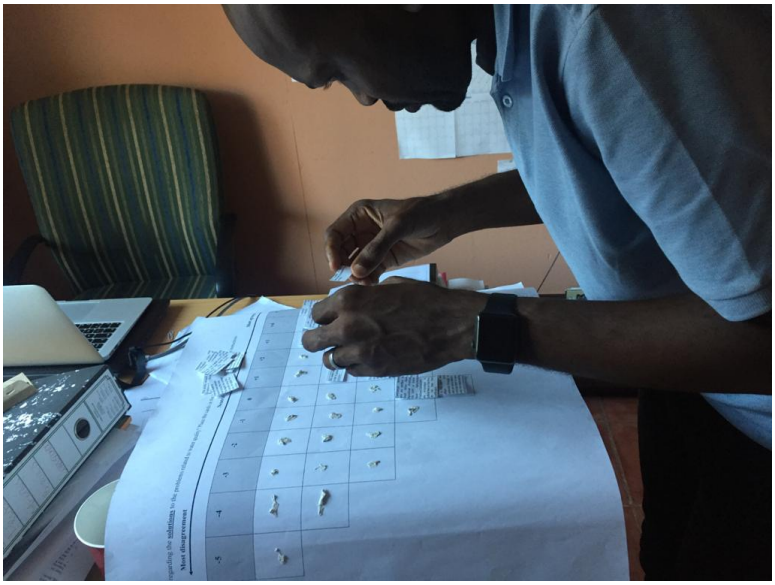

# Water Quality and Water Related Ecosystem Services in the Olifants - South Africa: A qualitative approach

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# Background

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# Introduction

## 1.1 Water Quality issues in the Olifants

South Africa is a water scarce country and the South African government acknowledges that water is a critical ingredient to achieve growth and development (Funke et al., 2007). The National Water Act – NWA (Act 36 of 1998) was enacted to regulate all water uses in the country and its main goal is the sustainable management of the water resources. It states that water should be protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner for the benefit of all. In addition, the National Water Resource Strategy (NWRS) serves 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 and Pietersen, 2004). These regulatory efforts are aimed at protecting water resources and improving the state of the country's water quality. The Olifants river catchment (Figure 1.1) is one of the six major Lowveld river systems of South Africa, occupying an area of around 54,000 $km^2$ (Gyamfi et al., 2016). It is one of South Africa's most important water resources (Dabrowski and de Klerk, 2013). However, the Olifants have also been identified as the most polluted water management area in the country (Kyei and Hassan, 2019). About 3.5 million people live on the South African side of the catchment. Its waters must meet the competing demands of mining, commercial farm irrigation, residential development, industrial use,

and the maintenance of ecological balance (Nieuwoudt et al., 2004). In addition, there is a general decline in the operation and management of waste-water treatment infrastructure, especially sewage treatment (Department of Water Affairs, 2011).

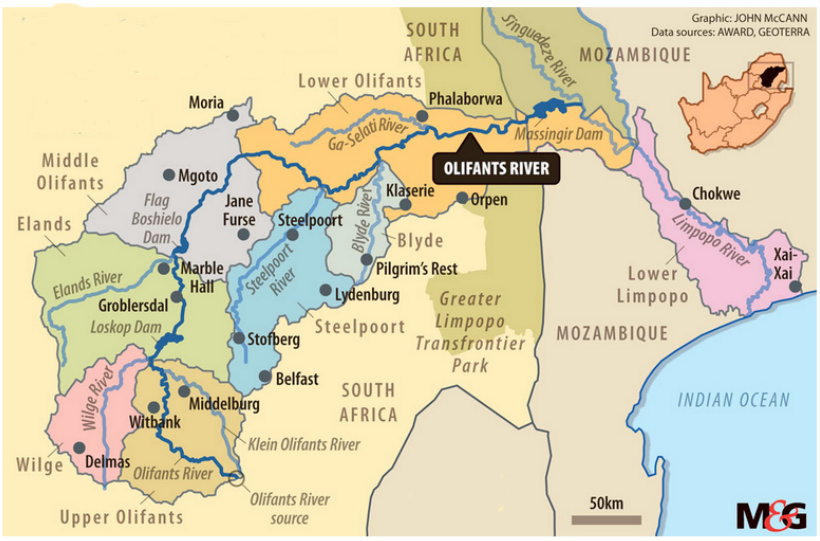


Figure 1.1: The Olifants river catchment

The pollution is reducing water-related systems' capacity to provide important ecosystem services (WES). CSIR (2011), De Villiers and Mkwelo (2009), and Ashton (2010) described the Olifants river as one of the most threatened river systems in South Africa with a declining population of fish, crocodiles and other aquatic life which could be related to the increasing levels of pollution. Case in point is the death of Nile crocodiles in the Kruger National Park in the years 2008, 2009, and 2010 (Lane et al., 2013). The Olifants rivers contains various human health-threatening substances such as heavy metals, acids, radioactive compounds, sulfates, 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. The concentration of these pollutants was reported to exceed the World Health Organization (WHO) guidelines for safe levels of intake by humans (Genthe et al., 2018). 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 wastes and mining effluents.

Dabrowski and de Klerk (2013) also found high nutrient concentrations, a condition likely to support a dense plant population leading to the death of aquatic animals by depriving them of oxygen. The high level of nutrients was emanating from sewage discharge from waste-water treatment works and run-off fertilizers from irrigation farms. Nutrient-enriched water bodies are susceptible to mass growth of toxic aquatic vegetation which is a health risk to humans and aquatic life alike, and reduces water resources available for drinking, irrigation and leisure activities (Codd, 2000). Other pollutants found by Dabrowski and de Klerk (2013) included sulfates, dissolved salts and metals, especially near mining sites. The concentration found was usually higher that the threshold concentrations set out in the South African water quality guidelines.

Acid mine drainage (AMD) also constitutes an important source of pollution in the Olifants. AMD has been described as the "single greatest threat to South Africa's water-scarce environment" (Sharife, 2011). The issues related to AMD in South Africa are well summarized by Kinna (2016a):

> One of the country's most highly publicized, politically sensitive, long-lasting and expensive forms of freshwater contamination, posing a threat to potable water but also industrial and agricultural sectors, many of which are water-intensive, including mining (...)
>
> A legacy of poorly regulated opencast mining, conducted especially during the 1970s and 1980s, has left much of the environment adjacent to the Olifants River severely impacted, most prominently by AMD pollution (...)
>
> With many of these mines now abandoned or closed, and without proper maintenance or monitoring, uncontrolled discharges of water from mines are resulting in subsoil leaching into the local groundwater as well as unimpeded and/or untreated toxic acid mine spillage into surface waters (...)
>
> (Kinna, 2016a)

Overall, the different studies show that the rivers contained too many nutrients leading potentially to eutrophication, and high levels of pollutants potentially harmful for humans and wildlife. Most of the pollution has been attributed to various human activities such as mining waste discharged into the river, run-off of pesticides and fertilizers,

sewage waste, acid mine water, and industrial refuse.

The various population groups living in the Olifants Catchment rely on the river and the catchment's natural biodiversity for their livelihoods – either directly or indirectly. Rural communities rely on it for things such as traditional medicine, grazing and browse, fuel, food and housing materials. River-side communities harvest reeds collect water from the river for washing and drinking and use it for recreational and spiritual practices. Subsistence farmers in Mozambique rely heavily on the Catchment's flood plains. There are also large mines and associated industries, large scale agriculture and the wildlife economy, also relying on a healthy, functioning river system.

## 1.2 A National and Trans-boundary Issue

The Olifants river catchment is part of the Limpopo River Basin, an international drainage basin that stretches across South Africa, Mozambique, Zimbabwe and Botswana (Figure 1.2).

In Mozambique, the river is known as the "Rio dos Elefantes", and it flows through the Gaza Province, which is home to about 700,000 people. It then flows into the Limpopo. The subsistence farmers rely heavily on the Catchment's flood plains, but as in South Africa, the population at large rely on the river and the catchment's natural biodiversity for their livelihoods – either directly or indirectly.

Due to the trans-boundary nature of the catchment, poor water management in South Africa, is likely to have negative impacts in Mozambique; this is particularly true for water quality management. However, in the case of the Olifants, a large part of the pollution is occurring in the upper-part of the catchment, with intensive mining activities and commercial agriculture. As such, South Africa faces the double incentive to better manage the quality of the Olifants waters: the first one is to improve the well-being of its own citizens, the second one is to avoid polluting neighboring countries (Kinna, 2016b).

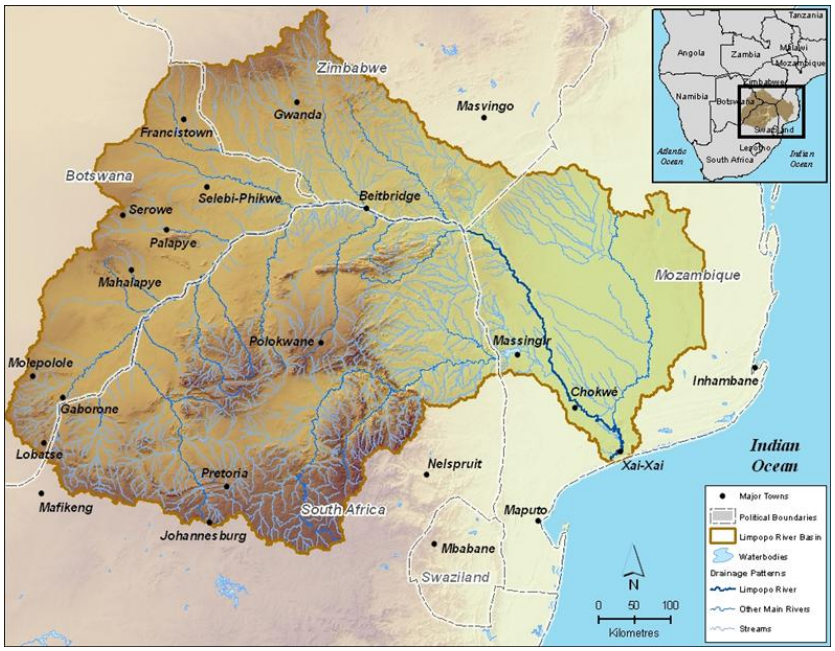


Figure 1.2: The Limpopo River Basin

## 1.3 Problem statement

In South Africa, despite extensive legislation formulated to ensure sustainable use of the water, the quality of waters of the Olifants river catchment are not adequate.

Given the diversity of stakeholders benefiting directly or indirectly from the water related ecosystem services of the Olifants catchment, water pollution issues in the Olifants hold many of the characteristics of a wicked problem (See Box 1 for a definition of wicked problems):

1. A large set of stakeholders, having different interests about the services provided, holding different views about the definition of the problems, and different views about the solutions,
2. A wide range of causes and effects leading to poor water quality; complex causality from multiple pollution sources; long lag times in system response.
3. Ecosystems are complex to manage, and we have a poor understanding of the mechanisms and of the possible solutions.

4. A separation in space and time between the creation and consequences of pollution. Decoupling pollution decisions from impacts reduces the likelihood of self-regulating feed-backs that would change management practices when negative impacts arise, such as political pressure to control local pollution. See, for example, our earlier discussion about AMD where pollution arises from mines that are already closed and without owners.
5. Although we can learn by doing, the consequences of each trial are very large given the number of persons affected.

Given these characteristics, there is neither a public policy nor a technological solution that can rapidly reduce pollution levels and restore affected ecosystems of the Olifants. However, this does not mean that nothing can be done about water pollution in the Olifants. A number of solutions have been suggested in the literature (DeFries and Nagendra, 2017; Conklin, 2005; Kumlien and Coughlan, 2018; Carter, 2019). Two of them seem particularly relevant to the issues of water pollution in the Olifants.

First, the involvement stakeholders is seen as a particularly important step (Camillus, 2008). In particular, a better understanding the perspectives of diverse stakeholders contributes to reduce the wickedness of ecosystem management (Head, 2008; Rissman and Carpenter, 2015). As mentioned by Rissman and Carpenter (2015), "Ecosystem management decisions that may seem to be a simple matter of setting scientific limits on resource use frequently fail because of the political process of decision-making, differing values and norms, and power imbalances." Camillus (2008) also suggested that "The aim should be to create a shared understanding of the problem and foster a joint commitment to possible ways of resolving it. Not everyone will agree on what the problem is, but stakeholders should be able to understand one another positions well enough to discuss different interpretations of the problem and work together to tackle it". The research reported here should be seen as the first steps in that direction.

Second, the ecosystem services affected by pollution are often public and non-marketed goods and changes in these ES are not factored into the individual and governmental decisions. Therefore, there is a need to progress in the identification of the WES provided by the water ecosystems of the Olifants. A first step in that direction will be to identify which, among the different services provided by the water ecosystems, are perceived

as most important by the different stakeholders. This information will be needed for subsequent valuation studies (Armatas et al., 2014; Jensen, 2019).

**Box 1: Wicked problem**

The first identification of a *wicked problem* emanated from researchers studying social problems. They identified 10 properties that separated wicked problems from hard but ordinary problems (Rittel and Webber, 1973; Camillus, 2008):

1. It's not possible to write a well-defined statement of the problem
2. The search for solutions never stops, since you can not tell when you've reached a solution
3. Solutions to wicked problems are not true or false, but good or bad. Choosing a solution to a wicked problem is largely a matter of judgment.
4. There is no immediate and no ultimate test of a solution to a wicked problem. Solutions to wicked problems generate unexpected consequences over time, making it difficult to measure their effectiveness.
5. There is no opportunity to learn by trial and error, every attempt has consequences that cannot be undone.
6. Wicked problems do not have an exhaustively describable set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
7. Every wicked problem is essentially unique and experience does not help you address it.
8. Every wicked problem can be considered to be a symptom of another problem. While an ordinary problem is self-contained, a wicked problem is entwined with other problems. However, those problems don't have one root cause.
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. A wicked problem involves many stakeholders, who all will have different ideas about what the problem really is and what its causes are.
10. The planner has no right to be wrong. Problem solvers dealing with a wicked issue are held liable for the consequences of any actions they take, because those actions will have such a large impact and are hard to justify.

## 1.4 Objectives of the study

The short term objective of our study is to document the consensus and distinct views about the water quality and the ecosystem services provided by water-related ecosys-

tems in the Olifants.

In particular, we will investigate the stakeholders' views about:

1. the main issues related with raw water quality in the Olifants
2. the main solutions to improve raw water quality in the Olifants
3. the relative importance of water-related ecosystem services they derived from the Olifants
4. the state of the ecosystem services provision and how they relate the state of WES with the quality of raw waters in the Olifants
5. the possible policy instruments to restore ecosystem service provision in the Olifants

This will help answering the following research questions:

1. What are the main water quality issues in the Olifants?
2. What do stakeholders regard as the solutions to improve water quality in the Olifants?
3. What views are common and what views are divergent among the stakeholders as far as improving water quality in the Olifants is concerned?
4. What ecosystem services do stakeholders see as most important for themselves?
5. What is the state of ecosystem services in the Olifants river and how the service levels relate to the current raw water quality.
6. What WES would need further research, especially to determine their economic values?
7. What views are common and what views are divergent among the stakeholders as far as improving ecosystem services in the Olifants is concerned?

Over the long term, we believe it will help create a shared understanding of the problem to solve this complex wicked problem. In particular, stakeholders should be able to understand the different positions well enough to discuss different interpretations of the problem and work together to tackle it. We also believe it can form a strong basis for a serious economic valuation of the ecosystem services identified here.

## 1.5 Structure of the report

The rest of the report is organized as followed.

The second part of the document is dedicated to the methodologies employed. In Chapter 2 we present the rationale that led us to select the two municipalities where the surveys were conducted and described them briefly. In Chapter 3 we describe in details the differents steps of a Q-methodology (from initiation to data analysis). In Chapter 4 we describe the different activities that have been conducted, i.e. give more details about the two surveys that were conducted.

The third part of the report is presenting the different results obtained. In Chapter 5 we present and discuss the consensus and distinguishing views about water pollution issues in the Olifants. This corresponds to the first objective. In Chapter 6 we present and discuss the consensus and distinguishing views on how to solve water pollution issues. This corresponds to the second objective. The Chapter 7 is dedicated to the WES in the Olifants; it is subdivided into three main sections. In Section 7.1, we present and discusss the consensus and distinguishing views on the relative importance of water-related ecosystem services of the Olifants, i.e. which of the services stakeholders viewed as most important to them. This corresponds to our third objective. In Section 7.2 we present the results about the perceptions about the current state of selected ecosystem services. This corresponds to our fourth objective. In Section 7.3 we discuss which ecosystem services would need to be further investigated and valued. This section should be viewed as adressing our sixth research question.
In the Chapter 8, we present the results about the consensus and distinguishing views about the policy instruments that could be used to restore ecosystem services in the Olifants.

The last part wrap-up the findings and draw some conclusions about future research needed and policy implications.

# Part II

# Methodology

# Chapter 2

# Study site selection

The criteria for selectiing the study locations were:

- closeness to the Olifants river (point source)
- closeness to the national borders to capture trans-boundary issues arising from the use a shared natural resource
- increasing distance from major sources of pollution (mainly in the upper-catchment area).

Thus, we purposely selected the two municipalities of Maruleng and Fetakgomo (Figure 2.1).

With an area of 324,699 ha, Maruleng is the smallest municipality of the Mopani district of the Limpopo province. It is bordered by the Kruger National Park to the east, so it is the last inhabited municipality along the Olifants river before it crosses to Mozambique. In 2011, it had a population of 94,857 people, of which 95% were black African. The town of Hoedspruit is considered the administrative and economic centre of the area (Statistics South Africa, 2019b). The dominant economic activity in Maruleng is commercial agriculture (Maruleng Municipality, 2017). The Fetakgomo municipality is located in Greater Sekhukhune district of the Limpopo province. In 2011, it had a population of 93,795 of which 99.4% were black African. Since then it has been merged with the Greater Tubase municipality.

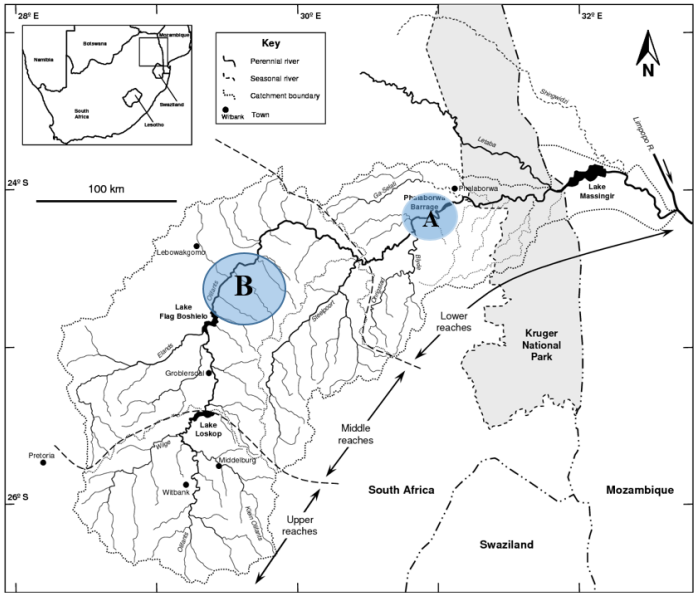


Figure 2.1: Map showing approximate location of study areas: A=Maruleng, B=Fetakgomo. Adapted from Ashton (2010)

Both municipalities had similar population structures in terms of size, gender ratio (82 and 85 respectively), and education levels (Table 2.1). The gender ratio is suggesting that men have moved outside the municipalities, most likely for seeking jobs. The education levels, with around 46% of the population did not complete primary education, are equally low in the two municipalities.

The municipalities are located close to the Olifants river, therefore many households collect their water from the river and its tributaries (Radingoana et al., 2019). This is particularly true of the Maruleng municipality where 28% of the households get their water from rivers and streams (Table 2.2).

However, the two municipalities are contrasted in terms of water sources and water access (Tables 2.2, 2.3). The Fetakgomo municipality gets more than 60% of the water it consumes from regional of local schemes whereas Maruleng relies only of these schemes for 30% of water uses. While the delivery of water trough schemes seems an advantage, it may also hide that the delivery of water through these schemes may not be very reliable. Many households mentioned the water received through those schemes was very

Table 2.1: Levels of education

| Group | Maruleng | Fetakgomo |
|---|---|---|
| No Schooling | 2.1 | 2.4 |
| Some Primary | 44.6 | 44.3 |
| Completed Primary | 5.8 | 6.0 |
| Some Secondary | 38.1 | 38.1 |
| Completed Secondary | 8.6 | 7.6 |
| Higher Education | 0.7 | 0.8 |

Source: Census 2011 (Statistics South Africa, 2019a,b)

Table 2.2: Sources of water

| Source of water | Maruleng | Fetakgomo |
|---|---|---|
| Regional/Local water scheme (a) | 33.50 | 61.70 |
| Borehole | 18.10 | 10.00 |
| Rain water tank | 0.90 | 2.80 |
| Dam/Pool/Stagnant water | 11.30 | 6.40 |
| River/Stream | 28.30 | 11.00 |
| Water vendor / tanker | 4.70 | 5.60 |
| Other | 3.20 | 2.50 |

(a) Operated by municipality or other water services provider)

Source: Census 2011 (Statistics South Africa, 2019a,b)

irregular (water is not delivered in large quantities and is not reaching them every day). The Table 2.3 also shows that there is a higher percentage of household having access to piped water reaching their dwellings or at least their houses in Maruleng, while in Fetakgomo the access is more likely to be through public taps.

Table 2.3: Type of access to water

| Local municipality | Piped water inside the dwelling | Piped water inside yard | Piped water on community stand | Borehole | Rain-water tank in yard | Neighbour tap | Public / communal tap |
|---|---|---|---|---|---|---|---|
| Maruleng | 13.2 | 38.6 | 25.4 | 8.9 | 0.6 | 7.1 | 6.3 |
| Fetakgomo | 4.6 | 26.0 | 25.7 | 11.1 | 4.0 | 9.2 | 19.3 |
| Limpopo | 14.4 | 39.2 | 17.4 | 11.3 | 1.0 | 6.9 | 9.8 |

Source: Community Census 2016 (Statistics South Africa, 2018)

# Chapter 3

# Q-methodology steps

This study used a Q methodology approach to elicit stakeholders' perceptions about water quality, important ecosystem services rendered by rivers of the catchment and the management of raw water quality in the Olifants river.

The data collection process of the Q methodology followed a typical five-steps procedure that includes (Watts and Stenner, 2012):

1. the concourse development,
2. the selection of the statements to be sorted[1],
3. the selection of the respondents[2],
4. the interviews during which respondents are sorting the statements. The results of these sorting exercises are the Q-sorts,
5. the analysis of the Q-sorts.

These steps are described in the following sections.

[1] also referred as the construction of the Q-set
[2] also referred as the construction of the P-set

## 3.1 Step 1: Concourse development

The first step of a Q-methodology survey is the construction of a concourse which involves collecting all the possible opinions from stakeholders about the research topic at hand (Fairweather and Swaffield, 2000). First, this requires a proper identification of the different types of stakeholders (stakeholder mapping). Once well identified, informal interviews are conducted with a small number of people representative of the identified types of stakeholders.

For both identification of the stakeholders and the construction of the concourse, we conducted an additional review of the grey literature.

## 3.2 Step 2: Selection of the statements (Q-set)

Based on the statements selected during the previous stage, we constructed the Q-sets. These statements correspond to the various point of views identified and deemed related to the research objectives. It is important to note a statement does not necessarily has to be fact but should represent a participant's subjective view (Watts and Stenner, 2012). As such, the selection of statements does not include a screening out of statements that would be deemed untrue by the researcher.

## 3.3 Step 3: Selection of the participant set (P-set)

Respondents are then selected in such a way that they are theoretically relevant to the research questions and representative of the broad range of stakeholders identified during the first phase. In our case, we retained regulators, water users, water suppliers, water boards, conservationists and private sector.

We followed (Watts and Stenner, 2012) suggestion of recruiting a minimum of one participant for every two Q set items, thus using half as many participants as there are statements in the Q set.

## 3.4 Step 4: Interviews

Each member of the P-set attended a one-on-one meeting in their own premises (home or office), without monetary compensation. During these meetings, the person completed the Q-sorting exercises and an exit interview.

For a Q-sorting exercise, a participant is required to rank the statements presented to her on a Q-board. A Q-board is a grid allowing to rank the statements according to a quasi-normal distribution[3] ranging from "Really Agree" through "neutral", to "Really Disagree".

The use of forced-choice prearranged distribution following a normal distribution facilitates standardizing the sorting procedure and has become the standard approach in Q methodology (Watts and Stenner, 2012).

Figure 3.1: A Q-sorting Exercise

The Q-sorting exercises are followed by informal conversation with the respondents to understand their rankings and to let them the opportunity to express views that would not be among the ones that she had to rank.

