THE RURAL AND AGRICULTURAL VALUE OF GROUNDWATER AS AN ECONOMIC RESOURCE IN THE LIMPOPO REGION

by

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DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the owner of the copyright thereof (unless to the extent explicitly otherwise stated) and that I have not previously, in its entirety or in part submitted it for obtaining any qualification.

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ABSTRACT

This thesis constitutes a socio-economic study that centres on determining the economic value of groundwater in rural and agricultural uses. Limpopo Water Management Area (WMA1) and Luvuvhu/Letaba Water Management Area (WMA2) were studied in this thesis. In WMA1 table potato irrigation in the Polokwane agricultural area was studied, while Gaphago, Leokaneng, Kanana and Mohlajeng villages were studied for rural household groundwater use. In WMA2 tomato irrigation in the Mooketsi agricultural area was studied, while Lemondokop, Sereni and Hamashamba villages were studied for rural household groundwater use.

Scoping field trips to the study area as well as secondary data revealed that groundwater was the dominant water source in all these selected study epicentres. In the Polokwane agricultural area, the farms typically relied on numerous boreholes. In the Mooketsi commercial farming area, groundwater was the dominant water source for most years, except when flush floods replenished farm dams. When flush floods occurred, farmers partially substituted surface water for groundwater because of economic reasons.

This study determined the economic value of groundwater in two use sectors. First, determining the utility value of groundwater in selected rural households using the contingent valuation method. Utility value was defined by Dupuit (1844) and Marshall (1879) as the maximum sacrifice expressed in money terms which each consumer would be willing to make in order to acquire an object. Open-ended questions were used to determine willingness to pay during contingent household groundwater valuation. The overall mean willingness to pay for satisfactory household groundwater for the study area was R2.28 per kilolitre of groundwater.

Second, determining the shadow values of irrigation groundwater in typical commercial farms using parametric linear programming. The shadow values derived are the values of the marginal product (VMP) of irrigation groundwater in tomato and table potato production. As such, it is highlighted that the VMP of irrigation groundwater cannot economically remain static, but it will depend on various dynamic parameters such as producer price and crop yield levels amongst others. In typical tomato production, the

VMP of irrigation groundwater was found to range from R0.58 to R10.38 per m^3/annum for producer price changes from R1.60/kg to R2.89/kg, and from R2.89 to R10.38 per m^3/annum for yield changes from 20 000kg/ha to 70 000kg/ha. In typical table potato production, the VMP of irrigation groundwater was found to range from R0.42 to R8.50 per m^3/annum for producer price changes from R1.45/kg to R2.42/kg, and from R2.11 to R5.92 per m^3/annum for yield changes from 25 000kg/ha to 50 000kg/ha.

The groundwater economic value recommendations made in this thesis provide information that can be used in the development of effective groundwater pricing policy for better groundwater demand management in both domestic and agricultural use. Such policies could contribute to meeting the societal goals of economic efficiency and social equity.

OPSOMMING

Hierdie tesis handel oor ‘n sosio-ekonomiese ondersoek wat fokus op die bepaling van die ekonomiese waarde van grondwater in plattelandse huishoudelike gebruike en as besproeiingswater in die landbou. Limpopo watergebruiksgebied (WGG1), asook die Luvuvhu/Letaba watergebruiksgebied (WGG2) het as ondersoekgebiede vir hierdie navorsingsprojek gedien. In WGG1 is tafelaartappelboerdery onder besproeiing in die Polokwane boerderygebied en huishoudings in Gaphago, Leokaneng, Kanana en Mohlajeng nedersettings in die ondersoek ingesluit. In WGG2 is tamatieboerdery onder besproeiing in die Mooketsi boerderygebied en huishoudings in Lemondokop, Sereni en Hamashamba nedersettings ingesluit.

Op grond van sekondêre data en ‘n vooraf studiebesoek is gevind dat grondwater die dominante waterbron in die geselekteerde ondersoekgebiede is. In die Polokwane boerderygebied is die boerderye afhanklik van die besproeiingswater uit verskeie boorgate. In die Mooketsi boerderygebied is grondwater ook die belangrikste bron van water, behalwe gedurende sekere tye wanneer besproeiingsdamme met vloedwater gevul word. Dan word grondwater om ekonomiese redes gedeeltelik met oppervlakwater vervang.

In hierdie studie is die ekonomiese waarde van grondwater in twee gebruiksektore bepaal. Eerstens is die nutwaarde van grondwater op grond van die voorwaardelike of gebeurlike (“contingent”) waardasiemetode by geselekteerde plattelandse huishoudings bepaal. Nutwaarde is deur Dupuit (1844) en Marshall (1879) beskryf as die maksimum geldbedrag wat ‘n verbruiker bereid sou wees om op te offer ten einde ‘n bepaalde voorwerp te bekom. Oop-end vrae is gebruik om die voorwaardelike waarde van grondwater aan die hand van die gewilligheid om vir grondwater te betaal, te bepaal. Die algehele gemiddelde gewilligheid om vir bevredigende huishoudelike grondwater diensverskaffing in die ondersoekgebied te betaal, het op R2.28 per kiloliter te staan gekom.

In die tweede gebruiksektor is die waarde van besproeiingsgrondwater as die skaduwaarde daarvan by tipiese kommersiële boerderye met behulp van parametriese

lineêre programmering bepaal. Die berekende skaduwaardes dui op die marginale produkwaarde (MPW) van besproeiingsgrondwater by die produksie van tamaties en tafelaartappels in die ondersoekgebiede. Die MPW van besproeiingswater is nie staties nie, maar word deur dinamiese parameters soos onder andere produkpryse en opbrengste beïnvloed. By die tipiese tamatie produksie het die MPW van besproeiingsgrondwater gewissel tussen R0.58 tot R10.38 per m^3/jaar vir produkprys verandering vanaf R1.60/kg tot R2.89/kg en vanaf R2.89 tot R10.38 per m^3/jaar vir opbrengs verandering vanaf 20 000 kg/ha tot 70 000 kg/ha. By die tipiese tafelaartappel produksie het die MPW van besproeiingsgrondwater gewissel tussen R0.42 tot R8.50 per m^3/jaar vir produkprys verandering vanaf R1.45/kg tot R2.42/kg en vanaf R2.11 tot R5.92 per m^3/jaar vir opbrengs verandering vanaf 25 000 kg/ha tot 50 000 kg/ha.

Die aanbevelings wat in hierdie tesis rakende die ekonomiese waarde van grondwater gemaak word, voorsien inligting wat in die ontwikkeling van effektiewe grondwaterbeleid vir beter bestuur van die vraag in beide die huishoudelike as landbougebruik van grondwater kan dien. Sodanige beleid kan bydra tot die bereiking van die gemeenskapsdoelwitte van ekonomiese doeltreffendheid en sosiale geregtigheid.

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DEDICATIONS

This research project is a special dedication to my parents, brothers and sisters for their moral, financial and technical support, without which this endeavour would have been unsuccessful.

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CHAPTER 1

INTRODUCTION

Historically, surface water has been the main source of water for human consumption, as it was easy and cost-effective to access. However, increased demand for water has resulted in the increased use of groundwater in order to satisfy the ever increasing domestic, industrial, agricultural, and environmental/ecosystem preservation water demands. Thus, from the second half of the 20th century, groundwater withdrawals have increased, up to a point that they now supply one third of the world's population (United Nations, 2001).

With time, population growth has increased the pressure on global water resources. Increasing food demand has called for growth in agricultural output, which requires water as a major input. The rise in abstraction from both surface and groundwater resources along with the deterioration in water quality has led to a need to manage our freshwater resources in a more responsible manner. Almost all of the water of the planet occurs as saltwater in the oceans. Of the 3% of the global resource that is fresh water, two-thirds comes as snow and ice in polar and mountainous regions. Hence, liquid freshwater constitutes about 1% of the global water resource. At any one time, almost all of this occurs as groundwater, while less than 2% of it is to be found in the rivers and lakes (FAO, 2002).

The extensive use of groundwater in many parts of the world has resulted in water level drawdown, groundwater depletion and related biodiversity loss, and pollution and seawater intrusion in coastal aquifers. As a result, groundwater management and the search for relevant backstop technologies and substitutes has become a practical concern in many arid and semiarid regions throughout the world. Groundwater is important for sustaining agricultural production patterns and freshwater consumption patterns as biodiversity and ecosystems' resilience. Combining this fact with the resource's acute scarcity in many parts of the world makes necessary the rules for allocating the resource efficiently among competing uses over time and space. This poses a very interesting question that the economics profession has addressed enthusiastically since the mid-1950s (Koundouri and Xepapadeas, 2004).

South Africa is a dry, water scarce and stressed country with the annual average rainfall of 497mm. It seems probable that water shortages will redirect economic development. As water scarcity increases, the need to manage water as a national asset and for overall social benefit becomes imperative. To meet water demand, South Africa is expected to develop water management strategies that will foster efficient use of water resources. During the past number of years the South African Water Research Commission (WRC) and the Department of Water Affairs and Forestry (DWAF) have initiated a number of economic research projects aimed at determining the value of water in different sectors of the economy and in different parts of the country (Nieuwoudt et al., 2004). This is being done to foster efficient use of water resources in South Africa through the use of appropriate water demand management strategies.

The change in focus from management of supply to management of demand has been accepted worldwide and is seen as the most efficient way of managing water resources. Managing demand involves minimizing volumes demanded in order to place water supply on a sound economic, social and environmental footing (Ngcobo, 2006).

The objective of this research is to offer decision makers and policy makers sound groundwater economic valuation and pricing recommendations that could possibly act as a platform for the development of effective groundwater demand management policies in domestic and agricultural groundwater use. If adopted correctly, these policies could enhance the attainment of societal goals of economic efficiency and social equity.

1.1 Problem statement

Groundwater and surface water are usually used conjunctively; this is the case in some areas of the study area. In areas where there are limited surface water resources (mostly rural areas) groundwater is the dominant water source. Likewise, surface water is the main water source where groundwater is limited. 30% of the annual available groundwater recharge is currently being utilized in water management area 1 (WMA1) also known as Limpopo WMA and WMA2 also known as Luvuvhu/Letaba WMA; yet surface water resources are basically fully allocated. These statistics reveal that groundwater offers much greater potential for further study and exploration, and this will mainly benefit rural areas because their dominant water source is groundwater. This study thus focuses on rural household groundwater use as one of the two dimensions looked into (the other one is agriculture).

With the surface water resources in many WMAs now fully utilised, almost the only opportunity left for further development lies in the exploration of groundwater. More particularly it is recognised that many of the more remote towns and villages, far from surface supplies, can in fact supply or supplement existing sources through groundwater, and that this must become a priority option. So, too, many small communities and subsistence farmers can avail themselves of groundwater when it would otherwise be impossible or impractical to lay pipes (DWAF, 2004a).

Of obvious concern is the likelihood of an interaction between groundwater and surface water. If the interaction is strong, then additional use of groundwater could simply reduce the surface water resources already allocated to someone else, thus imposing an externality. In some instances (such as in the case of dolomitic aquifers) this interaction can indeed be very strong, whilst across many areas of the country it is so weak as to be negligible. In the case of endorheic areas (areas with closed drainage basins) there is no interaction at all. Where interactions are weak, groundwater can significantly add to the availability of water to users, much in the way the construction of a dam would do, but without all the negative impacts a dam can have on the environment and the flows in rivers. Groundwater often comprises a huge pool of available water which is only of benefit if it is utilised. In Limpopo the realisation made is that groundwater offers a huge resource of water which can be tapped and that this can be a very significant supplement to the national water resource (DWAF, 2004a). Groundwater in Limpopo is relatively underutilized, and as such the responsible exploration of groundwater resources could greatly benefit water users.

However, groundwater is usually considered as a good that is impossible to value or as a "free" good. Such undervaluation of groundwater fosters misallocation in two ways: firstly the groundwater resource is not efficiently allocated relative to alternative current and future uses; and secondly authorities responsible for resource management and protection devote inadequate attention and funding to maintaining groundwater quality and quantity.

This study made use of two groundwater valuation methods - contingent valuation method and linear programming to determine the economic value (utility value and shadow value respectively) of groundwater in domestic and agricultural uses respectively. This economic valuation of groundwater was intended to prompt water authorities to devote adequate attention and funding to maintenance of groundwater quality and quantity through the use of appropriate valuation and pricing methods.

