conducted are given in the following paragraphs.

4.2.1 STEP 1: Concourse selection

The first stage of a Q study is the construction of the "concourse", which involves collecting all the possible opinions from stakeholders about the research topic at hand (Fairweather & Swaffield, 2000).

4.2.1.1 Stakeholder identification

Stakeholders were identified based on information gathered from published literature, grey literature, news sources, and interviews conducted by the researcher. The study also employed the snowball technique as suggested by Vogt and Johnson (2011), whereby each respondent interviewed gave suggestions, implicitly or explicitly, about other possible respondents who were in possession of the information that this study sought to extract. Key informant interviews were highly relied upon at this stage. The objective was to identify the water users and all those being affected by the actions or inactions of the water users and other concerned parties.

The different categories of stakeholders selected for these interviews belong to the following categories:

- Regulators (DWS, DAFF, DEA)
- Commercial water users (Farmers, Mines, Water User Associations)
- Domestic water users (Residents, Subsistence farmers)
- Suppliers (Municipalities)
- Water boards (Their role is to provide bulk municipal water and wastewater to other water institutions such as municipalities)
- Conservationists (Advocacy NGOs, SANParks)
- Private sector (Interested parties, Researchers)

4.2.1.2 Interviews

During this phase, seventeen different stakeholders were interviewed face-to-face, over the phone and via email, with open-ended questions about the issue of raw water quality in the rivers of the Olifants catchment and its management. Open-ended questions about water management were asked to respondents who were purposively selected based on the stakeholder identification process explained above. The interviews were conducted until the researcher felt that a saturation point had been attained, whereby addition of new interviewees did not bring about new information or add any diversity to the already collected set of ideas. The interviews were recorded by writing down the responses to the open-ended questions.

4.2.2 STEP 2: Q-set selection

A Q-set consists of the statements regarded as most relevant to be included for use in the study (Fairweather & Swaffield, 2000; Pagnussatt et al., 2018).

Based on the statements selected during the previous stage, two separate Q-sets were established; the first contained 27 statements (Table 4.1) about the ecosystem services provided by the rivers of the Olifants catchment, while the second contained 31 statements about solutions and policies to restore the ecosystem services in the Olifants River (Table 4.2). For the first Q-set, respondents were asked to sort the statements according to the importance of the ecosystem services provided by the rivers of the catchment. For the second Q-set, respondents were asked to rank the statements according to their levels of agreement.

Although the participants (P-set) in this study were literate (the least educated had completed secondary education), some of the Q-statements about ecosystem services were somewhat technical, and the researcher felt that it was important to explain the ecosystem services in simple language. Thus, the table (Table 4.1) shows the statements as they appeared on the cards and the accompanying explanations given to the participants during the Q-sorting process.

Table 4.1: List of statements in the Q-set of important ecosystem services

No.	Q statement as it appeared on cards	Accompanying Explanation given to respondent
1	Maintenance of water quality by diluting pollutants	Dangerous pollutants dissolve in the river to make them less harmful
2	Preventing floods	The river helps to redirect excess water from land
3	Control of soil erosion	Preventing surface run-off of soil and supporting vegetation whose roots hold the land/soil together
4	Conservation of ecosystem	By supporting the life of insects, plants and animals
5	Natural storage for water	A reservoir to store water
6	Habitat for fish and wildlife	The river as a home/conducive environment for fish and other animals
7	Water for irrigation	Water used to irrigate plants in farms and gardens
8	Water directly from the river for domestic use (washing, bathing, etc.)	Water for day-to-day use by households
9	Water for power generation	The water used by Eskom (National power supplier) in hydropower stations to produce electricity
10	Water transport (Boats and canoes)	Water used as a means of transport
11	Catching fish to eat or sell	Fish from the river which is sold by the roadside or eaten by households
12	Plants, herbs and natural products	The river supports the growth of plants which have different uses
13	Water for municipality use to supply tap water	The municipality uses the water from the river to provide tap water for residents
14	Water for industrial use (mining and manufacturing)	Water used for commercial purposes
15	Boat cruise, water viewing and water games	The river being used for enjoyment activities
16	Tourism of wildlife	The river supports animals and people can enjoy viewing those animals in the national parks
17	Traditional and religious rituals	Activities such as baptisms and initiation ceremonies
18	Fishing for fun	Fishing just to enjoy and pass time
19	Research and education purposes	Scientists and pupils can learn different things about the river
20	A nice view to look at (aesthetic values)	Just enjoying how beautiful the river looks

21	National pride of owning a clean river	Feeling proud and happy that the country has a clean river
22	Recycling nutrients	Useful nutrients are dissolved and trapped in the water and when the water is used again, those nutrients are reused
23	Preventing damage to the environment (ecosystem resilience)	The river helps the environment to survive even when there is pollution or other disturbances to the environment
24	A special environment for rare species of plants and animals (refugia)	Supporting those plants and animals which can only survive in moist areas like near the river
25	Making the landscape more beautiful	The river can make the surroundings more beautiful
26	Support plant growth processes (pollination and photosynthesis)	Plants need water to grow, to produce flowers and to make fruits
27	Water cycle	Water from the river evaporates into clouds and comes back as rain

The statements in Table 4.1 above were categorized into four categories of ecosystem services as shown below (respondents were not made aware of the categorization of the ecosystem services).

Statement	**Category of ecosystem service**
Statements 1 – 6 :	Regulating ecosystem services
Statements 7 – 14 :	Provisioning ecosystem services
Statements 15 – 21 :	Cultural ecosystem services
Statements 22 – 27 :	Supporting ecosystem services

Table 4.2: List of statements in the Q-set of solutions to restore ecosystem services

No.	Statement
1.	Increased sensitisation to raise awareness about negative impacts of water pollution
2.	Give incentives/rewards to water users who pollute less
3.	Invest in tools to detect water pollution
4.	Increase monitoring and enforcement of existing laws
5.	An independent regulator (not a government institution) will do a better job to control water pollution
6.	Department of water and sanitation should come up with ways of punishing water polluters
7.	First we must deal with the invisible pollution before we deal with the pollution we can see because the invisible pollution is the one that is mostly dangerous
8.	Further training of staff from Department of Water and sanitation in issues of water quality
9.	If all water users are affiliated and represented through a water user association, it will make them to use water more responsibly and reduce on pollution
10.	If the majority of households have piped water, then they will stop polluting the river
11.	More government funding to the municipalities will improve water quality
12.	Naming and shaming polluters encourages people to stop pollution
13.	Improving the quality of water will be expensive
14.	Pollution will stop if only the people upstream stopped polluting
15.	The mines should compensate the farmers because the waste from the mines kills their animals and plants
16.	The Olifants river catchment is too big to be controlled by one body
17.	The priority should be to prevent the effects of pollution on the environment
18.	The quality of water in the Olifants cannot be improved. It’s too late.
19.	There is need for all stakeholders to work together to improve water quality
20.	There is need to prevent new people from using the river. The bigger the number of people using the river, the higher the pollution.
21.	Those who pollute should pay all those who are affected by the pollution
22.	Those who pollute too much should stop using the river for a while
23.	Department of Water Affairs should ensure that everyone is using the correct amount of water for the right purpose (Validation and verification)
24.	We need more laws in order to prevent further water pollution
25.	Municipalities should allocate more money to water quality improvement
26.	All commercial farmers should be certified by SA GAP or Global GAP as a way to reduce water pollution from irrigation farms
27.	Improved garbage collection will prevent domestic waste (such as diapers) from polluting the river
28.	Regular stakeholder meetings are important in improving water quality
29.	Local people should decide how best to manage the river
30.	Capacity building of the municipality through training of staff to improve water quality management

31. Educating farm workers about water quality to prevent water pollution

4.2.3 STEP 3: Selection of P-set

A P-set consists of the participant group selected to take part in the study (Watts & Stenner, 2012). According to Watts and Stenner (2012), at least one participant is needed for every two sentences in the Q-set. Thus, given that the two Q-sets in this study had 27 and 31 statements, a minimum of 14 and 16 respondents were needed for each Q-set respectively. Note that this study was making use of the same respondents for both Q-sets. Therefore, a total of sixteen participants were purposively selected to participate in the Q-sorting exercise overall, but two participants declined to participate in one of the Q-sets (the Q-set about ecosystem services), saying they were not knowledgeable enough as they did not directly enjoy the ecosystem services provided by the Olifants River, hence only fourteen participants participated in the Q-sorting exercise to elicit perceptions about the most important ecosystem services, while all sixteen participants participated to elicit perceptions regarding the solutions to restore ecosystem services and improve water quality in the Olifants River. The sorting exercise was conducted over a period of 14 days. The participants were selected in such a way that they were representative of the broad range of stakeholders identified during the first phase, namely regulators, water users, water suppliers, water boards, conservationists, and private sector. The same P-set was used for both Q-sets, except for two respondents who were of the opinion that they did not directly enjoy the ecosystem services provided by the Olifants River, hence could not give an opinion about which ecosystem services they regarded as important. Thus, these two respondents did not complete both sets of the Q-sorts, but only did one each. The participants (P-set) were categorised as follows:

Table 4.3: Stakeholders in the P-set

Category of Stakeholder	No of participants (Important ecosystem services)	No of Participants (Solutions to restore ecosystem services and improve water quality
Commercial user	1	2
Domestic user	2	2
Water supplier	2	3
Water board	2	2
Conservationist	2	2
Private sector	2	2
Regulator	3	3
TOTAL	**14**	**16**

4.2.4 STEP 4: Q-sorts and exit interviews

The participants were interviewed in their own premises (home or office). They were asked to complete two separate Q-sorts (see **Appendix B** and **Appendix C**). The rule of thumb as suggested by Watts and Stenner (2012) of selecting two participants for every statement in the Q-set was followed. According to Watts and Stenner (2012), "a minimum ratio of two Q-set items to every participant or, in other words, a Q set that contains twice as many items as you have participants. That means, given a 60-item Q set, that your study might actually be judged harshly if you have more than 30 participants."

Participants were also asked to explain further why they agreed or disagreed with some statements or why they thought some ecosystem services were more important than others. Demographic data was also collected from the participants by way of questionnaire (see **Appendix J**).

Lastly, participants were asked about the state of ecosystem service provision by the Olifants River. They were asked to explain in detail why they thought ecosystem service provision was at that state.

4.2.5 STEP 5: Data analysis and factor interpretation

The two sets of Q-sorts were recorded separately in PQMethod Software, a dedicated software designed to analyse data in Q methodological studies (Watts & Stenner, 2012). A by-person factor analysis was done using centroid factor analysis to identify highly correlated Q-sorts. This means that they arranged their Q sorts in a highly similar manner, sharing similar perspectives. The data was inspected in different ways, where a different number of factors were extracted to determine the best solution. The specific analyses for the two separate Q-sets were done as follows:

(i.) Analysis of Q-set on most important ecosystem services

A centroid factor analysis was done. Seven factors were extracted as the maximum permissible number of factors in PQMethod. When prompted to adjust factor loadings that had a communality of more than 1, the response was yes. Thus, the Q-sorts that had a communality of greater than 1 were automatically adjusted. The communality for a Q-sort is calculated by summing its squared factor loading and it represents the percentage of variance in that Q-sort that has been accounted for by the study factors (see **Appendix D** for formulas and calculations).

A varimax rotation was done for only three factors because the data had been inspected and it showed that a maximum of three factors could be extracted, thus a three-factor solution was seen as the best solution after interacting with the data. Then, the extracted factors were flagged using program-generated factor flags. Flagging means that PQMethod highlighted Q-sorts that loaded significantly on a factor, meaning that they are Q-sorts that highly associate with that factor. Flagging is an important step, because the final definition of each factor is based on a weighted average of the Q-sorts flagged as loading significantly on that factor (Webler et al., 2009). In this analysis, there were no Q-sorts that were confounded. Q-sorts that load significantly on more than one factor (confounded) are not supposed to be used in the factor estimates, because they define more than one factor, and thus are not identifying a unique viewpoint (Watts & Stenner, 2012). According to Watts and Stenner (2012), the extracted factors should have factors with at least two Q-sorts loading significantly in that particular factor. These criteria were used to determine which factors PQMethod should include in the output.

(ii.) Analysis of Q-set on solutions to restore ecosystem services and improve water quality

A centroid factor analysis was done and seven factors were extracted. Factor loadings with a communality of greater than one were adjusted. Then all seven factors were varimax rotated as the goal was to automatically extract the maximum viewpoints in the study (Watts & Stenner, 2012) because the initial inspection of the data indicated that at least four factors could be extracted.

Program-generated flagging was done and factors with more than two significantly loading Q-sorts (at least two Q-sorts flagged per factor) were extracted. A four-factor solution was arrived at, meaning there were four different viewpoints held by stakeholders. Schmolck and Atkinson (2002) suggested that program-generated flagging may not always give the results expected, thus it is essential that the analyst need not accept the output as given but to further interact with the data by making adjustments in order to achieve a suitable result.

CHAPTER FIVE : RESULTS AND DISCUSSION

The chapter will begin by describing the demographic characteristics of the participants (P-set). Then, results from the study on stakeholders' perceptions of important ecosystem services derived from the Olifants river will be presented. Lastly, the results on the perceptions of stakeholders about possible solutions to restore ecosystem services in the Olifants River will be discussed.

5.1 Demographic characteristics of P-set

The mean age of the participants was 39.81 years old, with the youngest respondent being 27 years old while the oldest respondent was 63 years old. Out of the total 16 participants that took part in this survey, five (31.25%) were females, while 11 (68.75%) were males.

It was important that the participants in this study were literate because the survey involved reading statements written on cards and then placing them in a ranking order. The lowest level of education attained by the participants in this study was a secondary school qualification. The majority of the participants (43.80%) had acquired at least a postgraduate qualification. The proportion of participants with a diploma qualification was 31.30%, while 12.50% of the participants had obtained a bachelor's degree qualification. Lastly, the percentage of participants who had completed secondary school or attained a certificate as highest level of education was each 6.30%.

The participants were asked about the main source of the water that they used. the majority of participants (56.25%) used the water supplied by the local municipality (potable water). Only a small number of participants (6.25%) used the water directly from the Olifants River. The remaining proportion of participants (37.50%) said that their main source of water was boreholes. This finding was interesting for this study, because water from boreholes is regarded as raw water because it is untreated, emanating straight from the environment. The demographic characteristics of the participants are summarised in the table below:

Table 5.1: Demographic characteristics of participants (Source: Own survey, 2019)

Stakeholder type	Age	Sex	Highest level of education attained	Main source of water
Conservationist	27	Female	Postgraduate	Municipal water
Commercial user	51	Male	Undergraduate	River
Water board	63	Male	Diploma	Municipal water
Domestic user	28	Male	Postgraduate	Borehole
Regulator	35	Female	Diploma	Borehole
Commercial user	56	Male	Postgraduate	Borehole
Water supplier	28	Male	Postgraduate	Borehole
Water supplier	40	Male	Diploma	Municipal water
Regulator	54	Female	Diploma	Municipal water
Water board	50	Male	Diploma	Municipal water
Water supplier	27	Male	Certificate	Borehole
Private sector	35	Female	Postgraduate	Municipal water
Regulator	34	Male	Undergraduate	Municipal water
Private sector	38	Male	Postgraduate	Borehole
Conservationist	28	Female	Postgraduate	Municipal water
Domestic user	43	Male	Secondary school	Municipal water

5.2 Results of analysis of Q-set on important ecosystem services

A total of 14 Q sorts, each containing 27 statements were analysed. The Q-methodology literature suggests three alternative methods to solve the question of how many factors to extract from a data set (Watts and Stenner (2012).

The Kaiser-Guttman criterion suggests extracting factors with eigenvalues of greater than one. Brown (1980) suggested retaining factors with two or more “significantly loading” Q sorts. Finally, Humphrey’s rule proposes to extract significant factors, where a factor is significant if the cross-product of its two highest loadings exceed twice the standard error of the factor (Watts & Stenner, 2012). These criteria are used to extract factors that account for a large percentage in the study variance (at least 35 – 40%), and factors with two or more significantly loading Q sorts on each factor (Guttman, 1954; Kaiser, 1960; Watts & Stenner, 2012).

According to calculations by Brown (1980), the following formula was used to identify Q sorts that loaded significantly on each factor at the 95% level of significance:

Significant factor loading ($p<0.05$) = 1.96*Standard error……*equation (5.1)*

Where standard error = $1/\sqrt{Number\ of\ items\ in\ Q\ set}$…………….. *equation (5.2.)*

According to this study, where the number of items in the Q set was 27, the standard error was calculated as follows:

Standard error = $1/\sqrt{27}$ = 0.1925……………………..*equation (5.3.)*

Therefore, significant factor loading was calculated accordingly:

1.96*0.19245 = 0.3772………………………*equation (5.4)*

According to the above calculations, all rotated factor loadings that were greater than 0.3772 in absolute terms and met the flagging algorithm criteria in PQMethod and were considered significant. The three extracted factors explained a total of 49% of the variance in the data.