[3] For an example of Q-Board see Figure B.1

## 3.5 Step 5: Statistical analysis and Interpretation

The Q-sorting exercises are recorded and coded with the help of the PQMethod software. Internally, it is coded as a matrix where the columns correspond to a statement and the rows correspond to the respondents. Each cell corresponds to the rank given to the statement $ST_x$ by the respondent $r$. Therefore, a line corresponds to all the ranks given by one respondent. An extract of such table is presented in Table 3.1. For data checking, it can also be represented in the form of the quasi-normal distribution used for the exercise (Figure 3.2)

Table 3.1: Matrix view of hypothetical Q-sorts

| Name | ST1 | ST2 | ST3 | ST4 | ST5 | ST6 | ST7 | ST8 | ST9 | ST10 | ST11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 16TrdLdr | 0 | -5 | 4 | 0 | -3 | 3 | 0 | -3 | 0 | 1 | -5 |
| 06DWS | -3 | -4 | -5 | 3 | 5 | 0 | 0 | -1 | -3 | -1 | 0 |
| 13Agric | 1 | -2 | 4 | 2 | 4 | 1 | 1 | 0 | 5 | 3 | -4 |
| 15ComLdr | -4 | 0 | 1 | 4 | 3 | -1 | 2 | 1 | -5 | 3 | -4 |

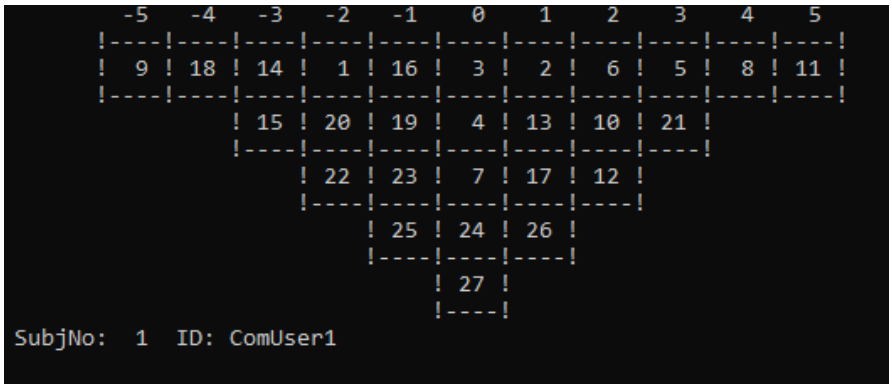


Figure 3.2: One interview coded into a Q-Sort in the PQMethod software

### 3.5.1 Centroid Factor Analysis and Factor Selection

The statistical procedure underlying the Q-methodology is a factor analysis where the variables to be classified are the Q-sorts. Therefore, the Q-methodology is a method for determining how respondents falls into natural groupings of “similar point of views”.

> "If two persons are like-minded on a topic, their Q sorts will be similar and they will end up on the same factor. Hence, we do not classify them: they classify themselves on their own terms, which emerge as factors." — Brown, 1980 p. 208

Among the possible factor extraction methodology, we chose the centroid extraction method. Both PCA and Centroid Factor Analysis are possible with the PQmethod software, but the centroid extraction method is often advised as it allows for greater flexibility in the analysis (See Watts & Stenner, 2012, p 98-99 for a discussion about the choice between PCA and Centroid Factor Analysis by Q-methodologists). The output of this initial factor analysis are *unrotated factors* and we need to decide the number of meaningful factors to be extracted.

The literature suggests at least four alternative methods to solve the question of how many factors to extract from a data set (Watts and Stenner, 2012): the Kaiser-Guttman criterion, the scree test, the minimum number of significantly loading Q sorts, the Humpfrey's rule.

The Kaiser-Guttman criterion suggests dropping factors with eigenvalues under one. The threshold value of one is suggested because it corresponds to the eigenvalue equal to the information accounted for by an average single item. It is not recommended to use the Kaiser-Guttman criterion as the sole criterion for estimating the number of factors as it tends to over-extract factors (Brown, 1980; Bandalos and Boehm-Kaufman, 2010)

The scree test is used frequently for factor analyses but it was designed for use only in the context of PCA. A way around this, when applied to Q methodology is to run an initial PCA extraction (in place of the centroid factor analysis). A scree test then involves the plotting of the eigenvalues on a line graph. The number of factors to extract is indicated by the point at which the line changes slope.

Brown (1980, p. 222) suggested that only factors with at least 2 significant Q-sorts should be extracted. 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 $SE_r = \frac{1}{\sqrt{S}}$ where $S$ is the number of statements. Therefore, for a loading to be significant at the $0.01$ level on a factor, it must exceed $2.58 \times SE_r$, and to be

significant at the $0.05$ level on a factor, it must exceed $1.96 \times SE_r$.

Finally, the Humpfrey's rule proposes to extract the factors for which the cross-product of its two highest loadings exceeds twice the standard error of the factor (Watts and Stenner, 2012)

### 3.5.2 Factor rotation

The unrotated output maximizes the variance accounted for by the first and subsequent factors. However, this often results in having many items load substantially on more than one factor. In order to make the output more understandable, it is a common practice to conduct some rotation of the factors to obtain "clearer" loadings, that is a solution where each item loads strongly on only one of the factors, and much more weakly on the other factors. Factor analysis allows for different types of rotation. In our case we opted for a varimax rotation.

### 3.5.3 Flagging of Q-sorts

Following the varimax rotation, the PQMethod software allows to select the Q-sorts that are representative of each factor. In the Q-methodology jargon, this selection process is known as "flagging".

To associate a Q-sort with a factor, we need to rely on the concept of communality. As explained in Brown (1980), a squared factor loading expresses a percentage. For example, if we express $load_{1,1}$ as the loading of Q-sort 1 on factor 1 (for ex. $load_{1,1} = 0.3$), the $load^2_{1,1}$= 0.09 means that 9 percent of the Q-sort 1 response is associated with factor 1. Based on this idea, a communality indicator $h^2$ is defined as the sum of squared factor loadings along each row. Therefore, $h^2$ for the first line is the percentage of percent no. 1's response that is in common with all other 3 factors, or, alternatively, is in common with all of the other subjects in the study since it is from their responses that the factors emerged. This means, that a person with a low $h^2$ has responded in a relatively unique way, hence has little in common with the other subjects.

The software proposes a pre-flagging algorithm to flag purest cases only. A Q-sort with a loading $a$ on the factor is pre-flagged if:

1. $a > 1.96/\sqrt{S}$, i.e., the loading is significant at p <.05
2. $a^2 > h^2/2$, i.e. the factor explains more than half of the common variance

In addition, the PQMethod software allows the researcher to manually flag additional Q-sorts, or un-flag Q-sorts that have been pre-flagged but that the researcher finds inadequate.

### 3.5.4 Tools to interpret the factors

Once the representative members of each factor are selected, the data analysis can proceed. The next step is to calculate the scores of each statement on each factors. After standardization to allow for comparisons across factors, i.e. the calculation of the Z-scores, it is a common practice to create prototypical Q-sorts for each factor.

#### 3.5.4.1 Z-scores and Factor Arrays

In order to get a view of the perspectives that is easier to interpret, it is a common practice to create "factor arrays" (FA). A factor array represents represents how a *weighted average member* of that group would have arranged their statements (Brown, 1980; Watts & Stenner, 2012; Yarar & Orth, 2018).

To calculate factor arrays, we need first to calculate the Z-scores of each statement for a particular array.

The Z-scores are weighted averages of the loadings of the statements on the factor for the defining Q-sort. The first step is to assign a factor weight to each Q-sort $q$ as a reflection of the fact that some Q sorts are closer approximations to a factor than are other Q sorts.

The expression for calculating factor weights is given by:

$$w_{q,f} = \frac{l_{q,f}}{1 - l_{q,f}^2}$$

where $l_{q,f}$ is the loading of Q-sort $q \in Q_f$ on factor $f$ (where $Q_f$ is the set of Q-sorts that were flagged to define the factor $f$), and $w_{q,f}$ is the weight. The weights are then normalized in a way that the highest weight is equal to one.

The weights are then used to calculate the weighted scores for each statement on the considered factor:

$$W_{s,f} = w_{q,f} \times S_{s,q,f}$$

The weighted scores for each statement are then summed. Since factors contain differing numbers of Q-sorts producing statement totals of differing magnitudes, it is convenient for purposes of comparability to normalize and standardize the total column, converting each item total to the Z-score . This removes the arbitrary effect of the number of subjects associated with each factor as well as the effect of their differing factor weights. The resulting Z-scores make possible direct comparisons with scores for the same statements in the different factors since all factor arrays having identical means ($\bar{Z} = 0$) and standard deviations ($s = 1$).

The factors array will display the "prototypical Q-sorts". During the interviews the Q-sorts were in a forced quasi-normal distribution. Based on either the totals or Z-scores, it is possible to select the item with the highest score and assign it the value of $+5$, the next-highest items the value of $+4$, etc. in order to reproduce the initial format of the Q-sorts. These rounded scores introduce a small amount of error due to the arbitrary grouping involved, but they are usually preferred for interpretation since they conform to the format in which the data were originally collected.

To interpret the results we will be relying on two tools that are using the Z-scores and the factors' array results: the crib sheets and the distinguishing statements for a given factor. They are described in the following subsections.

#### 3.5.4.2 Crib sheet

The crib sheet splits statements into four basic categories

- the items ranked highest
- the items ranked higher or equal by the factor than by any of the other factors
- the items ranked lower or equal by the factor than by any of the other factors
- the items ranked lowest

Note that a factor crib sheet will leave out the statements that have been ranked higher in some factors and lower in other factors.

#### 3.5.4.3 Distinguishing Statements vs. Consensus Statements

An important part of the analysis is based on the identification of the statements that are specific to one factor, thereafter called distinguishing statements . The specificity is measured by the difference in ranking of a given statement. We need to decide when the ranking of a statement in a group is considered different from the ranking given by another group. To be able to answer that question we need to use the concept of reliability of the coefficients, that is to what extent a person would give the same ranking if he had to repeat the same ranking exercise. Experience has indicated that reliability coefficients of a person with himself normally range from 0.80 upward Frank (1956). Given correlations of this magnitude, the reliability ($r_{xx}$) of a factor can be estimated using the expression:

$$r_{xx} = \frac{0.80 \times p}{1 + (p - 1) \times 0.80}$$

where $p$ is the number of persons defining a factor, 0.80 is their estimated average self-reliability coefficient.

Factor reliability is of importance since the standard error of factor scores is given by the expression

$$SEf_x = S_x \times \sqrt{1 - r_{xx}}$$

where $S_x$ is the standard deviation of the forced distribution.

Since we used normalized Z-scores, $S_x = 1$ and $SEf_x = \sqrt{1 - r_{xx}}$. The magnitude of difference required for significant difference between scores on the first two factors at the 0.01 level should be at least $2.58 \times \sqrt{SEf_1^2 + SEf_2^2}$.

This measure will allow us to screen out, for each factor, which statements having a significantly different scores than the other factors, i.e., the distinguishing statements. It also allows to identify the set of statements that do not differ significantly across the different factors, i.e. the consensus statements .

# Chapter 4

# Sequence of activities

Activities conducted for the project can be summarized into four major steps:

1. Stakeholder analysis and literature review
2. Pre-survey informal interviews
3. First Survey: Water quality issues in the Olifants
4. Second Survey: Ecosystem Services

Between each of these steps, we analyzed the information gathered before designing and preparing for the following step.

## 4.1 Stakeholder Analysis and Literature review

Stakeholders were identified based on information gathered from published literature, grey literature, news sources and interviews. After an initial round of stakeholders were identified, the study also employed the snowball technique as suggested by Vogt (2005) 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.

The objective was to identify the water users and all those being affected by the actions or in-actions of the water users and other concerned parties.The stakeholders fell into

the following categories:

- Regulators (DWS, DAFF, DEA)
- Commercial water users (Farmers, Mines, Water User Associations)
- Domestic water users (Residents, Subsistence farmers)
- Suppliers to domestic users (Municipalities)
- Water boards (Their role is to provide bulk potable and waste water to other water institutions such as municipalities)
- Conservationists (Advocacy NGOs, South Africa National Parks)
- Private sector
- Researchers

## 4.2 Pre-survey informal interviews

During this phase, **seventeen** persons purposely selected were interviewed face-to-face or over the phone with open-ended questions about the issue of raw water quality in the rivers of the Olifants catchment and its management. We conducted additional interviews until we felt that a saturation point had been attained, i.e., when we felt that 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.

Based on these interviews we built a large concourse of the statements relevant to water quality issues. We noticed that respondents tended to made statements relative to the problems associated with water quality and the impacts on well-being (either their own, or the one of others), but also made statements on how to improve the current situation. Anticipating the potential difficulties to rank statements of different nature (i.e., problems vs. solutions), we decided to split the statements into two concourses: one about problems, one about solutions.

## 4.3 First Q-methodology Survey

Based on the two concourses issued from informal interviews, we finalized two Q-sets: in the first one we selected **52** statements related to the *problems* associated with raw water management in the Olifants (Table 4.1), and in the second one we selected **31** statements related to the possible *solutions* to improve the the management of raw water that would improve water quality (Table 4.2).

Table 4.1: Statements for Problems related to Water Quality

| SID | Statements |
|---|---|
| 1 | Algae reduces the quality of the water |
| 2 | All water users are aware of the rules and regulations governing the use of the water |
| 3 | Budget constraints by the municipality contribute to failure to control pollution |
| 4 | Department of Water and Sanitation has adequate trained staff to ensure compliance in good water use |
| 5 | Department of Water and Sanitation has financial capacity to effectively monitor and regulate water users |
| 6 | Dump sites for garbage pollute the ground water |
| 7 | Fish and plants can no longer survive properly along the river |
| 8 | Ground water (boreholes) is more polluted than the water from the river |
| 9 | I also contribute to the pollution in the river through my activities |
| 10 | I am concerned about the users downstream in other municipalities |
| 11 | I am more concerned about the impacts of water pollution to humans than to the environment |
| 12 | I am more worried about the pollution that cannot be seen with the naked eye (such as dissolved acids and chemicals) than the pollution that can be seen (such as plastics and other garbage) |
| 13 | I am spending money to make the water usable |
| 14 | I do understand the regulations governing management of water quality |
| 15 | If things continue as they are there will be no usable water left to use by the year 2030 |
| 16 | Most of the water pollution comes from residents in communities. |
| 17 | Most of the water pollution comes from the mines |
| 18 | Most of the water pollution comes from the sewage from Waste Water Treatment Works (WWTWs) |
| 19 | Most of the water pollution comes from illegal water users |
| 20 | Most of the water pollution comes from large irrigation commercial farmers |
| 21 | Most of the water pollution comes from small livestock farmers |
| 22 | New water users are poorly planned and unregulated |
| 23 | Non-Governmental Organisations (NGOs) private sector initiatives are helping to control water pollution |
| 24 | Few stakeholders attend meetings called to discuss issues about water |
| 25 | Pollution levels in the water is higher during the rainy season than in other seasons |
| 26 | Poor water quality is impacting on human health |
| 27 | Problems of water quality are due to lack of leadership and governance rather than by activities of water users |
| 28 | Small-scale farmers? animals die from drinking polluted water |
| 29 | Some farmers are extracting more water than they should |

Table 4.1: Statements for Problems related to Water Quality *(continued)*

| SID | Statements |
|---|---|
| 30 | Staff at Waste Water Treatment Works do have the required skills to operate waste water treatment plants |
| 31 | The Integrated Development Plan (IDP) of municipalities includes a section talking about issues of water quality. |
| 32 | The loss in water quality is a result of climate change |
| 33 | The municipality is adequately funded to carry out safe disposal of wastewater |
| 34 | The water pollution in my region is coming from another region upstream |
| 35 | The pollution in the ground water (boreholes) is not caused by anyone. The water is naturally not good quality |
| 36 | The pollution in the water is getting worse. The water is more polluted now than it was a few years ago |
| 37 | The rules to control pollution are there but the implementation is hard |
| 38 | The water in the Olifants is unfit for any domestic use (washing bathing cleaning or bathing) |
| 39 | The water in the river looks dirty |
| 40 | The water in the river smells bad |
| 41 | The water pollution in the Olifants is beyond redemption. It cannot be controlled because it is too late |
| 42 | There are adequate channels to deal with stakeholder conflicts in the management of water quality |
| 43 | There are adequate communication channels for stakeholders to discuss issues of water management (through forums and stakeholder meetings) |
| 44 | There are enough tools technology and capacity to improve water quality all that is needed is political will |
| 45 | There are many institutions controlling water quality issues thus causing confusion among stakeholders |
| 46 | There isn?t enough quality water available for all users |
| 47 | Those who discharge effluent into the river test the effluent before they discharge into the river to make sure it won?t pollute the water |
| 48 | Unlawful use of water mainly affects the quantity and not the quality of the water |
| 49 | Waste water treatment works are meeting standards for green drop |
| 50 | Water availability/Quantity is more important than water quality |
| 51 | Water boards are meeting standards for blue water drop |
| 52 | When the quantity/flow of water in the river is down even the quality of water reduces |

We interviewed **Eighteen** participants, purposively selected to represent the different types of stakeholders. Each participant completed two Q-sorting exercises.

For the first Q-sorting exercise, each participant was required to rank the 52 water quality related issues on the Q-board illustrated in Figure B.1. Participants were instructed to carefully read all statements and then to roughly sort them into three stacks reflecting their relative agreement with the statements. Next, participants conducted a more fine-grained sorting by rank ordering the statements from each stack into the slots of a 13-point forced-choice quasi-normal distribution printed on the Q-board (Figure B.1) ranging from “Really Agree” (+6) through “neutral” (0) to “Really Disagree” (-6).

Table 4.2: Statements for Solutions

| SID | Statements |
|---|---|
| 1 | An independent regulator (not a government institution) will do a better job to control and regulate water pollution |
| 2 | Awarding users who are compliant makes other users to become compliant as well |
| 3 | Commercial farmers who are certified by South Africa Good Agricultural Practices (SA GAP) or Global Good Agricultural Practices(GlobalGAP) are encouraged to pollute less so that they do not lose their certification |
| 4 | 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 |
| 5 | Further training of staff at wastewater treatments will reduce discharge of sewerage into the river |
| 6 | I am willing to participate in any efforts to improve water quality |
| 7 | 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 |
| 8 | If municipalities allocate a larger share of their budget to water quality issues then water quality will be improved |
| 9 | If the majority of households have piped water then they will stop polluting the river |
| 10 | Improved garbage collection by municipality will reduce the amount of household waste that ends up polluting the river |
| 11 | Improving the quality of the water is too expensive |
| 12 | Increased monitoring by DWS (Department of Water and Sanitation) will reduce misuse of water and improve the quality of the water |
| 13 | Instead of throwing garbage at dumpsites recycling the garbage will prevent underground and surface water pollution |
| 14 | Integrating the different regulators will improve efficiency in controlling water pollution |
| 15 | More government funding to the municipalities will improve water quality |
| 16 | Naming and shaming polluters encourages people to stop pollution |
| 17 | People should be educated about water quality |
| 18 | Pollution will stop if only the people upstream stopped polluting |
| 19 | Regular stakeholder meetings will promote sustainable use of water resources |
| 20 | The mines should compensate the farmers because the waste from the mines kills their animals and plants |
| 21 | The Olifants river catchment is too big to be controlled by one body |
| 22 | The priority should be to prevent the effects of pollution on the environment |
| 23 | The quality of water cannot be improved. It?s too late. |
| 24 | There is need for all stakeholders to work together to improve water quality |
| 25 | There is need to prevent new people from using the river. The bigger the number of people using the river the higher the pollution. |
| 26 | There needs to be punishment for those who pollute the water |
| 27 | Those who pollute should pay all those who are affected by the pollution |
| 28 | Those who pollute too much should stop using the river for a while |
| 29 | Validation and verification (V&V) of water users is the solution to most of the water quality issues that we are facing (V&V is when the Department of Water Affairs ensures that everyone is using the correct amount of water for the right purpose) |
| 30 | We do not need more laws; we just need to enforce the ones already existing |
| 31 | We need more laws in order to prevent further pollution |

The same procedure was repeated for the second Q-sorting exercise: each participant was required to rank the 31 solutions to improve water quality on the Q-board illustrated in Figure B.2.

Finally, in the exit interviews, we asked the participants to explain why they agreed or disagreed with certain statements and what additional statements they felt should have been included from the study. Demographic data, including participants' age, gender, educational level and their main source of water for their day-to-day usage, was also collected. Exit interviews were conducted to understand the participant's thought process in arranging the Q-sort so as to help in explaining the different viewpoints during the analysis and factor interpretation.

The data were coded (see Figure 3.2 for an example) and analysed using the PQMethod software (Schmolck and Atkinson, 2014).

## 4.4 Second Q-methodology Survey: Water Related Ecosystem Services

After analysing the results of the two Q-sorting exercises, we felt that we lacked information about the ranking of ecosystem services. Therefore, we designed two new concourses, and then Q-sets using the procedure described above (scientific and grey literature review and interviews). The first Q-set established a list of water-related ecosystem services (WES) to be ranked in terms of importance. The second Q-set established a list of policy and institutional solutions to improve the provision of these WES by water ecosystems of the Olifants basin. The second Q-set was closely related to the second Q-set of the first survey. However, as we benefited from the feedbacks of the first survey, some statements were added, some were taken out, some were rewritten to be more explicit.

**Sixteen** participants, representing the different types of stakeholders identified in the first step, were interviewed for this second survey. Again, each participant completed two Q-sorting exercises.

For the first Q-sorting exercise, each participant was required to rank the 27 water

ecosystem services (WESs) in Table 4.3 on the Q-board illustrated in Figure B.3, using the procedure described for the first Q-sorting exercise (Section 4.3).

Table 4.3: Statements for Water Ecosystem Services

| SID | Statements |
|---|---|
| 1 | Maintenance of water quality by diluting pollutants |
| 2 | Preventing floods |
| 3 | Control of soil erosion |
| 4 | Conservation of ecosystem |
| 5 | Natural storage for water |
| 6 | Habitat for fish and wildlife |
| 7 | Water for irrigation |
| 8 | Water directly from the river for domestic use (washing bathing etc) |
| 9 | Water for power generation |
| 10 | Water transport (Boats and canoes) |
| 11 | Catching fish to eat or sell |
| 12 | Plants herbs and natural products |
| 13 | Water for municipality use to supply tap water |
| 14 | Water for industrial use (mining and manufacturing) |
| 15 | Boat cruise water viewing and water games |
| 16 | Tourism of wildlife |
| 17 | Traditional and religious rituals |
| 18 | Fishing for fun |
| 19 | Research and education purposes |
| 20 | A nice view to look at (aesthetic values) |
| 21 | National pride of owning a clean river |
| 22 | Recycling nutrients |
| 23 | Preventing damage to the environment (ecosystem resilience) |
| 24 | A special environment for rare species of plants and animals (refugia) |
| 25 | Making the landscape more beautiful |
| 26 | Support plant growth processes (pollination and photosynthesis) |
| 27 | Water cycle |

Then, the respondents were asked whether the WESs they ranked as more important were at the desired level, i.e., if they were benefiting from the WES provision by the Olifants river; in particular they were asked whether the current pollution levels in the rivers would hamper them to benefit from these WESs.

Then, the respondents carried-out a second Q-sorting exercise where they were required

to rank the 31 statements about instruments to reduce water pollution in the rivers 4.4 on the Q-board illustrated in Figure B.4. This time, the participants were instructed to rank order the statements on a scale ranging from "most agree with" (+5) to "most disagree with" (-5) where the middle of the Q-board was meant for statements to which they were indifferent, or had no clear opinion about it. Again we used the procedure described for the first Q-sorting exercise (Section 4.3).

Two respondents felt that they did not directly enjoy the WES provided by the Olifants river, hence could not give an opinion about which WES they regarded as important. Overall, we collected **14** valid Q-sorts for the ranking of WES, and **16** valid Q-sorts for the views about instruments that would improve WES provision and water quality.

Finally, the respondents provided demographic information and reasoning supporting their Q-sorts. We also offered them the opportunity to point out difficulties they faced during the sorting exercise, and to add missing viewpoints which they considered important. These additional data aided in subsequent interpretation.

Table 4.4: Statements for Instruments to Solve

| SID | Statements |
|---|---|
| 1 | Increased sensitization 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. |

Table 4.4: Statements for Instruments to Solve *(continued)*

| SID | Statements |
|---|---|
| 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 |

# Part III

# Results

# Chapter 5

# Water Quality Issues

In this chapter, we analyze the rankings of issues related to water quality in the Olifants catchment[1]. The 18 respondents were asked to rank each of the 52 statements (Table 4.1) in quasi-normal grid ranging from -6: Really disagree to +6: Really agree (Figure B.1).

## 5.1 Centroid Factor Analysis: Unrotated factors

Based on the loadings obtained (Table C.1), we explored the alternative methods to decide upon the number of factors to be selected. The eigenvalues of the first 7 unrotated factors are presented in Table 5.1. If we follow the Kaiser-Guttman criterion, we should select the factors 1, 2, 4. The scree plot of the eigenvalues generated with a standard PCA analysis are represented in Figure C.1. The scree plot suggests to select 2 or 4 factors.

Alternatively, if we follow the criterion that at least two Q-sorts should be significantly loaded on a factor[2], we should select the factors 1, 2, 4, 5.

Finally, if we follow the Humpfrey's rule (Table C.2) only the factors 1, 2 should be considered. If, as suggested in Watts and Stenner (2012), we follow a less strict interpretation

[1] For the sake of space, some tables and figures related to this chapter are presented in Annex C

[2] Significantly loaded Q-sorts are represented by "xx" in Table C.1

Table 5.1: Water Quality Issues: Eigenvalues and Percentage of Variance Explained

| | F1 | F2 | F3 | F4 | F5 | F6 | F7 |
|---|---|---|---|---|---|---|---|
| Eigen values | 3.01 | 1.46 | 0.31 | 1.29 | 0.86 | 0.20 | 0.63 |
| Var Explained | 16.74 | 8.09 | 1.71 | 7.16 | 4.76 | 1.10 | 3.51 |
| Cumulative Variance Explained | 16.74 | 24.84 | 26.55 | 33.71 | 38.47 | 39.57 | 43.08 |

of the rule, i.e. where the threshold is only $1 \times SE_r$, then we would select the factors 1, 2, 4, 5.

If we apply a strict interpretation of the criteria normally used for the selection of the factors, all criteria are suggesting an analysis with 2 factors[3]. Therefore we opted for an analysis with two factors.

## 5.2 Two Factors Analysis

The results of the varimax rotation with 2 factors and the selection of Q-sorts are presented in Table 5.2.