Similar to a study conducted by Van Heerden et al. (2008), this study investigated the typically irrigated field crops. It is in this groundwater intensive sector where a relatively small change in policy and tariffs is expected to have a significant impact on groundwater use. Irrigation is the biggest consumer of groundwater in WMA1, accounting for almost 75% of the total groundwater use in WMA1. Urban, industrial and mining uses account for a further 16% of the groundwater use, and the remaining 9% is being used for rural supply, stock watering and power generation (DWAF, 2003a). Due to low rainfall in this area, surface water is limited and highly seasonal. The Waterberg area, however, has better base flow and more surface water available as surface flow (DWAF, 2003a). Irrigation is also the biggest consumer of groundwater in WMA2, also accounting for almost 75% of the total water use in WMA2. Afforestation consumes approximately 13% of the available yield of groundwater resources, and 9% is being used for rural water supplies. Urban, industrial and mining purposes consume the remainder (3%). Within the urban and industrial sectors, a large portion of the groundwater becomes available to the environment again after being discharged following appropriate treatment (DWAF, 2003b).

This study also investigates issues of groundwater usage in rural households because according to (UN, 2005), 30% of rural households that need to gain access to improved water supply and 17% of rural households that need to gain access to improved sanitation are in sub-Saharan Africa. The RDP (Reconstruction and Development Programme), South Africa's socio-economic policy framework which seeks to alleviate poverty and address shortfalls in social services, is used by DWAF to measure the level of water supply and sanitation (WSS). Households at the RDP level of water service delivery have infrastructure necessary to supply 25 litres of potable water per person per day supplied within 200m of a household and with a minimum flow rate of 10 litres per minute (in the case of communal water points) or 6 000 litres of potable water supplied per formal connection per month (in the case of yard or house connections). According to DWAF (2008b) there are an estimated 251 806 households with access to a water supply below the RDP service level and an estimated 665 769 households with access to a sanitation below the RDP service level in Limpopo Province. The current estimated number of households with no access to any form of formal water infrastructure in Limpopo is 65 129.

This is the extent of the problem in Limpopo. As agriculture is the dominant groundwater user in the study area, shifting towards allocatively more efficient irrigation groundwater use could likely release groundwater benefits for other user sectors, primarily domestic use, with special focus on rural households.

1.2 Justification for doing this research

Water resources are relatively finite, with a given volume of freshwater in circulation at any one moment in time through the global hydrological cycle. Natural fluctuations in this hydrological cycle cause temporary disturbances to the distribution of this relatively finite volume of water, with extreme events such as droughts and floods impacting differently on various regions of the world. This fluctuation is more pronounced in some parts of the world than in others, with Southern Africa in general being one of the areas that is characterized by extreme variability (Rabie and Day, 1992). In fact, it is this variability that forms the basic driving force behind the ecosystems evolving under such conditions. In some instances humans have chosen to inhabit areas that are less well endowed with water. This means that they have had to evolve a set of coping strategies over time, inadvertently becoming what Descartes referred to in 1637 as “masters and owners of nature” (Anscombe and Geach, 1954).

The core problem is that South Africa is facing increasing competition for surface water and groundwater between its water-use sectors. As surface water reserves fall short of demand in South Africa, groundwater becomes the most practical bolster to meet increasing demand. According to Viljoen (2008), about 70% of water use in WMA1 and WMA2 is from groundwater. Overall, only about 30% of the annual available groundwater recharge is used in the two WMAs.

In the face of ever increasing demand due to population expansion this figure is sure to increase because surface water resources are basically fully allocated. Also there is growing recognition to meet environmental needs through allocations of water for the environment and protection of down stream impacts from agricultural pollution. Imbalances between availability and demand, the degradation of groundwater and surface water quality, intersectoral competition, interregional and international conflicts, all contribute to the problem of water scarcity. Water scarcity has its roots in water shortage, and it is in the arid and semiarid regions affected by droughts and wide climate variability combined with population growth and economic development (like South Africa), that the problems of water scarcity are most acute (FAO, 2008).

Figure 1.1 shows the global distribution of water scarcity in year 2000. One-third of the world’s population live in basins that have to deal with water scarcity.

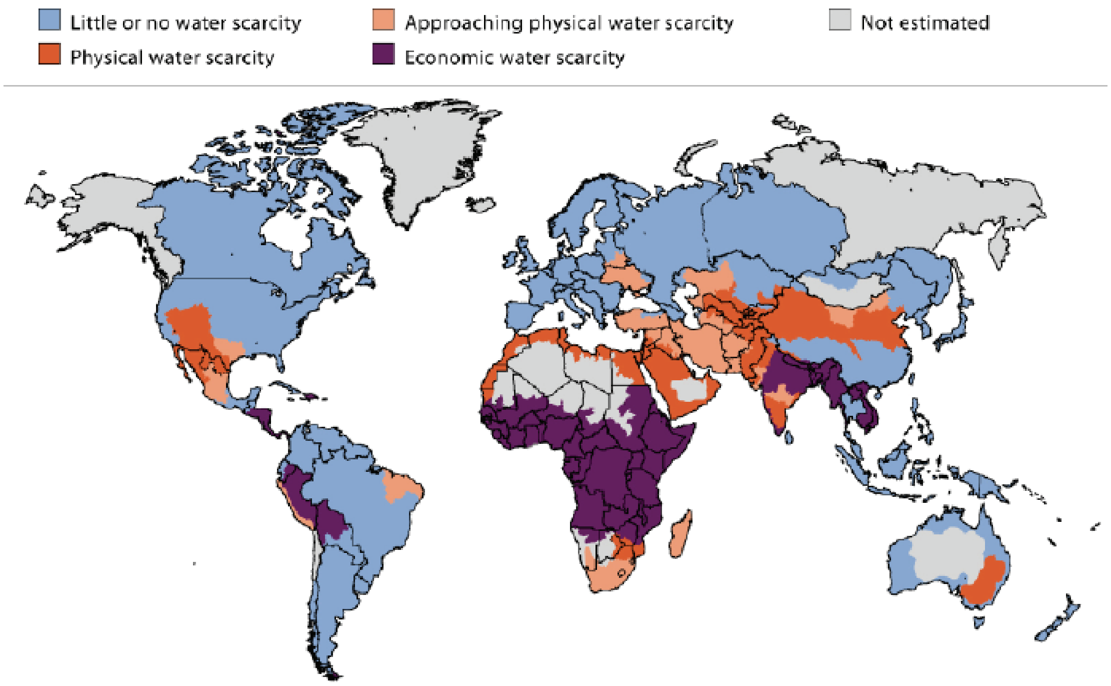


Figure 1.1: Global water scarcity profile 2000
Source: Dillaha (2008)

Water use has been growing at more than twice the rate of population increase in the last century, and, although there is no global water scarcity as such, an increasing number of regions are chronically short of water. By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions (FAO, 2008).

According to the United Nations Development Programme (UNDP) (2006), the roots of the crisis in water can be traced to poverty, inequality and unequal power relationships, as well as flawed water management policies that exacerbate scarcity. Access to water for life is a basic human need and a fundamental human right. Yet in our increasingly prosperous world, more than 1 billion people are denied that right to clean water and 2.6 billion people lack access to adequate sanitation. These headline numbers capture only one dimension of the problem. Every year some 1.8 million children die as a result of diarrhoea and other diseases caused by unclean water and poor sanitation.

At the start of the 21st century unclean water is the world's second biggest killer of children. Everyday millions of women and young girls collect water for their families – a ritual that reinforces gender inequalities in employment and education. Meanwhile, the ill health associated with deficits in water and sanitation undermines productivity and economic growth, reinforcing the deep inequalities that characterize current patterns of globalization and trapping vulnerable households in cycles of poverty. As national competition for water intensifies, people with the weakest rights – rural dwellers, small farmers (women among them) – will see their entitlements to water eroded by more powerful constituencies (UNDP, 2006).

The above-mentioned front burner issues pose a potential threat to our global groundwater resources and potentially undermine the resultant benefits emanating from groundwater – especially for the poor. As such, this research sought to determine the economically sound values of groundwater in its domestic and agricultural uses respectively. For the former use, the utility value was determined and for the latter the shadow value or value of the marginal product (VMP) per cubic meter was determined. Recognising the economic value of groundwater could result in improved pricing methods that bring about effective demand management. A caveat worth mentioning is that the goal of social equity should not be obscured by the goal of economic efficiency particularly for rural households' groundwater pricing policy.

1.3 The research question

At the core of this study was the research question: What is the economic value of groundwater in the rural and agricultural uses in Limpopo?

1.3.1 Sub-problems

In order to provide adequate answers to the research question, the following sub-problems were isolated:

a) Describe the quantity and quality of groundwater in the study area as observed in monitoring stations and surveys.
b) Investigate the important socio-economic issues of rural groundwater use in Limpopo.
c) Determine the utility value of rural household groundwater by contingent valuation.

d) Determine the shadow value of irrigation groundwater in typical tomato and table potato production.
e) Determine whether various produce price and crop yield situations can influence the shadow value of irrigation groundwater.

1.3.2 Hypotheses to be tested

a) The quantity and quality of groundwater in the study area makes groundwater adequate for domestic and agricultural abstraction.
b) The following socio-economic issues are important in rural areas:
    - Households are enjoying satisfactory groundwater supply and sanitation.
    - Households are willing to pay for improved groundwater supply and sanitation.
    - Households' water consumption can be significantly influenced by changing the groundwater tariff.
c) Rural groundwater has a utility value that can guide the formulation of domestic groundwater tariffs for water demand management.
d) Irrigation groundwater has a shadow value that can guide the formulation of agricultural groundwater tariffs for water demand management.
e) Higher crop prices and yields imply higher shadow values of groundwater and lower crop prices and yields imply lower shadow values of groundwater in agriculture.

1.4 Methods used

1.4.1 Rural household methods

It was observed that there is limited literature on the rural situation of water supply and sanitation services, as well as the linkages between and groundwater use characteristics and perceptions in the study area. The observed information gaps revealed that there was a need to gain primary information on the descriptive groundwater consumption patterns of rural households in this thesis. This is because it is important to understand the community being studied so as to come up with effective home grown recommendations. It is for this reason that this thesis paid quite some attention to the socio-economic dimensions of groundwater use in rural areas.

Household surveys were conducted using a systematic random sampling approach. Contingent Valuation Method (CVM) was chosen as the preferred method to determine the willingness to pay (WTP) for satisfactory WSS and the responsiveness of groundwater use to tariff changes in rural households. Open ended questions were used during CVM to determine the WTP value of groundwater, and by how much groundwater use will change at different tariffs. The WTP value represents the utility value (value in use) of groundwater to rural households. It is an economic value.

1.4.2 Agricultural methods

Group discussions were conducted with commercial farmers in the study area. The typical farm information elicitation approach was applied. Typical farm budgets for each crop were established from farmer group discussions. Information from the typical farm budgets formed the data set fed to a linear programming model. A parametric approach was adopted in the linear programming, where the shadow values of irrigation at various producer prices and yield levels were determined and mapped out. The shadow value is also an economic value.

1.5 Layout of the thesis

This study determined the utility value of groundwater in selected rural households and the shadow value of irrigation groundwater in typical tomato and table potato farms in the Mooketsi and Polokwane farming areas respectively. This study falls in line with the national goal of water demand management (WDM) across water use sectors in South Africa, but the scope if this thesis was on domestic and agricultural groundwater use. This thesis is organized as follows: Introduction in Chapter 1, literature review in Chapter 2. Thereafter, a description of the study area is given in Chapter 3. Chapter 4 shows the methodologies used. Chapters 5 to 7 outline the results and discussion and address the research questions. A general conclusion and policy implications are furnished in Chapter 8.

CHAPTER 2

LITERATURE REVIEW

This literature review explores the concepts of economic valuation of groundwater and issues of water demand management (WDM) along with its application. The discipline of WDM is defined and a perspective for the need to apply the discipline's tools is given. Discussion is given on how to determine the shadow value of irrigation groundwater in typical commercial farming setups and willingness to pay for groundwater in rural households. An evaluation of studies on groundwater economic valuation and WDM is also given.

2.1 The concept of water demand management

Many third world countries give priority to economic development, food security, poverty alleviation in towns and in rural areas, rural livelihood consolidation and development and environmental protection. Unless water is abundantly available – which is seldom the case – such aims can best be pursued if there is harmony between the demand for water and the availability of water (Nielsen, 2002).

2.1.1 Introduction

Recent studies claim that more than 40% of the world food and agricultural needs are produced on irrigated lands. As the developing countries and especially the urban populations in these countries continue to grow at a rapid rate, the forecasted food and agricultural demand will increase the pressures on the dwindling water resources in many of the world countries especially the developing ones. And as most of the feasible water resources in river basins and aquifers have already been connected and are being used in the various countries, one cannot avoid asking the question from where and how will the demand for more food and water be met (Arlosoroff, 2003)?

The following are frequently asked questions within water management: how much water is available, what is water needed for, how much water is needed, is there enough water and if not – what to do? Demand management is related to the last of these questions (Nielsen, 2002). According to Arlosoroff (2003) WDM has become a major shift of paradigm from the conventional supply management of water to the management of the demand side, providing additional quantities of water for the immediate needs of the society, through the creation of "virtual" quantities of water, whether by conservation strategies or by increased agricultural and industrial production per unit of water, as well as import of water intensive agricultural products and decreasing exports of such products.