The Q sorts that loaded significantly on each factor were considered as defining Q sorts because it means they have a high correlation with the meaning of that factor (Yarar & Orth, 2018). For example, factor 1 had five Q sorts that loaded significantly (Q sorts 2, 5, 12, 13 and 14), factor 2 had four Q sorts that loaded significantly (Q sorts 3, 6, 7 and 8), while factor 3 had two Q sorts that loaded significantly (Q sorts 4 and 10). This means that the significantly loaded Q sorts were highly representative of that factor. Hence, they are referred to as defining Q sorts. The table below (Table 5.2) summarises the factor-defining Q-sorts for the three extracted factors.

Table 5.2: Factor-defining Q-sorts for three factors

Factor number	Q-sort numbers	Total	Cumulative total
1	2, 5, 12, 13, 14	5	5
2	3, 6, 7, 8	4	9
3	4, 10	2	11
Confounded	None	0	11
Non-significant	1, 9, 11	3	14

The following table (Table 5.3) shows the extracted three-factor solution with the defining factors highlighted in bold text. Eigen values were calculated, according to Brown (1980) as EV = (Q-sort 1 loading on factor 1)^2 + (Q-sort 2 loading on factor 1)^2 + (Q-sort 3 loading on factor 1)^2 +……+(Q-sort N loading on factor)^2.

Table 5.3: Rotated factor loadings of the three factor solution, bold text shows significantly loading Q sorts (note that even though Q-sort 11 is 0.4782 on Factor 3, it was not flagged because $a^2 < h^2/2$)

Q-Sort	Stakeholder type	Factor loadings		
		Factor 1	Factor 2	Factor 3
1	Commercial user	0.3540	0.2368	-0.0024
2	**Domestic user**	**0.7357**	0.0530	0.1457
3	**Water board**	0.3640	**0.6021**	0.3445
4	**Private sector**	-0.1235	0.2019	**0.8473**
5	**Supplier**	**0.6496**	0.2083	-0.0976
6	**Conservationist**	0.3541	**0.7339**	-0.2059
7	**Domestic user**	0.1212	**0.5995**	-0.1296
8	**Supplier**	0.0783	**0.5930**	0.1735
9	Supplier	0.2841	0.3406	0.0971
10	**Regulator**	0.2376	-0.0561	**0.7888**
11	Private sector	0.3619	-0.3463	0.4782
12	**Regulator**	**0.7447**	0.1038	0.1275
13	**Regulator**	**0.4263**	0.1948	0.2465

14	**Conservationist**	**0.6381**	0.2873	0.0912
Eigenvalue		2.80	2.10	1.96
% Explained Variance		20	15	14
Cumulative % Explained variance		20	35	49

In order to obtain a clear understanding of the three distinct perspectives extracted above, the following table of factor arrays showed how a typical Q sort in a particular factor would be arranged. Factor arrays were calculated using all defining Q sorts weight-averaged in order to generate one prototypical Q sort per factor, such that it represents the way in which a typical member of that group would have arranged their Q sorts (Brown, 1980; Watts & Stenner, 2012; Yarar & Orth, 2018) (see **Appendix D** for calculations of factor weights used to determine factor arrays). The factor arrays for the three factors extracted in this study are shown in the table below (Table 5.4).

Table 5.4: Factor arrays showing a prototypical sorting of the 27 statements by each factor

No.	**Statement**	**Factor arrays**		
		1	**2**	**3**
1	Maintenance of water quality by diluting pollutants	0	+3	+2
2	Preventing floods	+1	-2	+2
3	Control of soil erosion	-3	-4	+4
4	Conservation of ecosystem	+4	0	-2
5	Natural storage for water	+3	0	+3
6	Habitat for fish and wildlife	+1	+2	-1
7	Water for irrigation	+5	+2	+1
8	Water directly from the river for domestic use	+3	+5	0
9	Water for power generation	-2	-3	+5
10	Water transport (Boats and canoes)	-4	0	-1
11	Catching fish to eat or sell	+1	+1	-3
12	Plants, herbs and natural products	-2	+3	+1
13	Water for municipality use to supply tap water	+2	+4	+3
14	Water for industrial use (mining and manufacturing)	+2	+1	+1
15	Boat cruise, water viewing and water games	-5	+1	-1
16	Tourism of wildlife	-1	-1	0
17	Traditional and religious rituals	-1	0	-2

18	Fishing for fun	-3	-5	-4
19	Research and education purposes	-1	0	-1
20	A nice view to look at (aesthetic values)	-2	-1	-5
21	National pride of owning a clean river	-1	-1	+1
22	Recycling nutrients	+1	-3	-2
23	Preventing damage to the environment (ecosystem resilience)	0	-1	0
24	A special environment for rare species of plants and animals	0	-2	-3
25	Making the landscape more beautiful	0	-2	0
26	Support plant growth processes (pollination and photosynthesis)	+2	2	+2
27	Water cycle	0	+1	0

Note: Ecosystem service categories 1-6 = Regulating, 7-14 = Provisioning, 15-21 = Cultural, 22 – 27 = Supporting.

5.2.1 Interpretation of the three factors (perspectives)

The three different perspectives about which ecosystem services were most important was interpreted using the crib sheet procedure as described by Watts and Stenner (2012). This procedure aimed at providing a holistic interpretation of the factor by considering the ranking of every single item in the factor array of that viewpoint and how it compared with other items in the other factor arrays. The crib sheet considered the highest ranked statement, the statements ranked higher or equal to other statements in the factor arrays of the other factors, statements ranked equal or lower than other statements in other factor arrays, and the least ranked statement. These criteria were used to explain the different perspectives in detail. Accordingly, the interpretation of the three factors as different perspectives was presented below.

Perspective 1: Employment creation by ecosystem services is important

This viewpoint was defined by five stakeholders, whose Q-sorts loaded significantly on this factor. The five categories of stakeholders included a domestic user, a water supplier, two regulators, and a conservationist. This perspective accounted for 20% of the variance in the study. The table below (Table 5.5) shows the particular groups of stakeholders that loaded significantly on this factor. Their factor loadings on Factor 1 are compared to the loading on the other factors.

Table 5.5: Significantly loading Q-sorts on factor 1

Q-sort ID	Stakeholder type	Factor loadings		
		Factor 1	Factor 2	Factor 3
2	Domestic user	**0.7357**	0.0530	0.1457
5	Supplier	**0.6496**	0.2083	-0.0976
12	Regulator	**0.7447**	0.1038	0.1275
13	Regulator	**0.4263**	0.1948	0.2465
14	Conservationist	**0.6381**	0.2873	0.0912

The table above shows how the factor loading of regulator with Q-sort 13 loaded very close to the margin of significance. To interpret this factor, the crib sheet approach was used. The crib sheet used for the interpretation of perspective 1 (factor 1) was as follows:

Statement ranked highest:

No	Statement	Category	Rank on each factor		
			F1	F2	F3
7	Water for irrigation	provisioning	**+5**	+2	+1

Statements ranked higher or equal:

No	Statement	Category	Rank on each factor		
			F1	F2	F3
7	Water for irrigation	provisioning	**+5**	+2	+1
4	Conservation of ecosystem	Regulating	**+4**	0	-3
14	Water for industrial use (mining and manufacturing)	Provisioning	**+2**	+1	+1
26	Support plant growth processes (pollination and photosynthesis)	Supporting	**+2**	+2	+2
11	Catching fish to eat or sell	Provisioning	**+1**	+1	-3
22	Recycling nutrients	Supporting	**+1**	-3	-2

23	Preventing damage to the environment (ecosystem resilience)	Supporting	**0**	-1	0
24	A special environment for rare species of plants and animals (refugia)	Supporting	**0**	-1	-2
25	Making the landscape more beautiful	Supporting	**0**	-2	0
20	A nice view to look at (aesthetic values)	Cultural	**-2**	-2	-5
18	Fishing for fun	Cultural	**-3**	-5	-4

Statements ranked lower or equal:

No	Statement	Category	Rank on each factor		
			F1	F2	F3
13	Water for municipality use to supply water	Provisioning	**+2**	+4	+3
26	Support plant growth processes (pollination and photosynthesis)	Supporting	**+2**	+2	+2
1	Maintenance of water quality by diluting pollutants	regulating	**0**	+3	+2
27	Water cycle	Supporting	**0**	+1	0
16	Tourism of wildlife	Cultural	**-1**	-1	0
17	Traditional and religious rituals	Cultural	**-1**	0	-1
19	Research and education purposes	Cultural	**-1**	0	-1
21	National pride of owning a clean river	Cultural	**-1**	-1	+1
12	Plants, herbs and natural products	Provisioning	**-2**	+3	+1
10	Water transport (boats and canoes)	Provisioning	**-4**	0	-1
15	Boat cruise, water viewing and water games	Cultural	**-5**	+1	-2

Statement ranked lowest:

No	Statement	Category	Rank on each factor		
			F1	F2	F3
15	Boat cruise, water viewing and water games	Cultural	**-5**	+1	-2

Using the information from the factor array and Z-scores for Factor 1 (**Appendix G**), a typical member of this group would arrange their Q sort as shown in the diagram below (Figure 5.1):

Least important ← **Neutral** → **Most important**

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
15	10	3	12	21	27	2	26	8	4	7
		18	20	17	23	11	14	5		
			9	19	1	6	13			
				16	24	22				
					25					

Figure 5.1: Prototypical Q sort for Factor 1

From the information revealed from the crib sheet and the prototypical arrangement of the Q-sort for Factor 1, it can be seen which particular ecosystem services were considered most important and least important by holders of this perspective. Overall, this group of stakeholders valued those ecosystem services that translated into job creation for stakeholders. The arrangement shows that members belonging to this perspective were of the view that water for irrigation was the most important ecosystem service provided by the Olifants River (7: +5). Even a conservationist pointed out how agriculture was a big employer for local people and so the irrigation water provided by the river translated into directly supporting local livelihoods in terms of employment and food provision. Thus, this group of stakeholders placed the highest ranking on irrigation than other uses for water. It could also explain why water for industrial use (14: 2) was ranked higher, for the same reason that industry is a big employer and source of livelihood as well as economic growth for the country. In addition, they regarded conservation of the ecosystem as another important ecosystem service (4: +4). It can be explained by the fact that this significantly loading Q-sorts in this factor included a conservationist and two regulators whose mandate is to ensure sustainability in how the environment is managed.

It is of importance to also note that the stakeholders with this viewpoint generally ranked a lot of the provisioning ecosystem services lower than other groups of stakeholders (10: -4, 12: -2, 13: 2).

The figure below (Figure 5.2) highlights how this group of participants ranked ecosystem services relative to other ecosystem services by category.

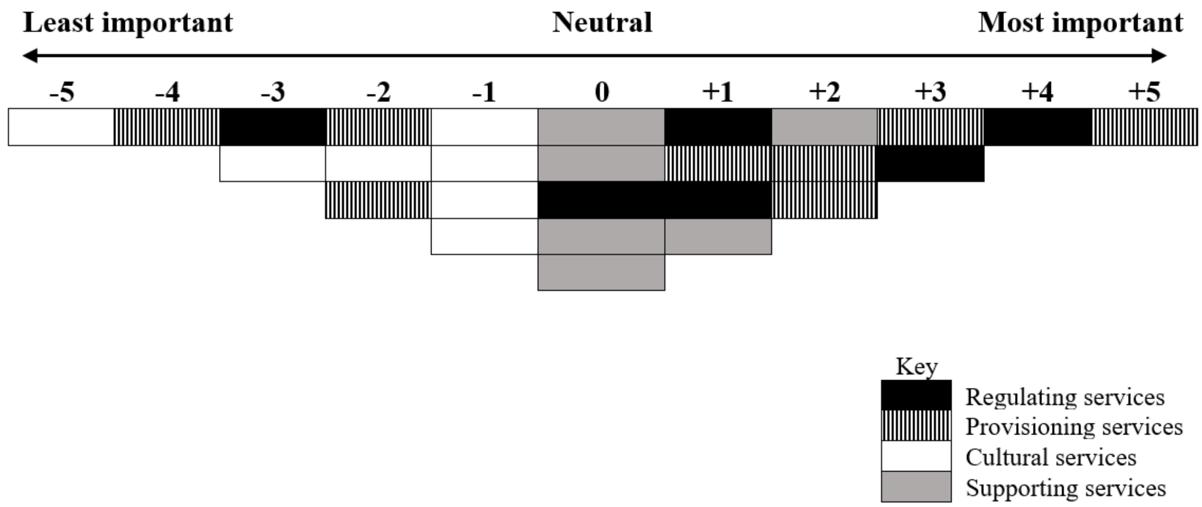

Figure 5.2: Factor 1 factor array of important ecosystem services

The arrangement above (Figure 5.2) generally reveals how this group of participants placed all the cultural services in the left half of the grid (lesser importance). The supporting services were generally located in the centre, denoting a general neutrality about their importance. Regulating services were generally in the right half, while provisioning services were scattered all over the Q-sort. The figure below (Figure 5.3) is a condensed form of the factor array, which gives a clear picture of how the different categories of the ecosystem services are ranked.

The least important ecosystem service for this group of stakeholders was recreation in the form of boat cruise, water viewing, and water games (15: -5). The exit interviews revealed that stakeholders regarded such ecosystem services as less important on the premise that it was non-existent in their area, meaning that they did not use the Olifants River for such recreational activities.

The figure below (Figure 5.3) shows how the different categories of ecosystem services are arranged on the Q-sort of stakeholders holding the point of view explained by Factor 1.

- Regulating services in grid (a) are shown by the following statements and ranking of the particular statement in brackets: Conservation of ecosystem (+4); Natural storage for water

(+3), Preventing floods (+1); Habitat for fish and wildlife (+1); Maintenance of water quality by diluting pollutants (0); and Control of soil erosion (-3). Most of the services in this category seem to range from generally neutral to important.

- Provisioning services in grid (b) are polarised with more importance shown by: Water for irrigation (+5); Water directly from the river for domestic use (+3); Water for industrial use (+2); Water for municipality use to supply tap water (+2); and Catching fish to eat or sell (+1); and less importance was placed on the following ecosystem services: Plants, herbs and natural products (-2); Water for power generation (-2); and Water transport (-4).
- Cultural services in grid (c) are generally considered less important as can be seen by the shaded areas showing the following statements and rankings: National pride of owning a clean river (-1); Traditional and religious rituals (-1); Research and education purposes (-1), Tourism of wildlife (-1); A nice view to look at (-2); Fishing for fun (-3) and Boat cruise; water viewing and water games (-5).
- Supporting services in (d) are shown to have a somewhat neutral ranking given by how they are located around the centre of the Q-sort denoted by the following statements with the corresponding rank in the bracket: Support plant growth processes (+2); Recycling nutrients (+1); Water cycle (0); Preventing damage to the environment (0); A special environment for rare species; (0) and Making the landscape more beautiful (0).

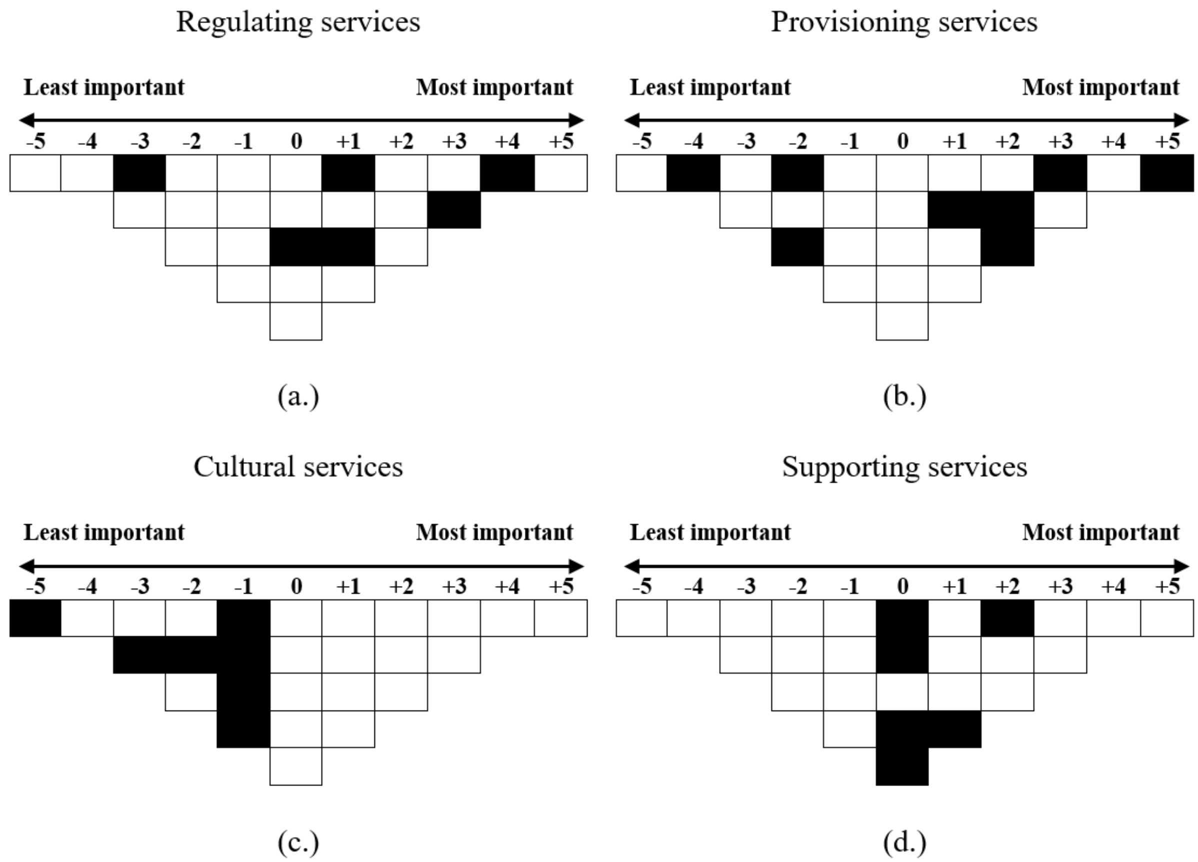

Figure 5.3: Pattern of categories of important ecosystem services for Factor 1

Perspective 2: Provisioning services are the most important

This perspective explained 15% of the variance in the study. It was defined by four Q-sorts that loaded significantly on this factor. The Q-sorts that loaded significantly were represented by the following category of stakeholders: water board, conservationist, domestic user, and supplier. The following table illustrates the significantly loading Q-sorts on Factor 2 with their factor loadings compared to other factors.