Table 5.2: Water Quality Issues: Rotated Factors

| QID | L1 | s1[a] | L2 | s2 | h2 |
|---|---|---|---|---|---|
| 1 | 0.60 | x | 0.20 | | 0.40 |
| 2 | -0.07 | | 0.29 | x | 0.09 |
| 3 | 0.14 | | 0.06 | | 0.02 |
| 4 | 0.21 | | 0.08 | | 0.05 |
| 5 | 0.31 | | 0.46 | x | 0.31 |
| 6 | 0.69 | x | -0.06 | | 0.48 |
| 7 | 0.60 | x | -0.19 | | 0.40 |
| 8 | 0.19 | | 0.04 | | 0.04 |
| 9 | 0.84 | x | 0.13 | | 0.73 |
| 10 | 0.45 | x | 0.08 | | 0.21 |
| 11 | 0.53 | x | 0.22 | | 0.33 |

[3] We actually tried an analysis four factors that could be justified with a less stringent version of the same criteria. However, the results obtained were not satisfactory and are not presented here

Table 5.2: Water Quality Issues: Rotated Factors *(continued)*

| QID | L1 | s1[a] | L2 | s2 | h2 |
|---|---|---|---|---|---|
| 12 | 0.29 | | 0.38 | x | 0.23 |
| 13 | 0.15 | | 0.40 | x | 0.18 |
| 14 | 0.27 | | 0.31 | x | 0.17 |
| 15 | 0.08 | | 0.53 | x | 0.28 |
| 16 | -0.07 | | 0.72 | x | 0.52 |
| 17 | 0.03 | | 0.16 | | 0.03 |
| 18 | 0.02 | | 0.06 | | 0.00 |

*Note:*

A varimax rotation with no additional corrections applied

[a] x indicates that the Q-sort has been flagged to define the factor

The first factor summarized 6 Q-sorts (1, 6, 7, 9, 10, 11). The eigenvalue of this first factor was 2.794, representing 15.52 % of the total variance. The second factor summarized 7 Q-sorts (2, 5, 12, 13, 14, 15, 16). The eigenvalue of this second factor was 1.677, representing 9.31 % of the total variance. Note that 5 Q-sorts (3, 4, 8, 17, 18) were not used to define any of the factors. This is due to their low commonality indices, i.e., because they were representing very specific point of views. Overall, the two factors represented 24.84 % of the data variance. When compared with similar studies, the % of variance captured by the factors is low.

The correlation between the two factors (Table 5.3) shows that the two factors are not correlated. This indicates we found two distinct views of the water quality issues.

Table 5.3: Water Quality Issues: Correlation between factors

| Z1 | Z2 |
|---|---|
| 1.000 | 0.234 |
| 0.234 | 1.000 |

## 5.3 Tools for the interpretation of the factors

Aiming for a "sound and holistic factor interpretation" (Watts and Stenner, 2012, p. 150), we closely followed the crib sheet procedure which forced us to analyse each single item

of the prototypical Q sorts presented in the Factors Array (Table 5.4). The crib sheets of the two factors are presented in Annex C (Tables C.3, C.5). In addition, we identified the statements that were ranked similarly by the different factors, i.e., the consensus statements (Table 5.5). Finally, we identified the statements that were distinctive, i.e., whose Z-score on that factor was significantly different of its Z-score on the other factor(Table C.4[4]).

Table 5.4: Water Quality Issues - Factors Array

| SID | *Statements* | FA1 | ZS1 | FA2 | ZS2 |
|---|---|---|---|---|---|
| 1 | *Algae reduces the quality of the water* | 0 | 0.27 | 0 | -0.06 |
| 2 | *All water users are aware of the rules and regulations governing the use of the water* | -5 | -1.97 | -3 | -1.21 |
| 3 | *Budget constraints by the municipality contribute to failure to control pollution* | 2 | 0.85 | -6 | -1.72 |
| 4 | *Department of Water and Sanitation has adequate trained staff to ensure compliance in good water use* | -5 | -1.56 | 3 | 1.04 |
| 5 | *Department of Water and Sanitation has financial capacity to effectively monitor and regulate water users* | -2 | -0.93 | 4 | 1.48 |
| 6 | *Dump sites for garbage pollute the ground water* | 1 | 0.47 | 0 | -0.05 |
| 7 | *Fish and plants can no longer survive properly along the river* | 1 | 0.46 | -1 | -0.78 |
| 8 | *Ground water (boreholes) is more polluted than the water from the river* | -3 | -1.15 | -4 | -1.48 |
| 9 | *I also contribute to the pollution in the river through my activities* | -1 | -0.39 | -2 | -0.92 |
| 10 | *I am concerned about the users downstream in other municipalities* | 2 | 0.90 | 0 | 0.12 |
| 11 | *I am more concerned about the impacts of water pollution to humans than to the environment* | 0 | 0.01 | 2 | 0.92 |
| 12 | *I am more worried about the pollution that cannot be seen with the naked eye (such as dissolved acids and chemicals) than the pollution that can be seen (such as plastics and other garbage)* | 3 | 1.04 | 3 | 0.98 |
| 13 | *I am spending money to make the water usable* | 0 | 0.09 | -5 | -1.66 |
| 14 | *I do understand the regulations governing management of water quality* | 1 | 0.54 | 1 | 0.46 |
| 15 | *If things continue as they are there will be no usable water left to use by the year 2030* | 3 | 1.11 | 1 | 0.19 |
| 16 | *Most of the water pollution comes from residents in communities.* | -2 | -0.91 | 0 | 0.15 |
| 17 | *Most of the water pollution comes from the mines* | 1 | 0.44 | -4 | -1.34 |
| 18 | *Most of the water pollution comes from the sewage from Waste Water Treatment Works (WWTWs)* | 1 | 0.60 | -1 | -0.15 |
| 19 | *Most of the water pollution comes from illegal water users* | -1 | -0.37 | -1 | -0.25 |
| 20 | *Most of the water pollution comes from large irrigation commercial farmers* | 0 | -0.25 | -3 | -0.96 |
| 21 | *Most of the water pollution comes from small livestock farmers* | -3 | -1.19 | -1 | -0.72 |
| 22 | *New water users are poorly planned and unregulated* | 4 | 1.44 | 1 | 0.27 |

[4]Because they were only two factors, we only presented the distinguishing factors of the first factor

Table 5.4: Water Quality Issues - Factors Array *(continued)*

| SID | *Statements* | FA1 | ZS1 | FA2 | ZS2 |
|---|---|---|---|---|---|
| 23 | *Non-Governmental Organisations (NGOs) private sector initiatives are helping to control water pollution* | 2 | 0.65 | 1 | 0.33 |
| 24 | *Few stakeholders attend meetings called to discuss issues about water* | 0 | 0.17 | 4 | 1.48 |
| 25 | *Pollution levels in the water is higher during the rainy season than in other seasons* | -1 | -0.49 | 4 | 1.38 |
| 26 | *Poor water quality is impacting on human health* | 5 | 1.56 | 5 | 1.61 |
| 27 | *Problems of water quality are due to lack of leadership and governance rather than by activities of water users* | 3 | 1.09 | 6 | 2.57 |
| 28 | *Small-scale farmers? animals die from drinking polluted water* | 0 | -0.17 | 0 | 0.17 |
| 29 | *Some farmers are extracting more water than they should* | 4 | 1.27 | 3 | 1.23 |
| 30 | *Staff at Waste Water Treatment Works do have the required skills to operate waste water treatment plants* | -4 | -1.24 | 5 | 1.56 |
| 31 | *The Integrated Development Plan (IDP) of municipalities includes a section talking about issues of water quality.* | -1 | -0.59 | 1 | 0.37 |
| 32 | *The loss in water quality is a result of climate change* | -1 | -0.62 | -2 | -0.89 |
| 33 | *The municipality is adequately funded to carry out safe disposal of wastewater* | -3 | -0.98 | -1 | -0.10 |
| 34 | *The water pollution in my region is coming from another region upstream* | 1 | 0.41 | -3 | -1.14 |
| 35 | *The pollution in the ground water (boreholes) is not caused by anyone. The water is naturally not good quality* | -2 | -0.86 | -2 | -0.82 |
| 36 | *The pollution in the water is getting worse. The water is more polluted now than it was a few years ago* | 6 | 1.94 | 0 | 0.11 |
| 37 | *The rules to control pollution are there but the implementation is hard* | 3 | 1.20 | 1 | 0.41 |
| 38 | *The water in the Olifants is unfit for any domestic use (washing bathing cleaning or bathing)* | 0 | 0.10 | -5 | -1.55 |
| 39 | *The water in the river looks dirty* | 2 | 0.97 | 1 | 0.45 |
| 40 | *The water in the river smells bad* | 1 | 0.42 | -2 | -0.86 |
| 41 | *The water pollution in the Olifants is beyond redemption. It cannot be controlled because it is too late* | -4 | -1.42 | -2 | -0.81 |
| 42 | *There are adequate channels to deal with stakeholder conflicts in the management of water quality* | -1 | -0.42 | -1 | -0.64 |
| 43 | *There are adequate communication channels for stakeholders to discuss issues of water management (through forums and stakeholder meetings)* | 0 | -0.33 | 3 | 1.15 |
| 44 | *There are enough tools technology and capacity to improve water quality all that is needed is political will* | 5 | 1.70 | 2 | 0.58 |
| 45 | *There are many institutions controlling water quality issues thus causing confusion among stakeholders* | -1 | -0.34 | 0 | -0.02 |
| 46 | *There isn?t enough quality water available for all users* | 2 | 1.03 | 2 | 0.62 |
| 47 | *Those who discharge effluent into the river test the effluent before they discharge into the river to make sure it won?t pollute the water* | -6 | -2.03 | -3 | -1.08 |
| 48 | *Unlawful use of water mainly affects the quantity and not the quality of the water* | -2 | -0.76 | 2 | 0.69 |
| 49 | *Waste water treatment works are meeting standards for green drop* | -4 | -1.32 | -4 | -1.32 |

Table 5.4: Water Quality Issues - Factors Array *(continued)*

| SID | *Statements* | FA1 | ZS1 | FA2 | ZS2 |
|---|---|---|---|---|---|
| 50 | *Water availability/Quantity is more important than water quality* | -2 | -0.63 | 0 | 0.08 |
| 51 | *Water boards are meeting standards for blue water drop* | -3 | -1.15 | 2 | 0.80 |
| 52 | *When the quantity/flow of water in the river is down even the quality of water reduces* | 4 | 1.31 | -1 | -0.69 |

## 5.4 Discussion about the water quality issues

### 5.4.1 Quality of the results

When compared with similar studies, the percentage of variance captured by the factors is low. This is partly due to the small number of surveys conducted with regard to the number of statements. This was taken into account during the second survey, where the ratio of interviews to the number of statements was higher.

### 5.4.2 Factors interpretation

The two factors are representative of contrasted point of views about the problems related to water quality in the Olifants.

#### 5.4.2.1 Factor 1: Pollution deserves more attention and budget

The first point of view (Factor 1), that we could also label "*We are not serious enough about water pollution!*" can be summarized in one short paragraph:

> Water pollution is really serious. The problem is mainly due to lack of adequate budget and skills to control water uses and pollution emissions; overall, there is a lack of political will to solve those issues and we are getting to a catastrophic situation.

In more details, this group strongly agrees with the idea that water pollution in the Olifants is getting worse. That the water is more polluted now than it was a few years ago. However, this group also believes that, even though the pollution in the Olifants is

getting worse, it is not too late to clean up the pollution. But they are somewhat skeptical about the future. They think that if things continue as they are, there will be no usable water left to use by the year 2030 (15:+3).

To explain this state of affairs, they agree that the rules to control pollution are there, but the implementation is not being done properly (37: +3). Among the problems, new water users are poorly planned and unregulated. Since water quantity and water quality are correlated, a decrease in water quantity leads to a decrease in water quality. Participants in this factor are also of the strong view that emitters of effluent into the river such as mines and WWTP do not test the effluent to make sure it will not cause pollution in the river. *Both are related to the capacity of authorities to control water uses and release of pollutants in the rivers*.

They view this problem as caused by inadequate budgets (3: +2, and 33:-3) and lack of skills at the water treatment plants (30:-4) or at the Department of Water and Sanitation (4: -5). They also believe that water users are not aware of the rules and regulations governing the use of water (2:-5), pointing to insufficient effort from authorities to diffuse knowledge and information about pollution regulation. This situation occurs despite the fact that that there are enough tools, technology and capacity in the country to improve water quality. In their eyes, all that is needed is political will (44:+5). For example, participant 7 reiterates, “we have all the tools at our disposal, all that is needed is to force compliance, especially upstream”. Participant 8 further adds that, “we do not even need more laws, we just need to enforce the ones already existing. They are enough!”.

#### 5.4.2.2 Factor 2: Better governance will reduce pollution

This second point of view (Factor 2) could also be labelled “*The problem of water quality is not acute and is related to poor Governance*”, and summarized in a short paragraph:

> Water pollution is a problem but it is not acute. There are sufficient skills and budget to tackle it at municipality and department levels. But changes in the Governance is needed to improve the water quality.

In more details, members of this group are much less concerned about water pollution.

They tend to disagree with the toxicity of rivers to fish and plants (7: -1), or in terms of smells (40:-2), or that the water is unfit for any domestic uses (38:-5). They actually do not spend money to make water usable (13:-5). They are also not really convinced that the situation is getting worse (36:0).

Somehow compatible with this view, they feel budget are adequate at municipality (3:-6) and Departments levels (5:+4). They also feel that there is adequate skills either in the water treatment plants (30:+5) and in the Departments (4:+3). They also see that unlawful uses of water tend to affect the quantity of water available more than its quality. Since money, skills and communication channels are adequate, what is only missing is good governance (27: +6).

In terms of who is polluting most the rivers, they disagreed with the role of mines (17:-4), other regions (34:-3), or residents in the communities (16:0). As seen earlier, they agree with the other group that farming activities are having a negative impact of water quality.

### 5.4.3 Shared views

In addition to these contrasted views, we also found a large set of consensus statements, with 19 over a total of 52 statements (Table 5.5). This set can be subdivided into two broad set of agreements: agreement on some of the factors leading to the decrease in water quality, and agreement of some of the current effects of pollution.

On the effect of the current levels of pollution, there was a general consensus that there is a shortage of good quality water (46: +2, +2) and that poor water quality is having an impact on human health. There is also a general agreement that non-visible pollution is more worrisome than the visible one (12: +3, +3), and that rivers look dirty (39: +2, +1).

Table 5.5: Water Quality Issues: Consensus Statements

| SID | Statement | Z1 | Z2 | m | *s* |
|---|---|---|---|---|---|
| 26 | Poor water quality is impacting on human health | 1.56 | 1.61 | 1.56 | *0.03* |
| 29 | Some farmers are extracting more water than they should | 1.27 | 1.23 | 1.27 | *0.02* |

| | | | | | |
|---|---|---|---|---|---|
| 12 | I am more worried about the pollution that cannot be seen with the naked eye (such as dissolved acids and chemicals) than the pollution that can be seen (such as plastics and other garbage) | 1.04 | 0.98 | 1.04 | *0.03* |
| 46 | There isn?t enough quality water available for all users | 1.03 | 0.62 | 1.03 | *0.26* |
| 39 | The water in the river looks dirty | 0.97 | 0.45 | 0.97 | *0.32* |
| 23 | Non-Governmental Organisations (NGOs) private sector initiatives are helping to control water pollution | 0.65 | 0.33 | 0.65 | *0.20* |
| 14 | I do understand the regulations governing management of water quality | 0.54 | 0.46 | 0.54 | *0.05* |
| 6 | Dump sites for garbage pollute the ground water | 0.47 | -0.05 | 0.47 | *0.32* |
| 1 | Algae reduces the quality of the water | 0.27 | -0.06 | 0.27 | *0.20* |
| 28 | Small-scale farmers? animals die from drinking polluted water | -0.17 | 0.17 | -0.17 | *0.21* |
| 45 | There are many institutions controlling water quality issues thus causing confusion among stakeholders | -0.34 | -0.02 | -0.34 | *0.20* |
| 19 | Most of the water pollution comes from illegal water users | -0.37 | -0.25 | -0.37 | *0.07* |
| 9 | I also contribute to the pollution in the river through my activities | -0.39 | -0.92 | -0.39 | *0.32* |
| 42 | There are adequate channels to deal with stakeholder conflicts in the management of water quality | -0.42 | -0.64 | -0.42 | *0.14* |
| 32 | The loss in water quality is a result of climate change | -0.62 | -0.89 | -0.62 | *0.17* |
| 35 | The pollution in the ground water (boreholes) is not caused by anyone. The water is naturally not good quality | -0.86 | -0.82 | -0.86 | *0.03* |
| 8 | Ground water (boreholes) is more polluted than the water from the river | -1.15 | -1.48 | -1.15 | *0.20* |
| 21 | Most of the water pollution comes from small livestock farmers | -1.19 | -0.72 | -1.19 | *0.29* |
| 49 | Waste water treatment works are meeting standards for green drop | -1.32 | -1.32 | -1.32 | *0.00* |

On the causes of pollution, there was a strong agreement that some farmers are extracting more water than they should (29: +4, +3). There was also agreement on the neutrality of certain statements; for example the statement about physical causes such as “dump sites for garbage pollute the ground water” (6: +1, 0), or institutional causes such as ”there are too many institutions controlling water quality (45: -1, 0), or the presence of adequate channels to deal on issues of water conflict (42: -1, -1), or accusing illegal uses of water (19: -1, -1). Finally, consensus were also found on the disagreement about mentioned possible causes such as climate change 32: -1, -2), or the fact that they were contributing to the problem (9: -1, -2). Finally, both group strongly agreed that waste water treatment plants were not meeting the standards (49: -4, -4).

## 5.5 Lessons learned and policy implications

We found a consensus about the shortage of good quality water. All also agreed that non-visible pollution (chemicals, AMD, etc.) was more worrisome than the visible one (color, rubbish, etc.). On the causes of pollution, there was a strong agreement that the farming sector is extracting more water than they should and that waste water treatment plants (WWTP) were not meeting the standards. The links between water extraction and pollution may appear unclear. However, one link described by respondents is that the lack of water in rivers no longer allows rivers to absorb, flush, or dilute pollutants.

*For decision-makers, this means that policy aiming at improving of the functioning of waste water treatment plants and reducing water use by the agricultural sector would meet a general agreement.*

However, we found two opposing views on the deep roots of the pollution problems, especially in terms of the allocation of funds allocated to the regulation and treatment activities.

A first group would like to see a higher priority given to pollution issues resulting in more funds being channeled to municipalities for training activities (especially for WWTP operators, but also to DWS staffs), day-to-day management of equipment (especially maintenance), and monitoring activities for the enforcement of existing laws about quantity of water uses and release of pollutants in rivers.

A second group would like to see this higher priority translated into a better use of existing funds, especially at the level of municipalities. For this second group, the problem is not a question of staffing and equipment, but a question to give these trained staff the means to be able to do their jobs, using better governance mechanisms.

For policy making, this points to a critical need to investigate further the causes of persistent pollution issues: *Are we failing because insufficient funds are allocated by/to municipalities to solve pollution issues (via better training and equipment), or are we failing because we do not make sure the money allocated is adequately used (via better governance mechanisms)?* This report cannot answer to this question, but points out that these two views are held by the different stakeholders.

# Chapter 6

# Solving Raw Water Quality Issues

In this chapter, we analyze the rankings of solutions to improve the quality of raw waters in the Olifants[1]. The 18 respondents were asked to rank each of the 31 statements (Table 4.2) in quasi-normal grid ranging from -5: Really disagree to +5: Really agree (Figure B.2).

## 6.1 Centroid Factor Analysis: Unrotated factors

Based on the unrotated loadings (Table D.1), we have to select the factors that will be used. The eigenvalues of the first 7 unrotated factors are presented in Table 6.1. The Kaiser-Guttman criterion suggests that we select the factors 1, 2, 4. The scree plot of the eigenvalues are represented in Figure D.1. The scree plot suggests to retain either 2 or 4 factors.

Alternatively, the criterion that at least 2 Q-sorts should be significantly loaded on a factor [2] suggests to retain the factors 1, 2, 3. Factor 4 has only one statement significantly loaded (at the 1% threshold), but two additional statements could be considered (8 and 15), since they are significantly loaded at the 5% threshold. To summarize, this criterion suggested that we could either retain the first three or the first four factors in our

[1] For the sake of space, additional tables and figures related to this chapter are presented in Annex D

[2] Significantly loaded Q-sorts are represented by "xx" in Table D.1

Table 6.1: Solving Issues - Eigenvalues and Percentage of Variance Explained

| | F1 | F2 | F3 | F4 | F5 | F6 | F7 |
|---|---|---|---|---|---|---|---|
| Eigen values | 3.01 | 1.46 | 0.31 | 1.29 | 0.86 | 0.20 | 0.63 |
| Var Explained | 16.74 | 8.09 | 1.71 | 7.16 | 4.76 | 1.10 | 3.51 |
| Cumulative Variance Explained | 16.74 | 24.84 | 26.55 | 33.71 | 38.47 | 39.57 | 43.08 |

analysis. This is consistent with the Kaiser-Guttman criterion.

Finally, if we strictly follow the Humpfrey's rule, only the factors 1, 2 should be considered. If we follow a relaxed interpretation of the rule, i.e. where the threshold is only $1 \times SE_r$, then we would select the factors 1, 2, 3, 4.

The four criteria are providing similar recommendations to use either two or four factors. After trying both solutions, we found that the solution with four factors provided a clearer picture of the different point of views. Therefore, the results of that analysis with four factors after a varimax rotation are presented in the next section.

## 6.2 Four Factors Analysis

The results of the varimax rotation with 4 factors and the selection of Q-sorts are presented in Table 6.2.

Table 6.2: Solving Issues - Rotated Factors

| QID | L1 | s1[a] | L2 | s2 | L3 | s3 | L4 | s4 | h2 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.16 | | 0.70 | x | -0.04 | | 0.09 | | 0.53 |
| 2 | -0.05 | | -0.10 | | 0.56 | x | 0.09 | | 0.33 |
| 3 | -0.11 | | 0.63 | x | -0.42 | | 0.35 | | 0.70 |
| 4 | -0.18 | | 0.47 | | 0.28 | | 0.44 | | 0.52 |
| 5 | 0.26 | | -0.04 | | 0.37 | | 0.35 | | 0.33 |
| 6 | 0.58 | x | -0.02 | | -0.22 | | 0.37 | | 0.52 |
| 7 | 0.65 | x | 0.16 | | 0.09 | | 0.07 | | 0.46 |
| 8 | 0.16 | | 0.03 | | -0.15 | | 0.53 | x | 0.33 |
| 9 | 0.61 | x | 0.07 | | 0.11 | | 0.33 | | 0.50 |
| 10 | 0.16 | | 0.08 | | 0.55 | x | 0.08 | | 0.34 |

Table 6.2: Solving Issues - Rotated Factors *(continued)*

| QID | L1 | s1[a] | L2 | s2 | L3 | s3 | L4 | s4 | h2 |
|---|---|---|---|---|---|---|---|---|---|
| 11 | 0.58 | x | 0.20 | | 0.16 | | 0.05 | | 0.41 |
| 12 | 0.84 | x | -0.19 | | 0.03 | | -0.20 | | 0.78 |
| 13 | 0.48 | x | 0.27 | | -0.20 | | 0.00 | | 0.35 |
| 14 | 0.64 | x | 0.17 | | -0.10 | | 0.56 | | 0.76 |
| 15 | 0.00 | | 0.12 | | 0.19 | | 0.54 | x | 0.34 |
| 16 | 0.28 | | 0.46 | x | -0.02 | | 0.24 | | 0.35 |
| 17 | 0.14 | | 0.64 | x | 0.23 | | -0.19 | | 0.51 |
| 18 | -0.10 | | 0.08 | | 0.52 | x | -0.14 | | 0.31 |

*Note:*
A varimax rotation without additional corrections applied
[a] x indicates that the Q-sort has been flagged to define the factor

The first factor summarized 7 Q-sorts (6, 7, 9, 11, 12, 13, 14). The eigenvalue of this first factor was 3.122, representing 17.35 % of the total variance.

The second factor summarized 4 Q-sorts (1, 3, 16, 17). The eigenvalue of this second factor was 1.97, representing 10.94 % of the total variance.

The third factor summarized 3 Q-sorts (2, 10, 18). The eigenvalue of this third factor was 1.533, representing 8.52 % of the total variance.

The fourth factor summarized 2 Q-sorts (8, 15). The eigenvalue of this fourth factor was 1.749, representing 9.72 % of the total variance.

Note that 2 Q-sorts (4, 5) were not used to define any of the factors. They were not used because their loadings were high on more than one factor. As such they represented "mixed" point of views and were not considered for further analysis. Overall, the four factors represented 46.5 % of the data variance.

The correlations between factors are low (Table 6.3), indicating that we extracted very contrasted point of views on how to solve water quality issues in the catchment.

Table 6.3: Solving Issues: Correlation between factors

| Z1 | Z2 | Z3 | Z4 |
|---|---|---|---|
| 1.000 | 0.191 | 0.056 | 0.219 |
| 0.191 | 1.000 | -0.064 | 0.270 |
| 0.056 | -0.064 | 1.000 | -0.022 |
| 0.219 | 0.270 | -0.022 | 1.000 |

## 6.3 Tools for the interpretation of the factors

We followed the crib sheet procedure which forced us to analyse each single item of the prototypical Q sorts presented in the Factors Array (Table 6.4). The crib sheets of the four factors are presented in Annex D. In addition, we identified the consensus statements (Table 6.5)and the distinguishing statements (Tables D.4, D.6, D.8, and D.10).