2.1.2 A definition of water demand management

WDM is a combination of measures to motivate people and their activities to regulate the amount, manner and price in which they access, use and dispose of water, thus alleviating pressure on freshwater supplies. It is also about protecting water quality. As freshwater supplies dwindle, conservation and efficient use of both quantity and quality of water, become imperative. Water demand can be done through a number of wide-ranging measures and practices: non-financial (like awareness, technology) or financial (incentives, pricing), mandatory (regulations) or optional (market systems) (Baroudy et al., 2005).

In its simplest sense, WDM means getting the most from the water we have (Brooks, 2002). In a somewhat more elaborate form, WDM includes any action that reduces the amount of freshwater we use, or that keeps water cleaner in the course of that use than it otherwise would be (Brooks et al., 2007).

In a review paper, Grover (2002) identified several other definitions of WDM:

- Any socially beneficial action that reduces or reschedules average or peak water withdrawals or consumption from either surface or groundwater, consistent with the protection or enhancement of water quality (Tate, 1993), where "socially beneficial" is defined to mean "that the benefits to society of adopting the measures should outweigh the costs of adoption (Tate, 1990).
- A practical strategy that improves the equitable, efficient and sustainable use of water (Deverill, 2001).

- The development and implementation of strategies aimed at influencing demand, so as to achieve efficient and sustainable use of a scarce resource (Savenjie and Van der Zaag, 2002).

2.1.3 Rationale behind water demand management

Figure 2.1 shows that WDM is a tool for achieving harmony between the demand for water and the availability of water. Before WDM is in place water demand is shown to be in excess of the available water, which precludes development. After WDM the actual water use is below water availability, allowing for infrastructural development.

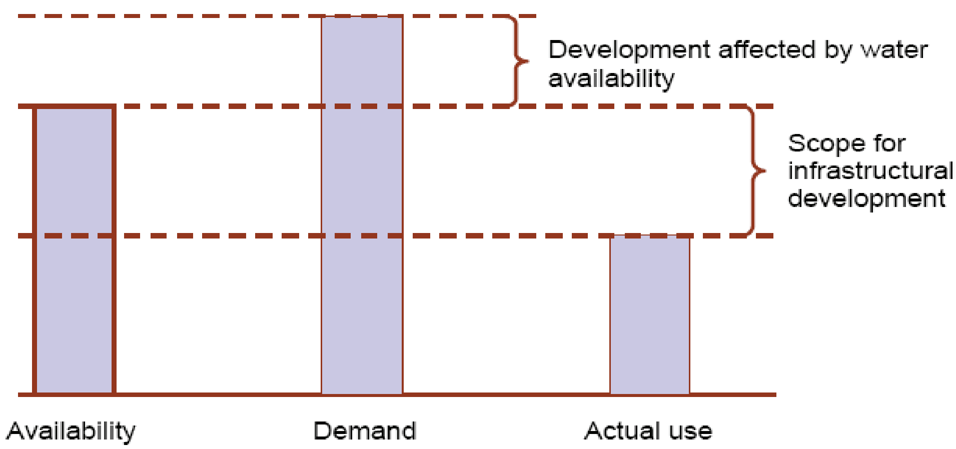


Figure 2.1: Achieving harmony between water demand and availability
Source: Nielsen (2002)

If water (or money) is limited, WDM can be required in support of important water-related development goals like in: (i) economic development; (ii) food security; (iii) poverty alleviation in towns and in rural areas; (iv) rural livelihood consolidation and development; and (v) environmental protection.

In some cases, the choice is open between increasing the supply of water and reducing the demand for water. In other cases, only one of the strategies is feasible, at least in the short term (Nielsen, 2002).

2.1.4 The South African perspective of water demand management

Water is a critical issue for developing countries where shortages of water, food, and energy are closely linked with poverty and other social disorders (Ashton and Haasbroek, 2002; Falkenmark, 1994). Water, as natural capital, is increasingly becoming the limiting factor to development (Aronson et al., 2006). As Scholes (2001) states in Van Heerden et al. (2008):

The availability of water of acceptable quality is predicted to be the single greatest and most urgent development constraint facing South Africa. Virtually all the surface waters are already committed for use, and water is imported from neighbouring countries. Groundwater resources are quite limited; maintaining their quality and using them sustainably is a key issue.

In the past, rising water demand was addressed through supply-side mechanisms (Smakhtin et al., 2001), but this is becoming less viable due to resource constraints and the increasing marginal cost of engineering solutions. Alternative management options, such as demand-side management, have to be considered (Ashton and Seetal, 2002).

The South African government, according to the National Water Act (DWAF, 1998) is the trustee and custodian of all water resources in the country. The government has responsibility, among others, to conduct water resource management, enact water pricing strategies, protect resources, and implement water augmentation schemes (Van Heerden et al., 2008). Hendricks (Minister of Water Affairs and Forestry, 2008) – in a speech titled ‘The Power of Water, the Power of a Nation’, stated that “in a water scarce country (South Africa) that is achieving significant social and economic growth, the challenge for government today is how to go beyond the provision of universal access to water and sanitation services in response to immediate needs and also ensure the continued availability of water well into the future. When looking at the available options it is clear that the efficient use of water through the implementation of water conservation and demand management measures provides us with one of the best ways of sustaining our water resources. However, when pursuing our goal to provide water to the people, we must not lose sight of the reasoning behind the goal, which is to create a better life for people through social and economic progress" (Hendricks, 2008).

2.1.5 Groundwater resources global importance and management need

2.1.5.1 Concept and importance of renewability of groundwater

Groundwater resources can be classified as renewable or non-renewable. Groundwater resources are never strictly non-renewable. But in certain cases the period needed for replenishment (hundreds or thousands of years) is very long in relation to the normal time-frame of human activity in general for water resource planning in particular. In such cases it makes practical good sense to talk in terms of 'non-renewable groundwater resources' (Margat et al., 2006). In this regard, WDM as a planning strategy seeks to regulate the demand for groundwater so that annual groundwater abstraction rates are kept below the annual groundwater recharge rates, thereby preserving aquifers.

2.1.5.2 Groundwater for life, livelihoods and signs of degradation

Groundwater is vital to most nations, irrespective of their stage of economic development, and worldwide some two billion people, many industries and countless farmers depend on it. Massive groundwater use commenced in the 1950s onwards, facilitated by improved hydrogeological knowledge, groundwater well drilling and pump technology. With this, great socio-economic benefits were generated from high-quality, low-cost, drought-resilient groundwater supplies for urban development, rural welfare and agricultural irrigation. Groundwater abstraction advances have brought about valuable socio-economic benefits, but in order to sustain the enjoyment of such benefits it is important for countries to engage WDM in one form or the other. Most nations now realise that groundwater also has a bequest value and have embarked on WDM strategies in order to forestall the potential destruction of their precious groundwater reserves.

Groundwater storage in aquifers is vast (representing 97% of global freshwater reserves), but its replenishment is finite and its quality can be degraded. Inappropriate resource development has widely led to excessive groundwater level decline, depletion of strategic aquifer reserves, salinisation and/or pollution of groundwater supplies and land subsidence, ecological damage to wetland habitats and mobilisation of naturally occurring arsenic and fluoride causing serious water supply problems, while uncontrolled urban and industrial effluent discharges and intensive agricultural land-use are also causing serious aquifer pollution (International Association of Hydrogeologists (IAH), 2006).

2.1.5.3 Groundwater a neglected resource and the need for management

Groundwater remains a neglected and misunderstood resource because funding for management and protection is often bottom of the 'environmental league' table. The sustainability of groundwater resources is closely linked to policy issues affecting land-use and surface water and groundwater is not confined to pipes and channels, its frontline managers are well owners and operators (such as municipalities, industrial enterprises and farmers) and those who make decisions on land-use and waste management. Although there is no simple blueprint for action, due to the intrinsic variability of both groundwater systems and socio-economic situations, it is always feasible to make incremental improvements in resource management and protection (IAH, 2006).

2.1.6 Water demand management tools

According to Nielsen (2002) the demand for water can be controlled using the following WDM tools in different groundwater use sectors:

- **Domestic**

The demand of water for domestic consumption can be controlled by: installing water meters, water fees, raising awareness of the need to save water, and rationing of water.

- **Industrial**

The demand of water for industrial consumption can be controlled by measures such as: installation of water meters (if not done already) and charging a water fee, applying different tariffs for different users and different seasons, promotion of new water-efficient technology, and/or rationing of water (normally in case of critical shortage only).

- **Agriculture (irrigation)**

The demand of water for irrigation can be controlled by measures such as: charging a water fee that depends on the volume of water used (rather than the irrigated area); generation of awareness about prudent use of water; promotion of good operation and maintenance; promotion of new, water-efficient technology (crops and cultivation routines); and/or rationing of water, possibly by de-central administration (water user groups).

2.1.7 Advantages and disadvantages of water demand management

The pros and cons or WDM are listed below (Nielsen, 2002).

Advantages

- Low investment required (except for repair of distribution network, which can be very expensive).
- Public income can be generated by water fees.
- Incentives to industries and agriculture to improve their efficiency (and thereby their competitiveness in an open market).
- Raw water is preserved for alternative uses downstream, including fisheries.
- Less sewage treatment capacity required.

Disadvantages

- Excessive demand management can affect general economic development.
- Risk of adverse social impact to the poor part of the population.

The negative effects to the poor will be less if regulation is introduced gradually, by small steps, and in a transparent and predictable way.

2.2 Water valuation and pricing

The range of environmental and economic services of groundwater needs to be accounted for in policy decisions. Non-recognition of these services imputes a lower value for the groundwater resource in establishing policies. Rational decision-making presupposes the forecasting of consequences, and assignment of values to these consequences. Because of the limited role played by the market forces in the allocation of groundwater, market prices upon which to base groundwater-related resource allocation decisions are seldom available. In the jargon of the economist, shadow prices reflecting the economic value of water must be developed in their place (Young, 1996).

Economists have in recent decades developed a number of techniques for measuring the economic values or benefits associated with non-market allocation in the subject matter areas relating to the environment and natural resources. These techniques call for a wedding of economic theory and applied economic practice. The theoretical foundations of non-market economic valuation of environmental resources have come to be well developed. Progress with methods for estimating economic benefits in actual cases is also well advanced. Mainstream economists treat values as extrinsic, and propose to measure impacts in terms of satisfaction of human preferences. To transform the concept of welfare into a single metric, the suggested measuring rod is that of money (Rhoads, 1985). A person's welfare change from some promised improvement is measured as the maximum amount of money a person would be willing to forego to obtain the improvement. Conversely, for a change which reduces welfare, the measure is the amount of compensation required to accept the change. The weaknesses of established market prices in capturing hidden values dictates economic valuation to be derived from a range of economic valuation techniques like estimation of the degree to which people are willing to pay for benefits (utility value of water) and mathematical programming techniques (Young, 1996).

Economic value is different from price. Price does not in general measure economic value, and items with no market price can still have a positive economic value. This was first pointed out by Dupuit (1844) and Marshall (1879). But it took until the 1970s for this to become well accepted within modern economics. It was around this time that operational procedures became available to measure economical value separately from price and it was around this time that non-market valuation emerged as a field in economics. It also happens that water as a commodity played a role in these developments, both clarifying the economic concept of value and developing operational procedures for measuring it (Hanemann, 2005).

2.2.1 Meaning of economic value

The distinction between market price and economic value was famously noted by Adam Smith in a passage in the Wealth of Nations describing the paradox of water and diamonds:

The word value, it is to be observed, has two different meanings, and sometimes expresses the utility of some particular object, and sometimes the power of purchasing other goods which the possession of that object conveys. The one may be called 'value in use', the other 'value in exchange' and on the contrary, those which have the greatest value in exchange have frequently little or no value in use. Nothing is more useful than water, but it will purchase hardly anything in exchange for it. A diamond, on the contrary has hardly any value in use but a great quantity of goods can be exchanged for it (Smith, 1776).

This gives a distinction between economic value (value in use) and price (value in exchange). In most policy-related applications of economic valuations involving water, the relevant quantity that needs to be known is the marginal value rather than the average or total value of water. Precisely because water is a necessity of life, most people have some access to some water, and most policy interventions therefore involve changing the quantity and/or quality of access rather than transforming the situation from no access to some access. The point is that, ceteris paribus, there is likely to be some degree of diminishing marginal utility for consumers, and diminishing returns for producers, which imply that there can be a substantial difference between the marginal value of an increase in water supply and its average value. This needs to be emphasized because researchers have often chosen to use an estimate of the average value of water to measure the benefits of a policy intervention (Hanemann, 2005).