Table 5.6: Q-sorts defining Factor 2

Q-sort ID	Stakeholder type	Factor loadings		
		Factor 1	**Factor 2**	Factor 3
3	Water board	0.3640	**0.6021**	0.3445
6	Conservationist	0.3541	**0.7339**	-0.2059
7	Domestic user	0.1212	**0.5995**	-0.1296
8	Supplier	0.0783	**0.5930**	0.1735

The table above (Table 5.6) shows significantly high factor loadings on Factor 2, the lowest being 0.5930 and the highest of 0.7339. This is a sign that these significant Q-sorts highly exemplify Factor 2 (Watts & Stenner, 2012). To explain Factor 2, the crib sheet that was used to interpret this factor was as follows:

Statement ranked highest:

Statement	Category	Q-score on factor		
		F1	**F2**	F3
8 Water directly from the river for domestic use (washing, bathing, etc)	Regulating	+3	**+5**	0

Statements ranked higher or equal:

Statement	category	Q-score on factor		
		F1	**F2**	F3
8 Water directly from the river for domestic use (washing, bathing, etc)	Provisioning	3	**5**	0
13 Water for municipality use to supply tap water	Provisioning	2	**4**	3
1 Maintenance of water quality by diluting pollutants	Regulating	0	**3**	2
12 Plants, herbs and natural products	Provisioning	-2	**3**	1
6 Habitat for fish and wildlife	Regulating	1	**2**	-1
26 Support plant growth processes (pollination and photosynthesis)	Supporting	2	**2**	2
11 Catching fish to eat or sell	Provisioning	1	**1**	-3
15 Boat cruise, water viewing and water games	Cultural	-5	**1**	-2
27 Water cycle	Supporting	0	**1**	0

10 Water transport (Boats and canoes)	Provisioning	-4	**0**	-1
17 Traditional and religious rituals	Cultural	-1	**0**	-1
19 Research and education purposes	Cultural	-1	**0**	-1
20 A nice view to look at (aesthetic values)	Cultural	-2	**-2**	-5

Statements ranked lower or equal

Statement	Category	Q-score on factor		
		F1	**F2**	F3
26 Support plant growth processes (pollination and photosynthesis)	Supporting	2	**2**	2
14 Water for industrial use (mining and manufacturing)	Provisioning	2	**1**	1
5 Natural storage for water	Regulating	3	**0**	4
16 Tourism of wildlife	Cultural	-1	**-1**	0
21 National pride of owning a clean river	Cultural	-1	**-1**	1
23 Preventing damage to the environment (ecosystem resilience)	Supporting	0	**-1**	0
2 Preventing floods	Regulating	1	**-2**	2
25 Making the landscape more beautiful	Supporting	0	**-2**	0
9 Water for power generation	provisioning	-2	**-3**	5
22 Recycling nutrients	Supporting	1	**-3**	-2
3 Control of soil erosion	Regulating	-3	**-4**	3
18 Fishing for fun	Cultural	-3	**-5**	-4

Statement ranked lowest

Statement	Category	Q-score on factor		
		F1	**F2**	F3
18 Fishing for fun	Cultural	-3	**-5**	-4

The crib sheet and factor array scores revealed that generally, provisioning services were ranked higher by stakeholders represented by this viewpoint (8: +5, 1: +3), 12: +3, 13: +4). A prototypical arrangement of the Q-sort in this perspective is shown below (Figure 5.4). This prototype Q-sort was based on the Z-scores output **(see Appendix G)**.

Least important — **Neutral** — **Most important**

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
18	3	22	24	21	19	14	7	1	13	8
		9	2	23	4	27	6	12		
			25	16	5	15	26			
				20	10	11				
					17					

Figure 5.4: Prototypical Q-sort for Factor 2

Stakeholders holding this perspective prioritised the ecosystem services that support human life directly (provisioning services). This could be attributed to the fact that the defining stakeholders for this factor are water board, conservationist, domestic user and supplier. The domestic users, suppliers and water boards enjoy the Olifants River for the goods and services it provides directly. This explains why these stakeholders were of the view that water for domestic use was the most important ecosystem service provided by the Olifants River (8: +5), where it was also important that the Olifants River provided water for municipality use to supply potable water to residents (13: +4). This factor also placed importance on the Olifants River being able to provide plants, herbs, and natural products for use in different activities (12: +3). They also prioritised the environment by saying it was important that the Olifants River was providing a habitat for fish and wildlife as well as maintaining the raw water quality by diluting pollutants (6: +2, 1: +3). This could be attributed to the conservationist whose factor loading on this perspective was significantly high.

Even though the following services were not ranked high in the factor array for Factor 2, they were ranked higher than in other factors, viz.: provision of water transport in the form of boats and canoes; as well as recreation in the form of boat cruise; water games and water viewing (10: 0, 15: +1). They also said it was important that the Olifants River was being used for traditional and religious rituals (17: 0) such as baptisms. Stakeholders holding this perspective also ranked higher the importance of indirect benefits, such as aesthetic values and water cycle supported by the river (20: -1, 27: +1).

The least important ecosystem service for stakeholders holding this perspective was sport fishing (18: -5). They were also of the view that recycling nutrients and control of soil erosion were not so important (22: -3, 3: -4), mainly because these stakeholders did not see how these services were beneficial to people. The same reason was given as to why they did not think preventing damage to the environment was an important ecosystem service (23: -1). This could also explain why they did not regard prevention of floods as an important service (2: -2), because it falls in the same category as the above services.

Water for power generation was ranked as less important by stakeholders holding this viewpoint (9: -3) because “the water levels in the river were low, thus very little water was available for power generation”, said the water supplier in this factor. The non-availability of a hydro power station in the study area could have also contributed to stakeholders regarding this ecosystem service as less important.

These stakeholders were also of the view that in its current form, the Olifants River was not important in making the landscape more beautiful (25: -2). This was attributed to the high levels of water pollution and dwindling water flow which had made it hard for the Olifants River to be enjoyed for its aesthetic values.

Even though they were somewhat neutral about the importance of the Olifants River for research and education purposes, they still ranked it relatively lower than other stakeholders holding different perspectives, meaning that they thought it was an unimportant ecosystem service (19: 0).

The figure below (Figure 5.5) shows how the stakeholders ranked ecosystem services by category.

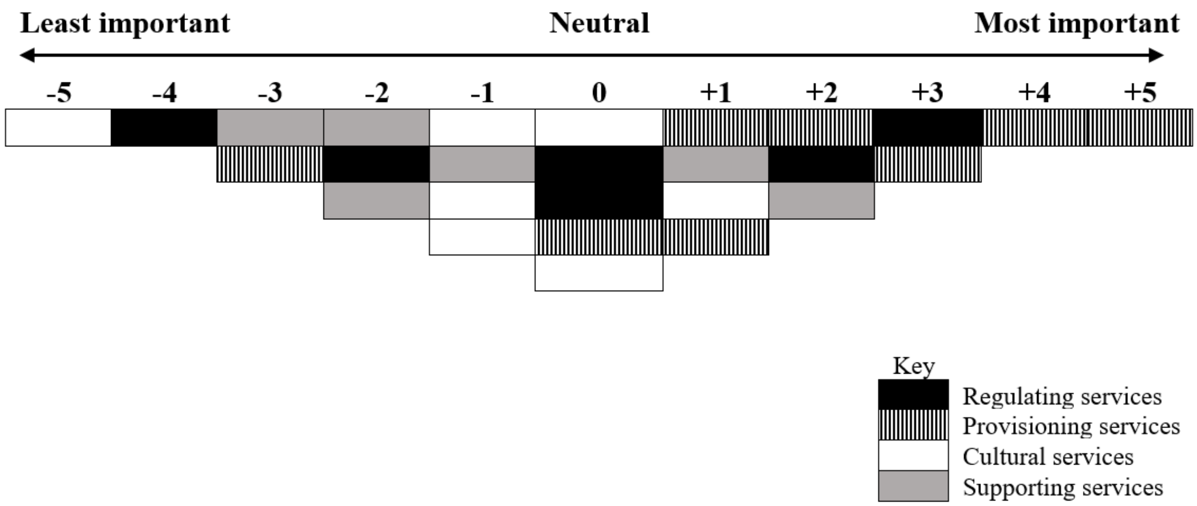

Figure 5.5: Factor 2 factor array of important ecosystem services

From the arrangement above (Figure 5.5), it can be noted how this group of stakeholders ranked provisioning services generally higher than other services. Cultural services were somewhat bundled in the middle of the Q-sorting pattern. The condensed pattern below (Figure 5.6) clearly displays how each category of ecosystem services was ranked. In the pattern below:

- Regulating services (a) are shown by the following number of statements and ranking of the particular statement with more importance shown on: Maintenance of water quality by diluting pollutants (+3), and Habitat for fish and wildlife (+2); while neutrality is shown on the following services Conservation of ecosystem (0), Natural storage for water (0); and less importance revealed on Preventing floods (-2), and Control of soil erosion (-4).
- Provisioning services (b) are shown by: Water directly from the river for domestic use (+5); Water for municipality use to supply tap water (+4); Plants, herbs and natural products (+3); Water for irrigation (+2); Water for industrial use (+1); Catching fish to eat or sell (+1); Water transport (0); and Water for power generation (-3). This pattern generally showed the importance placed on this particular category of ecosystem services.
- Cultural services in the grid (c) are denoted by the following statements with their corresponding ranking in the brackets: Boat cruise, water viewing and water games (+1); Research and education purposes (0); Traditional and religious rituals (0); National pride of owning a clean river (-1); Tourism of wildlife (-1); A nice view to look at (-1); and

Fishing for fun (-5). This pattern revealed a general neutrality about the importance of cultural ecosystem services to stakeholders represented by this factor.

- Supporting services in (d) are shown by: Support plant growth processes (+2); Water cycle (+1); Preventing damage to the environment (-1); A special environment for rare species of plants and animals (-2); Making the landscape more beautiful (-2); and Recycling nutrients (-3). This pattern show that strong opinions are held about supporting services, either they think it is important or it is not important. There seem to be no neutrality about this category of ecosystem services. It is, however, of importance to note that the perception about this category is more leaned towards less importance.

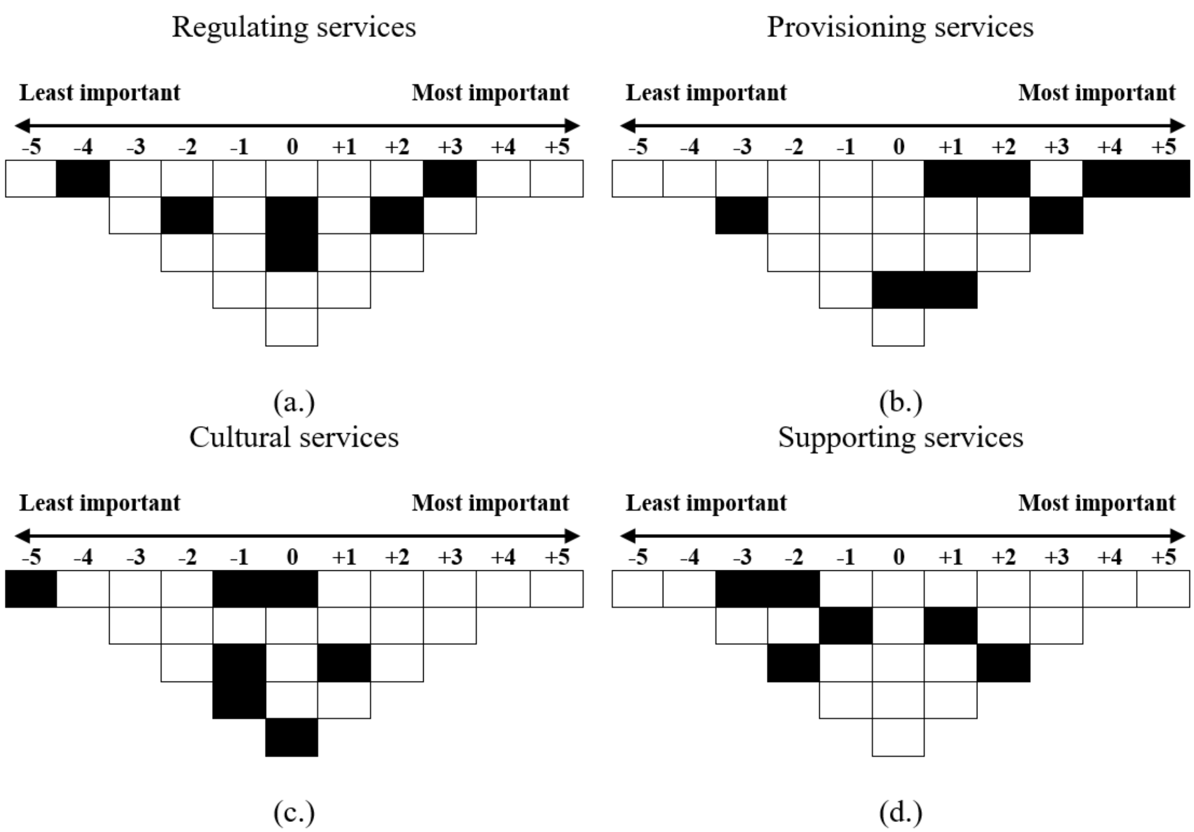

Figure 5.6: Pattern of important ecosystem services for Factor 2

Perspective 3: Mixed perspective

This viewpoint was represented by two categories of stakeholders, namely regulator and private sector. This factor accounts for 14% of the variation in the study. As shown in the table below (Table 5.7), these stakeholders highly exemplified this factor as shown by the highly significant loadings of 0.7888 and 0.8473, respectively.

Table 5.7: Significant loadings on Factor 3

Q-sort ID	Stakeholder type	Factor loadings		
		Factor 1	Factor 2	**Factor 3**
4	Private sector	-0.1235	0.2019	**0.8473**
10	Regulator	0.2376	-0.0561	**0.7888**

To explain this factor, the ranking of each statement was considered in the crib sheet procedure. The following crib sheet was used to interpret this perspective:

Statement ranked highest

Statement	Category	Q-score on factor		
		F1	F2	**F3**
9 Water for power generation	Provisioning	-2	-3	**5**

Statements ranked higher or equal

Statement	Categor y	Q-score on factor		
		F1	F2	**F3**
9 Water for power generation		-2	-3	**5**
5 Natural storage for water		3	0	**4**
3 Control of soil erosion		-3	-4	**3**
2 Preventing floods		1	-2	**2**

26 Support plant growth processes (pollination and photosynthesis)	2	2	**2**
21 National pride of owning a clean river	-1	-1	**1**
16 Tourism of wildlife	-1	-1	**0**
23 Preventing damage to the environment (ecosystem resilience)	0	-1	**0**
25 Making the landscape more beautiful	0	-2	**0**

Statements ranked lower or equal

Statement	Category	Q-score on factor		
		F1	F2	**F3**
26 Support plant growth processes (pollination and photosynthesis)	Supporting	2	2	**2**
7 Water for irrigation	Provisioning	5	2	**1**
14 Water for industrial use (mining and manufacturing)	Provisioning	2	1	**1**
8 Water directly from the river for domestic use (washing, bathing, etc)	Provisioning	3	5	**0**
27 Water cycle	Supporting	0	1	**0**
6 Habitat for fish and wildlife	Regulating	1	2	**-1**
17 Traditional and religious rituals	Cultural	-1	0	**-1**
19 Research and education purposes	Cultural	-1	0	**-1**
24 A special environment for rare species of plants and animals (refugia)	Supporting	0	-1	**-2**
4 Conservation of ecosystem	Regulating	4	0	**-3**
11 Catching fish to eat or sell	Provisioning	1	1	**-3**
20 A nice view to look at (aesthetic values)	Cultural	-2	-2	**-5**

Statement ranked lowest

Statement	Category	Q-score on factor		
		F1	F2	**F3**
20 A nice view to look at (aesthetic values)	Cultural	-2	-2	**-5**

Using the information from the factor arrays and crib sheet Factor 3 was interpreted accordingly. Firstly, a typical member of this group would arrange their Q sort as shown below (Figure 5.7):

Least important ← **Neutral** → **Most important**

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
20	18	24	17	10	27	14	26	13	3	9
		11	22	19	8	7	2	5		
			4	6	16	21	1			
				15	25	12				
					23					

Figure 5.7: Prototypical Q-sort for Factor 3

This factor represents a somewhat mixed perspective about which category of ecosystem services were the most important. This could be attributed to the fact that this perspective is exemplified by the private sector and a regulator. Most importantly, they were of the view that power generation was the most important ecosystem service (9: +5). One participant representing the stakeholders in the private sector supported this idea by saying that “the economy runs on power, therefore the availability of power is very crucial for the smooth running of the economy”. They reiterated the opinion that without power, a lot of production would cease and employment would be lost.