Table 6.4: Solving Issues - Factors Array

| SID | *Statements* | **FA1** | ZS1 | FA2 | ZS2 | FA3 | ZS3 | FA4 | ZS4 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | *An independent regulator (not a government institution) will do a better job to control and regulate water pollution* | **1** | 0.66 | -1 | -0.38 | 2 | 0.81 | -1 | 0.00 |
| 2 | *Awarding users who are compliant makes other users to become compliant as well* | **0** | 0.00 | -1 | -0.17 | -2 | -0.67 | 2 | 0.76 |
| 3 | *Commercial farmers who are certified by South Africa Good Agricultural Practices (SA GAP) or Global Good Agricultural Practices(GlobalGAP) are encouraged to pollute less so that they do not lose their certification* | **2** | 0.82 | -5 | -1.98 | 2 | 0.85 | -4 | -1.78 |
| 4 | *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* | **-2** | -0.69 | -4 | -1.33 | 1 | 0.21 | 3 | 1.02 |
| 5 | *Further training of staff at wastewater treatments will reduce discharge of sewerage into the river* | **1** | 0.82 | 0 | 0.29 | 1 | 0.34 | 1 | 0.27 |
| 6 | *I am willing to participate in any efforts to improve water quality* | **3** | 1.17 | 5 | 2.29 | -3 | -0.92 | 2 | 0.76 |
| 7 | *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* | **1** | 0.52 | -3 | -1.09 | 1 | 0.40 | 4 | 1.26 |
| 8 | *If municipalities allocate a larger share of their budget to water quality issues then water quality will be improved* | **-1** | -0.47 | -1 | -0.34 | 5 | 2.19 | 0 | 0.01 |

Table 6.4: Solving Issues - Factors Array *(continued)*

| SID | *Statements* | **FA1** | ZS1 | FA2 | ZS2 | FA3 | ZS3 | FA4 | ZS4 |
|---|---|---|---|---|---|---|---|---|---|
| 9 | *If the majority of households have piped water then they will stop polluting the river* | **-3** | -1.26 | 4 | 1.22 | -1 | -0.36 | 0 | 0.00 |
| 10 | *Improved garbage collection by municipality will reduce the amount of household waste that ends up polluting the river* | **-1** | -0.45 | 3 | 1.08 | -5 | -2.51 | 1 | 0.26 |
| 11 | *Improving the quality of the water is too expensive* | **-2** | -0.91 | -3 | -1.01 | 3 | 1.05 | -3 | -1.52 |
| 12 | *Increased monitoring by DWS (Department of Water and Sanitation) will reduce misuse of water and improve the quality of the water* | **2** | 0.88 | 0 | 0.21 | -1 | -0.51 | -2 | -0.52 |
| 13 | *Instead of throwing garbage at dumpsites recycling the garbage will prevent underground and surface water pollution* | **0** | 0.25 | 0 | -0.15 | -2 | -0.52 | 3 | 1.02 |
| 14 | *Integrating the different regulators will improve efficiency in controlling water pollution* | **0** | -0.26 | 1 | 0.46 | 0 | 0.15 | -3 | -1.02 |
| 15 | *More government funding to the municipalities will improve water quality* | **-5** | -1.83 | 1 | 0.38 | 4 | 1.24 | -2 | -0.51 |
| 16 | *Naming and shaming polluters encourages people to stop pollution* | **0** | -0.22 | 2 | 0.70 | -1 | -0.37 | -1 | -0.25 |
| 17 | *People should be educated about water quality* | **3** | 1.13 | 4 | 1.38 | 3 | 1.11 | 4 | 1.52 |
| 18 | *Pollution will stop if only the people upstream stopped polluting* | **-2** | -0.79 | 0 | -0.17 | -3 | -1.28 | 0 | 0.25 |
| 19 | *Regular stakeholder meetings will promote sustainable use of water resources* | **1** | 0.26 | 1 | 0.53 | 4 | 1.44 | -1 | -0.24 |
| 20 | *The mines should compensate the farmers because the waste from the mines kills their animals and plants* | **-1** | -0.60 | 0 | -0.01 | 1 | 0.35 | 0 | 0.25 |
| 21 | *The Olifants river catchment is too big to be controlled by one body* | **-3** | -1.17 | -3 | -1.25 | 0 | -0.33 | -4 | -2.03 |
| 22 | *The priority should be to prevent the effects of pollution on the environment* | **0** | -0.07 | 2 | 0.75 | 2 | 0.87 | -1 | -0.25 |
| 23 | *The quality of water cannot be improved. It?s too late.* | **-4** | -1.33 | -4 | -1.79 | -4 | -1.44 | -5 | -2.03 |
| 24 | *There is need for all stakeholders to work together to improve water quality* | **2** | 0.91 | 2 | 0.93 | 3 | 1.06 | 0 | 0.00 |
| 25 | *There is need to prevent new people from using the river. The bigger the number of people using the river the higher the pollution.* | **-3** | -1.20 | -2 | -0.82 | 0 | 0.18 | 3 | 1.01 |
| 26 | *There needs to be punishment for those who pollute the water* | **5** | 2.03 | 1 | 0.33 | -1 | -0.37 | 1 | 0.25 |

Table 6.4: Solving Issues - Factors Array *(continued)*

| SID | *Statements* | **FA1** | ZS1 | FA2 | ZS2 | FA3 | ZS3 | FA4 | ZS4 |
|---|---|---|---|---|---|---|---|---|---|
| 27 | *Those who pollute should pay all those who are affected by the pollution* | **4** | 1.51 | 3 | 0.93 | 0 | 0.00 | -3 | -1.01 |
| 28 | *Those who pollute too much should stop using the river for a while* | **-1** | -0.49 | -1 | -0.21 | -2 | -0.53 | 2 | 0.75 |
| 29 | *Validation and verification (V&V) of water users is the solution to most of the water quality issues that we are facing (V&V is when the Department of Water Affairs ensures that everyone is using the correct amount of water for the right purpose)* | **3** | 0.94 | -2 | -0.93 | 0 | -0.10 | 5 | 2.03 |
| 30 | *We do not need more laws; we just need to enforce the ones already existing* | **4** | 1.28 | -2 | -0.90 | -4 | -1.41 | -2 | -0.51 |
| 31 | *We need more laws in order to prevent further pollution* | **-4** | -1.44 | 3 | 1.06 | -3 | -0.94 | 1 | 0.26 |

## 6.4 Discussion about the solutions

### 6.4.1 Quality of the results

When compared with similar studies, the percentage of variance captured by the factors is high. This is probably due to the conjunction of two factors.

First, the ratio of surveys per statement was adequate (i.e., close to the rule of thumb of one survey for two statements). Second, the point of views could be easier to separate since people have clearer and more contrasted views about “what should be done”, than on the issues of “what is the problem”.

### 6.4.2 Factor interpretation

The results are suggesting some very contrasted point of views about what should be done to improve raw water quality.

#### 6.4.2.1 Factor 1: Law enforcers

The first point of view (Factor 1) that we labelled "Law enforcers" represents stakeholders who were in favor of strict enforcement of the current regulations (26:+5; 29:+3; 30:+4; 31:-4), in terms of respect of the volume of water extraction, and in terms of pollution of waters. There are also in favor of "stick" type of policy, requiring punishment for those who pollute water (26:+5), and the payment of compensations (27:+4). However, the specific statement about mining companies compensating farmers was not seen as a key solutions (20:-1), probably because it was too specific. Finally, this group did not think additional Governmental funding to the municipalities would actually have an impact (15: -5), nor that additional laws would help (31:-4).

#### 6.4.2.2 Improve household behaviors

The second point of view (Factor 2) that we labelled "Improve household behaviors" represents stakeholders who gave higher priority to reducing the pollution created by households. This is particularly reflected in the importance of providing piped water to all households (9:+4), and the improvement of garbage collection (10:+3). This group contrasted with the others with regard to the need for additional laws (31:+3): while all the other group felt the problem was the enforcement of existing laws, this group felt new laws and regulations were needed. Finally, this group did not see the Validation and Verification (V&V) process (29:-2) or the GAP certification of farmers (3:-5) as useful for improving water quality.

#### 6.4.2.3 Factor 3: Funding & Stakeholder Involvement

The third point of view (Factor 3) that we labelled "Funding & Stakeholder Involvement" represents stakeholders who thought that the improvement of water quality will require additional funding (11:+3). This would involve both increase the Governmental funding of municipalities (15:+4), and a change in the municipalities internal allocation of funds (8:+5). However, improving garbage collection by municipality was not seen as important (10:-5), meaning this group was more preoccupied by chemical pollution (22:+2). Beside changes in the funding, they also recognized some institutional changes would be required with the establishment of an independent regulator (instead of a govern-

ment body; 1:+2), as well as increased involvement of the stakeholders through regular meetings (19:+4).

#### 6.4.2.4 Factor 4: Regulate Water Quantitative Uses

The fourth point of view (Factor 4) that we labelled “” represents stakeholders who gave more priority to the enforcement of water quantitative uses through the Validation and Verification process (29:+5), but also the functioning of Water User Associations (7:+4). They also think that no additional users should be allowed (25:+3) as it could only worsen the situation. The regulation of pollution came as a second priority, and with mainly policy changes that included both “carrot” (2:+2), and “stick” such as the ban of water use for polluters (28:+2) approaches.

### 6.4.3 Consensus statements

Despite these contrasted views, we also found a set consensual statements; howerver, it was small with 4 statements out of 31 (Table 6.5).

Table 6.5: Solving Issues: Consensus Statements

| SID | Statement | Z1 | Z2 | Z3 | Z4 | m | s |
|---|---|---|---|---|---|---|---|
| 5 | Further training of staff at wastewater treatments will reduce discharge of sewerage into the river | 0.82 | 0.29 | 0.34 | 0.27 | 0.43 | 0.23 |
| 17 | People should be educated about water quality | 1.13 | 1.38 | 1.11 | 1.52 | 1.29 | 0.17 |
| 23 | The quality of water cannot be improved. It?s too late. | -1.33 | -1.79 | -1.44 | -2.03 | -1.65 | 0.28 |
| 24 | There is need for all stakeholders to work together to improve water quality | 0.91 | 0.93 | 1.06 | 0.00 | 0.73 | 0.42 |

*Note:*
All listed statements are non-significant at P>.05

First, all stakeholders refuted the idea that nothing could be done to improve water quality and that it was too late (23: -4 or -5). This is good news (!) and shows that people are still engaged in the debate and ready to do something about it.

Second, additional education on water quality was unanimously pointed (17: +3 or +4) as a tool to improve the situation. This consensus could be expected as it does not hurt

the interests of any of the stakeholders. However, its high ranking shows that further work along this line would be seen favorably and receive a large support among stakeholders. With the importance given to education, stakeholders implicitely recognize that pollution issues would be the fact of "un-educated" polluters. Therefore they tend to direct the blame to household users, since it is hard to believe that large mining companies or farmers would be unaware of the consequences of the release of pollutants in the environment.

Third, we also found a consensus about the statement "need to further train the staff of the waste water treatment plants". However, all the average scores were either 0 or 1. This suggests that stakeholders agreed that this might improve the situation but that they would not give it a high priority. In other words, "this could be done, but it will not really solve the problem". This result is compatible with our earlier consensus that the WWTP were not functioning well. However, in previous chapter we had two contrasting views about the level of training of the WWTP operators: some saying they were not trained enough, another group stating that their skills was not the main issue. In this second set of statements, the statements were phrased as a way to solve the problem, it seems there is again a consensus that training would help but this measure should not receive the highest priority to solve the issue.

Fourth, there is a relative consensus on the need for a better coordination among the different stakeholders. However, the average rankings are more variable ranging from 0 for factor 4, to 3 for factor 3. Again, and for the same reason, this consensus could be expected, as every stakeholders tend to believe the other stakeholders are not doing enough to cooperate. However, we should consider it as encouraging as it also shows a certain recognition that more work should be done to make the different stakeholders work together to solve the issue.

## 6.5 Lessons learned and policy implications

Overall, the results are suggesting a consensus around the need to:

- increase the efforts for the education about water quality
- increase the training so WWTP improve their performances

- better coordinate efforts between the different stakeholders

It is important to note that this consensus is formed around "soft" solutions, that do not require changes in the laws themselves or their enforcement, but would require additional budget dedicated to training and education on one side, and increasing the involvement of the stakeholders in the decision-making.

The divergence of views among stakeholders are becoming apparent when "hard" solutions are considered. Indeed, differences are becoming evident both in terms of the targets of interventions (pollution generated by households vs. other stakeholders), the instruments to be used (new stricter laws, new ways of applying the law, changes in institutions, new equipments especially for households), and the means to be allocated for this (new funding vs. better use of the current funding).

This is largely due to the broad-spectrum character of this research. The difference in perspectives are in part coming from considering different issues to be solved: water pollution by households, agriculture, or industries will probably require different mix of solutions. Additional, more focused research will be needed to get clear views of stakeholders to tackle more specific issues.

# Chapter 7

# Water-related ecosystem services (WES)

This chapter is structured slightly differently from the other result chapters because we are analyzing several issues about the WES in the Olifants, and found it more useful to group under a same chapter. We first analysed the declared priorities in terms of WES; this is reported in the first section. But in addition, we also analyzed the satisfaction for the WES they found important and the reasoning behind their answers. This is reported in the second section. Finally, as described in the introduction, and with the idea that making the economic value of services could help alleviating a wicked problem, we also discuss how the results obtained would help us identify the WES that would be worth considering if we do a valuation study. This is reported in the third section.

## 7.1 Relative importance of the water-related ecosystem services

In this section[1], we analyze the rankings of the WES in the Olifants basin. The respondents were asked to rank each of the 27 statements (Table 4.3) in quasi-normal grid ranging from -5: not important at all to +5: very important (Figure B.3).

[1] For the sake of space, some tables and figures related to this chapter are presented in Annex E

Table 7.1: Water Ecosystem Services: Eigenvalues

| | F1 | F2 | F3 | F4 | F5 | F6 | F7 |
|---|---|---|---|---|---|---|---|
| Eigen values | 3.81 | 1.68 | 1.33 | 0.38 | 0.95 | 0.25 | 0.69 |
| Var Explained | 27.22 | 11.98 | 9.53 | 2.73 | 6.77 | 1.81 | 4.92 |
| Cumulative Variance Explained | 27.22 | 39.20 | 48.73 | 51.45 | 58.22 | 60.03 | 64.95 |

### 7.1.1 Centroid Factor Analysis: Unrotated factors

We explored the alternative methods to decide upon the number of factors to be selected based on the results of the centroid factor analysis (Table E.1).

The eigenvalues of the first 7 unrotated factors are presented in Table 7.1. The Kaiser-Guttman criterion suggests to select the factors 1, 2, 3. The scree plot of the eigenvalues (Figure E.1) suggests to retain 2 to 3 factors. Alternatively, if we select the factors that have at least two significant (at the 1% threshold) loaded Q-sorts, we should retain the factors 1, 2. In a less stringent use of that criterion, the factors 1, 2, 3, and 5 could be retained. Finally, according to the Humpfrey's rule (calculations presented in Table E.2), only the factors 1, 2 should be considered. However, if we follow a less strict interpretation of the rule (Watts and Stenner, 2012), the factors 1, 2, 3, 5 could be considered.

The different criteria suggested slightly different selection of factors. However, they also suggest that factors higher than 3 are not providing a lot of additional information. We opted for a solution with three factors.

### 7.1.2 Three Factors Solution

The results of the varimax rotation and of the selection of active Q-sorts are presented in Table 7.2. The first factor summarized 5 Q-sorts (2, 5, 12, 13, 14). The eigenvalue of this first factor was 2.794, representing 19.96 % of the total variance. The second factor summarized 4 Q-sorts (3, 6, 7, 8). The eigenvalue of this second factor was 2.125, representing 15.18 % of the total variance. The third factor summarized 2 Q-sorts (4, 10). The eigenvalue of this third factor was 1.902, representing 13.59 % of the total variance.

Note that 3 Q-sorts (1, 9, 11) were not used for the definition of factors. They were not used either because they had low communalities (1 and 9), or because their loadings were split between two factors (11), represented "mixed" point of views.

Overall, the three factors represented 48.7 % of the data variance.

Table 7.2: Water Ecosystem Services: Rotated Factors

| QID | Names | L1 | s1[a] | L2 | s2 | L3 | s3 | h2 |
|---|---|---|---|---|---|---|---|---|
| 1 | ComUser1 | 0.354 | | 0.237 | | -0.002 | | 0.18 |
| 2 | DomUser1 | 0.736 | x | 0.053 | | 0.146 | | 0.57 |
| 3 | WBoard1 | 0.364 | | 0.602 | x | 0.345 | | 0.61 |
| 4 | PrivS1 | -0.124 | | 0.202 | | 0.847 | x | 0.77 |
| 5 | Supp1 | 0.650 | x | 0.208 | | -0.098 | | 0.47 |
| 6 | Cons1 | 0.354 | | 0.734 | x | -0.206 | | 0.71 |
| 7 | DomUser2 | 0.121 | | 0.599 | x | -0.130 | | 0.39 |
| 8 | Supp2 | 0.078 | | 0.593 | x | 0.173 | | 0.39 |
| 9 | Supp3 | 0.284 | | 0.341 | | 0.097 | | 0.21 |
| 10 | Regul1 | 0.238 | | -0.056 | | 0.789 | x | 0.68 |
| 11 | PrivS2 | 0.362 | | -0.346 | | 0.478 | | 0.48 |
| 12 | Regul2 | 0.745 | x | 0.104 | | 0.128 | | 0.58 |
| 13 | Regul3 | 0.426 | x | 0.195 | | 0.246 | | 0.28 |
| 14 | Cons2 | 0.638 | x | 0.287 | | 0.091 | | 0.50 |

*Note:*

A varimax rotation has been applied and no additional corrections were made

[a] x indicates that the Q-sort has been used to define the factor

### 7.1.3 Tools for the interpretation of the factors

We followed the crib sheet (Tables E.3, E.5, and E.7) procedure which forced us to analyse each single item of the prototypical Q sorts (summarized in the Factor Array in Table 7.5). In addition, we analyzed the consensus statements (Table 7.4) and for each factor, the distinguishing statements (Tables E.4, E.6, and E.8).

Table 7.3: Water Ecosystem Services: Correlation between factors

| Z1 | Z2 | Z3 |
|---|---|---|
| 1.000 | 0.443 | 0.199 |

Table 7.3: Water Ecosystem Services: Correlation between factors *(continued)*

| Z1 | Z2 | Z3 |
|---|---|---|
| 0.443 | 1.000 | 0.222 |
| 0.199 | 0.222 | 1.000 |

The correlation between factors (Table 7.3) shows that the first two factors are quite correlated and could correspond to slightly different versions of the same point of view[2]. However, as they were sufficient specificities in the views, we decided to consider them separately.

## 7.1.4 Discussion

### 7.1.4.1 Quality of the results

When compared with similar studies, the % of variance captured by the factors is high. The ratio of surveys per statement was adequate (i.e., following the rule of thumb of one survey for two statements).

### 7.1.4.2 Consensus statements

Seven out of twenty seven statements had Z-scores that were not significantly different across factors.

All stakeholders agreed on the importance of some supporting services such as pollination and photosynthesis (26: +2 for all factors). The relative importance of the use of water for industrial uses was also consensual (+2, +1, +1). However, given the average scores, they are not perceived as the most important services. All stakeholders also agreed that fishing for fun would not be an important service provided by rivers in the Olifants (-3, -5, -4). All respondents recognized, that given the current states of water quality this service could not be considered as important.

Finally, the other consensus statements fell into the mid-range (i.e. with average scores

[2]We conducted an analysis with two factors not presented here where the factor 1 and 2 of the three factor analysis are actually merged into one factor

falling between -1 and 1), showing some relative indifference about the importance of religious rituals (17: -1, 0, -2), or research and education services (19: -1,0, -1).

Overall, it should be noted that the consensus is that a service is not important at all or is of moderate importance, but there is no consensus on what groups found as the most important services.

Table 7.4: Water Ecosystem Services : Consensus statements

| SID | *Statement* | Z1 | QS1 | Z2 | QS2 | Z3 | QS3 | m | s |
|---|---|---|---|---|---|---|---|---|---|
| 26 | *Support plant growth processes (pollination and photosynthesis)* | 0.97 | 2 | 0.66 | 2 | 1.11 | 2 | 1.01 | 0.19 |
| 14 | *Water for industrial use (mining and manufacturing)* | 0.82 | 2 | 0.58 | 1 | 0.75 | 1 | 0.80 | 0.10 |
| 27 | *Water cycle* | 0.31 | 0 | 0.55 | 1 | -0.08 | 0 | 0.18 | 0.26 |
| 16 | *Tourism of wildlife* | -0.44 | -1 | -0.57 | -1 | -0.19 | 0 | -0.36 | 0.16 |
| 17 | *Traditional and religious rituals* | -0.34 | -1 | -0.38 | 0 | -0.75 | -2 | -0.47 | 0.18 |
| 19 | *Research and education purposes* | -0.44 | -1 | 0.12 | 0 | -0.55 | -1 | -0.48 | 0.30 |
| 18 | *Fishing for fun* | -1.36 | -3 | -1.60 | -5 | -1.60 | -4 | -1.44 | 0.11 |

*Note:*
All Listed Statements are Non-Significant P>.05

#### 7.1.4.3 Factor 1 : "Water for productive uses"

Overall, this group of stakeholders valued WES related to productive uses (agriculture, industries, etc.) or employment generation. Water for irrigation was seen as the most important WES (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. Water for industrial use was also ranked high (14: +2). Industry is a also an important source of employment and livelihood as well as economic growth for the country.

Table 7.5: Factor Arrays

| SID | *Statements* | **FA1** | ZS1 | **FA2** | ZS2 | FA3 | ZS3 |
|---|---|---|---|---|---|---|---|
| 1 | *Maintenance of water quality by diluting pollutants* | **0** | 0.22 | **3** | 1.16 | 2 | 0.94 |
| 2 | *Preventing floods* | **1** | 0.75 | **-2** | -0.85 | 2 | 1.05 |

Table 7.5: Factor Arrays *(continued)*

| SID | *Statements* | **FA1** | ZS1 | **FA2** | ZS2 | FA3 | ZS3 |
|---|---|---|---|---|---|---|---|
| 3 | *Control of soil erosion* | **-3** | -1.31 | **-4** | -1.45 | 4 | 1.41 |
| 4 | *Conservation of ecosystem* | **4** | 1.53 | **0** | -0.07 | -2 | -0.92 |
| 5 | *Natural storage for water* | **3** | 0.97 | **0** | -0.23 | 3 | 1.22 |
| 6 | *Habitat for fish and wildlife* | **1** | 0.36 | **2** | 0.87 | -1 | -0.58 |
| 7 | *Water for irrigation* | **5** | 1.59 | **2** | 0.96 | 1 | 0.66 |
| 8 | *Water directly from the river for domestic use (washing bathing etc)* | **3** | 1.12 | **5** | 2.29 | 0 | -0.19 |
| 9 | *Water for power generation* | **-2** | -0.98 | **-3** | -1.06 | 5 | 1.97 |
| 10 | *Water transport (Boats and canoes)* | **-4** | -1.76 | **0** | -0.31 | -1 | -0.39 |
| 11 | *Catching fish to eat or sell* | **1** | 0.72 | **1** | 0.16 | -3 | -1.24 |
| 12 | *Plants herbs and natural products* | **-2** | -0.69 | **3** | 1.16 | 1 | 0.47 |
| 13 | *Water for municipality use to supply tap water* | **2** | 0.78 | **4** | 2.14 | 3 | 1.24 |
| 14 | *Water for industrial use (mining and manufacturing)* | **2** | 0.82 | **1** | 0.58 | 1 | 0.75 |
| 15 | *Boat cruise water viewing and water games* | **-5** | -2.38 | **1** | 0.31 | -1 | -0.66 |
| 16 | *Tourism of wildlife* | **-1** | -0.44 | **-1** | -0.57 | 0 | -0.19 |
| 17 | *Traditional and religious rituals* | **-1** | -0.34 | **0** | -0.38 | -2 | -0.75 |
| 18 | *Fishing for fun* | **-3** | -1.36 | **-5** | -1.60 | -4 | -1.60 |
| 19 | *Research and education purposes* | **-1** | -0.44 | **0** | 0.12 | -1 | -0.55 |
| 20 | *A nice view to look at (aesthetic values)* | **-2** | -0.88 | **-2** | -0.82 | -5 | -1.97 |
| 21 | *National pride of owning a clean river* | **-1** | -0.19 | **-1** | -0.43 | 1 | 0.55 |
| 22 | *Recycling nutrients* | **1** | 0.36 | **-3** | -1.00 | -2 | -0.83 |
| 23 | *Preventing damage to the environment (ecosystem resilience)* | **0** | 0.27 | **-1** | -0.51 | 0 | -0.28 |
| 24 | *A special environment for rare species of plants and animals (refugia)* | **0** | 0.20 | **-1** | -0.82 | -3 | -0.94 |
| 25 | *Making the landscape more beautiful* | **0** | -0.18 | **-2** | -0.85 | 0 | -0.19 |
| 26 | *Support plant growth processes (pollination and photosynthesis)* | **2** | 0.97 | **2** | 0.66 | 2 | 1.11 |
| 27 | *Water cycle* | **0** | 0.31 | **1** | 0.55 | 0 | -0.08 |

The importance given to productive uses was somehow balanced by the importance given to the role of rivers in the preservation of ecosystems (4: +4) and natural storage of water (5: +4). It suggests that members of that groups are aware of the sustainability issues: seeing a value in the productive use of water, they also see the need to preserve the resource they are living upon. A possible explanation is that the members of this

group are mostly regulators or suppliers of water. Not being direct users of the water, they can maintain a more balanced (detached) view of the resource.

#### 7.1.4.4 Factor 2 : "Water for private or domestic uses"

Stakeholders holding this perspective generally gave high priorities to major provisioning services. The highest importance was given to the water directly extracted from the river for domestic use (8: +5), and the water extracted to supply potable water to residents (13: +4). This group 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 prioritized the environment by saying it was important that the Olifants river was providing a habitat for fish and wildlife (6: +2) as well as maintaining the raw water quality by diluting pollutants (1: +3).

Even though the following services were not ranked high in the factor array for factor 2, they were ranked higher than in other factors; 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.