2.2.2 Mathematical programming for irrigation water valuation

The challenge in assigning an accurate value to water in crop production is the complexity of allocation processes being modelled. The farmer must choose which crops to grow, how much land, labour, and capital resources to allocate to each crop, and what technologies to employ (Young, 2005).

- **Factors influencing the value of irrigation water**

When water economists are asked about the value of irrigation water, the answer, as usual in economics (and in other science), is: “it depends.” In this case it depends not only on the physical and market conditions where the production takes place, but also on the context in which the question is posed. Of course, as a component of agricultural production, the value of irrigation water is site-specific. The productivity of the location will vary according to factors such as climate, soil, and quality of irrigation water. Prices for outputs and inputs may also vary enough by region to influence willingness to pay for water. However, site considerations otherwise equal, there are a number of alternative formulations of the economic value of irrigation water. These vary between long-term and short-term values, private and social values, at-site and at-source values, and per-period and capitalized values. Estimates of irrigation benefits over long time horizons must consider the potential for technological change and fluctuations in commodity and input prices (Young, 2005).

- **Farm crop budget analysis**

In some places and for some crops, the actual physical productivity of water is not known. Crop-water production functions have not been scientifically established and the share of yield contributed by the water input has not been determined. Nonetheless, typical farm crop budgets can be used to estimate maximum revenue share of the water input, thus bypassing the need for a physical productivity measure. The total crop revenue less non-water input costs is a residual, the maximum amount the farmer could pay for water and still cover costs of production. It thus represents the on-site value of water. If water procurement costs are further subtracted, the net value for irrigation is then comparable to in-stream water values (Gibbons, 1986).

- **Mathematical programming**

Mathematical programming has been adapted to irrigation water valuation over the past several decades, driven by refinement of the method and more powerful computers. Mathematical programming allows much more realistic modelling of irrigation decisions than simple budgeting (Young, 2005). Mathematical modelling techniques can be used to explore many situations by simulating physical phenomena by means of mathematical models (linear programming is one such example). These techniques are very useful for analysing agricultural problems and are extremely flexible and can allow for different variables, such as, for example, soil types, different water saving technologies, fixed costs of irrigation investment and can incorporate portfolio risk (Williams et al., 2008).

There have been a number of applications of parametric linear programming to estimate the demand function for water in Australia. Flinn (1969) used a similar approach to that of Moore and Hedges (1963), by estimating the regional demand for water by aggregating the demand functions determined from five individual farm linear programming models. An important feature of Flinns's work was the estimation of intra-seasonal as well as seasonal demand functions. Flinn also pointed out that the shadow value of institutional constraints imposed on a quadratic programming model of a river basin are generated in the same way as opportunity cost of physical constraints, thus making it possible to compare the economic cost of administrative decisions with policies based on efficiency criteria alone. Gisser (1970) also used parametric linear programming to estimate demand functions for imported water as an alternative to depleting groundwater reserves in the Pecos River Basin in the USA (Williams et al., 2008).

LP models have been used extensively to assess economic impacts of proposed water policies. Bowen and Young (1986) studied the allocative and distributive effects of alternative irrigation water charging policies in Egypt. Michelsen and Young (1993) formulated a short-run programming model to measure foregone benefits when dry-year options might be sold to urban water supply agencies to provide adequate water supplies in case of periodic drought. Booker (1995) estimated foregone benefits of a severe, sustained drought in the Colorado River Basin. Adams and Cho (1998) studied tradeoffs between water use for agriculture and for enhancing habitat for endangered fish species in the Klamath Basin, Oregon with short-run models of below normal and drought scenarios (Young, 2005).

Anderson (1968), while retaining the fixed crop acreage assumption of the whole-farm budget approach, utilized computer simulation to represent multi-stage crop response to alternative amounts and timing of water application in a model of an irrigation delivery system. Numerous applications of linear programming to irrigation planning followed. Early models (e.g. Burt 1964) provided only for omission of marginal crops in response to increased price of scarcity. Young and Bradehoeft (1972) modelled sequential or multistage decision processes and crop response to varying water application rates, and found that the water application portion of the Anderson (1968) model could be easily and accurately presented by a linear program. Bernardo et al. (1987) included representations of seasonal crop response to water and irrigation application technology (Young, 2005). The following studies commissioned by the Water Research Commission (WRC) in South Africa also used mathematical modelling: Conradie (2002), Louw (2002), and Williams et al. (2008). Louw (2002) used linear programming, Conradie (2002) used risk modelling (MOTAD), and Williams et al. (2008) estimated demand curves using contingent valuation to determine the value of water.

Linear programming (LP) analysis relies on financial data from representative farms to determine irrigation water values. For the calculation of irrigation water values, the LP objective is to maximize net returns for a farm of specified acreage, subject to constraints which may be economic, institutional or physical, such as acreage limitations for each crop, input costs per unit, available technology, constant water requirements set for each crop, crop prices, and so forth. In the LP solution, limiting the acreage of certain risky crops is one way to incorporate the desired level of risk to the farmer. LP analysis can be used to estimate marginal values for irrigation water on a representative farm. Instead of water costs, water supply is varied and an LP solution is found for each quantity of water available to the farm, all other constraints remaining constant (Gibbons, 1986).

- **Conceptual framework for valuing irrigation groundwater**

The linear programming approach is also justified by Young (2005). According to Young (2005) "water-related net rents" are a sound, workable point measure of welfare gains and losses (in terms of willingness to pay for producers' goods). For the long term, this was shown to be calculated by estimating expected total revenue and subtracting from it anticipated costs of purchased inputs and opportunity costs of owned inputs. Considering the single product case where markets are competitive. According to Young (2005) we begin with a production function in Equation 2.1:

$$Y = f(X_m, X_h, X_k, X_l, X_c, X_w, E) \qquad \textit{(Eqn. 2.1)}$$

where

Y = the quantity of an output
X = the quantity of an input
m, h and k refer to inputs that are typically purchased (contractual)
m = materials, energy and equipment
h = labour
k = (borrowed) capital[1]
l = (unimproved or rain-fed) land
c = equity capital of the firm
w = water
E = opportunity costs of owned skills, management, technical knowledge, and entrepreneurial creativity.

To move from the production function to the long-run rent function, let R represent rents and P refer to price. The subscript W stands for water, while 1 identifies an at-site value. By convention, the net rent formulae are standardized in terms of land, i.e., expressed in per unit land (acres, hectares). Assuming durable input costs are expressed in annual

[1] The capital and operating costs of the farm's water distribution system here are treated as part of materials, energy, and equipment costs. Although they often may also be purchased, the remaining inputs are assumed here to be owned or non-contractual.

equivalent terms, the basic (at-site) annual water-related rent formula for a single commodity can be written symbolically as:

$$R_{W1} = [Y \bullet P_Y] - [(P_m \bullet X_m) + (P_h \bullet X_h) + (P_k \bullet X_k) + (P_l \bullet X_l) + c + E] \qquad \textit{(Eqn. 2.2)}$$

The formula represents the at-site measure of a long-run welfare change (i.e., the firm's long-run willingness to pay for water for a crop on a unit land area). The firm's receiving point may be either the connection to a canal delivery system or, for a groundwater supply, the wellhead. By convention, this is the value used in irrigation investment evaluations, to be compared with annualized costs of supplying water to the same point of use.

Likewise, this study evaluated the value of water as it is applied to a standing crop in the field only, and not the value of raw water. So Equation 2.2 only (and not Equation 2.3) will be the production function used in the analysis in order to get the shadow value of irrigation groundwater.

For the at-source (raw water) value, the delivery costs of moving water from the source to the site must be deducted. Because they are commensurate with the values computed for in-stream uses, such as environmental enhancement or energy production, at-source values are most appropriate for use in comparing intersectoral allocations. The delivery costs may be an annual fixed charge per unit land (denoted D) or, less often, a variable charge per unit water volume. Expressing delivery charges as an annual fixed charge per acre or hectare, the at-source water-related rent per unit land is:

$$R_{W2} = [Y \bullet P_Y] - [(P_m \bullet X_m) + (P_h \bullet X_h) + (P_k \bullet X_k) + (P_l \bullet X_l) + c + E + D] \qquad \textit{(Eqn. 2.3)}$$

Or combining the above two equations we then simplify to:

$$R_{W2} = R_{W1} - D \qquad \textit{(Eqn. 2.4)}$$

Dividing by W will give the rents and delivery costs in water volume terms (Young, 2005).

Conceptually, the typical farm process displayed in Equation 2.2 was the basis used to determine the shadow value of irrigation groundwater using LINDO linear programming software.

2.2.3 Groundwater valuation using willingness to pay

CVM has been elected as the approach to be used in determining willingness to pay in the case of direct users of water such as households. In social-psychological terms it is a measure of behavioural intention in situations involving the buying of goods or services (Williams et al., 2008). The WTP concept generally refers to the economic value of a good to a person (or a household) under given conditions. Net economic benefits of improved water supply and sanitation (WSS) services, in simple terms, are estimated as the difference between the consumers' maximum WTP for better services and the actual cost of the service (Gunatilake et al., 2007).

WTP values provide crucial information for assessing economic viability of projects, setting affordable tariffs, evaluating policy alternatives, assessing financial sustainability, as well as designing socially equitable subsidies (Brookshire and Whittington, 1993; Whittington, 2002a; Carson, 2003; Gunatilake et al., 2006; Van den Berg et al., 2006).

The WTP value of a good or service may be elicited: (i) directly by asking consumers, through carefully orchestrated elicitation methods; or (ii) indirectly by examining market prices. The contingent valuation (CV) method is a survey-based elicitation technique to estimate WTP values of a good that is not traded in the conventional market. The CV method directly asks consumers' WTP for a non-marketed good under a given condition or a prescribed circumstance. To elicit consumers' WTP values for non-marketed goods, a hypothetical market scenario should be formulated and described to the survey respondents. Thus, the elicited WTP values of a good are "contingent upon" the hypothetical market prescribed in the survey instrument (Cummins et al., 1986; Mitchell and Carson, 1989). Since a CV survey always asks WTP questions, it has been commonly called a "WTP study." Subsequently, the key fundamentals of "contingent" market scenarios are often overlooked by practitioners as the term "WTP" predominates over "CV method" (Gunatilake et al., 2007).

Despite its wide use for practical policy purposes, the CV method's ability to reliably estimate WTP is not universally accepted. While some economists have expressed scepticism on the use of direct questioning to estimate WTP, one of the early verdicts on the soundness of CV method came from a group of world-renowned economists: Kenneth Arrow, Roy Radner, Edward Leamer, and Howard Schumann (Arrow et al., 1993). Their Blue-Ribbon Panel report for the National Oceanic and Atomspheric Administration states:

CV studies convey useful information. We think it is fair to describe such information as reliable by standards that seem to be implicit in similar contexts, like market analysis for new innovation products and the assessments of other damages normally allowed in court proceedings (Arrow et al., 1993).

CV elicitation questions can be of two basic forms: open-ended or closed-ended. In an open-end question, the respondent is asked to state the maximum amount that he or she is willing to pay for the good that is being valued. With a closed-ended CV question (also referred to as a "dichotomous choice" or "referendum" question), the respondent is asked whether he or she is willing to pay a specified amount presented as the value of the improved service. The respondent is expected to answer "yes" or "no." Closed-ended questions have been the preferred form of elicitation question since it was introduced by Bishop and Heberlein (1979). On the other hand, open-ended questions provide more information than closed-ended questions; and do not require econometric modelling to analyze, as the mean WTP values of respondents can be readily estimated by simple arithmetic. However, answering an open-ended question on a new commodity requires a higher level of cognitive demand on the part of respondents, because individuals are typically not accustomed to performing such tasks in daily life decision making (Gunatilake et al., 2007).

According to Van Vuuren et al. (2004) in attempting to estimate household responsiveness to changes in water tariffs by means of a CV experiment it is first necessary to choose suitable samples of consumers for participating in the experiment. It is preferable to choose a sample that pays for water since such a sample already has some notion about the value of water, however, CV experiments can be conducted amongst consumers who do not pay for water since in the experiment a hypothetical market for water is created.

The household and community surveys combined with supplementary administrative data can add up to a big data set. While some variables are of independent interest, others must be combined to produce policy relevant statistics. In general, these data should be described at two levels. First, the analyst should compute descriptive statistics (e.g., mean, median, standard deviation, and range) to understand and describe all of the variables in the data set. Examining the descriptive statistics will serve as a quality assurance and quality control measure because the analyst will be able to identify anomalies, outliers, and improbable values (Gunatilake et al., 2007).

2.2.4 Economic aspects and efficient allocation of resources

Tariffs should send a clear and simple signal to consumers to encourage them to rationalize their demand for water. A low price gives the impression that there is an inexhaustible availability of water and saps the economic justification from efforts to curb consumption. This leads to misallocation and misuse of the resource. At the same time, a price that is too high departs from the Pareto optimum because it unduly limits the consumption of an available resource, reduces user satisfaction and penalizes the poor segments of society (Baroudy et al., 2005).