Compared to other groups of stakeholders, this group noted that regulating services such as preventing floods and controlling soil erosion were less important (2: -2, 3: -4). They also share the perspective that tourism of wildlife was an important ecosystem service supported by the Olifants River (16: 0), in the sense that the Olifants River provided water and a habitat for much of the wildlife dotted in the game parks along its length.

Those sharing this perspective were of the view that aesthetic values provided by the Olifants River were the least important ecosystem service (20: -5). This view was highly attributed to the high levels of visible water pollution which made it harder for the Olifants River to provide an aesthetic appeal to the environment. In the same vein, stakeholders holding this perspective noted that the Olifants river was no longer important to support rare species of plants and animals or provide a habitat for fish and wildlife (24: -3). Thus, compared to other factors, stakeholders holding this perspective regarded water for irrigation, water for domestic use, water to conduct traditional and religious affairs and water to support fishing activities as not important enough (7: +1, 8: 0, 17: -2). Hence, they ranked these ecosystem services lower than stakeholders from other factors. The figure below (Figure 5.8) highlights how this group of participants ranked ecosystem services relative to other ecosystem services.

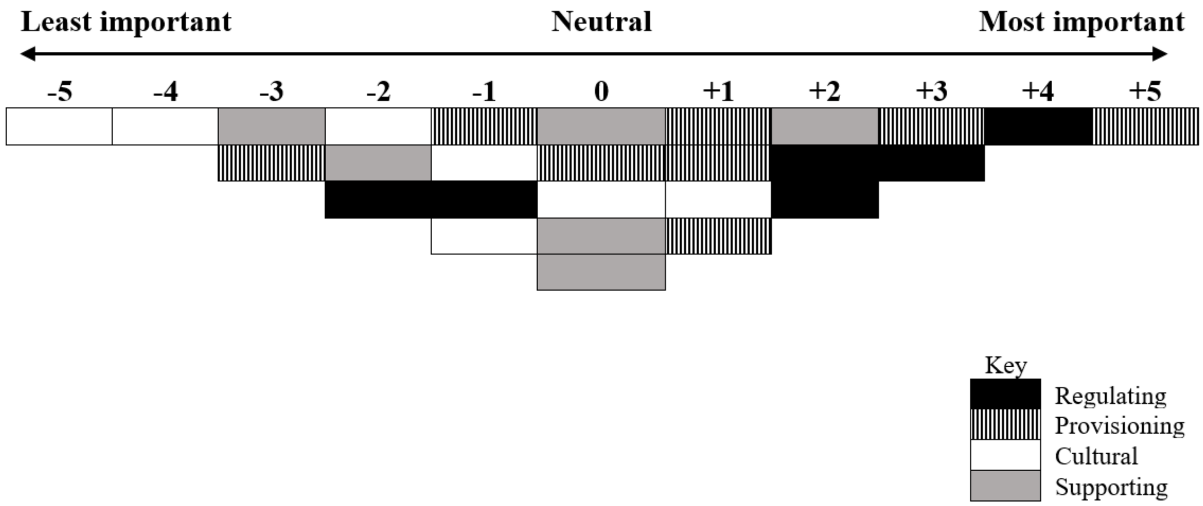

Figure 5.8: Factor 3 factor array of important ecosystem services

From the arrangement above (Figure 5.8), it can be seen that the categories of ecosystem services are splattered around with no particular category dominating a section of the Q-sort.

There was a general disagreement about the perception that water for irrigation was an important ecosystem service (7: +1) as it was ranked lower than other factors. Also, water for industrial use was perceived to be a lesser important ecosystem service (14: +1). Supporting plant growth processes such as pollination and photosynthesis were equally regarded as important ecosystem services as by other factors (26: +2).

Cultural ecosystem services like tourism of wildlife and the national pride of owning a clean river 16: 0; 21: +1) were ranked more important, while other cultural ecosystem services like traditional/religious rituals and research and development purposes were ranked as less important (17: -1; 19: -1). Meanwhile, there was a general neutrality about ecosystem services such as water cycle and ecosystem resilience (27: 0; 23: 0).

The following chart (Figure 5.9) illustrates this point by showing separately the arrangement of ecosystem services on the Q-sort.

- Regulating services (a) are shown by: Control of soil erosion (+4); Natural storage for water (+3); Preventing floods (+2); Maintenance of water quality by diluting pollutants (+2); Habitat for fish and wildlife (-1); and Conservation of ecosystem (-2). There is generally some importance attributed to these ecosystem services.
- Provisioning services (b) are shown by Water for power generation (+5); Water for municipality use to supply tap water (+3); Water for industrial use (+1); Water for irrigation (+1); Plants, herbs and natural products (+1); Water directly from the river for domestic use (0); Water transport (-1); and Catching fish to eat or sell (-3). As can be seen from the boxes in (c), the ecosystem services are dotted all over the pattern.
- Cultural services (c) are shown by: National pride of owning a clean river (+1); Tourism of wildlife (0); Water for power generation (-1); Boat cruise, water viewing and water games (-1); Fishing for fun (-4); and A nice view to look at (-5); a pattern depicting neutrality to less importance.
- Supporting services (d) are scattered around the middle area, to the right and to the left of the grid as shown by the pattern. The following statements and rankings are shown as follows: Support plant growth processes (+2); Water cycle (0); Making the landscape more beautiful (0); Preventing damage to the environment (0); Recycling nutrients (-2); and A special environment for rare species of plants and animals (-3).

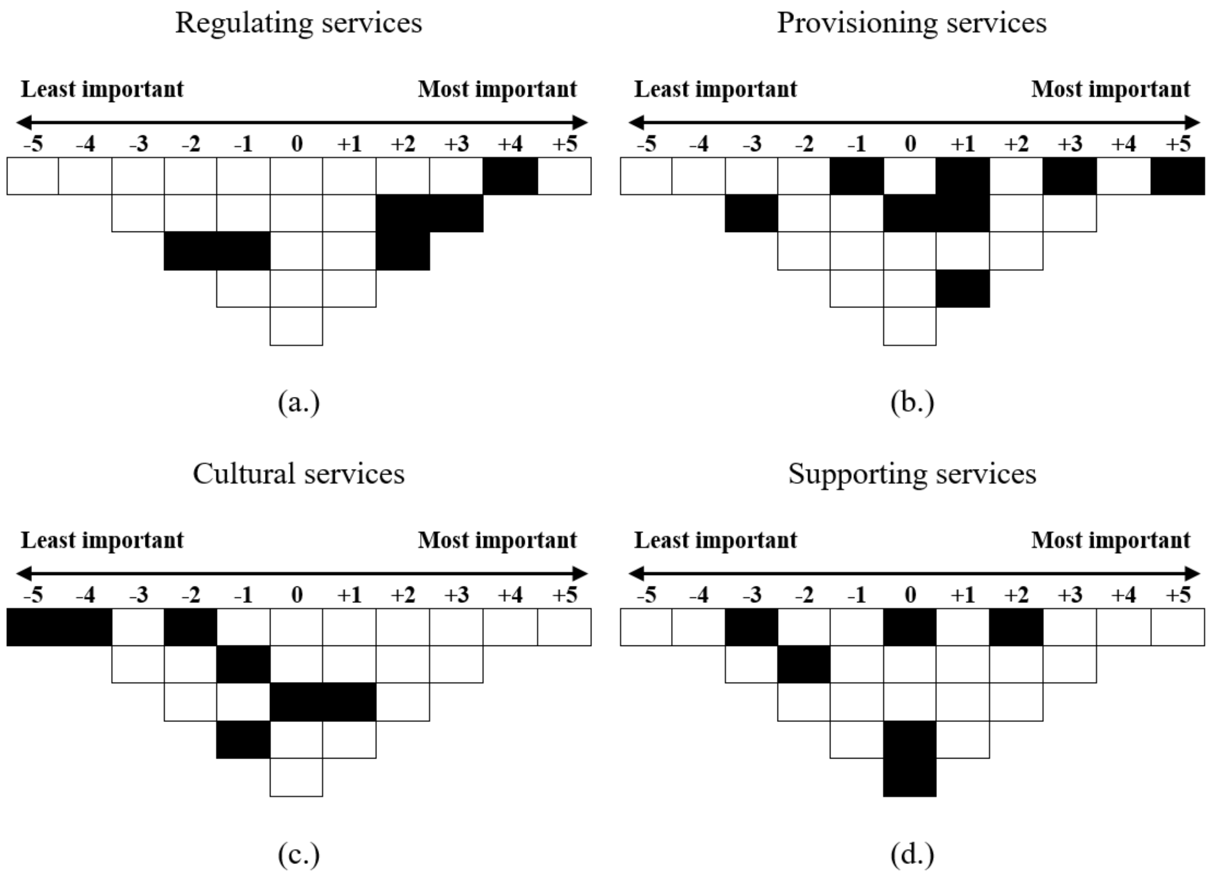

Figure 5.9: Pattern of important ecosystem services for Factor 3

5.2.2 Review about important ecosystem services

This section sought to understand which ecosystem services were ranked as most important and least important by analysing the level of consensus on highly ranked statements in the data captured in the Q-sorts. Since participants were asked to rank the ecosystem services on a scale of -5 to +5, the ecosystem services regarded as highly important would generally take on higher values. Similarly, lowly ranked ecosystem services would take on low values.

Therefore, for the sake of this analysis, statements ranked high were placed in order of disagreement by ranking them according to the variance in their scores. It would be expected that a higher variance would indicate a higher level of disagreement. The table below shows that 13 ecosystem services were highly ranked as the most important. The most important ecosystem services ranked in the order of disagreement are shown in the table below (Table 5.8):

Table 5.8: Ecosystem services ranked high in order of disagreement

No.	Statement	category	Q-score			Variance
			F1	F3	F3	
9	Water for power generation	Provisioning	-2	-3	5	2.5055894
3	Control of soil erosion	Regulating	-3	-4	3	2.3021954
4	Conservation of ecosystem	Regulating	4	0	-3	1.8530176
8	Water directly from the river for domestic use (washing, bathing, etc)	Provisioning	3	5	0	1.6600474
2	Preventing floods	Regulating	1	-2	2	1.4147673
12	Plants, herbs and natural products	Provisioning	-2	3	1	1.3212780
5	Natural storage for water	Regulating	3	0	4	1.2031082
6	Habitat for fish and wildlife	Regulating	1	2	-1	1.0521694
13	Water for municipality use to supply tap water	Provisioning	2	4	3	1.0082060
7	Water for irrigation	Provisioning	5	2	1	0.8198234
1	Maintenance of water quality by diluting pollutants	Regulating	0	3	2	0.6809801
26	Support plant growth processes (pollination and photosynthesis)	Supporting	2	2	2	0.3195231
14	Water for industrial use (mining and manufacturing)	Provisioning	2	1	1	0.2085696

It can be noted from the table above (Table 5.8) that the majority of highly ranked ecosystem services belonged to the provisioning category, followed by regulating ecosystem services and lastly only one ecosystem service from the category of supporting services. There were no cultural services in the highest ranked ecosystem services. The implication of these results is that it is being revealed which ecosystem services are regarded as most important by the stakeholders, which might form a basis for studies in environmental valuation of the ecosystem goods and services (Jensen, 2019).

Most disagreement about important ecosystem services were on water for power generation, which was regarded as most important by Factor 3, but factors 1 and 2 regarded this as less important. Similarly, control of soil erosion was highly placed by Factor 3, but factors 1 and 2 did not rank it so highly. The conservation of the ecosystem was not regarded as highly important for Factor 3, but very important for factors 1 and 2. These results reveal interesting viewpoints when it is reminded that a stakeholder from the private sector and regulator are the defining stakeholders on Factor 3.

The first and second factors seem to move in the same direction in terms of what ecosystem services they regard as most important, except when it comes to preventing floods or provision of plants, herbs and natural products, where they are on the opposite sides of the spectrum. When it comes to water for industrial use and water to support plant growth processes, all three factors are in agreement that these are important ecosystem services.

To investigate the consensus on the least important ecosystem services, the following table (Table 5.9) shows the ecosystem services that were ranked as less important by at least one factor. Table 5.9 is arranged by variance to denote most disagreement to most agreement in the statements. For example, even though water for power generation was ranked very low by factors 1 and 2, it was ranked very highly by Factor 3. Hence, the great disagreement. In the same vein, control of soil erosion was considered less important by factors 1 and 2 but somewhat more important for Factor 3. At the bottom of the table, there seems to be more agreement as the variance in the score lessens. It can be seen at the bottom of the table that all three factors agree that fishing for fun was the least important ecosystem service provided by the Olifants River.

Table 5.9: Ecosystem services ranked low by at least one factor

No.	**Statement**	**Category**	**Q-score**			**Variance**
			F1	F2	F3	
9	Water for power generation	Provisioning	-2	-3	5	2.5055894
3	Control of soil erosion	Regulating	-3	-4	3	2.3021954
15	Boat cruise, water viewing and water games	Cultural	-5	1	-2	1.9265796
4	Conservation of ecosystem	Regulating	4	0	-3	1.8530176
2	Preventing floods	Regulating	1	-2	2	1.4147673
11	Catching fish to eat or sell	Provisioning	1	1	-3	1.3402291
12	Plants, herbs and natural products	Provisioning	-2	3	1	1.3212780
10	Water transport (Boats and canoes)	Provisioning	-4	0	-1	1.1017116
22	Recycling nutrients	Supporting	1	-3	-2	1.0409986
20	A nice view to look at (aesthetic values)	Cultural	-2	-2	-5	0.8683980
24	A special environment for rare species of plants and animals (refugia)	Supporting	0	-1	-2	0.7943880
25	Making the landscape more beautiful	Supporting	0	-2	0	0.5488853
18	Fishing for fun	Cultural	-3	-5	-4	0.2017172

5.2.3 The state of ecosystem service provision by the Olifants river

Stakeholders were asked whether the ecosystem services they ranked as more important were at the desired level. That is, if they were benefitting from the ecosystem service provision by the Olifants river at the level that was not hampered by water pollution. The description of why the ecosystem services were not at the desired level are explained below.