The least important WES for stakeholders holding this perspective was sport fishing (18: -5), but as noted earlier, this was also the case of other factors. Recycling nutrients and control of soil erosion were not seen as important (22: -3, 3: -4) mainly because these stakeholders did not see how these services would be 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).

Water for power generation (9: -3) and prevention of floods (via dams or wetlands) (2: -2) were not considered important services. The water supplier argued that "the water levels in the river were low, thus very little water was available for power generation". 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 state, the Olifants river did not contribute to make 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.

This importance given to water provisioning services could be expected since the defining stakeholders for this factor were 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.

#### 7.1.4.5 Factor 3 : "Storage and Power Generation"

Contrary to the previous groups, these respondents saw an important role for the power generation (9: +5). They also gave a high importance to the function of natural storage for water (5:+3) which could be connected (although not exclusively) to the power generation. Finally the control of soil erosion (3:+4) and flood preventing services received also higher importance (2:+2).

However, this factor was easier to describe in terms of the WES that were considered not important, than in terms of the WES that were considered important. In particular, they gave very low importance to the supporting (24:-3; 22:-2, 17:-2, 4:-2) and recreational services (18:-4; 20:-5).

## 7.2 The state of water-related ecosystem services

### 7.2.1 A generalized dis-satisfaction

Stakeholders were asked whether the WES they ranked as more important were at the desired level. That is, whether the WES were at a level they deemed satisfactory.

In all cases, the provision of the WES stated as important were seen as not adequate. So we do not develop the results, but instead present the statements made on the reasons why the WES were not a desired level.

### 7.2.2 Reasons why ecosystem service provision is not at desired level

#### 7.2.2.1 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.

#### 7.2.2.2 Water for municipality use to supply tap water

Because of the high levels of pollution in the Olifants river, respondents also did not trust that the water supplied by municipalities was entirely safe to drink. So they 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.

#### 7.2.2.3 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 because of 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.

#### 7.2.2.4 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.

#### 7.2.2.5 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.

#### 7.2.2.6 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 toxins and pollutants to the level where it cannot cope anymore.

#### 7.2.2.7 Habitat for fish and wildlife

One regulator's advice was that there are very few fish that can survive in the Olifants River. This affects small-scale fishermen who consume these fish or make a living from selling them. There is also the case of crocodiles that have died because of pollution. Overall, many respondents related pollution levels with low wildlife and fish populations in the rivers.

#### 7.2.2.8 Support plant growth processes (pollination and photosynthesis)

Local residents described how certain species of plants have gone extinct. They were of the perception that the river system could no longer support the proper growth of delicate vegetation due to different reasons, that's why 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.

#### 7.2.2.9 Conservation of ecosystems

Some of the reasons given were that the ecosystem as a whole was being threatened by the toxins in the river. Also, 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.

## 7.3 Which Water Ecosystem Services should be valued

### 7.3.1 Introduction

As mentioned in our general introduction, the water-related ecosystem services are often public and non-marketed. Making these services visible to the decision makers and other stakeholders will be an important step to restore them. Visibility can be obtained when the WES economic value is made explicit, as we can evaluate the cost of inactions or the trade-offs between these WES and other economic activities. Therefore, the WES perceived as important would need to be further investigated in terms of economic value.

Discrete Choice Experiments (DCEs) have proven a successful method to estimate the economic value from changes in non-market goods and services (Johnston et al., 2017), including environmental goods. The method makes respondents choose between different goods described by a number of attributes. However, recent studies suggest that non-market valuation could benefit from an improved procedure to select the relevant ecosystem services (Armatas et al., 2014; Jensen, 2019).

Two issues must be tackled in order to get the right set of services to be valued.

First, we need to identify a proper list of end-point services with no missing or overlapping services (Zhao et al., 2013; Boyd and Krupnick, 2013). This was adressed when we designed the set of statements for the survey.

Second, if we find some heterogeneity in the preferences of WES, it may require some extra care when preparing the design. The traditional approach of DCEs is to use a single experimental design using a single set of attributes assuming that all attributes are relevant to all respondents. However, some WES up for valuation may be only relevant to sub-groups of beneficiaries, and this may cause problem when we ask a respondent to make trade-off between something he or she cares about and something he or she does not care about.

Two strategies can be used when designing a study in the presence of preference heterogeneity: a) create a design with a large set of attributes to make sure each respondent finds the attributes relevant for him, b) create some group-specific designs tailored with the attributes known to be relevant for each group. Both solutions have their own challenges.

Creating a design with many attributes will create some cognitive burden on the respondents if too many attributes are to be compared. Beside, if confronted with attributes that are not relevant to her, a respondent may respond less seriously or apply some decision heuristics such as non-attending some of the attributes (Jourdain and Vivithkeyoonvong, 2017; Caputo et al., 2018).

Using sub-designs poses its own set of challenges: increased number of survey required, additional questions to identify which sub-design should be applied to each respondent, more complex data analysis (Jensen, 2019).

In order to decide which WES could be used in a DCE, we will explore further the ranking of the statements on each factors.

### 7.3.2 Analysis of the heterogeneity

We first need to decide what is the threshold if a statement was considered as important. For this report, we considered that a statement as important if it fell into the top quartile

of the score. The Z-score have a zero mean and a standard deviation equal to onz, so a Z-score higher than $qnorm(0.75) = 0.67$ will fall in the first quartile[3].

In the Table 7.6, we reported the Q-scores and the Z-scores for the three factors, and calculated the number of factors on which they were important, and the number of factors on which they were minor. A scatterplot of the WES according to the mean and standard deviations of the Z-scores is also shown in Figure 7.1.

Table 7.6: Water Ecosystem Services: Heterogeneity of rankings

| SID | *Statement* | Z1 | Z2 | Z3 | NbImp | NbMinor | Mean | StDev |
|---|---|---|---|---|---|---|---|---|
| 13 | *Water for municipality use to supply tap water* | 0.78 | 2.14 | 1.242 | 3 | 0 | 1.389 | 0.564 |
| 8 | *Water directly from the river for domestic use (washing bathing etc)* | 1.12 | 2.29 | -0.193 | 2 | 0 | 1.071 | 1.013 |
| 7 | *Water for irrigation* | 1.59 | 0.96 | 0.663 | 2 | 0 | 1.070 | 0.387 |
| 26 | *Support plant growth processes (pollination and photosynthesis)* | 0.97 | 0.66 | 1.110 | 2 | 0 | 0.911 | 0.189 |
| 1 | *Maintenance of water quality by diluting pollutants* | 0.22 | 1.16 | 0.940 | 2 | 0 | 0.773 | 0.403 |
| 14 | *Water for industrial use (mining and manufacturing)* | 0.82 | 0.58 | 0.748 | 2 | 0 | 0.716 | 0.103 |
| 5 | *Natural storage for water* | 0.97 | -0.23 | 1.218 | 2 | 0 | 0.652 | 0.632 |
| 2 | *Preventing floods* | 0.75 | -0.85 | 1.049 | 2 | 1 | 0.316 | 0.833 |
| 6 | *Habitat for fish and wildlife* | 0.36 | 0.87 | -0.579 | 1 | 0 | 0.216 | 0.598 |
| 12 | *Plants herbs and natural products* | -0.69 | 1.16 | 0.470 | 1 | 1 | 0.314 | 0.762 |
| 4 | *Conservation of ecosystem* | 1.53 | -0.07 | -0.917 | 1 | 1 | 0.181 | 1.014 |
| 11 | *Catching fish to eat or sell* | 0.72 | 0.16 | -1.242 | 1 | 1 | -0.122 | 0.824 |
| 9 | *Water for power generation* | -0.98 | -1.06 | 1.965 | 1 | 2 | -0.022 | 1.406 |
| 3 | *Control of soil erosion* | -1.31 | -1.45 | 1.411 | 1 | 2 | -0.449 | 1.316 |
| 27 | *Water cycle* | 0.31 | 0.55 | -0.085 | 0 | 0 | 0.258 | 0.261 |
| 21 | *National pride of owning a clean river* | -0.19 | -0.43 | 0.555 | 0 | 0 | -0.023 | 0.420 |
| 23 | *Preventing damage to the environment (ecosystem resilience)* | 0.27 | -0.51 | -0.277 | 0 | 0 | -0.172 | 0.327 |
| 19 | *Research and education purposes* | -0.44 | 0.12 | -0.555 | 0 | 0 | -0.290 | 0.296 |
| 16 | *Tourism of wildlife* | -0.44 | -0.57 | -0.193 | 0 | 0 | -0.401 | 0.156 |
| 25 | *Making the landscape more beautiful* | -0.18 | -0.85 | -0.193 | 0 | 1 | -0.408 | 0.311 |
| 17 | *Traditional and religious rituals* | -0.34 | -0.38 | -0.748 | 0 | 1 | -0.490 | 0.183 |
| 10 | *Water transport (Boats and canoes)* | -1.76 | -0.31 | -0.386 | 0 | 1 | -0.821 | 0.668 |
| 15 | *Boat cruise water viewing and water games* | -2.38 | 0.31 | -0.663 | 0 | 1 | -0.913 | 1.114 |
| 22 | *Recycling nutrients* | 0.36 | -1.00 | -0.832 | 0 | 2 | -0.491 | 0.603 |

[3] $qnorm$ is the quantile function of the standardized normal distribution

Table 7.6: Water Ecosystem Services: Heterogeneity of rankings *(continued)*

| SID | *Statement* | Z1 | Z2 | Z3 | NbImp | NbMinor | Mean | StDev |
|---|---|---|---|---|---|---|---|---|
| 24 | *A special environment for rare species of plants and animals (refugia)* | 0.20 | -0.82 | -0.940 | 0 | 2 | -0.521 | 0.509 |
| 20 | *A nice view to look at (aesthetic values)* | -0.88 | -0.82 | -1.965 | 0 | 3 | -1.222 | 0.526 |
| 18 | *Fishing for fun* | -1.36 | -1.60 | -1.604 | 0 | 3 | -1.521 | 0.112 |

*Note:*
Low standard deviation expresses identical views across factors; high standard deviation expresses disagreement across factors

Based on the number of times they were ranked as important (or minor) and the mean and standard deviation of the Z-scores across the three groups, we can establish three groups of WES.

A first group of WES of interest corresponds to WES that were seen as important by at least two groups, and neutral (neither important nor minor) by the remaining group. We can make the hypothesis that all stakeholders would be able to give these WES an economic value, and would be in favor of(or at least not be opposed to) policies to improve those services. They include provisioning services such as the provision of water to municipalities or directly to households, agriculture and industries (in that order of priorities). But they also include regulating services such as “support of plant growth”, “maintenance of water quality by diluting pollutants”, and “Natural storage of water”. The regulating service “preventing floods” is a special case as it is considered important by two groups and minor by one group.

A second group of interest include the WES that are recognized important by only one group. This can be further subdivided into two sub-groups.

First, a group of WES that are important for one group and neutral for at least another group; this groups is composed of many regulating services the “Habitat for wildlife”, “Conservation of ecosystems”, but also some provisioning services: “Plant herbs and natural products”, “Catching fish to eat or sell”. These services could also be included in a valuation study.

A second sub-group includes the WES that are considered minor by at least two groups. This group includes the “Water for Power generation”, and “the control of erosion”. These

two services seem controversial or poorly understood among stakeholders. We will not consider them for further analysis.

All the other WES may not be considered for further analysis, because they are considered neutral or minor by all groups.

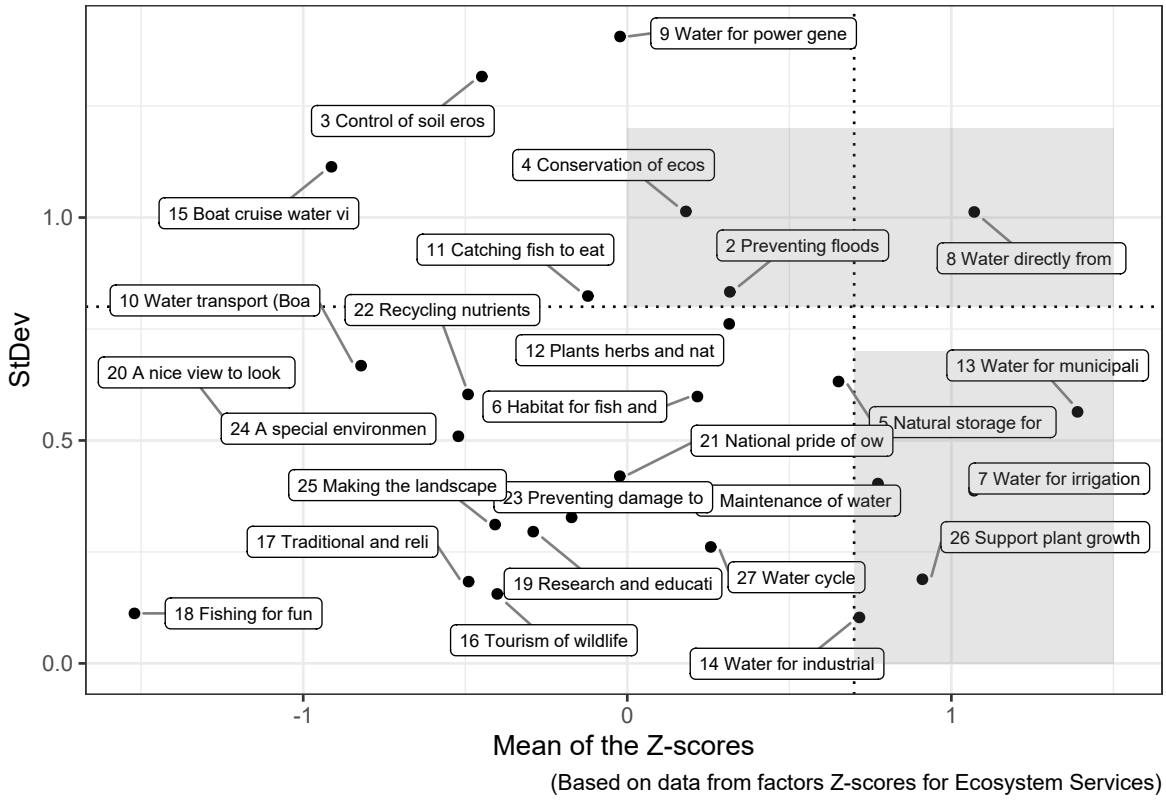


Figure 7.1: Caption

### 7.3.3 So which factor ?

The information provided by this survey will be very useful for the design of future valuation studies. We have retained 12 potential ecosystem services, many of them provisioning services, but also including some regulating and support services.

Two questions will need to be adressed when designing further studies about the WES. The first one need to adress the number of WES we will want to economically value,

the second one need to adress the issue of heterogeneity of preferences and its consequences for the design of DCE.

For the first issue, a number of the services considered are provisining services that are private goods (water for municipality, water for irrigation, water for industries, etc.); therefore, the valuation of these services may not require the use of DCE.

With regard to the heterogeneity of preferences, we were able to identify 2 main groups of services of interest. The first group consists of services that are perceived as important by a significant part of the population and neutral by the remaining part. For this group, we do not foresee any issues for the design of DCEs.

The second group includes services that are perceived as important by only one group, but considered minor by another group. These include specific provisioning services (fish, plants extracted from the ecosystems), but also some supporting services (conservation of ecosystems). For these services, we will need to pay attention to the attitudes of respondents towards these services with relatively extensive pre-surveys and debriefing questions about their choices.

However, since the 12 services considered do not have very low rankings on all factors, we do not anticipate to have to make different designs for different segments of the population. This is because, we do not anticipate negative reactions when respondents are asked to value those services.

## 7.4 Lessons learned and policy implications

The different sections about WES in the Olifants provided several useful information for decision-makers and for planning further research.

First, many of the provisioning services (water for households, agriculture, and industries) ranked high for at least 2 of the 3 groups identified. Yet, people are not considering these services are provided at an adequate level (either not receiving the service at all, or no trusting that the water they receive is clean enough). Overall, improving these services is likely to improve welfare and should be given a greater priority.

Second, some services are identified as important by only one segment of the popula-

tion. In that category, we find mostly some support services (e.g. maintenance of ecosystems). Therefore, only a portion of the population would see a benefit in making sure these WES are not affected by pollution. We can make several hypotheses about this: first, this could come from populations that are aware of the benefits but have more urgent needs than maintaining the ecosystems; second, this could come from populations that are not aware of the benefits of maintaining ecosystems. This survey because of its limited number of respondents and its focus on qualitative methods, cannot answer this question with precision. However, a more quantitative approach, such as a discrete choice experiment, would allow get some additional insights into the real value of these supporting services, as well as the diversity of this value across the population.

# Chapter 8

# Instruments to restore water-related ecosystem services

In this chapter[1], we analyze the rankings of the institutional and public policy statements regarding the maintenance of water ecosystem services. The 16 respondents were asked to rank each of the 31 statements (Table 4.4) in a quasi-normal grid ranging from -5: Strong disagreement) to +5: Strong agreement (Figure B.4)).

## 8.1 Centroid Factor Analysis: Unrotated factors

We explored the alternative methods to decide upon the number of factors to be selected based on the results of the centroid factor analysis (Table F.1). The eigenvalues of the first 7 unrotated factors are presented in Table 8.1. The Kaiser-Guttman criterion suggests to select the factors 1, 2, 4, 5. The scree plot of the eigenvalues suggests to retain 2 to 3 factors (Figure F.1). Alternatively, if we follow the criterion that at least two Q-sorts should be significantly loaded on a factor [2], we should retain the factors 1, 2, 4, 5 Finally, the Humpfrey's rule suggests retaining 1 (Table F.2). A less strict interpretation of the rule suggests retaining 1, 2, 4, 5.

[1] For the sake of space, some tables and figures related to this chapter are presented in Annex F

[2] Significantly loaded Q-sorts are represented by xx in Table F.1

Table 8.1: Instruments: Eigenvalues

| | F1 | F2 | F3 | F4 | F5 | F6 | F7 |
|---|---|---|---|---|---|---|---|
| Eigenvalues | 3.79 | 1.82 | 0.29 | 1.07 | 1.09 | 0.39 | 0.71 |
| Variance Explained | 23.68 | 11.35 | 1.84 | 6.70 | 6.84 | 2.41 | 4.44 |
| Cumulative Variance Explained | 23.68 | 35.03 | 36.87 | 43.57 | 50.41 | 52.82 | 57.26 |

We applied a non-strict interpretation of the criteria and we conducted an analysis with the factors 1, 2, 4, 5.

## 8.2 Four Factors Analysis

The results of the varimax rotation with 4 factors and the selection of Q-sorts are presented in Table 8.2.

The first factor is represented by the Q-sorts 2, 5, 12, 13, 14. The eigenvalue of this first factors was 2.79, representing 17.46 % of the total variance. The second factor is represented by the Q-sorts 3, 6, 7, 8. The eigenvalue of this first factors was 2.13, representing 13.28 % of the total variance.

Table 8.2: Instruments: Rotated Factors

| QID | Type | L1 | s1[a] | L2 | s2 | L3 | s3 | L4 | s4 | h2 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Commercial user | 0.41 | x | 0.06 | | 0.29827 | | -0.04816 | | 0.26 |
| 2 | Domestic user | 0.19 | | -0.03 | | 0.71246 | x | 0.03852 | | 0.54 |
| 3 | Water board | 0.26 | | 0.20 | | 0.13015 | | 0.56025 | x | 0.44 |
| 4 | Private sector | 0.62 | x | 0.23 | | 0.22830 | | 0.23938 | | 0.54 |
| 5 | Supplier | 0.01 | | 0.22 | | 0.54096 | x | 0.29777 | | 0.43 |
| 6 | Conservationist | 0.58 | x | 0.06 | | 0.35331 | | 0.29541 | | 0.55 |
| 7 | Domestic user | 0.63 | x | 0.00 | | -0.08875 | | -0.07059 | | 0.41 |
| 8 | Supplier | 0.09 | | 0.34 | | 0.42001 | x | 0.12319 | | 0.31 |
| 9 | Supplier | 0.05 | | 0.62 | x | 0.05623 | | 0.07852 | | 0.39 |
| 10 | Regulator | -0.02 | | 0.65 | x | -0.04716 | | 0.14750 | | 0.45 |
| 11 | Private sector | 0.16 | | 0.34 | | 0.66679 | x | -0.41765 | | 0.76 |
| 12 | Regulator | -0.02 | | 0.66 | x | 0.33030 | | 0.02805 | | 0.54 |
| 13 | Regulator | 0.35 | | -0.06 | | 0.52815 | x | 0.35535 | | 0.53 |

Table 8.2: Instruments: Rotated Factors *(continued)*

| QID | Type | L1 | s1[a] | L2 | s2 | L3 | s3 | L4 | s4 | h2 |
|---|---|---|---|---|---|---|---|---|---|---|
| 14 | Conservationist | 0.50 | x | -0.09 | | 0.09298 | | 0.34921 | | 0.39 |
| 15 | Commercial user | 0.64 | x | -0.22 | | 0.40293 | | -0.07875 | | 0.63 |
| 16 | Supplier | -0.03 | | 0.19 | | 0.03575 | | 0.77567 | x | 0.64 |

*Note:*

A varimax rotation has been applied, and no additional corrections were made

[a] x indicates that the Q-sort has been flagged to define the factor

The third factor is represented by the Q-sorts 2, 5, 8, 11, 13. The eigenvalue of this first factors was 2.28, representing 14.24 % of the total variance. The fourth factor is represented by the Q-sorts 3, 16. The eigenvalue of this first factors was 1.63, representing 10.19 % of the total variance. Note that all Q-sorts have been used for the following analyses.

Overall, the four factors represented 48.9 % of the data variance.

The types of stakeholders composing each factor are presented in Table 8.3.

Table 8.3: Instruments: Representation of Rotated Factors

| | F1 | F2 | F3 | F4 |
|---|---|---|---|---|
| Commercial user | 2 | 0 | 0 | 0 |
| Conservationist | 2 | 0 | 0 | 0 |
| Domestic user | 1 | 0 | 1 | 0 |
| Private sector | 1 | 0 | 1 | 0 |
| Regulator | 0 | 2 | 1 | 0 |
| Supplier | 0 | 1 | 2 | 1 |
| Water board | 0 | 0 | 0 | 1 |
| Total | 6 | 3 | 5 | 2 |

The first factor summarizes the Q-sorts 6. They are mainly water users and conservationists. The second factor summarizes the Q-sorts 3. They are mainly water regulators and suppliers. The third factor summarizes the Q-sorts 5. It is a mix of users and or suppliers. Finally, the fourth factor summarizes the Q-sorts 2. It represents mainly suppliers.

## 8.3 Tools for the interpretation of the factors

We followed the crib sheet procedure which forced us to analyse each single item of the prototypical Q sorts presented in the Factors Array table (Table 8.4). The crib sheets are presented in Tables F.3, F.5, F.7, and F.9. The consensus statements are presented in Table 8.6. Finally, for each factor, the distinguishing statements are presented in Tables F.4, F.6, F.8, and F.10.

Table 8.4: Factor Arrays

| SID | *Statements* | QS1 | ZS1 | QS2 | ZS2 | QS3 | ZS3 | QS4 | ZS4 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | *Increased sensitization to raise awareness about negative impacts of water pollution* | 0 | 0.11 | 3 | 1.19 | 3 | 1.10 | 1 | 0.38 |
| 2 | *Give incentives/rewards to water users who pollute less* | 0 | 0.29 | -2 | -0.82 | -3 | -0.98 | 3 | 1.03 |
| 3 | *Invest in tools to detect water pollution* | 1 | 0.45 | -1 | -0.63 | -2 | -0.59 | -1 | -0.48 |
| 4 | *Increase monitoring and enforcement of existing laws* | 5 | 2.09 | 0 | -0.08 | 3 | 0.94 | 2 | 0.85 |
| 5 | *An independent regulator (not a government institution) will do a better job to control water pollution* | 4 | 1.68 | 0 | 0.31 | 2 | 0.51 | 5 | 1.71 |
| 6 | *Department of water and sanitation should come up with ways of punishing water polluters* | 4 | 1.29 | -1 | -0.51 | 4 | 1.56 | 0 | 0.05 |
| 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 | 0.89 | 0 | -0.36 | 1 | 0.40 | -3 | -0.98 |
| 8 | *Further training of staff from Department of Water and sanitation in issues of water quality* | -2 | -0.81 | 3 | 1.29 | 2 | 0.64 | 3 | 1.33 |
| 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 | 0.83 | 4 | 1.46 | -1 | -0.33 | 1 | 0.68 |
| 10 | *If the majority of households have piped water then they will stop polluting the river* | -3 | -1.23 | -4 | -1.70 | -1 | -0.57 | -4 | -1.58 |
| 11 | *More government funding to the municipalities will improve water quality* | -5 | -2.00 | 1 | 0.72 | -4 | -1.29 | 2 | 0.85 |
| 12 | *Naming and shaming polluters encourages people to stop pollution* | 0 | 0.36 | -2 | -0.84 | 1 | 0.49 | 0 | 0.25 |
| 13 | *Improving the quality of water will be expensive* | 0 | 0.28 | 0 | -0.48 | -4 | -1.92 | -1 | -0.55 |
| 14 | *Pollution will stop if only the people upstream stopped polluting* | -3 | -1.17 | -2 | -0.86 | -2 | -0.80 | -2 | -0.81 |

Table 8.4: Factor Arrays *(continued)*

| SID | *Statements* | QS1 | ZS1 | QS2 | ZS2 | QS3 | ZS3 | QS4 | ZS4 |
|---|---|---|---|---|---|---|---|---|---|
| 15 | *The mines should compensate the farmers because the waste from the mines kills their animals and plants* | 2 | 0.81 | -1 | -0.51 | -1 | -0.27 | -3 | -1.20 |
| 16 | *The Olifants river catchment is too big to be controlled by one body* | -3 | -0.93 | -3 | -1.10 | -1 | -0.55 | -1 | -0.30 |
| 17 | *The priority should be to prevent the effects of pollution on the environment* | 3 | 0.87 | -3 | -0.98 | 1 | 0.37 | 0 | -0.17 |
| 18 | *The quality of water in the Olifants cannot be improved. It?s too late.* | -4 | -1.29 | -5 | -1.82 | -5 | -2.00 | -2 | -0.85 |
| 19 | *There is need for all stakeholders to work together to improve water quality* | 1 | 0.42 | 2 | 0.79 | 3 | 1.22 | 2 | 0.81 |
| 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 | -1.62 | 1 | 0.62 | -3 | -1.13 | 4 | 1.38 |
| 21 | *Those who pollute should pay all those who are affected by the pollution* | 3 | 1.02 | 0 | -0.37 | -2 | -0.76 | 0 | 0.00 |
| 22 | *Those who pollute too much should stop using the river for a while* | -2 | -0.82 | -4 | -1.14 | 0 | 0.18 | -1 | -0.38 |
| 23 | *Department of Water Affairs should ensure that everyone is using the correct amount of water for the right purpose (Validation and verification).* | 2 | 0.79 | 5 | 1.61 | 0 | -0.20 | 1 | 0.30 |
| 24 | *We need more laws in order to prevent further water pollution* | -1 | -0.70 | 4 | 1.50 | -3 | -0.85 | -5 | -2.14 |
| 25 | *Municipalities should allocate more money to water quality improvement* | -1 | -0.40 | -1 | -0.53 | 0 | -0.24 | 4 | 1.53 |
| 26 | *All commercial farmers should be certified by SA GAP or Global GAP as a way to reduce water pollution from irrigation farms* | -1 | -0.49 | 2 | 0.80 | 0 | 0.28 | -2 | -0.90 |
| 27 | *Improved garbage collection will prevent domestic waste (such as diapers) from polluting the river* | 1 | 0.48 | 1 | 0.55 | 4 | 1.42 | -4 | -1.41 |
| 28 | *Regular stakeholder meetings are important in improving water quality* | 0 | -0.17 | 2 | 1.01 | 2 | 0.58 | 1 | 0.78 |
| 29 | *Local people should decide how best to manage the river* | -1 | -0.57 | -3 | -1.01 | 0 | 0.02 | -3 | -1.03 |
| 30 | *Capacity building of the municipality through training of staff to improve water quality management* | 1 | 0.45 | 1 | 0.65 | 5 | 2.30 | 3 | 0.98 |
| 31 | *Educating farm workers about water quality to prevent water pollution* | -2 | -0.92 | 3 | 1.21 | 1 | 0.50 | 0 | -0.13 |

The correlation between factors is presented in 8.5. It shows the four factors are uncorrelated point of views. However, there is possible proximity of views between the factor 1 and the factor 3 ($r_{1,3} = 0.466$). This could originate from the fact that the factor 3 is composed of a mix of users and providers.