2.2.5 Pricing practices

Now that a differentiation has been made between the principles of economic valuation and market pricing, the following section provides a brief overview of some of the pricing mechanisms employed in WDM:

- **Volumetric**

The charge for water is based on direct measurement of the volume of water consumed. Variations of the volumetric method include indirect calculation based on the units of time, such as minutes, hours, of certain or uncertain water flow, from a reservoir or a river, respectively, and secondly a charge for a given minimal volume that must be paid even if water is not consumed (Tsur and Dinar, 1997).

- **Output or input**

Irrigation water is charged either on a per-output basis in which irrigators pay a certain water fee for each unit of their output, or by taxing other inputs, in which irrigators pay a water fee for each unit of a certain input used (Tsur and Dinar, 1997).

- **Per unit area**

Water is charged per irrigated area. In many countries, water rates are higher when water is taken from man-made reservoirs than when diverted directly from streams. In some cases, farmers are required to pay per acre charges also for unirrigated land (Tsur and Dinar, 1997).

- **Block-rate or tier**

This is a multi-rate volumetric method, in which water rates vary as the amount of water consumed exceeds certain threshold values (Tsur and Dinar, 1997). The block tariff system is the method employed by DWAF in South Africa.

- **Cross-subsidies**

In addition to the cross subsidies implicit in the block tariff system, another form of cross-subsidy makes it possible to improve and expand water services in rural areas that do not enjoy economies of scale through contributions from consumers in big cities. In order to make water prices reflect scarcity of water, Morocco applies tariffs that are differential by city or district served; production tariffs are distinguished from distribution tariffs; and there is a surcharge on wholesale prices that is used to improve and expand services in rural areas (Baroudy et al., 2005).

- **Two-part tariff**

A two-part tariff involves charging irrigators a constant marginal price per unit of water purchased (MCP) and a fixed annual or admission charge for the right to purchase the water (Tsur and Dinar, 1997).

- **Betterment levy**

Water fees are charged per unit area, based on the increase in land value accruing from the provision of irrigation (Tsur and Dinar, 1997).

- **Water markets**

Such markets exist in different forms throughout the world, in developed as well as less-developed-countries (LDCs). They may be formal or informal, organised or spontaneous. Their participants may trade water rights, for example, the right to purchase some volumes of water at a particular price at specific periods of time, or they may trade water at the spot or to be delivered in the future (Tsur and Dinar, 1997).

- **Metering**

Consumption metering is widely used to ensure that tariffs are fairly applied. A case study conducted in Jordan describes the process of widespread installation of meters at private wells so that billing can be introduced to discourage over-exploitation of aquifers (Al Hadidi, 2002).

2.2.6 Price and income elasticity of demand

Research conducted in Tunisia on price elasticity of demand revealed that in some cases a 21% increase in tariffs led to a 5% drop in water consumption and a 38% increase in crop intensification. This amounts to a 32% saving in water, achieved largely through greater crop intensification and, consequently, greater efficiency. In some cases, the scarcity of water combined with a hike in water tariffs led farmers to employ water-saving irrigation techniques, particularly localized drip irrigation. In Tunisia, the price elasticity of demand for agricultural water is relatively low, but is varies by region (Hamdane, 2002)

An observation made in Middle East and North Africa (MENA) is that in much of the literature on "getting the price right", the implicit assumption is that, as prices rise, consumption decreases. This is a good assumption but the relevant question is: By how much? In order to estimate the consumption effect, it is necessary to review price and income (or, in the case of industry, scale) elasticities (Brooks, 2004).

2.3 Water demand management for agriculture

2.3.1 Introduction

The agricultural sector, which consumes the most water in South Africa, is regarded as the primary source to meet demand through water savings. Despite this realization, irrigated agriculture will have to maintain and improve productivity to meet growing food demand in future. This will require an enabling environment that allocates water optimally. Water marketing is one such mechanism that can allocate water to its highest use in an efficient and flexible manner (Armitage, 1999). According to a study by Nieuwoudt et al. (2004) on the shadow value of surface water, average ratios indicate that agriculture is an inefficient user of water in terms of gross income generated per unit of water and that water efficiency could be significantly enhanced if transfers within and between river reaches are promoted as water shadow values differed. However, for groundwater on the other hand, the inefficiency of agricultural groundwater use poses a different challenge because the South African water market traditionally trades in surface water only. Groundwater demand will have to be redressed by using a synergy of economic valuation techniques together with pricing strategies.

2.3.2 Objective of water demand management in agriculture

According to Pereira et al. (2002) the objectives of irrigation water demand management can be summarised as follows:

- Reduced water demand – through selection of low water demand crop varieties or crop patterns, and adopting deficit irrigation, i.e. deliberately allowing crop stress due to under-irrigation, which is essentially an agronomic and economic decision.

- Water saving – mainly by improving the irrigation systems, particularly the uniformity of water distribution and the application efficiency, reuse of water spills and runoff return flows, controlling evaporation from the soil, and adopting soil management practices appropriate for augmenting the soil water reserve.
- Higher yields per unit of water – which requires adopting best farming practices, i.e. practices well adapted to the prevailing environmental conditions, and avoiding crop stress at critical periods. These improvements result from a combination of agronomic and irrigation practices.
- Higher farm income – which implies to produce high quality products, and to select cash crops. This improvement is mainly related to economic decisions.

Agronomic and economic decisions and farming practices, including those related to the use of improved crop varieties, are often dealt with in literature (e.g. Bucks et al., 1990; Tarjuelo and De Juan, 1999). Often issues for irrigation WDM refer mainly to irrigation scheduling, therefore giving a minor role to irrigation methods. However, a combination approach is required (Pereira, 1999), particularly when wastewater and low quality saline water are used (Pereira et al., 2002).

2.3.3 Global experience on pricing mechanisms

Pricing mechanisms have been given high priority in dealing with the increasing constraint of water scarcity in food production. Yang et al. (2003) probed the effectiveness of pricing-based water policies in selected districts of the Yellow River, Huaihe and Haihe River basins in addressing challenges facing irrigated agriculture under China's current water management institutions. Their examination shows that the rapid increase in irrigation cost during the past decade has failed to generate a force for water conservation. Over-exploitation of groundwater resources has even intensified with the shift to higher value-added but often more water intensive crops. Pricing mechanisms were found to provide little incentive to water authorities to reduce irrigation water supply, and farmers are not motivated to adopt water-saving technologies. The response of water use behaviour to price signals is intrinsically weak. For water authorities, the main gain of increasing water prices has been to raise revenue to alleviate the financial situation. Little has been done in improving management efficiency. For farmers, increasing irrigation prices means a loss of income, with little change in their water-use behaviour (Yang et al., 2003).

In groundwater irrigated areas, the lack of effective water licensing and extraction control leads to unrestricted withdrawal of groundwater. Imposing a resource levy may not halt this trend. Instead, a revenue gain from the resource levy may encourage water authorities to issue more water licenses, causing acceleration of resource depletion. In groundwater irrigated areas, imposing water extraction restriction through effective water licensing must take place to limit the total volume of groundwater withdrawal. Improving irrigation efficiency through better management and the adoption of water-saving technologies is the ultimate way to deal with the challenges facing irrigated agriculture (Yang et al., 2003).

As prices for irrigation water were gradually raised in Tunisia (one of the MENA countries), farmers sensibly shifted to higher value crops, notably vegetables and fruit, and away from cereals. The same studies suggest that the income elasticity of demand is positive, and this justifies the policy of increasing block rates (tariffs). Though not perfect – for example, higher rates could penalize poor people growing their own food in the city – the assumption that water use will drop more rapidly for higher than for lower income people is a good starting point. The question is, by how much (Brooks, 2004)?

Of key importance to the Tunisia case would be to investigate whether a move to higher value crops generated the desired reduction in water use. The Chinese case revealed that a move to these higher value crops actually exacerbated the water demand levels. Hence, for pricing mechanisms in agriculture to generate positive WDM results, it calls for further research and development. Therefore, linkages between WDM and saving water must be made explicit; they cannot be assumed. Fortunately, this is not an area in which precision is required; it is only necessary that one be certain of the direction of the effect to be determined, along with a rough idea of its size (Brooks, 2004).

Irrigated agriculture consumes more than 75% of water resources use in most MENA countries. This fact emphasizes the importance and need for better water management in the agriculture sector, and more specifically, for improved irrigation efficiency. The use of modern irrigation techniques like drip irrigation, together with micro-sprinklers and other water-saving devices has become widespread in some countries of the region, resulting in substantial water savings. Extensive water savings have also been realized through careful implementation of a variety of on-farm irrigation management practices (Ghezhawi, 1997).

Water prices will not always be a sufficient incentive for users to enhance use efficiency. This is the case when price elasticity for water demand is close to nil, for example when the water bill accounts for only a small proportion of the farmers' total production costs or income; when alternative ways of growing crops or alternative water resources are not available, due to technical, social, or economic constraints; or when the bulk of the total water charge consists of fixed costs (Rieu, 2005).

In the Charente river basin, pricing water appears to be a convenient instrument for water demand management as an increase in water price lowers significantly the irrigation water use due to higher price elasticity of demand (Montginoul and Rieu, 2001). Nevertheless, even the very first increase in prices has a significant impact on farmers' revenues which is unacceptable. This led the local authorities and the water agency to abandon the pricing instrument and shift to a quota system (Rieu, 2005).

From research conducted in France, it can be derived that water pricing is always needed even if quotas are implemented. Secondly, it makes very little sense to speak about the design of water pricing in general because a tariff has to be defined according to an objective that has to be shared among the main stakeholders. Thirdly, like irrigation tariffs have their own life cycle, a pricing system will have to evolve over time depending on the economic situation and, once again, the objectives of public authorities and water managers (Rieu, 2005).

A study by Lipton (2007) in Asia shows that price reforms in agriculture raise incentives to use water more carefully, because the user pays for it; but that will cut seepage, evaporation and/or percolation (SEP) only if (i) the water-buyer is the same as the water-loser, or (ii) participatory cooperation involves water users grouped by an entire shared water system affected by losses from SEP on any members' irrigated land. These are stiff conditions. If neither is being met, SEP might not decline, it may even rise, after otherwise desirable institutional reforms.

2.3.4 The concept of virtual water in agriculture

Virtual water is the water embedded in commodities. Producing goods and services requires water; the water used to produce agricultural or industrial products that are traded between countries is called the virtual water of the product. The global volume of virtual water flows related to the international trade in commodities is 1 600km^3 per year. About 80% of these virtual water flows relate to the trade in agricultural products, while the remainder is related to the industrial product trade. The production of 1kg of rice requires 3 000 litres of water, wheat requires 1 350 litres of water and beef requires 16 000 litres of water. Globally, water is saved if agricultural products are traded from regions with higher water productivity to those with low water productivity. In 2030, irrigated agriculture should account for over 70% of the projected increase in cereal production in 93 developing countries. In these countries, the area equipped for irrigation is expected to expand by 20% (40 million ha) between 1998 and 2030. This projected increase in irrigated land is less than half of the increase of the preceding period (100 million ha). Due to increased cropping intensity, the area of harvested crops in irrigation is expected to increase by 34% by 2030. In the same period, the amount of freshwater that will be appropriated for irrigation is expected to grow by about 14% to 2 420 km^3 in 2030 (UNESCO, 2006).

These statistics show that agriculture is a key sector in the drive towards WDM. If about 80% of these virtual water flows relate to the trade in agricultural products, it shows that even a small change in the positive direction towards WDM in this water intensive sector will yield significant results. If valuation strategies are cleverly tied in with pricing mechanisms, groundwater saving could be observed. This could even be further guaranteed if water efficient methods are promoted in agriculture like improving irrigation management, using non-water-intensive crop varieties as well as water-saving irrigation equipment.

2.3.5 Water competition in agriculture – a need for demand management

Research shows that adjustment to water competition is already taking place around the world. In many countries the dominant governance model is a path of least resistance approach, with powerful constituencies in industry, commercial agriculture and municipalities transferring water by stealth from those – including the rural poor – with the weakest political voice. Unequal outcomes in the adjustment to greater competition mirror wider inequalities based on land, wealth, gender and political influence. Governance systems can redress these inequalities but all too often they exacerbate them (UNDP, 2006).

2.3.5.1 Water and human development – the livelihoods links

Poor people in agriculture experience the link between water and human development as a living reality. For millions of small farmers, pastoralists and agricultural labourers the stakes associated with water insecurity are high. Variations in rainfall or disruptions in water supply can make the difference between adequate nutrition and hunger, health and sickness and – ultimately – life and death (UNDP, 2006).