5.2.4 Reasons why ecosystem service provision is not at desired level

i. Water directly from the river for domestic use

Participants generally described how they do not trust that the water from the river would be safe for domestic use. Residents highlighted cases of cattle that died due to drinking contaminated water from the river so the same thing might happen to human beings if they consumed the water without treating it. However, they pointed out that a vast number of local resident still have to use the water from the river because they have minimal or no alternative sources of water.

ii. Water for municipality use to supply tap water

Stakeholders gave reasons that because of the high levels of pollution in the Olifants River, they did not trust that the water supplied as municipal water would be entirely safe to drink. So they would have to treat it or boil it before they can feel safe to drink it. Water suppliers were also of the opinion that it is now becoming more expensive to treat the water to a level where it is safe for consumption. The presence of heavy metals and other complicated pollutants means that water suppliers must invest in chemicals to kill pathogens in the polluted water, as well as make frequent use of water filters which have to be changed more regularly if they are to be effective.

iii. Water for irrigation

It was highlighted by conservationists that the amount of water in the river has been on the decrease over the years. Thus, there was less and less water available for large scale irrigation. Most of this decrease in amount of water in the river was attributed to climate change. Stakeholders confessed that they did not really understand the science of climate change, but they think that the river is drying up due to climate change, which is causing a reduction in average rainfall over the years. Commercial farmers revealed that they have invested in water treatment facilities such as sedimentation and filtration systems to treat the water before it was used to irrigate crops. They said some dissolved pollutants in the river water were harmful to crops or they would reduce the efficacy of fertilizers and herbicides.

iv. Natural storage for water

A conservationist said that although the river was still serving as a natural storage for water, it was not a very useful storage vessel now because it was serving as a storage for polluted water. Other participants also noted that the low levels of water in the river meant that some sections of the river were completely dry. Therefore, the river system was becoming more unpredictable as a natural storage for water because it was not storing water to its capacity.

v. Water for industrial use (mining and manufacturing)

Commercial users who described this ecosystem service as not being at the desired level were of the view that climate change is the leading cause of the decreasing flow of water in the Olifants

River. Therefore, there is less water available for local industrial processes such as brick-making. As a result, local people are losing employment.

vi. Maintenance of water quality by diluting pollutants

The reasons given were that “there is a lot of water pollution that occurs upstream so the water in the river reaches us already saturated such that it cannot take in any more pollutants.” They further added that the river system is overloaded with an untenable level of toxins and pollutants.

vii. Habitat for fish and wildlife

The opinion by one regulator was that there are very few fish that survive in the Olifants River to the extent that even the small-scale fishers that fish to sell by the roadside have a hard time in sourcing fish. There are also instances of crocodiles dying due to pollution. These reasons were forwarded to motivate that the ecosystem service was not being provided at the desired level.

viii. Preventing floods

The assertion for this ecosystem service not providing services at desired level were that the river itself does not prevent floods, it is the man-made dams that have been constructed at different points of the river. Local residents reported that the community used to be flooded in the rainy season until a dam was built upstream. Therefore, the river is a contributor to flooding.

ix. Support plant growth processes (pollination and photosynthesis)

Local residents described how certain species of plants have gone extinct. They were of the view that the river system could no longer support the proper growth of delicate vegetation due to different reasons, noting that a good number of plant species can no longer be found along the riverbed. Also, the decreasing levels of water in the river meant that the forests and other vegetation along the river were starved of enough water to enable them carry out their plant growth processes effectively.

x. Catching fish to eat or sell

Regulators talked about how they discouraged residents from fishing in the river, because there was a high concentration of faecal matter and other metals in most parts of the river. Thus, eating fish from the river could cause diseases, of which most residents were reportedly aware.

xi. Conservation of ecosystem

Some of the reasons given were that the ecosystem as a whole was being threatened by the toxins in the river. Additionally, the lack of enough water in the river meant that plants and animals had less water to consume. Hence, the ecosystem is threatened as a result of the river not being in its ideal state.

xii. Water cycle

This was also attributed to the fact that the water levels in the river have been decreasing. Hence, there is not enough water available for the water cycle, compared to when the river was full to capacity.

xiii. Water for power generation

One resident said that there was no power station in their area that made use of the Olifants River, but they were aware of how water pollution had affected all the activities along the river. Therefore, they were of the view that even water for power supply has been affected, even though they could not ascertain how exactly power stations had been affected by water pollution.

5.3 Results of Q-Analysis for solutions to restore ecosystem services

To achieve the objective of getting stakeholders' perceptions about the solutions to restore ecosystem services and improve the management of raw water quality in Maruleng and Fetakgomo municipalities, a total of sixteen Q-sorts, each Q-sort contained thirty-one statements were analysed in PQMethod. The criteria used to obtain the best answer was the Kaiser-Guttman criteria, Humphrey's rule and Brown's calculations of significant loadings.

According to Brown (1980), Q sorts that loaded significantly on each factor were calculated as follows:

$$\text{Significant factor loading}(p<0.05) = 1.96*(1/\sqrt{number\ of\ items\ in\ Qset} \text{.........} \textit{equation (5.5)}$$

Where number of items in Q-set = 31

Therefore, significant factor loading = 0.3520

All factor loading greater than 0.35 in absolute terms were considered significant. After a thorough inspection of the data, a four factor solution was eventually arrived at with six, three, two and two significant factor loadings on the respective four factors. Together, the four factors explain 42% of the study variance.

The table below (Table 5.10) shows the extracted four factors with defining factors highlighted in bold. The Eigen values were calculated using the formula by Brown (1980) as EV=Variance*(Number of Q-sorts in the study/100)

Table 5.10: Rotated factor loadings of the four-factor solution, bold text shows significantly loading Q sorts, with significant factor loadings in bold

Q-Sort	Stakeholder type	Factor Loadings			
		Factor 1	Factor 2	Factor 3	Factor 4
1	Commercial user	**0.4001**	0.0478	0.1772	-0.0761
2	Domestic user	0.2132	0.0377	**0.7585**	0.0502
3	Water board	0.2438	0.1630	0.0081	**0.4996**
4	Private sector	**0.6164**	0.2722	0.2496	0.2014
5	Supplier	0.0199	0.2566	**0.5365**	0.2358
6	Conservationist	**0.5548**	0.0075	0.1356	0.1811
7	Domestic user	**0.6205**	-0.0369	-0.1973	-0.028
8	Supplier	0.0569	0.2447	0.0874	0.0373
9	Supplier	0.0527	**0.6440**	0.0718	0.0966
10	Regulator	-0.0279	**0.6256**	-0.1307	0.1527
11	Private sector	0.1511	0.2772	0.3582	-0.2054
12	Regulator	-0.0211	**0.6780**	0.2922	0.0158
13	Regulator	0.3431	-0.0947	0.3544	0.2475
14	Conservationist	**0.5198**	-0.0369	0.2077	0.311
15	Commercial user	**0.6714**	-0.1804	0.4437	-0.111
16	Supplier	-0.0025	0.2188	0.1407	**0.8327**
Eigenvalue		2.24	1.60	1.60	1.28
% Explained variance		14	10	10	8
Cumulative % explained variance		14	24	34	42

The Q-sorts that loaded significantly on a factor are considered as defining Q sorts of that factor. The table above reveals that the defining Q sorts for factor 1 were Q-sorts 1, 4, 6, 7, 14 and 15, represented by a commercial water user, private sector, conservationist, domestic user, conservationist and commercial user, respectively. Factor 2 was defined by a water supplier and two regulators as Q-sorts 9,10 and 12, respectively. Q-sorts 2 and 5 loaded significantly on factor 3, while Q-sorts 3 and 16 loaded significantly on factor 4.

The output was inspected and it was found that Q-sort 6 had a factor loading of 0.5548 (see Q-sort 6 loading on factor 1, which meets both criteria for flagging according the flagging algorithm used in PQMethod (**Appendix D (c)**). Therefore, Q-sort 6 was re-flagged on Factor 1 before proceeding with the analysis, because the flagged Q-sorts are the ones used to calculate factor estimates. Also, Q-sort 15 had a factor loading of 0.4437 on Factor 3, but it was not flagged in the automatic output and there was no need to re-flag it before proceeding with the analysis. This can be explained by the fact that it was because the same Q-sort 15 also had a factor loading of 0.6714 on Factor 1. This means that factor 1 accounts for 45.01% (0.6714*0.6714) of the variance in Q-sort 15 while Factor 3 only accounts for 19.69% (0.4437*0.4437) of its variance. Given the large proportion of variance explained by Factor 1, it can be concluded that Factor 1 should be left to explain the variation in Q-sort 15 (see **Appendix F**: take note of Q-sort 15 loading on factors 1 and 3).

The table below (Table 5.11) shows the factor-defining Q-sorts for the four factors.

Table 5.11: Factor-defining Q-sorts for the four factors

Factor number	Q-sort	Total	Cumulative total
1	1, 4, 6, 7, 14, 15	6	6
2	9, 10, 12	3	9
3	2, 5	2	11
4	3, 16	2	13
Confounded	None	0	13
Non-significant	8, 11, 13	3	16

As defining Q-sorts, their weighted averages represent a prototypical perspective held by someone from that factor. This information is contained in the factor arrays which show how a typical holder of that perspective would have arranged their Q-sort. The factor arrays for the four factors extracted in this analysis are shown in the following table below (Table 5.12).

Table 5.12: Factor arrays for four extracted factors

No.	Statement No.	Factor Arrays			
		Factor 1	Factor 2	Factor 3	Factor 4
1	Increased sensitisation to raise awareness about negative impacts of water pollution	0	+3	+3	+1
2	Give incentives/rewards to water users who pollute less	0	-2	-1	+3
3	Invest in tools to detect water pollution	+1	-1	0	-1
4	Increase monitoring and enforcement of existing laws	+5	0	+2	+2
5	An independent regulator (not a government institution) will do a better job to control water pollution	+4	0	+4	+5
6	Department of Water and Sanitation (Department of Water and Sanitation (DWS)) should come up with ways of punishing water polluters	+4	0	+5	0
7	First we must deal with the invisible pollution before we deal with the pollution we can see because the invisible pollution is the one that is mostly dangerous	+3	0	+1	-2
8	Further training of staff from Department of Water and Sanitation (Department of Water and Sanitation (DWS)) in issues of water quality	-2	+3	0	+4
9	If all water users are affiliated and represented through a water user association, it will make them to use water more responsibly and reduce on pollution	+2	+4	0	+1
10	If the majority of households have piped water, then they will stop polluting the river	-3	-4	0	-4
11	More government funding to the municipalities will improve water quality	-5	+1	-3	+2
12	Naming and shaming polluters encourages people to stop pollution	0	-2	+1	0
13	Improving the quality of water will be expensive	0	-1	-5	-1
14	Pollution will stop if only the people upstream stopped polluting	-3	-2	-3	-2
15	The mines should compensate the farmers because the waste from the mines kills their animals and plants	+2	-1	-2	-4
16	The Olifants River catchment is too big to be controlled by one body	-3	-3	-1	-1
17	The priority should be to prevent the effects of pollution on the environment	+3	-3	-1	-1
18	The quality of water in the Olifants cannot be improved. It's too late	-4	-5	-4	-2
19	There is need for all stakeholders to work together to improve water quality	+1	+2	+1	+1
20	There is need to prevent new people from using the river. The bigger the number of people using the river, the higher the pollution	-4	+1	-2	+4
21	Those who pollute should pay all those who are affected by the pollution	+3	0	-3	0
22	Those who pollute too much should stop using the river for a while	-1	-4	+3	0
23	Department of Water Affairs should ensure that everyone is using the correct amount of water for the right purpose (Validation and verification)	+2	+5	0	+1
24	We need more laws in order to prevent further water pollution	-2	+4	-4	-5
25	Municipalities should allocate more money to water quality improvement	-1	-1	-2	+3
26	All commercial farmers should be certified by SA GAP or Global GAP as a way to reduce water pollution from irrigation farms	-1	+2	+1	-3

27	Improved garbage collection will prevent domestic waste (such as used diapers) from polluting the river	+1	+1	+2	-3
28	Regular stakeholder meetings are important in improving water quality	0	+2	+2	+3
29	Local people should decide how best to manage the river	-1	-3	-1	-3
30	Capacity building of the municipality through training of staff to improve water quality management	+1	+1	+4	+2
31	Educating farm workers about water quality to prevent water	-2	+3	+3	0

5.3.1 Interpretation of the four extracted factors

The interpretation of the extracted factors was done using the crib sheet procedure as outlined by Watts and Stenner (2012).

Factor 1: Polluters must be made accountable through monitoring and enforcement of regulations

Factor 1 has an eigenvalue of 2.24 and explains 14% of the study variance. The stakeholders defining this factor are two commercial users, a domestic water user two conservationists and a stakeholder from the private sector. The table below (Table 5.13) shows the stakeholders whose Q-sorts significantly loaded on Factor 1.

Table 5.13: Q-sorts defining Factor 1

Q-sort ID	Stakeholder Type	Loadings on each factor			
		F1	F2	F3	F4
1	Commercial user	**0.40009**	0.04778	0.17720	-0.07606
4	Private	**0.61643**	0.27222	0.24961	0.20139
6	Conservationist	**0.55485**	0.00753	0.13562	0.18112
7	Domestic	**0.62048**	-0.03690	-0.19730	-0.02802
14	Conservationist	**0.51982**	-0.03688	0.20775	0.31098
15	Commercial user	**0.67144**	-0.18038	0.44374	-0.11099

In explaining this factor, the following crib sheet was used to interpret this factor as follows:

Statement ranked highest

Statement	Q-score on each factor			
	F1	F2	F3	F4
4 Increase monitoring and enforcement of existing laws	**5**	0	2	2

Statement ranked higher or equal

Statement	Q-score on each factor			
	F1	F2	F3	F4
7 First we must deal with the invisible pollution before we deal with the pollution we can see because the invisible pollution is the one that is mostly dangerous	**3**	0	1	-2
17 The priority should be to prevent the effects of pollution on the environment	**3**	-3	-1	-1
21 Those who pollute should pay all those who are affected by the pollution	**3**	0	-3	0
15 The mines should compensate the farmers because the waste from the mines kills their animals and plants	**2**	-1	-2	-4
3 Invest in tools to detect water pollution	**1**	-1	0	-1
13 Improving the quality of water will be expensive	**0**	-1	-5	-1
29 Local people should decide how best to manage the river	**-1**	-3	-1	-3

Statements ranked lower or equal

Statement	Q-score on each factor			
	F1	F2	F3	F4
19 There is need for all stakeholders to work together to improve water quality	**1**	2	1	1
30 Capacity building of the municipality through training of staff to improve water quality management	**1**	1	4	2
1 Increased sensitisation to raise awareness about negative impacts of water pollution	**0**	3	3	1
28 Regular stakeholder meetings are important in improving water quality	**0**	2	2	3
8 Further training of staff from Department of Water and sanitation in issues of water quality	**-2**	3	0	4
31 Educating farm workers about water quality to prevent water pollution	**-2**	3	3	0
14 Pollution will stop if only the people upstream stopped polluting	**-3**	-2	-3	-2
16 The Olifants River catchment is too big to be controlled by one body	**-3**	-3	-1	-1

20 There is need to prevent new people from using the river. The bigger the number of people using the river, the higher the pollution.	**-4**	1	-2	4

Statement ranked lowest

Statement	Q-score on each factor			
	F1	F2	F3	F4
11 More government funding to the municipalities will improve water quality	**-5**	1	-3	2

Holders of this perspective were of the view that water polluters must pay those were affected by the water pollution (21: +3). A specific example would be mines, to compensate the farmers whose livestock and crops get destroyed by mine waste (15: +2). Notably, this group of stakeholders is of the view that dissolved substances such as acid mine water is a more dangerous form of water pollution than physical waste such as plastic waste (7: +3).

This group of stakeholders also holds the opinion that the environment should be protected from the effects of water pollution (17: +3). That is why they are of the view that there is need to invest in tools for early detection of water pollution (3, +1) so that further environmental degradation could be mitigated.

Even though these stakeholders think that improving water quality would be expensive, they do not think these expenses should be allocated to more funding allocated to municipalities or to fund further training of staff at the Department of Water and Sanitation (Department of Water and Sanitation (DWS)) (13:0, 11: -5, 8: -2). One commercial user said "the problem with municipalities has not really been about lack of funds, but rather about misuse of funds. Thus, more funding would only entail more misuse of funds."

This perspective was not in agreement that new users should be prevented from using the river (20: -4), simply because "it was unfair to assume that news users will cause water pollution". The conservationists highlighted the studies that said the Olifants River was fully allocated, but they were of the view that preventing new users would mean denying citizens access to a fundamental basic need (water). All that was needed was to increase monitoring of existing laws (4: +5), because according to one conservationist, "South Africa has some of the best laws in the world as far as water resource management is concerned." The conservationist added that "most water polluters were only getting away with it because there was poor enforcement and monitoring of existing laws."

Finally, this group of stakeholders did not believe more engagement with stakeholders (28: 0) or sensitisation (31: -2) would prevent water pollution, because these efforts were already being made, but remain to yield more positive results.

Factor 2: More organisation and coordination is needed

This factor has an eigenvalue of 1.6 and explains 10% of the study variance. Factor 2 is explained by a supplier and two regulators. The table below (Table 5.14) shows the Q-sorts defining this factor with their significant loadings on the extracted factors.

Table 5.14: Q-sorts defining Factor 2

QID	Type	Loading on factor			
		F1	**F2**	F3	F4
9	Supplier	0.05274	**0.64400**	0.07175	0.09663
10	Regulator	-0.02792	**0.62559**	-0.13066	0.15268
12	Regulator	-0.02107	**0.67795**	0.29222	0.01579

The table above (Table 5.14) shows how the factor loadings are not very different from one another. Thus, this perspective is somewhat proportionally exemplified by the three stakeholders representing this viewpoint. The following is the crib sheet used to interpret this factor.