Table 8.5: Instruments: Correlation between factors

| ZS1 | ZS2 | ZS3 | ZS4 |
|---|---|---|---|
| 1.000 | 0.075 | 0.466 | 0.171 |
| 0.075 | 1.000 | 0.326 | 0.310 |
| 0.466 | 0.326 | 1.000 | 0.218 |
| 0.171 | 0.310 | 0.218 | 1.000 |

## 8.4 Discussion

### 8.4.1 Quality of the analysis

Overall, the four factors represented 48.9 % of the data variance, showing the factors are capturing a large share of the information. This is consistent with the results of the first survey where it was easier to capture the diversity of point of views about "what should be done".

### 8.4.2 Factor interpretation

#### 8.4.2.1 Factor 1: Enforcement of existing regulations

The factor 1 could be summarized by the following statement: "Polluters must be made *accountable* through monitoring and *enforcement of existing regulations*". 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), especially that this group of stakeholders is of the view that the presence of dissolved substances is a more dangerous form of water pollution than physical waste such as plastic waste (7: +3).

The environment should be also be protected from the effects of water pollution (17:

+3). That is why there is need to invest in tools for early detection of water pollution (3, +1) so that further environmental degradation could be mitigated[3].

Even though these stakeholders think that improving water quality would be expensive, they disagree with additional funding allocated to municipalities or to additional training of the staff of the Department of Water and Sanitation (DWS) (13:0, 11: -5, 8: -2). One commercial user said that "*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*".

People holding this perspective disagreed with the idea that new users should be prevented from using the river (20: -4), simply because "it was unfair to assume that new users will cause water pollution". The conservationists also 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 "South Africa has some of the best laws in the world as far as water resource management is concerned" according to one conservationist. They added that "*most water polluters were only getting away with the pollution they generated because there was poor enforcement and monitoring of existing laws*".

Finally, this group of stakeholders did not really believe more engagement with stakeholders (28: 0) or sensitization (31: -2) would prevent water pollution because these efforts were being done already but they have not yielded much positive results.

#### 8.4.2.2 Factor 2 : Better organization and coordination

The factor 2 could be summarized by the following statement: "**More organization and coordination is needed**"; the ranking suggested an approach that calls for more organization and coordination in the management of water resources as a way to improve water quality, prevent further pollution and restore ecosystem services. The role of the Government is seen as prevalent, especially DWS (23:+5), and to certain extent to the water user associations (9:+4).

[3]This statement did not really came out as a strong agreement (+1), but came stronger than for the other factors (-1, -1, and -2 for the other factors)

For this group, it is not too late to improve the quality of water in the Olifants (18: -5) because there is still hope that the situation could be made better. Before anything else, the 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. However, they agreed with the need for more laws to prevent and deter water pollution offenders (24:4). These stakeholders want government to take an active role in water resources management. This also explains why they do not really think an independent regulator might be more effective in enforcing laws than a government-affiliated regulator (5: 0).

In addition, these stakeholders also thought that water user associations have a big 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).

Finally, they did not think incentivizing non-polluters or simply naming and shaming polluters would lead 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).

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

The factor 3 could be summerized by the following statement: "*Innovation and creativity is needed in water management through capacity building*". This group thought that improving water quality will require innovative ways of doing things. For example, they

suggest that the Department of Water and Sanitation as a regulator (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 meeting out punishments to water polluters such that it does not deters would-be offenders*", said a supplier. So they agreed to unconventional approaches such as preventing water polluters from using the river for a while (22: +3) as a new 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). That is why they 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). Further training of municipalities staff would build capacity was also seen as leading to improving water quality (30: +4). This viewpoint 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 a domestic user.

#### 8.4.2.4 Factor 4: Change institutions and funding

The factor 4 could be summerized by the following statement: "*Change institutions and funding*". This group of stakeholders held the opinion that if things continue as they are, it might actually be too late to improve the quality of water in the Olifants river (18: -2). Thus, these stakeholders holding this view 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 programs (25: +3). Similarly, they perceive that further training of staff

from 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, so it explains 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 have a positive effect in encouraging sustainable water use (2: +3).

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 it 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 Olifants 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 does not see a need for more laws in order to prevent water pollution (24: -5). They did not see the need for compensation mechanisms (for ex. 15: -4). The water supplier said 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 group views all manner of pollution as equally dangerous, whether it comes from domestic waste or acid mine drainage. Therefore, all types of water pollution must be treated as equally dangerous regardless of the source of that pollution (7: -2).

### 8.4.3 Consensus statements

Table 8.6: Instruments: Consensus statements

| SID | Statement | Z1 | Z2 | Z3 | Z4 | *m* | s |
|---|---|---|---|---|---|---|---|
| 14 | Pollution will stop if only the people upstream stopped polluting | -1.17 | -0.86 | -0.80 | -0.81 | *-0.91* | 0.08 |
| 16 | The Olifants river catchment is too big to be controlled by one body | -0.93 | -1.10 | -0.55 | -0.30 | *-0.72* | 0.16 |

*Note:*
All Listed Statements are Non-Significant P>.05

The consensus statements are presented in Table 8.6. The results showed that the number of statements that created consensus is very small (2 out of 31 statements). Besides, it also showed that they agreed only on their disagreement with certain statements. For example, all factors gave low rank to the sentence "Pollution will stop if only the people upstream stopped polluting". But we do not seem to have an agrement on a positive ranking for a statement.

Overall this confirms the presence of very contrasted views about what should be done.

## 8.5 Lessons learned and policy implications

The results indicates that very few instruments would draw a consensus. In fact, the only consensus was about the fact that some instruments would not be effective in restoring WES.

The results also suggests 4 contrasted point of views to restore ecosystem services in the Olifants:

- The first POV asked for strict enforcement of existing laws: polluters must be made *accountable* through monitoring and enforcement of existing regulations. No additional funding is required, but a better use of the funding (better allocation by the municipalities) would be required.
- The second POV asked for more organization and coordination. The role of DWS and of the WUA would be prevalent. Incentivizing non-polluters or punishing polluters (for ex. with fines) are not seen as effective measures.
- The third POV asked for innovative water management/governance and capacity building : the current way of doing things has done very little in terms of meeting out punishments to water polluters such that it does not deters would-be offenders. Household waste is seen as the most important 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. Finally, training of municipalities staff would build capacity would be required.
- The fourth POV asked for a change in institutions and funding methods: an inde-

pendent body to regulate water resources would improve efficiency (since DWS both set the rules and monitor them). More government funding to municipalities, and a greater share of the municipality budgets should be allocated to water quality improvement programs. Further training of staff from Department of Water and Sanitation (DWS) would also improve the capacity to tackle water quality issues.

The difference in views can be represented by the different fault lines:

- The sufficiency or not of funding dedicated to the maintenance of WES;
- The necessity or not of training and education at different levels (WWTP, DWS, Municipalities);
- The adequacy of management style and its effectiveness in curbing pollution: punishment vs. better coordination;
- The overall organization: sufficient involvement of stakeholders? need for an independent regulator?

Ecosystem management decisions that may seem to be a simple matter of setting limits on resource use and pollution emissions frequently fail because of the political process of decision-making, differing values and norms, and power imbalances (DeFries and Nagendra, 2017).

In our case, we have identified difference in values (what ecosystems are important), and the ways we should proceed. The different solutions are likely to be driven by interest-groups. For example, stakeholders who are emitting large amount of pollutants may not see the need for increased funding and trained of officers to control their activities, and are more likely to advocate for self-regulation and education measures. On the other side, Governmental bodies are likely to require for more funding to carry their activities given the difficulty of the task.

Continual engagement among policy-makers, communities, sectoral representative and researchers will progressively balance views between economic activies and health of the ecosystems. In that respect, the interplays at different scales proposed by Young (2006) will be essential to reach negotiated agreements and systemic changes.

# Part IV

# Conclusions

In order to identify the perceptions about what WES are important in the Olifants, the state of these WES, and the policy instruments that could be used to restore them, we conducted several interviews based on the Q-methodology approach.

We conducted four Q-surveys. In a first step, we reviewed existing published and grey literature related to water pollution in the Olifants, we identified the various stakeholders related to water pollution, and we conducted 17 interviews with persons representative of each type of stakeholder. In a second step, we conducted a Q-survey (18 respondents) aiming at identifying the issues related to water pollution of raw water and the possible solution to reduce that pollution. In a third step, we conducted a Q-survey aiming at identifying the different point of views about the main WES in the Olifants and the instruments that would help improving them. In this third step we conducted 16 surveys.

Overall, we conducted 51 detailed individual interviews that allowed us to get a good understanding of the issues at stakes and point of views on how to improve water quality and the provision of WES in the Olifants.

Regarding the importance of WES, we found three contrasted groups : a group that gave priority to water for productive uses (agriculture, industries, etc.) but also the maintenance of ecosystems; a group that gave priority to individual uses (municipality, direct extraction, fishing, etc.); and finally a group that gave priority to storage of water (dams) and erosion control provided by some water-ecosystems. Overall, the highest priority were given to provisioning WES, especially those related to the provision of water for domestic uses, industrial and agricultural uses. Some supporting and regulating services seemed to be recognized by some specific groups.

Despite a significant set of laws and regulations, as well as a significant range of infrastructure (dams, wastewater treatment plants, etc.) to manage raw water in terms of quantity and quality, most of the stakeholders interviewed were dissatisfied with the current levels of WES in the Olifants Basin. They also felt that that these WES were declining over time, and a large part in the decline is due to increasing polluted waters in the Basin. This is consistent with the more quantitative assessments carried out in South Africa (Nel and Driver, 2015). Finally in terms of instruments to restore the ecosystems, we found more heterogeneity with four contrasted groups, that were divided on issues about different instruments leading to better WES. The division were about the neces-

sity to channel more funds, the amount of training of the different stakeholders, and the overall governance (e.g., the need for an independant regulator).

Overall, we found more contrasting views about the solutions (what needs to be done) than about the WES that should be improved. However, the relative consensus about the importance of provisioning service also highlight the fact that there seems to be very little consensus to protect the supporting and regulating services. These services are seen as important only by sub-groups of the population (while often seen as minor by other sub-groups). This might partly explain the difficulties to maintain them.

# Part V

# Annexes

# Appendix A

# Terms used in Q-methodology

| Term | Definition |
|---|---|
| Concourse | A collection of all possible statements containing all relevant ideas of the subject at hand |
| Consensus statement | A statement with not significantly different scores across the different factors |
| Distinguishing statement of a factor | A statement whose score is significantly different for that factor |
| Factor Array | A factor-exemplifying Q sort: using the weighted average scores of the respondents representing the factor, an average Q-sort is created for that factor |
| Factor loadings | A measure that indicates the extent to which an individual Q sort is typical of a factor. It is expressed in the form of a correlation coefficient. |
| P-Set | The set of participants selected to take part in the study |
| Q-Set | The set of statements about the subject matter that need to be sorted |
| Q-Sort | A grid in which the respondent must sort the statements/items which are proposed into several ordered categories (e.g., from most to least important) while respecting certain proportions (most often, those of a normal distribution). Also refers to the final ranking made by a respondent |
| Z-scores | Normalized (mean= 0, sd =1) value of the the weighted average statement score, to remove the effect of differences in numbers of defining respondents per factor, and making statements' factor scores comparable across factors |

# Appendix B

# Q-grids used during the interviews

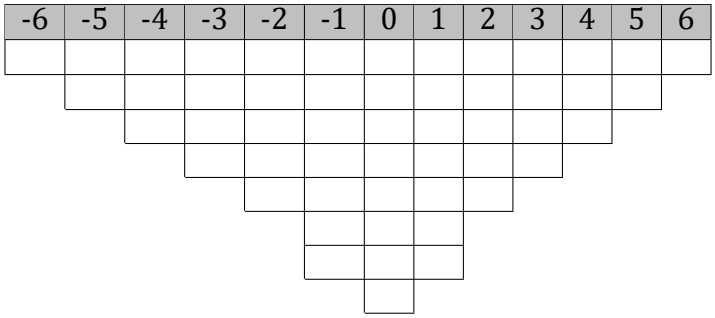


Figure B.1: Pre-arranged distribution for ranking of water quality issues in the Olifants

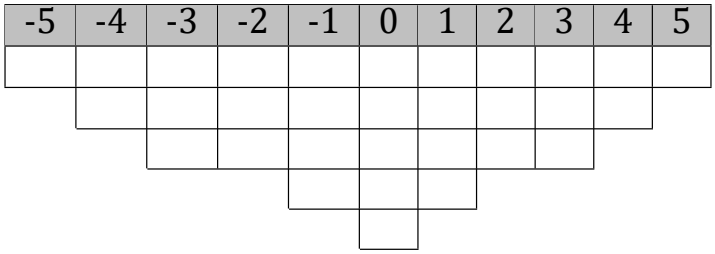


Figure B.2: Pre-arranged distribution for ranking of solutions to improve water quality

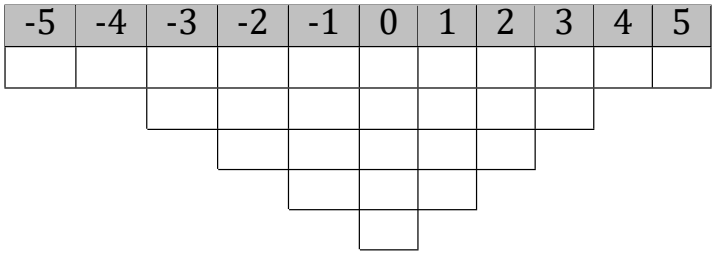


Figure B.3: Pre-arranged distribution for ranking of Water-related ecosystem services

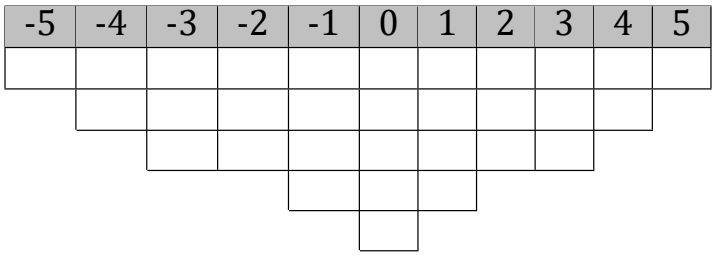


Figure B.4: Pre-arranged distribution for ranking of Instruments

# Appendix C

# Water Quality Issues: Additional Tables and Figures

Table C.1: Water Quality Issues - Unrotated factors

| QID | F1 | | F2 | | F3 | | F4 | | F5 | | F6 | F7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.600 | xx | -0.196 | | 0.030 | | -0.105 | | -0.061 | | 0.012 | 0.217 | |
| 2 | 0.111 | | 0.272 | x | 0.058 | | 0.486 | xx | 0.150 | | 0.191 | 0.119 | |
| 3 | 0.154 | | -0.032 | | 0.001 | | 0.148 | | 0.111 | | 0.017 | -0.237 | |
| 4 | 0.222 | | -0.058 | | 0.003 | | 0.148 | | -0.057 | | 0.023 | 0.118 | |
| 5 | 0.524 | xx | 0.186 | | 0.027 | | 0.170 | | -0.303 | x | 0.110 | -0.293 | x |
| 6 | 0.522 | xx | -0.460 | xx | 0.185 | | 0.217 | | 0.271 | | 0.067 | -0.107 | |
| 7 | 0.373 | xx | -0.506 | xx | 0.235 | | -0.164 | | -0.052 | | 0.020 | 0.059 | |
| 8 | 0.179 | | -0.079 | | 0.005 | | 0.331 | x | -0.285 | x | 0.168 | 0.166 | |
| 9 | 0.760 | xx | -0.388 | xx | 0.127 | | 0.085 | | -0.091 | | 0.018 | -0.144 | |
| 10 | 0.412 | xx | -0.201 | | 0.031 | | -0.328 | x | 0.108 | | 0.069 | -0.115 | |
| 11 | 0.556 | xx | -0.136 | | 0.014 | | -0.370 | xx | 0.059 | | 0.087 | -0.102 | |
| 12 | 0.459 | xx | 0.131 | | 0.013 | | -0.494 | xx | 0.143 | | 0.176 | 0.257 | |
| 13 | 0.356 | x | 0.234 | | 0.042 | | -0.059 | | 0.319 | x | 0.048 | -0.181 | |
| 14 | 0.404 | xx | 0.090 | | 0.006 | | -0.139 | | 0.196 | | 0.023 | 0.092 | |
| 15 | 0.376 | xx | 0.379 | xx | 0.118 | | 0.322 | x | -0.096 | | 0.091 | 0.116 | |
| 16 | 0.369 | xx | 0.621 | xx | 0.425 | xx | 0.130 | | 0.368 | xx | 0.082 | 0.294 | x |
| 17 | 0.116 | | 0.109 | | 0.009 | | -0.020 | | -0.398 | xx | 0.144 | -0.343 | x |
| 18 | 0.053 | | 0.035 | | 0.001 | | -0.381 | xx | -0.281 | x | 0.180 | 0.063 | |

*Note:*
x, xx indicate significant loading at 0.05 and 0.01 levels respectively

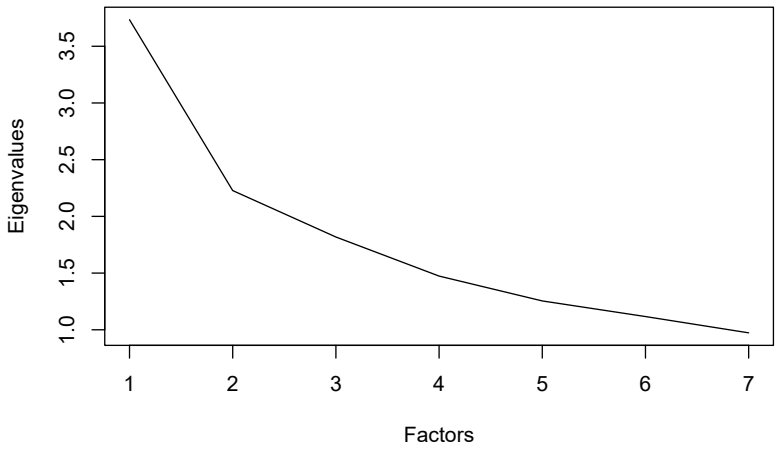


Figure C.1: Water Quality Issues - Scree Plot based on PCA Analysis

Table C.2: Water Quality Issues - Humprey rule calculations

| | Highest | 2nd Highest | Product | 2SE | 1SE |
|---|---|---|---|---|---|
| F1 | 0.76023 | 0.59981 | 0.4559936 | 1 | 1 |
| F2 | 0.62099 | 0.50618 | 0.3143327 | 1 | 1 |
| F3 | 0.42523 | 0.23462 | 0.0997675 | 0 | 0 |
| F4 | 0.49450 | 0.48626 | 0.2404556 | 0 | 1 |
| F5 | 0.39813 | 0.36836 | 0.1466552 | 0 | 1 |
| F6 | 0.19087 | 0.18041 | 0.0344349 | 0 | 0 |
| F7 | 0.34265 | 0.29430 | 0.1008419 | 0 | 0 |

Table C.3: Water Quality Issues: Crib Sheet - Factor 1

| Ranking | SID | *Statement* | **FA1** | FA2 |
|---|---|---|---|---|
| **Highest** | 36 | *The pollution in the water is getting worse. The water is more polluted now than it was a few years ago* | **6** | 0 |
| **Higher or equal** | 44 | *There are enough tools technology and capacity to improve water quality all that is needed is political will* | **5** | 2 |
| | 22 | *New water users are poorly planned and unregulated* | **4** | 1 |
| | 29 | *Some farmers are extracting more water than they should* | **4** | 3 |
| | 52 | *When the quantity/flow of water in the river is down even the quality of water reduces* | **4** | -1 |
| | 15 | *If things continue as they are there will be no usable water left to use by the year 2030* | **3** | 1 |
| | 37 | *The rules to control pollution are there but the implementation is hard* | **3** | 1 |
| | 3 | *Budget constraints by the municipality contribute to failure to control pollution* | **2** | -6 |
| | 10 | *I am concerned about the users downstream in other municipalities* | **2** | 0 |
| | 23 | *Non-Governmental Organisations (NGOs) private sector initiatives are helping to control water pollution* | **2** | 1 |
| | 39 | *The water in the river looks dirty* | **2** | 1 |
| | 6 | *Dump sites for garbage pollute the ground water* | **1** | 0 |
| | 7 | *Fish and plants can no longer survive properly along the river* | **1** | -1 |
| | 17 | *Most of the water pollution comes from the mines* | **1** | -4 |
| | 18 | *Most of the water pollution comes from the sewage from Waste Water Treatment Works (WWTWs)* | **1** | -1 |
| | 34 | *The water pollution in my region is coming from another region upstream* | **1** | -3 |
| | 40 | *The water in the river smells bad* | **1** | -2 |
| | 13 | *I am spending money to make the water usable* | **0** | -5 |
| | 20 | *Most of the water pollution comes from large irrigation commercial farmers* | **0** | -3 |
| | 38 | *The water in the Olifants is unfit for any domestic use (washing bathing cleaning or bathing)* | **0** | -5 |
| | 9 | *I also contribute to the pollution in the river through my activities* | **-1** | -2 |
| | 32 | *The loss in water quality is a result of climate change* | **-1** | -2 |
| | 8 | *Ground water (boreholes) is more polluted than the water from the river* | **-3** | -4 |
| | 27 | *Problems of water quality are due to lack of leadership and governance rather than by activities of water users* | **3** | 6 |
| | 11 | *I am more concerned about the impacts of water pollution to humans than to the environment* | **0** | 2 |
| | 24 | *Few stakeholders attend meetings called to discuss issues about water* | **0** | 4 |
| | 43 | *There are adequate communication channels for stakeholders to discuss issues of water management (through forums and stakeholder meetings)* | **0** | 3 |
| | 25 | *Pollution levels in the water is higher during the rainy season than in other seasons* | **-1** | 4 |
| | 31 | *The Integrated Development Plan (IDP) of municipalities includes a section talking about issues of water quality.* | **-1** | 1 |

Table C.3: Water Quality Issues: Crib Sheet - Factor 1 *(continued)*

| **Ranking** | SID | *Statement* | **FA1** | FA2 |
|---|---|---|---|---|
| | 45 | *There are many institutions controlling water quality issues thus causing confusion among stakeholders* | **-1** | 0 |
| | 5 | *Department of Water and Sanitation has financial capacity to effectively monitor and regulate water users* | **-2** | 4 |
| **Lower or equal** | 16 | *Most of the water pollution comes from residents in communities.* | **-2** | 0 |
| | 48 | *Unlawful use of water mainly affects the quantity and not the quality of the water* | **-2** | 2 |
| | 50 | *Water availability/Quantity is more important than water quality* | **-2** | 0 |
| | 21 | *Most of the water pollution comes from small livestock farmers* | **-3** | -1 |
| | 33 | *The municipality is adequately funded to carry out safe disposal of wastewater* | **-3** | -1 |
| | 51 | *Water boards are meeting standards for blue water drop* | **-3** | 2 |
| | 30 | *Staff at Waste Water Treatment Works do have the required skills to operate waste water treatment plants* | **-4** | 5 |
| | 41 | *The water pollution in the Olifants is beyond redemption. It cannot be controlled because it is too late* | **-4** | -2 |
| | 2 | *All water users are aware of the rules and regulations governing the use of the water* | **-5** | -3 |
| | 4 | *Department of Water and Sanitation has adequate trained staff to ensure compliance in good water use* | **-5** | 3 |
| | 2 | *All water users are aware of the rules and regulations governing the use of the water* | **-5** | -3 |
| **Lowest** | 4 | *Department of Water and Sanitation has adequate trained staff to ensure compliance in good water use* | **-5** | 3 |
| | 47 | *Those who discharge effluent into the river test the effluent before they discharge into the river to make sure it won?t pollute the water* | **-6** | -3 |