Water insecurity presents a powerful risk factor, for poverty and vulnerability. Like land, water is part of the natural capital base that underpins the production systems that sustain livelihoods. Access to a reliable supply of water makes it possible for people to diversify their livelihoods, increase productivity and reduce risk associated with drought. The links between rural livelihoods, water and global poverty reduction efforts are immediately apparent. Some three-quarters of all people surviving on less than $1.00 a day live in rural areas, where their livelihoods are dependent on agriculture (UNDP, 2006).

In Ethiopia distance from a water point is one of the most accurate indicators for vulnerability and poverty (UNDP, 2006). The predictability of water supply and the sustainability of water based ecosystems are crucial dimensions of water security. Predictability helps to explain why access to irrigation is associated with a lower prevalence and reduced severity of poverty. Cross-country research shows that poverty levels are often 20% to 30% lower within irrigated systems than in non-irrigated areas (Hussain, 2005).

The insidious conflict for water emerging between the more powerful users like commercial agriculture, industries and municipalities versus small scale agriculture and rural households has been highlighted in numerous cases around the world (UNDP, 2006). Small scale farmers and rural water users are inevitably on the disadvantage because of their limited political influence on water resources. This development has been exacerbated by turning to supply side solutions that seek to increase groundwater supply instead of turning to WDM that if implemented correctly precludes the need for industry, commercial agriculture and municipalities to resort to depriving the less influential users of groundwater which constitutes much needed natural capital to them. WDM of groundwater resources needs to target the large volume abstractors first as this will trickle down more socio-economic and ecological groundwater benefits to the other users.

2.3.5.2 Agriculture under pressure – the emerging scenarios

Future water management in agriculture faces pressure from two directions. On the demand side industrialization, urbanization and changing diets will increase demand for food and the water used in its production. On the supply side the scope for expanding access to irrigation water is limited. It is this imbalance between supply and demand that is driving adjustment pressures. Looking to the future, prospects for extending irrigation are limited, while pressures from industry and domestic water users are rising. New sources of water for irrigation are increasingly expensive and ecologically damaging to exploit, setting limits on the potential for expansion (Rosegrant et al., 2002). Logically the starting point towards offsetting rising adjustment pressures will be to manage the demand for groundwater, and this is what ecological economists are advocating for – a shift towards WDM.

Large areas of China, South Asia and the Middle East are now maintaining irrigation through unsustainable mining of groundwater or over-extraction from rivers. The groundwater overdraft rate (when rate of groundwater removal exceeds the rate of groundwater recharge) is more than 25% in China and 56% in parts of India. Correcting the overdraft would require cutting down groundwater use from 817 billion cubic meters to 753 billion cubic meters, sharply curtailing the water for irrigation in many areas (UNDP, 2006). The groundwater problem now presents a risk to food production in large swathes of the developing world, with attendant risks for rural livelihoods.

2.3.5.3 Water competition around agriculture

The consequences of competition are not just theoretical outcomes of a plausible future scenario. They are already evident in the mounting conflict surrounding adjustments to water shortages in many countries. Consider these conflicts (Molle and Berkoff, 2006):

- On the outskirts of Mumbai a multinational soft drink company has provoked protests by farmers against its water abstraction operations to serve the fast growing middle-class mineral water market in the city (Gandy, 2006).
- In China, the government has embarked on a $2.7 billion programme to divert water from irrigated areas in Shanxi and Hebei provinces encountering significant opposition.
- In Thailand agricultural producers in the Mae Teng irrigation system are protesting the transfer of water to Chiang Mai, where municipal authorities are struggling to cope with rising demand of urban and industrial users.
- In Yemen farmers are protesting the transfer of water from agriculture to fast growing urban centres such as Ta'iz and Shana'a.
- In the Pakistan province of Sindh hundreds of "tail-end" irrigation farmers have protested against water shortages and the management of an irrigation system that favours upstream water-intensive crop production (UNDP, 2006).

Sub-Saharan Africa faces distinctive challenges. As the developing region is most heavily dependent on rainfed agriculture, green water (the condition in which the microscopic (diatomic) algae turn the water green) management will remain the central priority. The region accounts for less than 5% of global irrigation, just two countries (Madagascar and South Africa) account for two-thirds of sub-Saharan Africa's current capacity. Mozambique and Tanzania have developed only 5% to 10% of their potential (FAO, 2005; Grey and Sadoff, 2006).

Increasingly, governments in the region and aid donours see the development of irrigation as a route to higher productivity and greater food security. The Commission for Africa has recommended a doubling of the area under irrigation over the next decade, adding 7 million more hectares by 2010 (Commission for Africa, 2005). Progress in this direction could generate important gains for human development: research on rice productivity in Tanzania suggests that irrigation could raise yields by 5% a year. However, the outcomes will depend on the distribution of benefits – which is a governance issue.

2.3.6 Water demand management in South African agriculture

WDM in agriculture is on-going and being a young discipline, much work still needs to be done to come up with appropriate strategies. Appropriate strategies seem to be the way forward since climatic and water resource endowments are unique characteristics. Despite the need for appropriateness in WDM application in agriculture, generally acceptable norms and standards will have to be adhered to, and lessons from other regions will have to be emulated in the area of WDM in South African agriculture.

The agricultural sector accounts for more than 60% (around 62%) of water utilisation in South Africa. It is estimated that less than 60% of water used through conventional irrigation methods reaches the root systems of plants. Approximately 35% of irrigation system losses return to the river systems by overland flow and return seepage. This return water can be nutrient enriched and polluted with herbicides, pesticides and other pollutants that can affect water quality of the receiving river systems. A significant amount of irrigation water is also lost through evaporation. This general scenario is indicative of the great potential for WDM in the agricultural sector (DWAF, 2004c).

Irrigation methods, irrigation scheduling, soil type, soil preparation and crop selection all have a significant impact on the efficient use of water. A strategy promoting the equitable and efficient use of water should provide regulatory support and an incentive framework that will improve irrigation efficiency and increase productivity. The strategy will also seek to promote optimal use of water so as to release water for use by new entrants in the agriculture sector and by other sectors. While established irrigators should implement water conservation measures, new entrants should develop appropriate and efficient irrigation infrastructure and practices before claiming their water allocations (DWAF, 2004c).

Finally, the agriculture sector has the potential to make use of partially treated effluent water from urban areas. This re-use of water is a contribution that should be fully encouraged (DWAF, 2004c).

2.4 Water demand management for households

2.4.1 Introduction

In many regions of the world water has been regarded as a free commodity. This has led in many instances to over-exploitation of the available resource as well as uncontrolled releasing of pollutants into water resources by households, industry and agriculture (WRC, 1995). Numerous studies conducted on economics and water supply show that valuation plays a major role in facilitating a more sustainable use of available water resources, hence, the important role of valuing groundwater exploitation. Although groundwater is rechargeable, it must not be considered limitless. Availability is largely dependent on the prevailing recharge rate.

2.4.2 Poverty analysis and water

Poverty is usually defined in socio-economic terms, and perceived as a condition in which people’s livelihood capacity is inadequate to meet their basic needs. An International Fund for Agricultural Development (IFAD) (1992) study showed that out of 4 billion people in 114 developing countries, more than 2.5 billion lived in rural areas, of which half live on highly degraded soil and 1 billion below the poverty line. Such people are vulnerable to rainfall variation and seasonal food and fodder shortages that have serious implications for their livelihoods. Water stress is implicit in life expectancy rates, malnutrition levels, epidemic disease tolls, poverty rates among women employment migration, urbanization rates, flood displacement, even school retention. These interactions are usually overlooked (Black and Hall, 2003).

When analysis is broadened beyond coverage statistics for drinking water and sanitation – which are a very important surrogate for understanding the water poverty relationship – the ‘water poor emerge as follows (Black and Hall, 2003):

- Those whose livelihood base is persistently threatened by severe drought or flood.
- Those whose livelihood depends on cultivation of food and natural products, and whose water source is not dependable.
- Those whose livelihood base is subject to erosion, degradation, or confiscation (e.g. for construction of major infrastructure) without due compensation.
- Those living far (over a kilometre) from a year-round supply of safe drinking water.
- Those obliged to spend a high (e.g. over 5%) percentage of household income on water; slum and rural dwellers obliged to pay for water at well above market rates.
- Those whose water supply is contaminated bacteriologically or chemically, and who cannot afford to use, or have no access to, an alternative source.
- Women and girls who spend hours a day collecting water, and whose security, education, productivity and nutritional status is thereby put at risk.
- Those living in areas with high levels of water-associated diseases (bilharzia, malaria, trachoma, cholera, typhoid, etc.) without means of protection.

The most vulnerable include children, the elderly, minorities (especially indigenous groups), those affected by HIV/AIDS or other kinds of illness, those living in shanty-towns and surviving in the informal or invisible economy (Black and Hall, 2003).

2.4.3 Why the poor pay more for water and get less water

Although professionals widely agree on what constitutes sound water resource management, debate continues about the best ways of implementing policies in this sector. Policy makers have considered pricing water – an ever-debated policy intervention – in many variations. Setting the price "right" some say, might guide different types of consumers in utilizing water efficiently by sending a signal about the value of the scarce resource (Tsur et al., 2004).

Why are some 1.1 billion people denied access to sufficient clean water to meet their basic needs? And why are so many people forced to turn to water sources that jeopardize their health and sometimes lives? People in the slums of Jakarta, Mumbai and Nairobi face shortage of clean water, while their neighbours in high-income suburbs have enough water not only to meet household needs but to keep their lawns green and their swimming pools topped up. There are some obvious parallels between water insecurity and food insecurity for households. Some of the world's highest levels of malnutrition occur in countries that are well endowed with food: one in five people in "self-sufficient" India is undernourished. People go malnourished amidst abundant food for the same reason that they go without access to clean water when there is more than enough to go round: unequal distribution and poverty (UNDP, 2006).

The concept of entitlements (developed by Sen and Dreze, 1999) can help unlock the apparent paradox of scarcity amid abundance. Entitlements can be thought of as 'the set of alternative commodity bundles that can be acquired through the use of various legal channels'. They refer not to rights or moral claims in the normative sense but to the ability of people to secure a good or service through purchase (an exchange entitlement) or through a legally recognised and enforceable claim on a provider (a service entitlement). The entitlements approach offers useful insights on water insecurity because it draws attention to the market structures, institutional rules and patterns of service provision that exclude the poor. It also highlights the underlying market structures that result in poor people paying more for their water than the wealthy (UNDP, 2006).

People get access to water through exchange in the form of payments (to utilities, informal providers or water associations), legal claims on providers and their own labour (collecting and carrying water from streams and rivers or digging wells, for example). Whether households can meet their basic need for clean water depends partly on how public policy shapes access to infrastructure and water through investment decisions, pricing policies and legislation governing providers (UNDP, 2006).

2.4.4 "Improved" and "unimproved" water

The language of international data gathering can sometimes obscure the way poor households access water. International statistics draw a distinction between "improved" and "unimproved" access. Improved encompasses three dimensions of water security: quality, proximity and quantity. In-house connections, standpipes, pumps and protected wells are all defined as improved. Water acquired from vendors and water trucks along with water from streams or unprotected wells, is not. The distinction between improved and unimproved is clear-cut and convenient for international reporting purposes. It is also a deeply misleading guide to reality on the ground. In the real world of water-insecure households, the simple border between improved and unimproved is illusory. For millions of poor households, daily water use patterns combine recourse to improved and unimproved water. Women living in slums in the Indian city of Pune report using water from public taps (an improved source) for drinking but going to a canal for washing. Research in Cebu, Philippines, found five patterns of water use among households not connected to the main water network (UNDP, 2006).

In urban slums and rural villages poor household might draw water from a protected well or standpipe for part of the year but then be forced to draw water form rivers or streams during the dry season. The configuration of water use in any one day will depend on factors ranging from price to availability to perceptions of quality (UNDP, 2006). It is estimated that in order to meet the water millennium development goals (MDGs), an extra 1.6 billion people need to be connected to a water supply between 2006 and 2015, and an extra 2.1 billion people to sanitation. Eight percent of those are in the regions of sub-Saharan Africa, South Asia and East Asia and the Pacific (UN, 2005).

Research indicates that the diversity of demand is because the use of water varies temporally and seasonally, due to changes in water quality and pressure. Low pressure and irregularity of supply in piped network mean that households in Jakarta for example, seek a backup source – usually a shallow well. But in many urban areas groundwater cannot be used for drinking because of salination or pollution (UNDP, 2006).