Statement ranked highest

Statement	Q-score on each factor			
	F1	**F2**	F3	F4
23 Department of Water Affairs should ensure that everyone is using the correct amount of water for the right purpose (validation and verification).	2	**5**	0	1

Statements ranked higher or equal

Statement	Q-score on each factor			
	F1	**F2**	F3	F4

9 If all water users are affiliated and represented through a water user association, it will make them to use water more responsibly and reduce on pollution	2	**4**	0	1
24 We need more laws in order to prevent further water pollution	-2	**4**	-4	-5
1 Increased sensitisation to raise awareness about negative impacts of water pollution	0	**3**	3	1
31 Educating farm workers about water quality to prevent water pollution	-2	**3**	3	0
19 There is need for all stakeholders to work together to improve water quality	1	**2**	1	1
26 All commercial farmers should be certified by SA GAP or Global GAP as a way to reduce water pollution from irrigation farms	-1	**2**	1	-3
14 Pollution will stop if only the people upstream stopped polluting	-3	**-2**	-3	-2

Statements ranked lower or equal:

Statement	Q-score on each factor			
	F1	**F2**	F3	F4
30 Capacity building of the municipality through training of staff to improve water quality management	1	**1**	4	2
4 Increase monitoring and enforcement of existing laws	5	**0**	2	2
5 An independent regulator (not a government institution) will do a better job to control water pollution	4	**0**	4	5
6 Department of water and sanitation should come up with ways of punishing water polluters	4	**0**	5	0
3 Invest in tools to detect water pollution	1	**-1**	0	-1
2 Give incentives/rewards to water users who pollute less	0	**-2**	-1	3
12 Naming and shaming polluters encourages people to stop pollution	0	**-2**	1	0
16 The Olifants River catchment is too big to be controlled by one body	-3	**-3**	-1	-1
17 The priority should be to prevent the effects of pollution on the environment	3	**-3**	-1	-1
29 Local people should decide how best to manage the River	-1	**-3**	-1	-3
10 If the majority of households have piped water, then they will stop polluting the river	-3	**-4**	0	-4
22 Those who pollute too much should stop using the River for a while	-1	**-4**	3	0

Statement ranked lowest

Statement	Q-score on each factor			
	F1	**F2**	F3	F4
18 The quality of water in the Olifants River cannot be improved. It’s too late.	-4	**-5**	-4	-2

This group of stakeholders seemed to suggest an approach that called for more organisation and coordination in the management of water resources as a way to improve water quality, prevent further pollution and restore ecosystem services. It is interesting to note that the responsibility to organise and coordinate better is placed on the regulators such as DWS and not so much emphasis is placed on what the ordinary water users can do.

Most notably, they were of the view that water quality in the Olifants River can be improved (18: -5). The regulators said that it is not true that it is too late to improve the quality of water in the Olifants, because there is still hope that the situation could be made better (i.e. water quality could be improved). They were of the opinion that before anything else, the Department of Water and Sanitation (Department of Water and Sanitation (DWS)) must confirm that every water user is using correct and lawful amounts of water through the process of validation and verification (23: +5) as a way to ensure sustainable use of the water resources in the country. These stakeholders also think that water user associations have a significant role to play in ensuring lawful and correct use of water. They believe that affiliation to a water user association would encourage a water user to use water more responsibly (9: +4) as members of the association are expected to conform to the rules of the association. Similar reasoning was given for the need for commercial farmers to be certified by a good practice certification authority nationally or internationally. They argued that if irrigation farmers are certified, they would be expected to conform to the rules of the certification authority lest they lose the certification (26: +2), which is a prerequisite for them to participate in certain international markets. Emphasis is also placed on the need for all stakeholders to work together to improve water quality through concerted and coordinated efforts (19: +2).

This group of stakeholders was also of the opinion that the current laws on water resource management are not enough to maintain water quality (4: 0), where there is need for more laws to prevent and deter water pollution offenders. These stakeholders want government to take an active role in water resources management. This also explains why they do not think an independent regulator might be more effective in enforcing laws than a government-affiliated regulator (5: 0).

This viewpoint did not think incentivising non-polluters or simply naming and shaming polluters would encourage water polluters to pollute less (2: -2, 12: -2). They called for tougher action against polluters. One supplier argued that excessive water polluters should be excluded from using the river forever and not just for short while (22: -4).

Factor 3: Innovation and creativity is needed in water management through capacity building

Factor 3 has an eigenvalue of 1.6 and explains 10% of the study variance. The perception held by this factor is defined by a domestic user and a supplier. The table below (Table 5.15) shows the stakeholders defining this factor.

Table 5.15: Q-sorts defining factor 3

QID	Type	Loading on factor			
		F1	F2	**F3**	F4
2	Domestic	0.21320	0.03771	**0.75846**	0.05020
5	Supplier	0.01988	0.25655	**0.53647**	0.23578

The crib sheet used in the interpretation of this factor is shown below.

Statement ranked highest

Statement	Q-score on each factor			
	F1	F2	**F3**	F4
6 Department of water and sanitation should come up with ways of punishing water polluters	4	0	**5**	0

Statements ranked higher or equal

Statement	Q-score on each factor			
	F1	F2	**F3**	F4
30 Capacity building of the municipality through training of staff to improve water quality management	1	1	**4**	2
1 Increased sensitisation to raise awareness about negative impacts of water pollution	0	3	**3**	1
22 Those who pollute too much should stop using the River for a while	-1	-4	**3**	0
31 Educating farm workers about water quality to prevent water pollution	-2	3	**3**	0
27 Improved garbage collection will prevent domestic waste (such as diapers) from polluting the river	1	1	**2**	-3
12 Naming and shaming polluters encourages people to stop pollution	0	-2	**1**	0
10 If the majority of households have piped water, then they will stop polluting the River	-3	-4	**0**	-4
16 The Olifants River catchment is too big to be controlled by one body	-3	-3	**-1**	-1
29 Local people should decide how best to manage the River	-1	-3	**-1**	-3

Statements ranked lower or equal:

Statement	Q-score on factor			
	F1	F2	**F3**	F4
19 There is need for all stakeholders to work together to improve water quality	1	2	**1**	1
9 If all water users are affiliated and represented through a water user association, it will make them to use water more responsibly and reduce on pollution	2	4	**0**	1
23 Department of Water Affairs should ensure that everyone is using the correct amount of water for the right purpose (Validation and verification).	2	5	**0**	1
25 Municipalities should allocate more money to water quality improvement	-1	-1	**-2**	3
14 Pollution will stop if only the people upstream stopped polluting	-3	-2	**-3**	-2
21 Those who pollute should pay all those who are affected by the pollution	3	0	**-3**	0

Statement ranked lowest

Statement	Q-score on factor			
	F1	F2	**F3**	F4
13 Improving the quality of water will be expensive	0	-1	**-5**	-1

Stakeholders with this view hold that improving water quality demands innovative ways of doing things. For example, they suggest that the Department of Water and Sanitation as a regulator (Department of Water and Sanitation (DWS)) should come up with ways of punishing water polluters (6: +5) because “the current way of doing things has done very little in terms of meting out punishments to water polluters such that it does not deters would-be offenders”, said a supplier.

This viewpoint agrees on unconventional approaches, such as preventing water polluters from using the river for a while (22: +3) as punishment for polluting. However, they do not agree that punishing water polluters should involve polluters compensating pollutees (21: -3).

These stakeholders did not agree that improving water quality in the Olifants River would be expensive (13: -5), and so do not think allocating more money to water quality improvement efforts is the answer to the water quality problems (25: -2). Instead, these stakeholders hold the perception that it is innovative ideas like naming and shaming water polluters or improving garbage collection that will help in water quality improvement (12: +1, 27: +2). This group of stakeholders was of the view that household waste was the leading source of water pollution, hence providing piped to water to majority of households would stop them from using the river to do their washing, defecation and other domestic activities that cause pollution (10: 0).

These stakeholders were of the view that further training of municipalities staff would build capacity in improving water quality (30: +4). They also did not think that the validation and verification process by DWS or affiliation to a water user association by water users would make water users to reduce on water pollution (23: 0, 9: 0) because “there is no guarantee that they would be compliant”, as suggested by one domestic user.

Factor 4: Changes have to be made to how things are done

Factor 4 had an eigenvalue of 1.28 and explains 8% of the study variance. The perception held by this factor is defined by stakeholders categorised as water board and supplier. The Q-sorts defining this factor are shown in the table below (Table 5.16) with their loadings on each factor.

Table 5.16: Q-sorts defining Factor 4

QID	Type	Loading on each factor			
		F1	F2	F3	**F4**
3	Water board	0.24377	0.16297	0.00808	**0.49961**
16	Supplier	-0.00246	0.21876	0.14068	**0.83269**

The table above (Table 5.16) shows how much the supplier significantly exemplifies this factor in comparison to the water board. This could be an indication that the viewpoint expressed by Factor 4 is highly typical of the perceptions held by the water supplier. The crib sheet used in the interpretation of this factor shown below.

Statement ranked highest:

Statement	Q-score on factor			
	F1	F2	F3	**F4**
5 An independent regulator (not a government institution) will do a better job to control water pollution	4	0	4	**5**
Statement	**Q-score on factor**			

	F1	F2	F3	**F4**
8 Further training of staff from Department of Water and sanitation in issues of water quality	-2	3	0	**4**
20 There is need to prevent new people from using the river. The bigger the number of people using the river, the higher the pollution.	-4	1	-2	**4**
2 Give incentives/rewards to water users who pollute less	0	-2	-1	**3**
25 Municipalities should allocate more money to water quality improvement	-1	-1	-2	**3**
28 Regular stakeholder meetings are important in improving water quality	0	2	2	**3**
11 More government funding to the municipalities will improve water quality	-5	1	-3	**2**
16 The Olifants river catchment is too big to be controlled by one body	-3	-3	-1	**-1**
14 Pollution will stop if only the people upstream stopped polluting	-3	-2	-3	**-2**
18 The quality of water in the Olifants River cannot be improved. It's too late	-4	-5	-4	**-2**

Statements ranked lower or equal:

Statement	Q-score on factor			
	F1	F2	F3	**F4**
19 There is need for all stakeholders to work together to improve water quality	1	2	1	**1**
6 Department of water and sanitation should come up with ways of punishing water polluters	4	0	5	**0**
3 Invest in tools to detect water pollution	1	-1	0	**-1**
7 First we must deal with the invisible pollution before we deal with the pollution we can see because the invisible pollution is the one that is mostly dangerous	3	0	1	**-2**
26 All commercial farmers should be certified by SA GAP or Global GAP as a way to reduce water pollution from irrigation farms	-1	2	1	**-3**
27 Improved garbage collection will prevent domestic waste (such as diapers) from polluting the River	1	1	2	**-3**
29 Local people should decide how best to manage the River	-1	-3	-1	**-3**
10 If the majority of households have piped water, then they will stop polluting the River	-3	-4	0	**-4**
15 The mines should compensate the farmers because the waste from the mines kills their animals and plants	2	-1	-2	**-4**

Statement ranked lowest:

Statement	Q-score on factor			
	F1	F2	F3	**F4**

24 We need more laws in order to prevent further water pollution	-2	4	-4	**-5**

This group of stakeholders held the opinion that if things continue as they are, it might actually become too late to improve the quality of water in the Olifants River (18: -2), and call for changes in how water resources are managed, such as introducing an independent regulator to regulate water resources in order to improve efficiency (5: +5). These stakeholders agree that more government funding to municipalities will improve the capacity of the municipalities to maintain water quality (11: +2) if municipalities allocate more of that funding towards water quality improvement programmes (25: +3). Similarly, they perceive that further training of staff from Department of Water and Sanitation (Department of Water and Sanitation (DWS)) would also improve the capacity to tackle water quality issues (8: +4). DWS was perceived to be incapacitated as a water quality regulator, explaining why they thought an independent regulator might be more effective (8: +4, 5: +5). They also have the perception that giving incentives or rewards to users who pollute less would encourage sustainable water use (2: +3).

This group of stakeholders thought that stakeholders have a big role to play in ensuring water quality improvement, hence, regular stakeholder meetings are important in improving water quality (28: +3). The water supplier explained that this is "because stakeholders can engage one another on various ways to improve the quality of water in the Olifants River". They are also of the perception that the River is over allocated so new users must be prevented from using the river in order to ensure sustainability (20: +4).

This group of stakeholders is of the perception that there is no need for more laws in order to prevent water pollution (24: -5).

These stakeholders were of the opinion that water pollution coming from the mines was very minimal, with no need for them to compensate farmers (15: -4). The water supplier noted that mines in their area had invested in tools to ensure that they do not discharge harmful chemicals into the river system.

These stakeholders also did not see certification of farmers or improved garbage collection as measures that will prevent water pollution (26: -3, 27: -3).

Lastly, this factor represents the view that all manner of pollution is dangerous, whether it comes from domestic waste or acid mine drainage, where all types of water pollution must be treated as equally dangerous regardless of the source of that pollution (7: -2).

5.3.2 Consensus and disagreements about solutions to improve water quality

Consensus statements revealed the items over which the four extracted factors shared some similar perceptions. They were all of the opinion that it is important for all stakeholders to work together in improving water quality. Similarly, there was consensus that it is not too late to improve water quality in the Olifants River, as it is still possible to improve water quality. However, all stakeholders did not seem to be of the view that local people should decide on how best to manage the River. They also did not blame water users upstream for the water pollution downstream.

Finally, it was thought that a centralised water management authority would be effective in coordinating the different stakeholders, as it was generally agreed that the Olifants River catchment can be controlled by one body. The table below (Table 5.17) shows the consensus statements for the four perspectives with their corresponding Q-score values and Z-scores.

Table 5.17: Consensus statements for all four factors

Statement	Factors							
	1		2		3		4	
	Q-SV	Z-SCR	Q-SV	Z-SCR	Q-SV	Z-SCR	Q-SV	Z-SCR
14* Pollution will stop if only the people upstream stopped polluting	-3	-1.14	-2	-0.82	-3	-0.99	-2	-0.66
16* The Olifants River catchment is too big to be controlled by one body	-3	-0.94	-3	-1.11	-1	-0.3	-1	-0.33
18 The quality of water in the Olifants cannot be improved. It's too late	-4	-1.32	-5	-1.86	-4	-1.47	-2	-0.83
19* There is need for all stakeholders to work together to improve water quality	1	0.39	2	0.78	1	0.43	1	0.66
29* Local people should decide how best to manage the river	-1	-0.58	-3	-0.95	-1	-0.38	-3	-1.09

All listed statements are non-significant at p>0.01, and Those flagged with an * are also non-Significant at p>0.05

The following table (Table 5.18) shows statements deemed important by at least one factor, placed in descending order by standard deviation on their score. This means the table is running from statements showing most agreement to least agreement. The statements reveal that there seems to be general agreement on solutions that involve capacity building, regular meetings, sensitisation, and so forth. Disagreement start to build when solutions involve major policy changes like enforcing laws and redefining budgetary allocation.

Table 5.18: Solutions agreed with by at least one factor

SID	Statement	QS1	QS2	QS3	QS4	m	s
30	Capacity building of the municipality through training of staff to improve water quality management	1	1	4	2	0.9150	0.400
28	Regular stakeholder meetings are important in improving water quality	0	2	2	3	0.6075	0.456
1	Increased sensitisation to raise awareness about negative impacts of water pollution	0	3	3	1	0.6875	0.490
9	If all water users are affiliated and represented through a water user association, it will make them to use water more responsibly and reduce on pollution	2	4	0	1	0.7075	0.513
5	An independent regulator (not a government institution) will do a better job to control water pollution	4	0	4	5	1.2675	0.541
23	Department of Water Affairs should ensure that everyone is using the correct amount of water for the right purpose (validation and verification).	2	5	0	1	0.6625	0.621
17	The priority should be to prevent the effects of pollution on the environment	3	-3	-1	-1	-0.2000	0.703
7	First we must deal with the invisible pollution before we deal with the pollution we can see because the invisible pollution is the one that is mostly dangerous	3	0	1	-2	0.0825	0.731
2	Give incentives/rewards to water users who pollute less	0	-2	-1	3	-0.0150	0.764
4	Increase monitoring and enforcement of existing laws	5	0	2	2	0.8700	0.766
21	Those who pollute should pay all those who are affected by the pollution	3	0	-3	0	-0.1300	0.839
22	Those who pollute too much should stop using the river for a while	-1	-4	3	0	-0.2600	0.842
31	Educating farm workers about water quality to prevent water pollution	-2	3	3	0	0.3400	0.891
25	Municipalities should allocate more money to water quality improvement	-1	-1	-2	3	-0.1325	0.906
6	Department of water and sanitation should come up with ways of punishing water polluters	4	0	5	0	0.7675	0.953

8	Further training of staff from Department of Water and sanitation in issues of water quality	-2	3	0	4	0.4450	0.953
20	There is need to prevent new people from using the river. The bigger the number of people using the river, the higher the pollution	-4	1	-2	4	-0.0200	1.216
24	We need more laws in order to prevent further water pollution	-2	4	-4	-5	-0.6925	1.341

In terms of disagreements on solutions to improve water quality, the following table (Table 5.19) compiles a list of solutions with which at least two factors disagreed. The solutions are arranged form the most disagreeable to the most agreeable. Even though some factors disagreed with the idea of allocating more funding to municipalities, some stakeholders think it could be a good solution. Generally, all factors do not think the water pollution upstream solely responsible for the water pollution downstream. All stakeholders were also of the view that the Olifants River catchment is not too big for a centralised management authority such as a Catchment Management Agency to act as an authority to ensure sustainable management of the Olifants River. There is also a general disagreement about the need for more laws because stakeholders perceive that the current laws are enough, albeit the process of enforcing and monitoring is what needs to be enhanced.

Stakeholders do not place the blame of reduced raw water quality on the lack of piped water by households, which is why they disagree with the statement that if the majority of households have piped water, this would stop them polluting the River. It is also important to note that stakeholders did not think that local people should decide how best to manage the River. Lastly, all stakeholders are optimistic about the state of raw water quality in the Olifants River. As such, they did not agree that it is too late to improve the quality of water in the Olifants River.