Table C.4: Water Quality Issues: Factor 1 Distinguishing statements

| SID | *Statement* | **Z1** | Z2 | s |
|---|---|---|---|---|
| 36 | *The pollution in the water is getting worse. The water is more polluted now than it was a few years ago* | **1.94** | 0.11 | 1.119 |
| 44 | *There are enough tools technology and capacity to improve water quality all that is needed is political will* | **1.70** | 0.58 | 0.687 |
| 22 | *New water users are poorly planned and unregulated* | **1.44** | 0.27 | 0.719 |
| 52 | *When the quantity/flow of water in the river is down even the quality of water reduces* | **1.31** | -0.69 | 1.223 |
| 37 | *The rules to control pollution are there but the implementation is hard* | **1.20** | 0.41 | 0.489 |
| 15 | *If things continue as they are there will be no usable water left to use by the year 2030* | **1.11** | 0.19 | 0.566 |
| 27 | *Problems of water quality are due to lack of leadership and governance rather than by activities of water users* | **1.09** | 2.57 | 0.910 |
| 3 | *Budget constraints by the municipality contribute to failure to control pollution* | **0.85** | -1.72 | 1.574 |
| 7 | *Fish and plants can no longer survive properly along the river* | **0.46** | -0.78 | 0.764 |
| 17 | *Most of the water pollution comes from the mines* | **0.44** | -1.34 | 1.088 |
| 40 | *The water in the river smells bad* | **0.42** | -0.86 | 0.787 |
| 34 | *The water pollution in my region is coming from another region upstream* | **0.41** | -1.14 | 0.948 |
| 24 | *Few stakeholders attend meetings called to discuss issues about water* | **0.17** | 1.48 | 0.798 |
| 38 | *The water in the Olifants is unfit for any domestic use (washing bathing cleaning or bathing)* | **0.10** | -1.55 | 1.006 |
| 13 | *I am spending money to make the water usable* | **0.09** | -1.66 | 1.070 |
| 11 | *I am more concerned about the impacts of water pollution to humans than to the environment* | **0.01** | 0.92 | 0.556 |
| 43 | *There are adequate communication channels for stakeholders to discuss issues of water management (through forums and stakeholder meetings)* | **-0.33** | 1.15 | 0.907 |
| 25 | *Pollution levels in the water is higher during the rainy season than in other seasons* | **-0.49** | 1.38 | 1.147 |
| 31 | *The Integrated Development Plan (IDP) of municipalities includes a section talking about issues of water quality.* | **-0.59** | 0.37 | 0.586 |
| 48 | *Unlawful use of water mainly affects the quantity and not the quality of the water* | **-0.76** | 0.69 | 0.891 |
| 16 | *Most of the water pollution comes from residents in communities.* | **-0.91** | 0.15 | 0.651 |
| 5 | *Department of Water and Sanitation has financial capacity to effectively monitor and regulate water users* | **-0.93** | 1.48 | 1.479 |
| 33 | *The municipality is adequately funded to carry out safe disposal of wastewater* | **-0.98** | -0.10 | 0.538 |
| 51 | *Water boards are meeting standards for blue water drop* | **-1.15** | 0.80 | 1.195 |
| 30 | *Staff at Waste Water Treatment Works do have the required skills to operate waste water treatment plants* | **-1.24** | 1.56 | 1.715 |
| 4 | *Department of Water and Sanitation has adequate trained staff to ensure compliance in good water use* | **-1.56** | 1.04 | 1.593 |
| 47 | *Those who discharge effluent into the river test the effluent before they discharge into the river to make sure it won?t pollute the water* | **-2.03** | -1.08 | 0.581 |

Table C.5: Water Quality Issues: Crib Sheet - Factor 2

| **Ranking** | SID | *Statement* | **FA1** | FA2 |
|---|---|---|---|---|
| **Highest** | 27 | *Problems of water quality are due to lack of leadership and governance rather than by activities of water users* | **3** | 6 |
| | 30 | *Staff at Waste Water Treatment Works do have the required skills to operate waste water treatment plants* | **-4** | 5 |
| | 5 | *Department of Water and Sanitation has financial capacity to effectively monitor and regulate water users* | **-2** | 4 |
| | 24 | *Few stakeholders attend meetings called to discuss issues about water* | **0** | 4 |
| | 25 | *Pollution levels in the water is higher during the rainy season than in other seasons* | **-1** | 4 |
| | 4 | *Department of Water and Sanitation has adequate trained staff to ensure compliance in good water use* | **-5** | 3 |
| | 43 | *There are adequate communication channels for stakeholders to discuss issues of water management (through forums and stakeholder meetings)* | **0** | 3 |
| | 11 | *I am more concerned about the impacts of water pollution to humans than to the environment* | **0** | 2 |
| | 48 | *Unlawful use of water mainly affects the quantity and not the quality of the water* | **-2** | 2 |
| **Higher or equal** | 51 | *Water boards are meeting standards for blue water drop* | **-3** | 2 |
| | 31 | *The Integrated Development Plan (IDP) of municipalities includes a section talking about issues of water quality.* | **-1** | 1 |
| | 16 | *Most of the water pollution comes from residents in communities.* | **-2** | 0 |
| | 45 | *There are many institutions controlling water quality issues thus causing confusion among stakeholders* | **-1** | 0 |
| | 50 | *Water availability/Quantity is more important than water quality* | **-2** | 0 |
| | 21 | *Most of the water pollution comes from small livestock farmers* | **-3** | -1 |
| | 33 | *The municipality is adequately funded to carry out safe disposal of wastewater* | **-3** | -1 |
| | 41 | *The water pollution in the Olifants is beyond redemption. It cannot be controlled because it is too late* | **-4** | -2 |
| | 2 | *All water users are aware of the rules and regulations governing the use of the water* | **-5** | -3 |
| | 47 | *Those who discharge effluent into the river test the effluent before they discharge into the river to make sure it won?t pollute the water* | **-6** | -3 |
| | 29 | *Some farmers are extracting more water than they should* | **4** | 3 |
| | 44 | *There are enough tools technology and capacity to improve water quality all that is needed is political will* | **5** | 2 |
| | 15 | *If things continue as they are there will be no usable water left to use by the year 2030* | **3** | 1 |
| | 22 | *New water users are poorly planned and unregulated* | **4** | 1 |
| | 23 | *Non-Governmental Organisations (NGOs) private sector initiatives are helping to control water pollution* | **2** | 1 |
| | 37 | *The rules to control pollution are there but the implementation is hard* | **3** | 1 |
| | 39 | *The water in the river looks dirty* | **2** | 1 |
| | 6 | *Dump sites for garbage pollute the ground water* | **1** | 0 |

Table C.5: Water Quality Issues: Crib Sheet - Factor 2 *(continued)*

| **Ranking** | SID | *Statement* | **FA1** | FA2 |
|---|---|---|---|---|
| **Lower or equal** | 10 | *I am concerned about the users downstream in other municipalities* | **2** | 0 |
| | 36 | *The pollution in the water is getting worse. The water is more polluted now than it was a few years ago* | **6** | 0 |
| | 7 | *Fish and plants can no longer survive properly along the river* | **1** | -1 |
| | 18 | *Most of the water pollution comes from the sewage from Waste Water Treatment Works (WWTWs)* | **1** | -1 |
| | 52 | *When the quantity/flow of water in the river is down even the quality of water reduces* | **4** | -1 |
| | 9 | *I also contribute to the pollution in the river through my activities* | **-1** | -2 |
| | 32 | *The loss in water quality is a result of climate change* | **-1** | -2 |
| | 40 | *The water in the river smells bad* | **1** | -2 |
| | 20 | *Most of the water pollution comes from large irrigation commercial farmers* | **0** | -3 |
| | 34 | *The water pollution in my region is coming from another region upstream* | **1** | -3 |
| | 8 | *Ground water (boreholes) is more polluted than the water from the river* | **-3** | -4 |
| | 17 | *Most of the water pollution comes from the mines* | **1** | -4 |
| | 13 | *I am spending money to make the water usable* | **0** | -5 |
| | 38 | *The water in the Olifants is unfit for any domestic use (washing bathing cleaning or bathing)* | **0** | -5 |
| **Lowest** | 3 | *Budget constraints by the municipality contribute to failure to control pollution* | **2** | -6 |

# Appendix D

# Solving Water Issues: Additional Tables and Figures

Table D.1: Solving Issues - Unrotated factors

| QID | F1 | | F2 | | F3 | | F4 | | F5 | | F6 | | F7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.509 | xx | -0.386 | x | 0.141 | | -0.321 | | -0.124 | | -0.151 | | -0.377 | x |
| 2 | -0.048 | | 0.205 | | 0.506 | xx | 0.177 | | 0.178 | | 0.373 | x | 0.133 | |
| 3 | 0.412 | x | -0.708 | xx | -0.171 | | -0.046 | | 0.116 | | -0.038 | | 0.292 | |
| 4 | 0.320 | | -0.425 | x | 0.448 | x | 0.187 | | -0.191 | | 0.248 | | 0.128 | |
| 5 | 0.339 | | 0.229 | | 0.287 | | 0.283 | | 0.044 | | -0.111 | | -0.069 | |
| 6 | 0.593 | xx | 0.207 | | -0.323 | | 0.165 | | 0.208 | | -0.278 | | 0.141 | |
| 7 | 0.574 | xx | 0.327 | | -0.011 | | -0.162 | | -0.435 | x | 0.089 | | 0.128 | |
| 8 | 0.398 | x | -0.108 | | -0.148 | | 0.376 | x | 0.089 | | 0.080 | | 0.126 | |
| 9 | 0.637 | xx | 0.294 | | 0.010 | | 0.110 | | 0.096 | | -0.049 | | 0.077 | |
| 10 | 0.191 | | 0.224 | | 0.503 | xx | 0.033 | | -0.189 | | -0.394 | x | 0.121 | |
| 11 | 0.536 | xx | 0.286 | | 0.086 | | -0.171 | | -0.054 | | 0.351 | | 0.378 | x |
| 12 | 0.399 | x | 0.714 | xx | -0.216 | | -0.253 | | -0.099 | | -0.145 | | 0.144 | |
| 13 | 0.478 | xx | 0.063 | | -0.214 | | -0.260 | | 0.293 | | 0.248 | | -0.259 | |
| 14 | 0.818 | xx | 0.115 | | -0.158 | | 0.225 | | 0.084 | | 0.045 | | -0.103 | |
| 15 | 0.329 | | -0.146 | | 0.232 | | 0.394 | x | 0.001 | | 0.030 | | 0.010 | |
| 16 | 0.550 | xx | -0.191 | | 0.063 | | -0.101 | | 0.120 | | -0.131 | | 0.088 | |
| 17 | 0.318 | | -0.188 | | 0.362 | x | -0.492 | xx | 0.306 | | 0.162 | | -0.013 | |
| 18 | -0.108 | | 0.109 | | 0.524 | xx | -0.088 | | 0.197 | | -0.327 | | 0.067 | |

*Note:*
x, xx indicate significant loading at 0.05 and 0.01 levels respectively

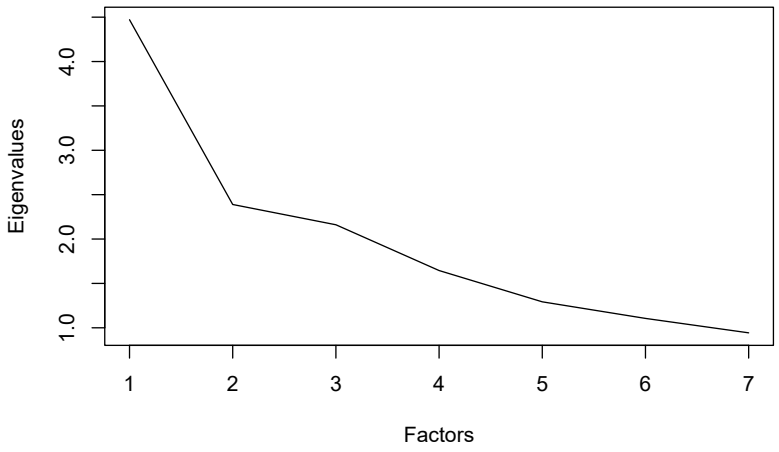


Figure D.1: Solving Issues - Scree Plot based on PCA Analysis

Table D.2: Solving Issues - Humprey rule calculations

| | Highest | 2nd Highest | Product | 2SE | 1SE |
|---|---|---|---|---|---|
| F1 | 0.81786 | 0.63680 | 0.5208132 | 1 | 1 |
| F2 | 0.71407 | 0.70823 | 0.5057258 | 1 | 1 |
| F3 | 0.52379 | 0.50573 | 0.2648963 | 0 | 1 |
| F4 | 0.49222 | 0.39362 | 0.1937476 | 0 | 1 |
| F5 | 0.43526 | 0.30585 | 0.1331243 | 0 | 0 |
| F6 | 0.39443 | 0.37311 | 0.1471658 | 0 | 0 |
| F7 | 0.37779 | 0.37663 | 0.1422870 | 0 | 0 |

Table D.3: Solving Issues: Crib Sheet - Factor 1

| **Ranking** | SID | *Statement* | **FA1** | FA2 | FA3 | FA4 |
|---|---|---|---|---|---|---|
| **Highest** | 26 | *There needs to be punishment for those who pollute the water* | **5** | 1 | -1 | 1 |
| | 27 | *Those who pollute should pay all those who are affected by the pollution* | **4** | 3 | 0 | -3 |
| | 30 | *We do not need more laws; we just need to enforce the ones already existing* | **4** | -2 | -4 | -2 |
| | 3 | *Commercial farmers who are certified by South Africa Good Agricultural Practices (SA GAP) or Global Good Agricultural Practices(GlobalGAP) are encouraged to pollute less so that they do not lose their certification* | **2** | -5 | 2 | -4 |
| **Higher or equal** | 12 | *Increased monitoring by DWS (Department of Water and Sanitation) will reduce misuse of water and improve the quality of the water* | **2** | 0 | -1 | -2 |
| | 5 | *Further training of staff at wastewater treatments will reduce discharge of sewerage into the river* | **1** | 0 | 1 | 1 |
| | 23 | *The quality of water cannot be improved. It?s too late.* | **-4** | -4 | -4 | -5 |
| | 20 | *The mines should compensate the farmers because the waste from the mines kills their animals and plants* | **-1** | 0 | 1 | 0 |
| | 9 | *If the majority of households have piped water then they will stop polluting the river* | **-3** | 4 | -1 | 0 |
| **Lower or equal** | 25 | *There is need to prevent new people from using the river. The bigger the number of people using the river the higher the pollution.* | **-3** | -2 | 0 | 3 |
| | 31 | *We need more laws in order to prevent further pollution* | **-4** | 3 | -3 | 1 |
| **Lowest** | 15 | *More government funding to the municipalities will improve water quality* | **-5** | 1 | 4 | -2 |

Table D.4: Solving Issues: Distinguishing statements of factor 1

| SID | *Statement* | **Z1** | Z2 | Z3 | Z4 |
|---|---|---|---|---|---|
| 26 | *There needs to be punishment for those who pollute the water* | **2.03** | 0.33 | -0.37 | 0.25 |
| 30 | *We do not need more laws; we just need to enforce the ones already existing* | **1.28** | -0.90 | -1.41 | -0.51 |
| 29 | *Validation and verification (V&V) of water users is the solution to most of the water quality issues that we are facing (V&V is when the Department of Water Affairs ensures that everyone is using the correct amount of water for the right purpose)* | **0.94** | -0.93 | -0.10 | 2.03 |
| 9 | *If the majority of households have piped water then they will stop polluting the river* | **-1.26** | 1.22 | -0.36 | 0.00 |
| 15 | *More government funding to the municipalities will improve water quality* | **-1.83** | 0.38 | 1.24 | -0.51 |

Table D.5: Solving Issues: Crib Sheet - Factor 2

| Ranking | SID | Statement | FA1 | **FA2** | FA3 | FA4 |
|---|---|---|---|---|---|---|
| **Highest** | 6 | *I am willing to participate in any efforts to improve water quality* | 3 | **5** | -3 | 2 |
| | 9 | *If the majority of households have piped water then they will stop polluting the river* | -3 | **4** | -1 | 0 |
| | 17 | *People should be educated about water quality* | 3 | **4** | 3 | 4 |
| | 10 | *Improved garbage collection by municipality will reduce the amount of household waste that ends up polluting the river* | -1 | **3** | -5 | 1 |
| | 31 | *We need more laws in order to prevent further pollution* | -4 | **3** | -3 | 1 |
| **Higher or equal** | 16 | *Naming and shaming polluters encourages people to stop pollution* | 0 | **2** | -1 | -1 |
| | 22 | *The priority should be to prevent the effects of pollution on the environment* | 0 | **2** | 2 | -1 |
| | 14 | *Integrating the different regulators will improve efficiency in controlling water pollution* | 0 | **1** | 0 | -3 |
| | 18 | *Pollution will stop if only the people upstream stopped polluting* | -2 | **0** | -3 | 0 |
| | 23 | *The quality of water cannot be improved. It?s too late.* | -4 | **-4** | -4 | -5 |
| | 5 | *Further training of staff at wastewater treatments will reduce discharge of sewerage into the river* | 1 | **0** | 1 | 1 |
| | 29 | *Validation and verification (V&V) of water users is the solution to most of the water quality issues that we are facing (V&V is when the Department of Water Affairs ensures that everyone is using the correct amount of water for the right purpose)* | 3 | **-2** | 0 | 5 |
| **Lower or equal** | 7 | *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* | 1 | **-3** | 1 | 4 |
| | 4 | *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* | -2 | **-4** | 1 | 3 |
| **Lowest** | 3 | *Commercial farmers who are certified by South Africa Good Agricultural Practices (SA GAP) or Global Good Agricultural Practices(GlobalGAP) are encouraged to pollute less so that they do not lose their certification* | 2 | **-5** | 2 | -4 |

Table D.6: Solving Issues: Distinguishing statements of factor 2

| SID | Statement | Z1 | **Z2** | Z3 | Z4 |
|---|---|---|---|---|---|
| 6 | *I am willing to participate in any efforts to improve water quality* | 1.17 | **2.29** | -0.92 | 0.76 |
| 9 | *If the majority of households have piped water then they will stop polluting the river* | -1.26 | **1.22** | -0.36 | 0.00 |
| 7 | *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* | 0.52 | **-1.09** | 0.40 | 1.26 |

Table D.7: Solving Issues: Crib Sheet - Factor 3

| **Ranking** | SID | *Statement* | FA1 | FA2 | **FA3** | FA4 |
|---|---|---|---|---|---|---|
| **Highest** | 8 | *If municipalities allocate a larger share of their budget to water quality issues then water quality will be improved* | -1 | -1 | **5** | 0 |
| **Higher or equal** | 15 | *More government funding to the municipalities will improve water quality* | -5 | 1 | **4** | -2 |
| | 19 | *Regular stakeholder meetings will promote sustainable use of water resources* | 1 | 1 | **4** | -1 |
| | 11 | *Improving the quality of the water is too expensive* | -2 | -3 | **3** | -3 |
| | 24 | *There is need for all stakeholders to work together to improve water quality* | 2 | 2 | **3** | 0 |
| | 1 | *An independent regulator (not a government institution) will do a better job to control and regulate water pollution* | 1 | -1 | **2** | -1 |
| | 3 | *Commercial farmers who are certified by South Africa Good Agricultural Practices (SA GAP) or Global Good Agricultural Practices(GlobalGAP) are encouraged to pollute less so that they do not lose their certification* | 2 | -5 | **2** | -4 |
| | 22 | *The priority should be to prevent the effects of pollution on the environment* | 0 | 2 | **2** | -1 |
| | 5 | *Further training of staff at wastewater treatments will reduce discharge of sewerage into the river* | 1 | 0 | **1** | 1 |
| | 20 | *The mines should compensate the farmers because the waste from the mines kills their animals and plants* | -1 | 0 | **1** | 0 |
| | 21 | *The Olifants river catchment is too big to be controlled by one body* | -3 | -3 | **0** | -4 |
| | 23 | *The quality of water cannot be improved. It?s too late.* | -4 | -4 | **-4** | -5 |
| **Lower or equal** | 29 | *Validation and verification (V&V) of water users is the solution to most of the water quality issues that we are facing (V&V is when the Department of Water Affairs ensures that everyone is using the correct amount of water for the right purpose)* | 3 | -2 | **0** | 5 |
| | 26 | *There needs to be punishment for those who pollute the water* | 5 | 1 | **-1** | 1 |
| | 2 | *Awarding users who are compliant makes other users to become compliant as well* | 0 | -1 | **-2** | 2 |
| | 13 | *Instead of throwing garbage at dumpsites recycling the garbage will prevent underground and surface water pollution* | 0 | 0 | **-2** | 3 |
| | 28 | *Those who pollute too much should stop using the river for a while* | -1 | -1 | **-2** | 2 |
| | 6 | *I am willing to participate in any efforts to improve water quality* | 3 | 5 | **-3** | 2 |
| | 18 | *Pollution will stop if only the people upstream stopped polluting* | -2 | 0 | **-3** | 0 |
| | 30 | *We do not need more laws; we just need to enforce the ones already existing* | 4 | -2 | **-4** | -2 |
| **Lowest** | 10 | *Improved garbage collection by municipality will reduce the amount of household waste that ends up polluting the river* | -1 | 3 | **-5** | 1 |

Table D.8: Solving Issues: Distinguishing statements of factor 3

| SID | *Statement* | Z1 | Z2 | **Z3** | Z4 |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| 8 | *If municipalities allocate a larger share of their budget to water quality issues then water quality will be improved* | -0.47 | -0.34 | **2.19** | 0.01 |
| 11 | *Improving the quality of the water is too expensive* | -0.91 | -1.01 | **1.05** | -1.52 |
| 6 | *I am willing to participate in any efforts to improve water quality* | 1.17 | 2.29 | **-0.92** | 0.76 |
| 10 | *Improved garbage collection by municipality will reduce the amount of household waste that ends up polluting the river* | -0.45 | 1.08 | **-2.51** | 0.26 |

Table D.9: Solving Issues: Crib Sheet - Factor 4

| **Ranking** | SID | *Statement* | FA1 | FA2 | FA3 | **FA4** |
|---|---|---|---|---|---|---|
| **Highest** | 29 | *Validation and verification (V&V) of water users is the solution to most of the water quality issues that we are facing (V&V is when the Department of Water Affairs ensures that everyone is using the correct amount of water for the right purpose)* | 3 | -2 | 0 | **5** |
| | 7 | *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* | 1 | -3 | 1 | **4** |
| | 17 | *People should be educated about water quality* | 3 | 4 | 3 | **4** |
| | 4 | *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* | -2 | -4 | 1 | **3** |
| | 13 | *Instead of throwing garbage at dumpsites recycling the garbage will prevent underground and surface water pollution* | 0 | 0 | -2 | **3** |
| | 25 | *There is need to prevent new people from using the river. The bigger the number of people using the river the higher the pollution.* | -3 | -2 | 0 | **3** |
| **Higher or equal** | 2 | *Awarding users who are compliant makes other users to become compliant as well* | 0 | -1 | -2 | **2** |
| | 28 | *Those who pollute too much should stop using the river for a while* | -1 | -1 | -2 | **2** |
| | 5 | *Further training of staff at wastewater treatments will reduce discharge of sewerage into the river* | 1 | 0 | 1 | **1** |
| | 18 | *Pollution will stop if only the people upstream stopped polluting* | -2 | 0 | -3 | **0** |
| | 24 | *There is need for all stakeholders to work together to improve water quality* | 2 | 2 | 3 | **0** |
| | 1 | *An independent regulator (not a government institution) will do a better job to control and regulate water pollution* | 1 | -1 | 2 | **-1** |
| | 19 | *Regular stakeholder meetings will promote sustainable use of water resources* | 1 | 1 | 4 | **-1** |
| | 22 | *The priority should be to prevent the effects of pollution on the environment* | 0 | 2 | 2 | **-1** |
| | 12 | *Increased monitoring by DWS (Department of Water and Sanitation) will reduce misuse of water and improve the quality of the water* | 2 | 0 | -1 | **-2** |
| **Lower or equal** | 11 | *Improving the quality of the water is too expensive* | -2 | -3 | 3 | **-3** |
| | 14 | *Integrating the different regulators will improve efficiency in controlling water pollution* | 0 | 1 | 0 | **-3** |
| | 27 | *Those who pollute should pay all those who are affected by the pollution* | 4 | 3 | 0 | **-3** |
| | 3 | *Commercial farmers who are certified by South Africa Good Agricultural Practices (SA GAP) or Global Good Agricultural Practices(GlobalGAP) are encouraged to pollute less so that they do not lose their certification* | 2 | -5 | 2 | **-4** |
| | 21 | *The Olifants river catchment is too big to be controlled by one body* | -3 | -3 | 0 | **-4** |
| **Lowest** | 23 | *The quality of water cannot be improved. It?s too late.* | -4 | -4 | -4 | **-5** |

Table D.10: Solving Issues: Distinguishing statements of factor 4

| SID | *Statement* | Z1 | Z2 | Z3 | **Z4** |
|---|---|---|---|---|---|
| 29 | *Validation and verification (V&V) of water users is the solution to most of the water quality issues that we are facin* | 0.94 | -0.93 | -0.1 | **2.03** |