2.4.5 Catering for poor livelihoods - recommendations

Research conducted by the Global Water Partnership (GWP) on Integrated Water Resource Management (IWRM) (2000) revealed that since 'water poverty' is an important and unrecognised component of poverty generally, a paradigm shift in poverty thinking should be energetically promoted. Purely sectoral approaches should be avoided, not only on grounds of inefficiency and unsustainability, but because they are unlikely to promote equity. Another important finding made was that care needs to be taken that certain principles – water is a scarce resource and an economic good – are not introduced in a way that discriminates against poor people. Efforts should be made to solve the problems of introducing catchment management of natural resource bases on which so many livelihoods depend. Reforms of laws, policies, institutional and management structures should place an important emphasis on equity and poverty reduction. Specific policies and programmes should be undertaken to redress the disadvantages of at-risk and vulnerable groups (Black and Hall, 2003).

IWRM contains prospects for the equitable allocation of benefits from water and services dependent on it, it is important that these opportunities for healthier and more productive lives among the most at-risk and disadvantaged population groups are not lost, but are transformed into reality (Black and Hall, 2003). These pillars of IWRM which are also evident in the umbrella discipline of WDM should be focused on if the plight of rural denizens and informal settlement dwellers as regards 'water poverty' is to be redressed.

2.4.6 Social and cultural considerations for water demand management

Keshavarzi et al. (2006) investigating rural domestic water consumption pattern in the Fars province in Iran showed that household size and age of the household's head affect per capita water consumption. Other descriptive and behavioural variables were not shown to be statistically significant in explaining the pattern of water consumption. The results of discriminant function analysis showed that in rural households, garden size, greenhouse size, and garden watering times per month with tap treated water are associated with water consumption. Also, the relationship between household's head education and water consumption was found to be negative. This was attributed to the fact that the higher the education level of the individual, the more is the concern to use water for hygiene. Furthermore, factors such as religious obligations, average and marginal tap water price, personal and household income, and climate condition should be considered in future studies. And as such, this study will investigate some of these cited information gaps.

Nyong and Kanaraglou (1999) conducted research in Katarko, a semiarid village in North-eastern Nigeria to determine whether the level of domestic water demand in arid and semiarid rural areas of developing countries is closely related to their culture, social organization and demographic structure. They observe that traditionally, the search for solutions to the problem of water scarcity has focused on technology, much less on economic instruments and even less on population dynamics, growth, and distribution. Population, although a dominant factor in developing regions, seldom is taken into account in formulating water policies. When it is taken into consideration, analysis is often based on aggregate data at national and regional levels, which conceals the spatial pattern of demand for domestic water. A good policy should be based on data collected at the micro-level, where water development and use are seen through the decision-making process of small groups and household economies (Ruddle and Rondinelli, 1983).

A related issue is that water planners often do not take into consideration the social and cultural inclinations of local water users. In drought-prone regions locals have adapted their water use to varying levels of water availability. They have accumulated valuable information and practices that ought to be incorporated into more formal analyses of sustainable water development (Mabobunje, 1995; Sharma et al., 1996).

Nyong and Kanaraglou (1999) through regression analysis demonstrated that domestic water demand in rural areas of developing countries is dependent on social, cultural, and demographic factors. From a theoretical perspective, these findings are consistent with Rathgeber's (1996) contention that local people's customs, culture, intergroup relations, social organization, gender relations, and social structure have a direct bearing on issues of water use.

A study by Madulu (2003) in Tanzania showed that in most cases the poor suffer much or are denied the right to access water, hence, forced by circumstances to use water sources that are not safe for human consumption. Another observation was that much emphasis is put on improving water sources for drinking/domestic water uses, yet evidence seems to suggest that much more water is used for other uses (bathing, laundry, livestock, and cleaning) than for drinking and cooking alone. In fact, rural communities often do not abandon their traditional sources even after having improved water source. The health benefits of water used for these other uses are just as important as any other uses. It was also observed that local people are sometimes compelled to go far outside the village to access water especially for livestock and other uses. This suggests that the most pressing water uses at the household, community, and village levels are rarely considered in most of the donour funded water programmes.

Taking a leaf from the highlighted observations of information gaps, this study sought to investigate the socio-economic aspects of groundwater use and determine groundwater's economic value in domestic and agricultural uses. Better demand management can then be achieved by coupling sound economic valuation methods with pricing methods. Effective water demand management calls for appropriate methods that depend upon observations and results obtained from studying the situation on the ground. Not much has been done in the area of WDM in the selected villages and typical farming setups, so this research aims to bridge this information gap and assist policy-makers to improve WDM in Limpopo Province.

2.5 Summary

The economic valuation of groundwater and its input to WDM formed the centrepiece of this chapter. Modern water resource management focuses on WDM and not supply management as was historically the case. WDM as a discipline seeks to regulate the amount, manner and price at which water is accessed, used and disposed of in order to facilitate economic development and social equity.

The key groundwater use sectors studied in this thesis are domestic (rural households) and agriculture (irrigation). Hydrological cycle variability has resulted in water shortages, and it seems probable that water shortages will redirect economic development in these two water use sectors (amongst other water use sectors); therefore the need to manage groundwater resources as a national asset and for overall social benefit becomes imperative.

The range of environmental and economic services of groundwater needs to be accounted for in policy decisions. Non-recognition of these services imputes a lower value for the groundwater resource in establishing policies. Because of the limited role played by the market forces in the allocation of groundwater, market prices upon which to base groundwater-related resource allocation decisions are seldom available. In the jargon of the economist, shadow prices reflecting the economic value of water must be determined.

Economic value (value in use) and price (value in exchange) of groundwater are differentiated and two methods to determine the economic value of groundwater are explained: Mathematical programming for agricultural groundwater and the Contingent Valuation Method (CVM) for domestic groundwater respectively. Global and local experiences in agricultural and domestic WDM are given, and the socio-economic dimensions in each of the two water use sectors are highlighted.

CHAPTER 3

DESCRIPTION OF THE STUDY AREA

Groundwater is often referred to as a hidden resource. It is not directly observable, though in a given region its existence might be inferred with some degree of certainty from the region's topographic and geologic features. But even so, the magnitude of the resource, more specifically, the yield withdrawal that may be sustained over some finite period of time in relation to water demands, is sometimes uncertain. Thus it is not surprising that a region's surface water resources have been the primary focus of development. In more arid regions, however, limited surface water resources have been the stimulus for exploiting the groundwater resources (Bachmat et al., 1980). This is particularly the case in the Limpopo river basin which is a semi-arid region. According to the Köppen Classification (Köppen, 1918), the Limpopo basin is predominantly semi-arid, dry and hot. The Limpopo river basin traverses four countries, namely Botswana, Mozambique, South Africa and Zimbabwe.

The National Water Act divides the country into 19 Water Management Areas (WMAs) based on river catchments, each to be managed by a Catchment Management Agency (CMA). Two WMAs fall almost squarely within the margins of the Limpopo Province, i.e. Limpopo WMA and Luvuvhu/Letaba WMA. Limpopo WMA is WMA number one (WMA1), while Luvuvhu/Letaba WMA is WMA number two (WMA2), as shown in Figure 3.1. These two WMAs will be referred to as WMA1 and WMA2 respectively in this study. WMA1 and WMA2 therefore constitute the study area in this research. Figure 3.1 also shows the location of the 19 WMAs in South Africa, and the relative location of the Limpopo Province.

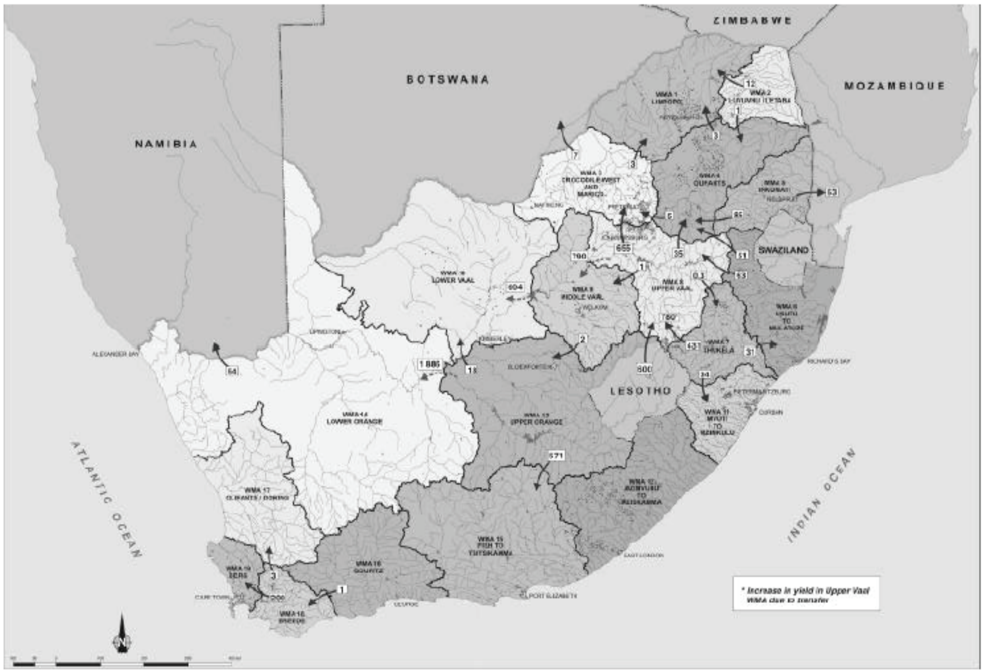


Figure 3.1: Water Management Areas of South Africa
Source: DWAF (2004e)

According to the Statistics South Africa Community Survey (2007), Limpopo Province had a population size of 5.24 million people and total households numbered 1.2 million.

3.1 Water management area 1

In WMA1, the mean annual temperature ranges from 16˚C in the south to 22˚C in the north, with an average of 20˚C. The average maximum monthly temperature is 30˚C in the month of January, while the average minimum monthly temperature is 4˚C in the month of July. The mean annual precipitation (MAP) in WMA1 ranges widely from as little as 200mm per annum in the north to over 1 200mm per annum in the Soutpansberg mountains. In general rainfall decreases from the south to the north, with the lowest rainfall occurring in the Limpopo valley in the north-east of WMA1 (DWAF, 2004a).

3.1.1 Demography

By far the greatest proportion (82%) of the population in WMA1 is classified as rural, living in approximately 760 rural communities scattered throughout the WMA. These rural communities are concentrated in, but not limited to, tribal or communal land. The urban population is only 277 000 (DWAF, 2000) with almost half found in Polokwane. Other towns with significant population are Modimolle, Mokopane and Makhado, Lephalale and Musina. The urban population is concentrated near the south eastern border where water is very limited. Fortunately this is in close proximity to water resources in other WMAs and this has resulted in inter-basin transfers from the Letaba, Olifants, and Crocodile WMAs. Growth in water requirements will probably also have to be sourced from neighbouring WMAs.

3.1.2 Land use

Most of WMA1 is too dry for dryland agriculture and there are limited surface water resources to support irrigation. Land use is therefore dominated by livestock farming (mostly cattle) while there is an increasing tendency to replace this with game farming. Most of WMA1 is still covered by natural vegetation. Plantation forestry is very limited and as a land use, covers only a very small portion of the total surface area of WMA1.

3.1.3 Irrigation

Irrigation is one of the most important extractive uses of groundwater and agriculture is by far the largest water use sector in WMA1, followed by the requirements for the natural environment. Except for the Ecological Reserve, agriculture is by far the largest use sector in WMA1, followed by the afforestation and domestic water sector. The available information on irrigation methods only stipulates the dominant irrigation method per sub-catchment. The irrigation methods used for specific crop type however do not vary significantly between different catchments. The methods used include the full range of flood irrigation, sprinkler systems, mechanical systems, micro systems and drip systems.

It is generally recognised that the future growth in irrigation will be severely limited by the availability of water. In more water-scarce areas it may even become necessary to curtail some irrigation to meet the growing requirements of domestic and urban water use. In order to do this it will be necessary to base such decisions on sound economic principles that include the economic return per unit of water. Return flows as a result of irrigation can be broken down into two components:

- **Return flow due to leaching beyond the root zone**

Irrigation water not used by the plant is returned to the groundwater or streams due to leaching and is largely dependent on the soil characteristics and water quality. The total return flow due to leaching are estimated at 29.95 million m^3/a for WMA1 (DWAF, 2004a).

- **Additional return flow**

The return flow from irrigation can further increase due to the increased rainfall runoff due to the higher level of soil moisture when compared with the natural state. This increased return flow can be calculated for a seasonal or yearly crop. Based on the different crops under irrigation in WMA1 the additional return flow generated is estimated at 3.22 million m^3/a (DWAF, 2004a).

3.1.4 Economy

Approximately 1.5% of the South African Gross Domestic Product (GDP) originates in WMA1, which is amongst the lowest of all WMAs in the country. The composition of the economy in WMA1 in terms of contribution to Gross Geographic Product[2] (GGP) is as follows (DWAF, 2004a):

- Government (provincial and local government structures) 24.2%
- Electricity (Matimba Power Station at Lephalale) 17.7%
- Trade (trade due to the high population density) 14.9%
- Agriculture (commercial and subsistence) 9.0%
- Financial services (due to the population density) 8.3%
- Mining (mainly platinum and coal) 7.5%

[2] This is the total value of all final goods and services produced within the economy in a geographic area for a given period. It is the most commonly used measure of total domestic activity in an area and is also the basis for the national account (DWAF, 2003c).