Table 5.19: Statements disagreed with by at least two factors

SID	Statement	QS1	QS2	QS3	QS4	m	s	nneg
11	More government funding to the municipalities will improve water quality	-5	1	-3	2	-0.4550	1.253	2
14	Pollution will stop if only the people upstream stopped polluting	-3	-2	-3	-2	-0.9025	0.180	2
16	The Olifants River catchment is too big to be controlled by one body	-3	-3	-1	-1	-0.6700	0.360	2
24	We need more laws in order to prevent further water pollution	-2	4	-4	-5	-0.6925	1.341	2
29	Local people should decide how best to manage the river	-1	-3	-1	-3	-0.7500	0.283	2
10	If the majority of households have piped water, then they will stop polluting the river	-3	-4	0	-4	-1.0775	0.717	3
18	The quality of water in the Olifants River cannot be improved. It's too late	-4	-5	-4	-2	-1.3700	0.369	3

CHAPTER SIX : CONCLUSIONS AND RECOMMENDATIONS

As the human population grows and water scarcity cases increase, the demand for water, in quantity and quality, is on the rise. This has increased pressure on water resources to cater for the demands in irrigation, municipal water supply, recreation, wastewater management, among other numerous uses. Just as there is demand for numerous uses, the demand for water is also by numerous users. Thus, the need to prioritise water quality problems cannot be avoided, as has been shown by the results of this research.

This study was conducted in Maruleng and Fetakgomo municipalities in Limpopo Province of South Africa, to determine the perceptions of stakeholders about the most important ecosystem services provided by the Olifants River and the solutions needed to restore the ecosystem services that have deteriorated as a result of water pollution of the raw water in the river system. Through the use a Q methodological approach, the challenges and opportunities for improvement in the management of raw water quality were revealed and ranked in order of priority based on the opinions of the stakeholders identified in this study. Priority ecosystem services were identified, and the stakeholders expressed their opinions about the best approach to restore ecosystem services that have been hampered by water quality problems in the River.

These are the perceptions that were found. Firstly, stakeholders were concerned about the deterioration in water quality and how it affected ecosystem services provision by the Olifants river. In terms of importance of ecosystem services, three distinct groups of stakeholders were identified: the first group was of the view that the most important ecosystem services were those that created employment. The second group of stakeholders was of the view that the most important ecosystem services were those that provided ecosystem goods and services. Lastly, the third group of stakeholders had a mixed perspective, meaning that they ranked all categories of ecosystem services as most important.

The four perspectives that were revealed concerning the management of water quality were that polluters must be made accountable, better organisation is needed, more innovation is key and there is need for major changes in how water quality is managed. Therefore, policy interventions should be designed to incorporate these points of views.

This research answered the research problems by first identifying the stakeholders, finding out the ecosystem services they enjoyed from the Olifants River, their most important ecosystem services and how ecosystem service provision was disturbed by water pollution. The research also answered what perceptions were shared among stakeholders about water quality improvement.

It was found that three factors were extracted from the study about which ecosystem services were most important. This means that three distinct viewpoints about important ecosystem services were found amongst the stakeholders. Also, four distinct viewpoints were found about the best solutions to restore ecosystem services and prevent further water pollution in the Olifants River.

This research advocates for an approach that involves all stakeholders in the quest to improve water quality in the Olifants River. Advertently, engaging all the different stakeholders involved in the use and management of the water in the Olifants River. Future policy development must not assume the traditional top-down approach in formulating policy as this research has shown that stakeholders also hold strong opinions about how water resources should be managed, thereby excluding them in the process might not yield the intended results.

For future researchers, it is recommended that the research be extended to other areas in the Olifants river catchment beyond Maruleng and Fetakgomo municipalities, where the scope of this study covered. Additionally, the process of identifying stakeholders is generally iterative and non-exhaustive. Therefore, diversifying the categories of stakeholders or getting larger samples in future research would help to validate the research findings.

It is also useful to note that stakeholders revealed attributes about the Olifants River ecosystem that they regarded as most important. This information can be used to conduct non-market valuation methods used in Environmental Economics to determine the marginal changes in welfare to society caused by changes in the quality of water in the Olifants River.

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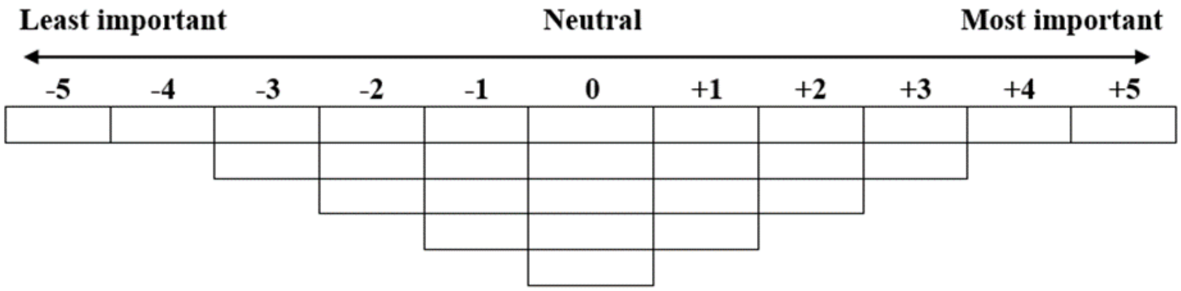
APPENDICES

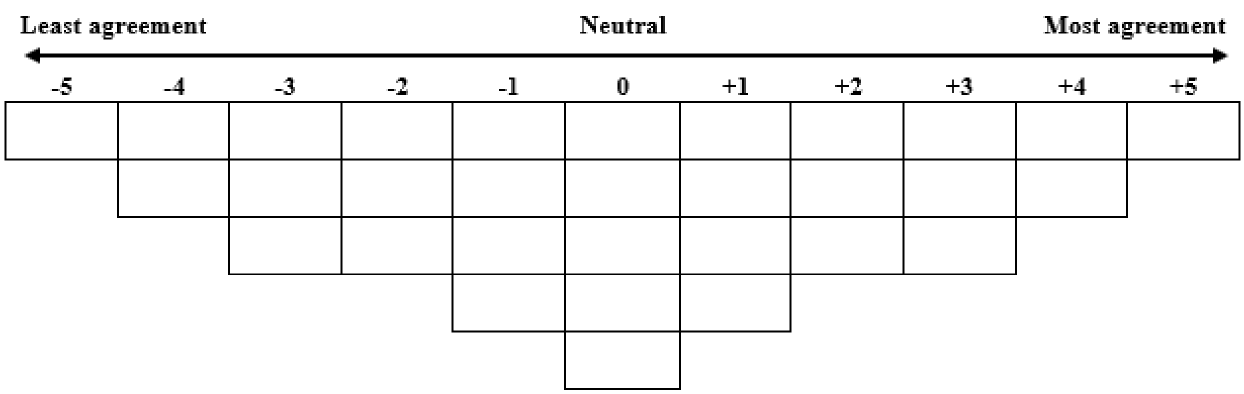
Appendix A: Definition of terminologies in Q-methodological study

Z-scores	The individual sorts that were flagged as the best representatives of the factor are aggregated or "averaged" into one set of statement scores, standardised to make cross-factor comparison of a statement possible
Factor Array	Represents the prototypical pattern of how statements would be ranked for that particular factor
Q-sorting	The process of arranging statements/items on the board based on whether it is positively agreeable or negative according to the participant's viewpoint
P-set	The participant group selected to take part in the study by doing the Q-sorts
Q-set	Set of all statements about the subject matter that need to be sorted
Q-sort	A rank order arrangement of the provided statements/items
Concourse	A collection of all possible statements containing all relevant ideas of the subject at hand
Q-Statement/Statement/Item	A short statement containing an opinion that participants can either be positive or negative about
Flagging	Highlighting those Q-sorts that load significantly on a factor, meaning that they are Q-sorts that highly associate with that factor (see Appendix D (c.))

Appendix B: Q-sorting pattern used to rank perceptions on important ecosystem services



Appendix C: Q-sorting pattern used to rank perceptions on solutions to restore ecosystem services and improve water quality



Appendix D: Formulas for calculations

(a.) Communality (h^2) of Q-sort = (Q-sort loading on factor 1)^2 + (Q-sort loading on factor 2)^2 +…………+ (Q-sort loading on factor N)^2
For example, a communality of 0.90 means that the Q-sort holds 90% in common with other Q-sorts in the study group

(b.) Eigenvalue for factor = (Q-sort 1 loading on factor 1)^2 X (Q-sort 2 loading on factor 1)^2 X…………X (Q-sort N loading on factor 1)^2
Eigenvalue is similar to communality, except it explains variance of a factor in relation to each factor rather than each Q-sort

(c.) Flagging algorithm used in PQMethod:

loading a is flagged,

if **(1)** $a^2 > h^2/2$, meaning that factor explains more than half of the common variance:

where h^2 = communality

and **(2)** $a > 1.96 / \sqrt{number\ of\ statements}$, meaning that the factor loading is significant at $p<0.05$

(d.) The factor weights:

This is calculated in 3-steps using only the Q sorts that loaded significantly on a factor as follows.

STEP 1: Initial factor weight for Q-sort = Factor loading/(1- Factor Loading^2)

STEP 2: Reciprocal of largest Factor weight from step 1

STEP 3: Multiply answer from step 1 by step 2

The factor weight is an indication of how much each Q-sort will contribute to the final factor estimate compared to the highest weighted Q-sort. The higher the final factor estimate, the higher the ranking on the Factor array.

(e.) Weighted score = Item ranking*Weight

The higher the weight score, the more positive the item is placed in the Factor array (within a factor)

(f.) Z-scores make it possible for cross-factor comparison by converting weighted scores for each statement into Z-scores (standard scores) using the following formula (Brown, 1980): Z-score for Item 1 (in relation to Factor 1) = (Total weighted score for Item 1 – Mean of Total weighted score for all items)/ Standard Deviation of Total Weighted scores for All items

Appendix E: Factor selection criteria

Eigenvalues

A factor's eigenvalue is calculated by summing the squared loadings of all the Q sorts on that factor. The sum of all eigenvalues is equal to the no of statements (N). So, the % of variance explained by that factor is obtained by dividing the eigenvalue by N (and multiply by 100)

The EV and % variance are closely related. Together, they offer us a clear indication of the strength and potential explanatory power of an extracted factor. Factor 1 currently accounts for 23.683 % of the common variance present in the study and hence around 24 % of everything that the Q sorts have in common.

Eigenvalues and the Kaiser–Guttman criterion

EV is indicative of a factor's statistical strength and explanatory power. It follows that low factor EVs – specifically EVs of less than 1.00 – are often taken as a cut-off point for the extraction and retention of factors. This is known as the Kaiser–Guttman criterion (Guttman, 1954; Kaiser, 1960, 1970). This cut-off point is used *because an extracted factor with an EV of less than 1.00 actually accounts for less study variance than a single Q sort* (Watts and Stenner, 2005a: note 7).

- The major plus point for this method is its general acceptance by the factor analytic community. A reviewer is very unlikely to object if you cite the Kaiser–Guttman criterion as your justification for extracting, and focusing on, X number of factors. EVs are a decent place to start when making this decision.
- On the downside, however, it is now widely accepted that this criterion often results in solutions containing an overly large number of factors, particularly in the context of larger data sets (Cattell, 1978; Kline, 1994; Wilson and Cooper, 2008). Brown agrees that this method can lead to the extraction of meaningless or 'spurious factors' (with eigenvalues greater than 1.00) although, in contrast to much of the literature, he also argues that it can lead to meaningful and 'significant factors' (with eigenvalues of less than 1.00) being left behind (1980: 222). **In fact, he goes so far as to suggest that "eigenvalues and total variance are relatively meaningless in Q-technique studies" (Brown, 1980).**

The Humphrey's rule: Two (or more) significantly loading Q sorts

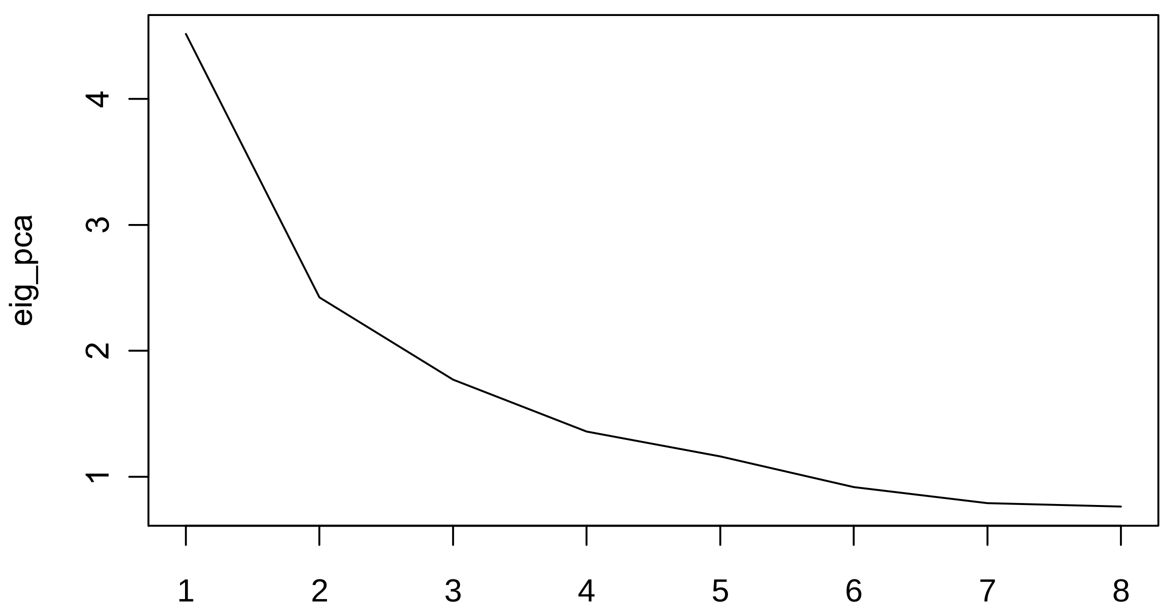
The rule is to accept those factors that have two or more significant factor loadings following extraction. A significant factor loading at the 0.01 level can be calculated using the following equation (Brown, 1980):

Factor loadings are correlation coefficients representing the degree to which a Q sort correlates with a factor. The standard error of a zero-order loading is given by the expression $SE_r = 1/\sqrt{No. statements}$

The Scree test

The Cattell's (1966) scree test.

An immediate word of warning though; despite the scree test being used frequently in factor analytic circles **it was designed for use only in the context of PCA**. A way around this, for purposes of Q methodology, is to run an initial PCA extraction on your data, taking note of the displayed component EVs (which will differ from those produced by a factor extraction). A scree test then involves the plotting of these EVs on a line graph. The number of factors to extract is indicated by the point at which the line changes slope.