# Appendix E

# Water Ecosystem Services: Additional Tables and Figures

Table E.1: Water Ecosystem Services: Unrotated factors

| QID | F1 | | F2 | | F3 | | F4 | F5 | | F6 | | F7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.392 | x | 0.167 | | -0.008 | | 0.032 | 0.407 | x | 0.173 | | -0.084 | |
| 2 | 0.640 | xx | 0.148 | | 0.366 | | 0.122 | 0.094 | | 0.007 | | -0.355 | |
| 3 | 0.727 | xx | -0.096 | | -0.277 | | 0.027 | -0.150 | | 0.022 | | 0.045 | |
| 4 | 0.342 | | -0.795 | xx | -0.159 | | 0.333 | 0.163 | | 0.023 | | 0.035 | |
| 5 | 0.563 | xx | 0.361 | | 0.167 | | 0.139 | -0.247 | | 0.061 | | 0.454 | x |
| 6 | 0.575 | xx | 0.424 | x | -0.442 | x | 0.268 | 0.045 | | 0.001 | | 0.157 | |
| 7 | 0.358 | | 0.249 | | -0.448 | x | 0.170 | -0.514 | xx | 0.393 | x | -0.402 | x |
| 8 | 0.440 | x | -0.046 | | -0.439 | x | 0.088 | 0.246 | | 0.055 | | 0.048 | |
| 9 | 0.432 | x | 0.065 | | -0.123 | | 0.012 | -0.184 | | 0.034 | | -0.042 | |
| 10 | 0.456 | x | -0.643 | xx | 0.246 | | 0.234 | -0.188 | | 0.035 | | 0.183 | |
| 11 | 0.276 | | -0.353 | | 0.528 | xx | 0.236 | 0.143 | | 0.017 | | 0.198 | |
| 12 | 0.667 | xx | 0.175 | | 0.326 | | 0.112 | -0.123 | | 0.015 | | 0.015 | |
| 13 | 0.520 | xx | -0.040 | | 0.089 | | 0.005 | -0.130 | | 0.017 | | -0.287 | |
| 14 | 0.669 | xx | 0.195 | | 0.112 | | 0.053 | 0.462 | x | 0.241 | | 0.013 | |

*Note:*
x, xx indicate significant loading at 0.05 and 0.01 levels respectively

Table E.2: Water Ecosystem Services: Humpfrey rule calculations

| | Highest | 2nd Highest | Product | 2SE | 1SE |
|---|---|---|---|---|---|
| F1 | 0.72667 | 0.66908 | 0.4862004 | 1 | 1 |
| F2 | 0.79473 | 0.64287 | 0.5109081 | 1 | 1 |
| F3 | 0.52833 | 0.44829 | 0.2368451 | 0 | 1 |
| F4 | 0.33310 | 0.26813 | 0.0893141 | 0 | 0 |
| F5 | 0.51389 | 0.46250 | 0.2376741 | 0 | 1 |
| F6 | 0.39300 | 0.24141 | 0.0948741 | 0 | 0 |
| F7 | 0.45447 | 0.40219 | 0.1827833 | 0 | 0 |

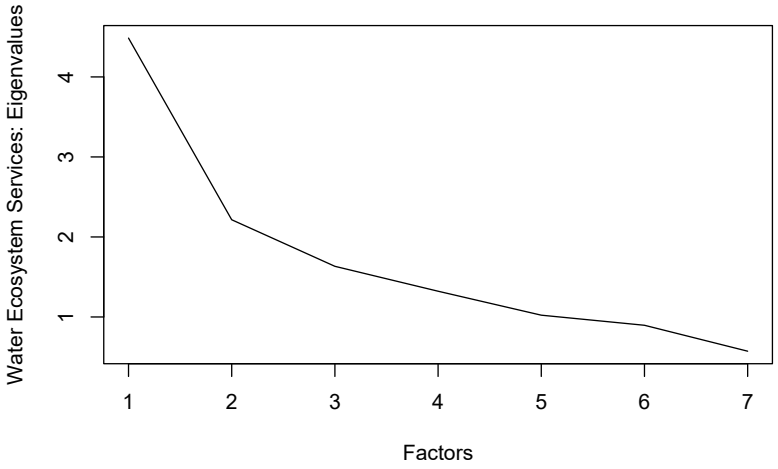


Figure E.1: Scree Plot based on PCA Analysis

Table E.3: Water Ecosystem Services Crib Sheet - Factor 1

| **Ranking** | SID | *Statement* | **FA1** | FA2 | FA3 |
|---|---|---|---|---|---|
| **Highest** | 7 | *Water for irrigation* | **5** | 2 | 1 |
| **Higher or equal** | 4 | *Conservation of ecosystem* | **4** | 0 | -2 |
| | 5 | *Natural storage for water* | **3** | 0 | 3 |
| | 14 | *Water for industrial use (mining and manufacturing)* | **2** | 1 | 1 |
| | 26 | *Support plant growth processes (pollination and photosynthesis)* | **2** | 2 | 2 |
| | 11 | *Catching fish to eat or sell* | **1** | 1 | -3 |
| | 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 (refugia)* | **0** | -1 | -3 |
| | 25 | *Making the landscape more beautiful* | **0** | -2 | 0 |
| | 20 | *A nice view to look at (aesthetic values)* | **-2** | -2 | -5 |
| | 18 | *Fishing for fun* | **-3** | -5 | -4 |
| **Lower or equal** | 13 | *Water for municipality use to supply tap water* | **2** | 4 | 3 |
| | 1 | *Maintenance of water quality by diluting pollutants* | **0** | 3 | 2 |
| | 12 | *Plants herbs and natural products* | **-2** | 3 | 1 |
| | 10 | *Water transport (Boats and canoes)* | **-4** | 0 | -1 |
| **Lowest** | 15 | *Boat cruise water viewing and water games* | **-5** | 1 | -1 |

Table E.4: Water Ecosystem Services: Distinguishing statements of factor 1

| SID | *Statement* | **Z1** | **QS1** | Z2 | Z3 | s |
|---|---|---|---|---|---|---|
| 4 | *Conservation of ecosystem* | **1.53** | **4** | -0.07 | -0.92 | 1.014 |
| 8 | *Water directly from the river for domestic use (washing bathing etc)* | **1.12** | **3** | 2.29 | -0.19 | 1.013 |
| 22 | *Recycling nutrients* | **0.36** | **1** | -1.00 | -0.83 | 0.603 |
| 24 | *A special environment for rare species of plants and animals (refugia)* | **0.20** | **0** | -0.82 | -0.94 | 0.509 |
| 12 | *Plants herbs and natural products* | **-0.69** | **-2** | 1.16 | 0.47 | 0.762 |
| 10 | *Water transport (Boats and canoes)* | **-1.76** | **-4** | -0.31 | -0.39 | 0.668 |
| 15 | *Boat cruise water viewing and water games* | **-2.38** | **-5** | 0.31 | -0.66 | 1.114 |

Table E.5: Water Ecosystem Services Crib Sheet - Factor 2

| **Ranking** | SID | *Statement* | FA1 | **FA2** | FA3 |
|---|---|---|---|---|---|
| **Highest** | 8 | *Water directly from the river for domestic use (washing bathing etc)* | 3 | **5** | 0 |
| **Higher or equal** | 13 | *Water for municipality use to supply tap water* | 2 | **4** | 3 |
| | 1 | *Maintenance of water quality by diluting pollutants* | 0 | **3** | 2 |
| | 12 | *Plants herbs and natural products* | -2 | **3** | 1 |
| | 6 | *Habitat for fish and wildlife* | 1 | **2** | -1 |
| | 26 | *Support plant growth processes (pollination and photosynthesis)* | 2 | **2** | 2 |
| | 11 | *Catching fish to eat or sell* | 1 | **1** | -3 |
| | 15 | *Boat cruise water viewing and water games* | -5 | **1** | -1 |
| | 27 | *Water cycle* | 0 | **1** | 0 |
| | 10 | *Water transport (Boats and canoes)* | -4 | **0** | -1 |
| | 17 | *Traditional and religious rituals* | -1 | **0** | -2 |
| | 19 | *Research and education purposes* | -1 | **0** | -1 |
| | 20 | *A nice view to look at (aesthetic values)* | -2 | **-2** | -5 |
| **Lower or equal** | 5 | *Natural storage for water* | 3 | **0** | 3 |
| | 23 | *Preventing damage to the environment (ecosystem resilience)* | 0 | **-1** | 0 |
| | 2 | *Preventing floods* | 1 | **-2** | 2 |
| | 25 | *Making the landscape more beautiful* | 0 | **-2** | 0 |
| | 9 | *Water for power generation* | -2 | **-3** | 5 |
| | 22 | *Recycling nutrients* | 1 | **-3** | -2 |
| | 3 | *Control of soil erosion* | -3 | **-4** | 4 |
| **Lowest** | 18 | *Fishing for fun* | -3 | **-5** | -4 |

Table E.6: Water Ecosystem Services: Distinguishing statements of factor 2

| SID | *Statement* | Z1 | **Z2** | **QS2** | Z3 | s |
|---|---|---|---|---|---|---|
| 8 | *Water directly from the river for domestic use (washing bathing etc)* | 1.12 | **2.29** | **5** | -0.19 | 1.013 |
| 5 | *Natural storage for water* | 0.97 | **-0.23** | **0** | 1.22 | 0.632 |
| 2 | *Preventing floods* | 0.75 | **-0.85** | **-2** | 1.05 | 0.833 |

Table E.7: Water Ecosystem Services Crib Sheet - Factor 3

| **Ranking** | SID | *Statement* | FA1 | **FA2** | FA3 |
|---|---|---|---|---|---|
| **Highest** | 9 | *Water for power generation* | -2 | **-3** | 5 |
| **Higher or equal** | 3 | *Control of soil erosion* | -3 | **-4** | 4 |
| | 5 | *Natural storage for water* | 3 | **0** | 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 |
| **Lower or equal** | 7 | *Water for irrigation* | 5 | **2** | 1 |
| | 14 | *Water for industrial use (mining and manufacturing)* | 2 | **1** | 1 |
| | 8 | *Water directly from the river for domestic use (washing bathing etc)* | 3 | **5** | 0 |
| | 6 | *Habitat for fish and wildlife* | 1 | **2** | -1 |
| | 4 | *Conservation of ecosystem* | 4 | **0** | -2 |
| | 17 | *Traditional and religious rituals* | -1 | **0** | -2 |
| | 22 | *Recycling nutrients* | 1 | **-3** | -2 |
| | 11 | *Catching fish to eat or sell* | 1 | **1** | -3 |
| | 24 | *A special environment for rare species of plants and animals (refugia)* | 0 | **-1** | -3 |
| | 18 | *Fishing for fun* | -3 | **-5** | -4 |
| **Lowest** | 20 | *A nice view to look at (aesthetic values)* | -2 | **-2** | -5 |

Table E.8: Water Ecosystem Services: Distinguishing statements of factor 3

| SID | *Statement* | Z1 | Z2 | **Z3** | **QS3** | s |
|---|---|---|---|---|---|---|
| 9 | *Water for power generation* | -0.98 | -1.06 | **1.97** | **5** | 1.406 |
| 3 | *Control of soil erosion* | -1.31 | -1.45 | **1.41** | **4** | 1.316 |
| 8 | *Water directly from the river for domestic use (washing bathing etc)* | 1.12 | 2.29 | **-0.19** | **0** | 1.013 |
| 11 | *Catching fish to eat or sell* | 0.72 | 0.16 | **-1.24** | **-3** | 0.824 |
| 20 | *A nice view to look at (aesthetic values)* | -0.88 | -0.82 | **-1.97** | **-5** | 0.526 |

# Appendix F

# Instruments: Additional Tables and Figures

Table F.1: Instruments: Unrotated factors

| QID | F1 | | F2 | | F3 | | F4 | | F5 | | F6 | | F7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.429 | x | -0.210 | | 0.031 | | -0.177 | | -0.052 | | 0.026 | | 0.075 | |
| 2 | 0.554 | xx | -0.128 | | 0.012 | | 0.033 | | -0.475 | xx | 0.152 | | -0.316 | |
| 3 | 0.511 | xx | 0.084 | | 0.005 | | 0.315 | | 0.277 | | 0.111 | | 0.187 | |
| 4 | 0.678 | xx | -0.159 | | 0.018 | | -0.080 | | 0.257 | | 0.051 | | -0.199 | |
| 5 | 0.535 | xx | 0.210 | | 0.031 | | 0.193 | | -0.249 | | 0.057 | | -0.174 | |
| 6 | 0.678 | xx | -0.270 | | 0.053 | | 0.073 | | 0.093 | | 0.007 | | 0.285 | |
| 7 | 0.267 | | -0.415 | x | 0.130 | | -0.242 | | 0.297 | | 0.108 | | 0.180 | |
| 8 | 0.492 | xx | 0.225 | | 0.036 | | -0.041 | | -0.139 | | 0.013 | | 0.413 | x |
| 9 | 0.325 | | 0.447 | x | 0.153 | | -0.191 | | 0.182 | | 0.052 | | -0.193 | |
| 10 | 0.249 | | 0.513 | xx | 0.212 | | -0.117 | | 0.252 | | 0.055 | | 0.046 | |
| 11 | 0.498 | xx | 0.119 | | 0.010 | | -0.517 | xx | -0.484 | xx | 0.458 | x | 0.161 | |
| 12 | 0.443 | x | 0.507 | xx | 0.206 | | -0.198 | | -0.085 | | 0.035 | | -0.175 | |
| 13 | 0.631 | xx | -0.215 | | 0.033 | | 0.259 | | -0.162 | | 0.051 | | 0.209 | |
| 14 | 0.426 | x | -0.339 | | 0.084 | | 0.201 | | 0.224 | | 0.054 | | -0.195 | |
| 15 | 0.451 | x | -0.642 | xx | 0.387 | x | -0.065 | | -0.227 | | 0.036 | | -0.126 | |
| 16 | 0.351 | | 0.274 | | 0.053 | | 0.601 | xx | 0.281 | | 0.328 | | -0.150 | |

*Note:*
x, xx indicate significant loading at 0.05 and 0.01 levels respectively

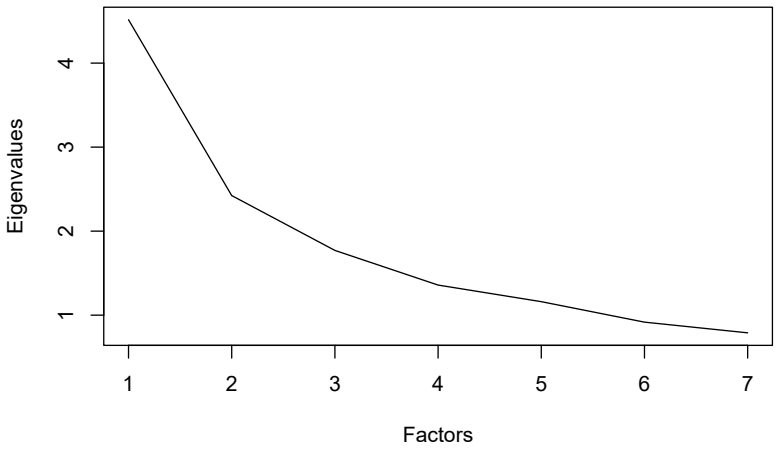


Figure F.1: Instruments: Scree Plot

Table F.2: Instruments: Humprey rule calculations

| | Highest | 2nd Highest | Product | 2SE | 1SE |
|---|---|---|---|---|---|
| F1 | 0.67796 | 0.67796 | 0.4596298 | 1 | 1 |
| F2 | 0.64245 | 0.51318 | 0.3296925 | 0 | 1 |
| F3 | 0.38695 | 0.21183 | 0.0819676 | 0 | 0 |
| F4 | 0.60136 | 0.51725 | 0.3110535 | 0 | 1 |
| F5 | 0.48430 | 0.47493 | 0.2300086 | 0 | 1 |
| F6 | 0.45826 | 0.32822 | 0.1504101 | 0 | 0 |
| F7 | 0.41287 | 0.31643 | 0.1306445 | 0 | 0 |

Table F.3: Instrument: Factor 1 Crib Sheet

| **Ranking** | SID | *Statement* | **FA1** | FA2 | FA3 | FA4 |
|---|---|---|---|---|---|---|
| **Highest** | 4 | *Increase monitoring and enforcement of existing laws* | **5** | 0 | 3 | 2 |
| **Higher or equal** | 6 | *Department of water and sanitation should come up with ways of punishing water polluters* | **4** | -1 | 4 | 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 | -3 |
| | 17 | *The priority should be to prevent the effects of pollution on the environment* | **3** | -3 | 1 | 0 |
| | 21 | *Those who pollute should pay all those who are affected by the pollution* | **3** | 0 | -2 | 0 |
| | 15 | *The mines should compensate the farmers because the waste from the mines kills their animals and plants* | **2** | -1 | -1 | -3 |
| | 3 | *Invest in tools to detect water pollution* | **1** | -1 | -2 | -1 |
| | 13 | *Improving the quality of water will be expensive* | **0** | 0 | -4 | -1 |
| **Lower or equal** | 19 | *There is need for all stakeholders to work together to improve water quality* | **1** | 2 | 3 | 2 |
| | 1 | *Increased sensitization 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 | 1 |
| | 8 | *Further training of staff from Department of Water and sanitation in issues of water quality* | **-2** | 3 | 2 | 3 |
| | 31 | *Educating farm workers about water quality to prevent water pollution* | **-2** | 3 | 1 | 0 |
| | 14 | *Pollution will stop if only the people upstream stopped polluting* | **-3** | -2 | -2 | -2 |
| | 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 | -3 | 4 |
| **Lowest** | 11 | *More government funding to the municipalities will improve water quality* | **-5** | 1 | -4 | 2 |

Table F.4: Instruments: Distinguishing statements of factor 1

| SID | *Statement* | **Z1** | Z2 | Z3 | Z4 | s |
|---|---|---|---|---|---|---|
| 4 | *Increase monitoring and enforcement of existing laws* | **2.09** | -0.08 | 0.94 | 0.85 | 0.385 |
| 21 | *Those who pollute should pay all those who are affected by the pollution* | **1.02** | -0.37 | -0.76 | 0.00 | 0.331 |
| 15 | *The mines should compensate the farmers because the waste from the mines kills their animals and plants* | **0.81** | -0.51 | -0.27 | -1.20 | 0.363 |
| 8 | *Further training of staff from Department of Water and sanitation in issues of water quality* | **-0.81** | 1.29 | 0.64 | 1.33 | 0.434 |

Table F.5: Instrument: Factor 2 Crib Sheet

| **Ranking** | SID | *Statement* | FA1 | **FA2** | FA3 | FA4 |
|---|---|---|---|---|---|---|
| **Highest** | 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 |
| **Higher or equal** | 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** | -1 | 1 |
| | 24 | *We need more laws in order to prevent further water pollution* | -1 | **4** | -3 | -5 |
| | 1 | *Increased sensitization to raise awareness about negative impacts of water pollution* | 0 | **3** | 3 | 1 |
| | 8 | *Further training of staff from Department of Water and sanitation in issues of water quality* | -2 | **3** | 2 | 3 |
| | 31 | *Educating farm workers about water quality to prevent water pollution* | -2 | **3** | 1 | 0 |
| | 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** | 0 | -2 |
| | 28 | *Regular stakeholder meetings are important in improving water quality* | 0 | **2** | 2 | 1 |
| | 13 | *Improving the quality of water will be expensive* | 0 | **0** | -4 | -1 |
| | 14 | *Pollution will stop if only the people upstream stopped polluting* | -3 | **-2** | -2 | -2 |
| **Lower or equal** | 4 | *Increase monitoring and enforcement of existing laws* | 5 | **0** | 3 | 2 |
| | 5 | *An independent regulator (not a government institution) will do a better job to control water pollution* | 4 | **0** | 2 | 5 |
| | 6 | *Department of water and sanitation should come up with ways of punishing water polluters* | 4 | **-1** | 4 | 0 |
| | 12 | *Naming and shaming polluters encourages people to stop pollution* | 0 | **-2** | 1 | 0 |
| | 17 | *The priority should be to prevent the effects of pollution on the environment* | 3 | **-3** | 1 | 0 |
| | 22 | *Those who pollute too much should stop using the river for a while* | -2 | **-4** | 0 | -1 |
| **Lowest** | 18 | *The quality of water in the Olifants cannot be improved. It?s too late.* | -4 | **-5** | -5 | -2 |

Table F.6: Instruments: Distinguishing statements of factor 2

| SID | *Statement* | Z1 | **Z2** | Z3 | Z4 | s |
|---|---|---|---|---|---|---|
| 24 | *We need more laws in order to prevent further water pollution* | -0.7 | **1.5** | -0.85 | -2.14 | 0.655 |

Table F.7: Instrument: Factor 3 Crib Sheet

| **Ranking** | SID | *Statement* | FA1 | FA2 | **FA3** | FA4 |
|---|---|---|---|---|---|---|
| **Highest** | 30 | *Capacity building of the municipality through training of staff to improve water quality management* | 1 | 1 | **5** | 3 |
| **Higher or equal** | 6 | *Department of water and sanitation should come up with ways of punishing water polluters* | 4 | -1 | **4** | 0 |
| | 27 | *Improved garbage collection will prevent domestic waste (such as diapers) from polluting the river* | 1 | 1 | **4** | -4 |
| | 1 | *Increased sensitization to raise awareness about negative impacts of water pollution* | 0 | 3 | **3** | 1 |
| | 19 | *There is need for all stakeholders to work together to improve water quality* | 1 | 2 | **3** | 2 |
| | 28 | *Regular stakeholder meetings are important in improving water quality* | 0 | 2 | **2** | 1 |
| | 12 | *Naming and shaming polluters encourages people to stop pollution* | 0 | -2 | **1** | 0 |
| | 22 | *Those who pollute too much should stop using the river for a while* | -2 | -4 | **0** | -1 |
| | 29 | *Local people should decide how best to manage the river* | -1 | -3 | **0** | -3 |
| | 10 | *If the majority of households have piped water then they will stop polluting the river* | -3 | -4 | **-1** | -4 |
| | 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 | **-2** | -2 |
| **Lower or equal** | 5 | *An independent regulator (not a government institution) will do a better job to control water pollution* | 4 | 0 | **2** | 5 |
| | 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 |
| | 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 | **-1** | 1 |
| | 3 | *Invest in tools to detect water pollution* | 1 | -1 | **-2** | -1 |
| | 21 | *Those who pollute should pay all those who are affected by the pollution* | 3 | 0 | **-2** | 0 |
| | 2 | *Give incentives/rewards to water users who pollute less* | 0 | -2 | **-3** | 3 |
| | 13 | *Improving the quality of water will be expensive* | 0 | 0 | **-4** | -1 |
| **Lowest** | 18 | *The quality of water in the Olifants cannot be improved. It?s too late.* | -4 | -5 | **-5** | -2 |

Table F.8: Instruments: Distinguishing statements of factor 3

| SID | *Statement* | Z1 | Z2 | **Z3** | Z4 | s |
|---|---|---|---|---|---|---|
| 30 | *Capacity building of the municipality through training of staff to improve water quality management* | 0.45 | 0.65 | **2.30** | 0.98 | 0.359 |
| 13 | *Improving the quality of water will be expensive* | 0.28 | -0.48 | **-1.92** | -0.55 | 0.397 |

Table F.9: Instrument: Factor 4 Crib Sheet

| **Ranking** | SID | *Statement* | FA1 | FA2 | FA3 | **FA4** |
|---|---|---|---|---|---|---|
| **Highest** | 5 | *An independent regulator (not a government institution) will do a better job to control water pollution* | 4 | 0 | 2 | **5** |
| **Higher or equal** | 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 | -3 | **4** |
| | 25 | *Municipalities should allocate more money to water quality improvement* | -1 | -1 | 0 | **4** |
| | 2 | *Give incentives/rewards to water users who pollute less* | 0 | -2 | -3 | **3** |
| | 8 | *Further training of staff from Department of Water and sanitation in issues of water quality* | -2 | 3 | 2 | **3** |
| | 11 | *More government funding to the municipalities will improve water quality* | -5 | 1 | -4 | **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 | -2 | **-2** |
| | 18 | *The quality of water in the Olifants cannot be improved. It?s too late.* | -4 | -5 | -5 | **-2** |
| **Lower or equal** | 4 | *Increase monitoring and enforcement of existing laws* | 5 | 0 | 3 | **2** |
| | 6 | *Department of water and sanitation should come up with ways of punishing water polluters* | 4 | -1 | 4 | **0** |
| | 17 | *The priority should be to prevent the effects of pollution on the environment* | 3 | -3 | 1 | **0** |
| | 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 | 0 | **-2** |
| | 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 | **-3** |
| | 15 | *The mines should compensate the farmers because the waste from the mines kills their animals and plants* | 2 | -1 | -1 | **-3** |
| | 29 | *Local people should decide how best to manage the river* | -1 | -3 | 0 | **-3** |
| | 10 | *If the majority of households have piped water then they will stop polluting the river* | -3 | -4 | -1 | **-4** |
| | 27 | *Improved garbage collection will prevent domestic waste (such as diapers) from polluting the river* | 1 | 1 | 4 | **-4** |
| **Lowest** | 24 | *We need more laws in order to prevent further water pollution* | -1 | 4 | -3 | **-5** |

Table F.10: Instruments: Distinguishing statements of factor 4

| SID | *Statement* | Z1 | Z2 | Z3 | **Z4** | s |
|---|---|---|---|---|---|---|
| 25 | *Municipalities should allocate more money to water quality improvement* | -0.40 | -0.53 | -0.24 | **1.53** | 0.420 |
| 27 | *Improved garbage collection will prevent domestic waste (such as diapers) from polluting the river* | 0.48 | 0.55 | 1.42 | **-1.41** | 0.516 |
| 24 | *We need more laws in order to prevent further water pollution* | -0.70 | 1.50 | -0.85 | **-2.14** | 0.655 |

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