Appendix F: PQMethod automatic generated flagging

Factor Matrix with an X Indicating a Defining Sort

Loadings

QSORT	1	2	3	4
1 1	0.4001X	0.0478	0.1772	-0.0761
2 2	0.2132	0.0377	0.7585X	0.0502
3 3	0.2438	0.1630	0.0081	0.4996X
4 4	0.6164X	0.2722	0.2496	0.2014
5 5	0.0199	0.2566	0.5365X	0.2358
6 6	0.5548	0.0075	0.1356	0.1811
7 7	0.6205X	-0.0369	-0.1973	-0.0280
8 8	0.0569	0.2447	0.0874	0.0373
9 9	0.0527	0.6440X	0.0718	0.0966
10 10	-0.0279	0.6256X	-0.1307	0.1527
11 11	0.1511	0.2772	0.3582	-0.2054
12 12	-0.0211	0.6780X	0.2922	0.0158
13 13	0.3431	-0.0947	0.3544	0.2475
14 14	0.5198X	-0.0369	0.2077	0.3110
15 15	0.6714X	-0.1804	0.4437	-0.1110
16 16	-0.0025	0.2188	0.1407	0.8327X
% expl.Var.	14	10	10	8

Appendix G: Z-scores for Factors 1, 2 and 3 (refer to Appendix 4 on calculation of Z-scores)

Factor Scores -- For Factor 1

No.	Statement	No.	Z-SCORES
7	Water for irrigation	7	1.591
4	Conservation of ecosystem	4	1.528
8	Water directly from the river for domestic use (washing, bat	8	1.118
5	Natural storage for water	5	0.968
26	Support plant growth processes (pollination and photosynthes	26	0.965
14	Water for industrial use (mining and manufacturing)	14	0.824
13	Water for municipality use to supply tap water	13	0.784
2	Preventing floods	2	0.750
11	Catching fish to eat or sell	11	0.717
6	Habitat for fish and wildlife	6	0.362
22	Recycling nutrients	22	0.356
27	Water cycle	27	0.308
23	Preventing damage to the environment (ecosystem resilience)	23	0.271
1	Maintenance of water quality by diluting pollutants	1	0.218
24	A special environment for rare species of plants and animals	24	0.196
25	Making the landscape more beautiful	25	-0.183
21	National pride of owning a clean river	21	-0.194
17	Traditional and religious rituals	17	-0.337
19	Research and education purposes	19	-0.438
16	Tourism of wildlife	16	-0.444
12	Plants, herbs and natural products	12	-0.686
20	A nice view to look at (aesthetic values)	20	-0.879
9	Water for power generation	9	-0.976
3	Control of soil erosion	3	-1.306
18	Fishing for fun	18	-1.362
10	Water transport (Boats and canoes)	10	-1.765
15	Boat cruise, water viewing and water games	15	-2.385

Factor Scores -- For Factor 2

No.	Statement	No.	Z-SCORES
8	Water directly from the river for domestic use (washing, bat	8	2.286
13	Water for municipality use to supply tap water	13	2.142
1	Maintenance of water quality by diluting pollutants	1	1.162
12	Plants, herbs and natural products	12	1.159
7	Water for irrigation	7	0.956
6	Habitat for fish and wildlife	6	0.866
26	Support plant growth processes (pollination and photosynthes	26	0.657
14	Water for industrial use (mining and manufacturing)	14	0.577
27	Water cycle	27	0.549
15	Boat cruise, water viewing and water games	15	0.309
11	Catching fish to eat or sell	11	0.160
19	Research and education purposes	19	0.122
4	Conservation of ecosystem	4	-0.069
5	Natural storage for water	5	-0.231
10	Water transport (Boats and canoes)	10	-0.314
17	Traditional and religious rituals	17	-0.384
21	National pride of owning a clean river	21	-0.430
23	Preventing damage to the environment (ecosystem resilience)	23	-0.510
16	Tourism of wildlife	16	-0.567
24	A special environment for rare species of plants and animals	24	-0.819
20	A nice view to look at (aesthetic values)	20	-0.822
25	Making the landscape more beautiful	25	-0.848
2	Preventing floods	2	-0.849
22	Recycling nutrients	22	-0.998
9	Water for power generation	9	-1.057
3	Control of soil erosion	3	-1.451
18	Fishing for fun	18	-1.597

Factor Scores -- For Factor 3

No.	Statement	No.	Z-SCORES
9	Water for power generation	9	1.965
3	Control of soil erosion	3	1.411
13	Water for municipality use to supply tap water	13	1.242
5	Natural storage for water	5	1.218
26	Support plant growth processes (pollination and photosynthes	26	1.110
2	Preventing floods	2	1.049
1	Maintenance of water quality by diluting pollutants	1	0.940
14	Water for industrial use (mining and manufacturing)	14	0.748
7	Water for irrigation	7	0.663
21	National pride of owning a clean river	21	0.555
12	Plants, herbs and natural products	12	0.470
27	Water cycle	27	-0.085
8	Water directly from the river for domestic use (washing, bat	8	-0.193
16	Tourism of wildlife	16	-0.193
25	Making the landscape more beautiful	25	-0.193
23	Preventing damage to the environment (ecosystem resilience)	23	-0.277
10	Water transport (Boats and canoes)	10	-0.386
19	Research and education purposes	19	-0.555
6	Habitat for fish and wildlife	6	-0.579
15	Boat cruise, water viewing and water games	15	-0.663
17	Traditional and religious rituals	17	-0.748
22	Recycling nutrients	22	-0.832
4	Conservation of ecosystem	4	-0.917
24	A special environment for rare species of plants and animals	24	-0.940
11	Catching fish to eat or sell	11	-1.242
18	Fishing for fun	18	-1.604
20	A nice view to look at (aesthetic values)	20	-1.965

Appendix H: Z-Scores for factors 1, 2, 3 and 4

Factor Scores -- For Factor 1

No.	Statement	No.	Z-SCORES
4	Increase monitoring and enforcement of existing laws	4	2.051
5	An independent regulator (not a government institution) will	5	1.686
6	Department of water and sanitation should come up with ways	6	1.286
21	Those who pollute should pay all those who are affected by t	21	1.087
7	First we must deal with the invisible pollution before we de	7	0.931
17	The priority should be to prevent the effects of pollution o	17	0.911
15	The mines should compensate the farmers because the waste fr	15	0.829
9	If all water users are affiliated and represented through a	9	0.819
23	Department of Water Affairs should ensure that everyone is u	23	0.750
27	Improved garbage collection will prevent domestic waste (suc	27	0.474
30	Capacity building of the municipality through training of st	30	0.468
3	Invest in tools to detect water pollution	3	0.396
19	There is need for all stakeholders to work together to impro	19	0.389
12	Naming and shaming polluters encourages people to stop pollu	12	0.331
13	Improving the quality of water will be expensive	13	0.297
2	Give incentives/rewards to water users who pollute less	2	0.284
1	Increased sensitization to raise awareness about negative im	1	0.150
28	Regular stakeholder meetings are important in improving wate	28	-0.164
25	Municipalities should allocate more money to water quality i	25	-0.447
26	All commercial farmers should be certified by SA GAP or Glob	26	-0.520
29	Local people should decide how best to manage the river	29	-0.577
22	Those who pollute too much should stop using the river for a	22	-0.733
24	We need more laws in order to prevent further water pollutio	24	-0.739
8	Further training of staff from Department of Water and sanit	8	-0.817
31	Educating farm workers about water quality to prevent water	31	-0.919
16	The Olifants river catchment is too big to be controlled by	16	-0.935
14	Pollution will stop if only the people upstream stopped poll	14	-1.136
10	If the majority of households have piped water, then they wi	10	-1.210
18	The quality of water in the Olifants cannot be improved. It’	18	-1.317
20	There is need to prevent new people from using the river. Th	20	-1.609
11	More government funding to the municipalities will improve w	11	-2.017

Factor Scores -- For Factor 2

No.	Statement	No.	Z-SCORES
23	Department of Water Affairs should ensure that everyone is u	23	1.625
24	We need more laws in order to prevent further water pollutio	24	1.475
9	If all water users are affiliated and represented through a	9	1.430
8	Further training of staff from Department of Water and sanit	8	1.313
1	Increased sensitization to raise awareness about negative im	1	1.230
31	Educating farm workers about water quality to prevent water	31	1.186
28	Regular stakeholder meetings are important in improving wate	28	0.980
26	All commercial farmers should be certified by SA GAP or Glob	26	0.818
19	There is need for all stakeholders to work together to impro	19	0.784
11	More government funding to the municipalities will improve w	11	0.724
30	Capacity building of the municipality through training of st	30	0.723
20	There is need to prevent new people from using the river. Th	20	0.601
27	Improved garbage collection will prevent domestic waste (suc	27	0.430
5	An independent regulator (not a government institution) will	5	0.355
4	Increase monitoring and enforcement of existing laws	4	-0.093
7	First we must deal with the invisible pollution before we de	7	-0.290
21	Those who pollute should pay all those who are affected by t	21	-0.357
6	Department of water and sanitation should come up with ways	6	-0.418
15	The mines should compensate the farmers because the waste fr	15	-0.452
13	Improving the quality of water will be expensive	13	-0.506
25	Municipalities should allocate more money to water quality i	25	-0.584
3	Invest in tools to detect water pollution	3	-0.667
14	Pollution will stop if only the people upstream stopped poll	14	-0.819
12	Naming and shaming polluters encourages people to stop pollu	12	-0.863
2	Give incentives/rewards to water users who pollute less	2	-0.873
29	Local people should decide how best to manage the river	29	-0.947
17	The priority should be to prevent the effects of pollution o	17	-1.035
16	The Olifants river catchment is too big to be controlled by	16	-1.107
22	Those who pollute too much should stop using the river for a	22	-1.152
10	If the majority of households have piped water, then they wi	10	-1.649
18	The quality of water in the Olifants cannot be improved. It’	18	-1.864

Factor Scores -- For Factor 3

No.	Statement	No.	Z-SCORES
6	Department of water and sanitation should come up with ways	6	2.034
30	Capacity building of the municipality through training of st	30	1.554
5	An independent regulator (not a government institution) will	5	1.345
31	Educating farm workers about water quality to prevent water	31	1.169
1	Increased sensitization to raise awareness about negative im	1	1.122
22	Those who pollute too much should stop using the river for a	22	1.089
27	Improved garbage collection will prevent domestic waste (suc	27	0.993
28	Regular stakeholder meetings are important in improving wate	28	0.689
4	Increase monitoring and enforcement of existing laws	4	0.689
7	First we must deal with the invisible pollution before we de	7	0.608
19	There is need for all stakeholders to work together to impro	19	0.433
26	All commercial farmers should be certified by SA GAP or Glob	26	0.433
12	Naming and shaming polluters encourages people to stop pollu	12	0.399
10	If the majority of households have piped water, then they wi	10	0.128
3	Invest in tools to detect water pollution	3	0.000
9	If all water users are affiliated and represented through a	9	0.000
23	Department of Water Affairs should ensure that everyone is u	23	-0.048
8	Further training of staff from Department of Water and sanit	8	-0.128
16	The Olifants river catchment is too big to be controlled by	16	-0.304
29	Local people should decide how best to manage the river	29	-0.385
17	The priority should be to prevent the effects of pollution o	17	-0.433
2	Give incentives/rewards to water users who pollute less	2	-0.561
20	There is need to prevent new people from using the river. Th	20	-0.656
15	The mines should compensate the farmers because the waste fr	15	-0.865
25	Municipalities should allocate more money to water quality i	25	-0.913
14	Pollution will stop if only the people upstream stopped poll	14	-0.993
21	Those who pollute should pay all those who are affected by t	21	-1.250
11	More government funding to the municipalities will improve w	11	-1.345
24	We need more laws in order to prevent further water pollutio	24	-1.426
18	The quality of water in the Olifants cannot be improved. It’	18	-1.473
13	Improving the quality of water will be expensive	13	-1.906

Factor Scores -- For Factor 4

No.	Statement	No.	Z-SCORES
5	An independent regulator (not a government institution) will	5	1.667
20	There is need to prevent new people from using the river. Th	20	1.591
8	Further training of staff from Department of Water and sanit	8	1.421
25	Municipalities should allocate more money to water quality i	25	1.414
2	Give incentives/rewards to water users who pollute less	2	1.086
28	Regular stakeholder meetings are important in improving wate	28	0.922
30	Capacity building of the municipality through training of st	30	0.915
11	More government funding to the municipalities will improve w	11	0.833
4	Increase monitoring and enforcement of existing laws	4	0.833
19	There is need for all stakeholders to work together to impro	19	0.663
9	If all water users are affiliated and represented through a	9	0.581
23	Department of Water Affairs should ensure that everyone is u	23	0.335
1	Increased sensitization to raise awareness about negative im	1	0.246
6	Department of water and sanitation should come up with ways	6	0.171
12	Naming and shaming polluters encourages people to stop pollu	12	0.164
21	Those who pollute should pay all those who are affected by t	21	-0.000
31	Educating farm workers about water quality to prevent water	31	-0.082
22	Those who pollute too much should stop using the river for a	22	-0.246
17	The priority should be to prevent the effects of pollution o	17	-0.253
16	The Olifants river catchment is too big to be controlled by	16	-0.335
13	Improving the quality of water will be expensive	13	-0.499
3	Invest in tools to detect water pollution	3	-0.587
14	Pollution will stop if only the people upstream stopped poll	14	-0.663
18	The quality of water in the Olifants cannot be improved. It’	18	-0.833
7	First we must deal with the invisible pollution before we de	7	-0.915
26	All commercial farmers should be certified by SA GAP or Glob	26	-1.004
29	Local people should decide how best to manage the river	29	-1.086
27	Improved garbage collection will prevent domestic waste (suc	27	-1.332
15	The mines should compensate the farmers because the waste fr	15	-1.338
10	If the majority of households have piped water, then they wi	10	-1.585
24	We need more laws in order to prevent further water pollutio	24	-2.083

Appendix I: Pilot study

This study involved a pilot study that made use of the Q methodology technique just as has been outlined. The pilot study involved the steps of constructing a concourse, selecting a Q-set, P-set selection, Q-sorting and Q-analysis. Then the results, lessons picked up from the study and participants’ comments in the exit interviews were incorporated into the refining of the Q statements that were used for the main study. The process of conducting the pilot study was done as a learning process to strengthen the validity and effectiveness of the final study. This section briefly outlines how the pilot study was conducted.

Statement selection (Q-set) for the pilot study

This stage involved the compilation of the "Q statements" or Q-set, which is a full spectrum of opinions about the research topic with each statement written separately on a card (Paige & Morin, 2016). The Q-set was based on the information gathered from the concourse.

Each card contained a statement about the research topic expressed by one of the stakeholders during the concourse selection. This statement does not necessarily have to be fact, but it should be a relevant opinion that expresses a participant's subjective view (Watts & Stenner, 2012). A total of 52 statements were collected about the problems associated with raw water management in the Olifants River. The other Q-set contained a set of 31 statements about solutions to improve the management of raw water quality.

Selection of participants (P-set) for the pilot study

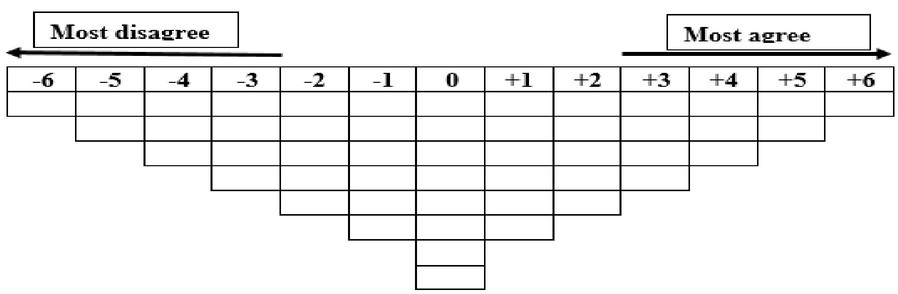
The participants (P-set) were be purposively selected in a way that they were representative of the variety of stakeholders involved in the study and were relevant to the research question. According to Watts and Stenner (2012), it is suggested that a minimum of one participant should be recruited for every two Q statements. This assertion is more a rule of thumb than a technique backed by theory. In theory, Q methodology does not require a large sample to produce robust and externally valid results as long as the participants making the P-set are enough to establish the existence of common perspectives (factors) for purposes of comparing one factor with another (Živojinović & Wolfslehner, 2015). As Brown (1993) stresses in his paper that the interest of Q methodology is in the nature of segmented views and how people's views are similar or dissimilar to one another, thus it is not necessary to have a large sample of respondents. Therefore, a total of 18 participants were used for the pilot study. These participants were representative of the range of the types of stakeholders already identified in the stakeholder identification stage.

Q-sorts and exit interviews for the pilot study

Each respondent completed two Q-sorts, one with 52 statements and the other with 31 statements. The Q-sort with 52 statements was about the problems of raw water quality in the Olifants River while the one with 31 statements was about the solutions to improve raw water quality in the Olifants River.

A Q-sort consists of a grid with columns and rows that respondents were asked to place the cards containing the statements (Q-set). The cards are supposed to be placed in a rank-order from what they most agree with to what they most disagree with (Watts & Stenner, 2012) in a forced normal distribution arrangement.

Participants were asked to place the cards in three different bundles of “agree”, “disagree” and “neutral” depending on whether they agreed, disagreed or were neutral about each statements. After that, the respondents was asked to place the cards on a board like the one shown below, according to the extent to which they agree with the statement (+6 being “most agree” and -6 being “least agree”). Each statement card was placed in its own box until all the statements filled the forced normal distribution as shown in the Q-sort below.



Example of Q-sort

Each respondent completed two separate Q-sorts. In the exit interviews, the participants were also asked to explain why they agreed or disagreed with certain statements and what statements they felt should have been included or excluded from the study.

Demographic data of the respondents was also collected. Demographic data included participants’ age, gender, educational level and their main source of water for their day-to-day usage. Exit interviews were conducted to understand the participant’s thought process in arranging the Q-sort in that particular pattern so as to help in explaining the different viewpoints during the analysis and factor interpretation.

Data analysis and factor interpretation of the pilot study

All the Q-sorts were recorded and analysed using PQMethod, a software which is specifically designed to analyse Q methodological data (Yarar & Orth, 2018). Factor analysis was done on by-person basis to identify groups whose Q-sorts are correlated to determine which groups of respondents shared perceptions on raw water quality and its management in Maruleng and Fetakgomo.

The results extracted two factors on the problems of raw water quality in the Olifants, meaning that there were two distinct perspectives held by stakeholders about the problems of raw water quality. Meanwhile, the analysis of the solutions to improve raw water quality revealed four different perspectives extracted from the analysis.

Appendix J: Questionnaire and Q-sort

PART 1: Ecosystem services Q-sort

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5

PART 2: Status of ecosystem services

Ecosystem service	At desired level (Yes/No)	Describe why ecosystem service is at this level

PART 3: Q-sort for solutions to restore ecosystem services

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5

PART 4: Demographic data

i.) Age …………
ii.) Sex …………..
iii.) Occupation/Department ………………………………….
iv.) Education level……………………………………………
v.) Main water source………………………………………...

PART 5: Exit interview

1. Why do you most agree with the statement/s?

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2. Why do you most disagree with the statement/s?

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3. What interesting thing/s did you notice about the statements?

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