In terms of sales value, agriculture in Limpopo is dominated by table potato, tomato and then followed by subtropical fruit production (Statistics SA, 2002). These crops constitute some of the most economically important agricultural enterprises in the WMA1 and WMA2. It is for this reason that table potato and tomato crops were studied to obtain the shadow value for irrigation groundwater. In WMA1, agriculture is also important as a result of cotton, grain sorghum and tobacco production. A large part of the population in WMA1 is dependent on subsistence agriculture. Mining is largely driven by rich deposits of the platinum group metals which extend across the south-eastern part of WMA1. Coal and other metals are also mined in the area. There are huge coal reserves in the Lephalala/Mokolo area, where an estimated 45% of South Africa's coal reserves are found. Of the workforce of 410 000 people in WMA1 in 1994, 46% were active in the formal economy and 43% were unemployed, which was substantially higher than the national average of 29%. The remainder of 11% was active in the informal economy. Of those that were formally employed, 45% were in the government sector, while 21% were involved in agriculture and 11% in trade.

3.2 Water management area 2

In WMA2, the mean annual temperature ranges from about 18˚C in the mountainous areas to more than 28˚C in the northern and eastern parts, with an average of about 25.5˚C for WMA2 as a whole. Maximum temperatures are experienced in January and minimum temperatures occur on average in July. Rainfall is seasonal and occurs mainly during the summer months (i.e. October to March). It is strongly influenced by the topography. The peak rainfall months are January and February. The MAP varies from less than 450mm in the lowland plain (northern and eastern part of WMA2) to more than 2300mm at Entambeni in the Soutpansberg in the mountainous areas (South-Western and North-Western parts of WMA2) (DWAF, 2004b).

3.2.1 Demography

Some 1 535 000 people, which is about 3.5% of the country's total reside in WMA2 (DWAF, 2003a). More than 90% of the population is rural based, with most living in rural villages and informal settlements. The population is relatively evenly distributed throughout the region and the density is comparatively high for rural areas. Lower population densities occur in the escarpment and mountainous areas as well as in the extreme north of WMA2. Very few people live in the Kruger National Park (KNP). Most of the urban population is found in Tzaneen, Nkowakowa, Thohoyandou and Giyani (DWAF, 2004b).

3.2.2 Land use

The limited water resources has given rise to intense competition between the ever growing water use sectors and thus land use sectors, such as agriculture, industry, domestic and nature. Present land use is dominated by the large undeveloped expanse, which demarcates the KNP. Extensive areas under rain fed cultivation together with a large number of rural villages, occur throughout most of the remaining lowveld area. Agriculture is the largest land use sector in WMA2 with irrigation areas measuring some 364km^2. Dryland cultivation has increasingly been converted to pastures in the commercial farming areas. Large parts of WMA2 are being used for game and stock farming. Certain areas particularly in the former Venda, Gazankulu and Lebowa were over-stocked, but the stock numbers have decreased considerably due to the drought during the late 1980s and early 1990s (DWAF, 2004b).

Afforestation occurs in the high rainfall mountainous areas. This area also has considerable indigenous forests. A few proclaimed nature reserves also occur in WMA2. Intensive irrigation farming is practised in the upper parts of the Klein Letaba River catchment, upstream and downstream of the Middle Letaba Dam, and particularly along the Groot Letaba and Letsitele Rivers, as well as in the upper Luvuvhu river catchment. Vegetables (including the largest tomato production area in the country), citrus and a variety of fruits such as bananas, mangoes, avocados and nuts are grown. Large areas have been planted with commercial forests in high rainfall parts of the Drakensberg escarpment and on the Soutpansberg (DWAF, 2004b).

Thohoyandou, Tzaneen and Giyani are the largest urban centres, with some agro-based industries mainly at Tzaneen. Approximately 35% of the land area along the eastern boundary falls within the KNP, with the rivers flowing through the park being of particular importance with regard to maintaining ecosystems. Major industries are mainly situated within the urban areas except for a few small industries located near Letsitele adjacent to the Groot Letaba River. Gold, magnesite and coal are mined in the Mutale, Shingwedzi and Letaba River catchments; however, there has been a decrease in mining activity in most instances. The gold mining sector has decreased considerably (DWAF, 2004b).

3.2.3 Irrigation

The irrigated area has been accepted as the maximum of the mid summer crop area and the mid-winter crop area. Considering the given full range of crops being irrigated, mid summer has been defined as January/February while mid-winter was defined as July/August. It is generally recognized that the future growth in irrigation will be severely limited by the availability of water and new irrigation developments are not anticipated. In more water scarce areas it may even become more necessary to curtail some irrigation to meet growing requirements of domestic and urban water use. In order to do this, it will be necessary to base such decisions on sound economic principles that include the economic return per unit of water (DWAF, 2004b).

3.2.4 Economy

WMA2 contributes less than 1% of the country’s GDP. The largest economic sectors in WMA2 in 1997 in terms of GGP were (DWAF, 2004b):

- Government (administration, defence and others - 41.3%
- Trade (trade, sale of goods and services, hotels etc.) - 13.5%
- Agriculture (agriculture, fishing, forestry, hunting) - 11.l9%
- Mining (coal and gold, stone quarrying, limestone) - 10.0%

Most of the economic activity in WMA2 is centred around Thohoyandou (government and trade), followed by Tzaneen with the surrounding activities in irrigation and afforestation (agriculture, trade). The government is the largest contributor to the local economy, but largely due to the comparatively small contributions by other sectors of the economy of the region. Trade in WMA2 is supported by a relatively large population density. This is also supported by the tourism industry associated with the KNP, private game parks and surrounds. The large irrigation developments in WMA2, as well as the extensive forestry make significant contributions to agricultural, which in turn is the third largest contributor to the local economy. Most of the rain fed cultivation and cattle herding are practised as subsistence farming on communal lands (DWAF, 2004b).

The workforce in WMA2 was, in 1994, estimated at 343 000. Of these 41% were employed in the formal economy and 49% were unemployed. WMA2 has the highest unemployment rate compared to other WMAs in the country. Of those formally employed, 53% were in the government sector, whilst 19% were in agriculture and 9% in trade. Agriculture and mining in WMA2 are relatively more competitive than the rest of the country. Favourable climate, the variety of products as well as the good performance of the agricultural sector contributes to its comparative advantage. Land and water resources available for agriculture are already highly developed and utilised, particularly with respect to irrigation and afforestation. This limits the potential for much further growth in the agricultural sector. The greatest potential for economic growth in WMA2 lies in the processing of agricultural products as well as with new mining developments (DWAF, 2004b).

The next section of this research forms a description of the methods used to obtain results in this thesis.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 Data collection in the study area

Findings made during scoping field trips to the study area revealed that groundwater was the dominant water source in the following study epicentres: In WMA1 the Polokwane agricultural area was selected as being representative of irrigated table potato commercial farming, while the rural area between Dendron and Gilead was selected for the study of rural household groundwater use. In WMA2, the Mooketsi agricultural area was selected as being representative of irrigated tomato commercial farming, while the rural area between Mooketsi and Elim was selected for the study of rural household groundwater use.

In the Polokwane farming area (WMA1), the selected typical commercial table potato farms relied on numerous boreholes for irrigation groundwater and the dominant commercial crop grown was table potato, while to a lesser extent onion. In WMA1, four villages were identified for study because of their observed reliance on groundwater for household use, namely Gaphago, Leokaneng, Kanana and Mohlajeng.

In the Mooketsi commercial farming area (WMA2), groundwater was the dominant irrigation water source for most years except when flush floods replenished farm dams, in the typical commercial tomato farms. When flush floods occurred, the commercial tomato farmers substituted surface water for groundwater because of economic reasons for their irrigation water needs. Tomato was the dominant commercial crop grown. In WMA2 three villages were selected for their (partial) reliance on groundwater, namely Lemondokop, Sereni and Hamashamba.

4.2 Data collection

This study used survey research as the primary data collection method for farms and rural households. The purpose of this study was to investigate the economic value of groundwater. A better appreciation of groundwater value is expected to assist in WDM. To overcome constraints such as cost and time, the survey took the form of a sample survey, where generalizations were made about the study area using the inference from a fraction of the population. The personal survey method, with separate discussions for each household head, was used in this study.

From the relevant research issues of this study, two survey instruments (questionnaires) were developed. One was the household questionnaire and the other was the farm questionnaire (refer to Appendices 1 and 2), which were administered to the rural household and the typical commercial farm respondents respectively.

4.3 Research methods used for household water

4.3.1 Sampling and questionnaire administration

The household data for this research were derived from personal interview surveys undertaken in July 2008 in Masamba (Ha-Mashamba), Sereni, Lemondokop, Kanana, Gaphago, Mohlajeng, and Leokaneng villages. The household was the primary unit of observation. The household questionnaire consisted of six sections. Section A solicited information on household characteristics such as name, gender, age, marital status, occupation, income and education of the household head, as well as the relationship of the respondent to the household head (if not the same person). Section B contained questions that aimed at assessing attitudes and perceptions towards groundwater. The purpose of Section C was to collect information on groundwater consumption for indoor and outdoor use. Section D concentrated on investigating household respondents' groundwater consumption behaviour at different tariffs, and willingness to pay for satisfactory groundwater services delivery using the open-ended question approach. Section E investigated the existence of restrictions to groundwater access. Section F elicited comments and suggestions regarding the groundwater situation, and it also requested respondents to highlight any opportunities and threats regarding groundwater.

Kanana, Mohlajeng, Gaphago and Leokaneng villages fall within WMA1, and they are all located south-west of Dendron Growth Point. Dendron is approximately 57km north-west-north of Polokwane City. Mashamba, Sereni and Lemondokop villages fall within WMA2, and they are all located south-east of Elim Growth Point. Elim is approximately 25km south-east of Makhado Town, which is approximately 113km north-east of Polokwane City. Available resources allowed the researcher to sample 106 households in the seven selected villages. According to Statistics South Africa Provincial Profile (2004), the average number of households in Limpopo was 1 283 000 and approximately 85% of these were rural based. Hence a total of 106 households represented approximately 0.01% of rural households.

To ensure proportional representation from all the wards, systematic random sampling was chosen as the sampling method. This method is an adaptation of the simple random sampling process that is used when the working population list is quite large and the sampling units cannot be conveniently or feasibly numbered (Rea and Parker, 1992), as was the case in the study area. A systematic random sample assumes that the sampling frame, or working population list, is randomly distributed; therefore the researcher can systematically choose sample members by selecting them from the list at fixed intervals (every *n*th entry) (Rea and Parker, 1992).

The household questionnaire was administered by the researcher and two field assistants who spoke all the local languages in the area (Venda, Sotho and Shangaan) and English. These interviewers were recruited and trained in July 2008. Systematic sampling was applied at intervals depending on the population size and settlement pattern. The village settlement pattern first had to be determined by conducting a village reconnaissance, and then the random sampling interval was determined using the information gathered. Data collection took on a door-to-door approach. Availability of respondents at their homestead also influenced household sampling because when no-one was found at home the household would automatically be skipped from the sample.

CVM was chosen as the preferred method to determine the willingness to pay for satisfactory WSS and the responsiveness of households to groundwater tariff changes.

Following the approach taken by Thomas and Syme (1988), an interview survey and a statistical analysis of the results of the survey was undertaken for this study. Open-ended questions were used during CV to determine the utility (WTP) value of groundwater, the respondents were asked to state the maximum amount that they were willing to pay for a kl of groundwater contingent upon WSS having been improved. Respondents were also asked how they would change their groundwater use in the wake of tariff change. Open-ended questions provided more information than closed-ended questions; and did not require econometric modelling to analyze, as the mean WTP values of respondents was readily estimated by simple arithmetic (Gunatilake et al., 2007).

4.3.2 Descriptive statistical methods

Variables for the data collected were presented graphically in the form of histograms to be able to see the nature of the distribution of the particular variables and to be able to identify possible outliers. Another method that could have been used was to present the data in frequency tables. Histograms and the frequency tables give the same information, but it is easier to identify outliers in the histograms, this is why this study used histograms (StatSoft Inc., 2008).

4.3.3 Statistical inferential analysis[3]

- **Comparing a continuous variable to a nominal (categorical) variable**

Nominal variables indicate different categories. To test whether a continuous variable differed over the different categories of a nominal variable analysis of variance was used (ANOVA). In the analysis of a continuous variable (like age) versus nominal variables (like borehole ownership), ANOVA was used to investigate if the means of the continuous variables differ between the levels of the nominal variable.

The means of the continuous variables differed significantly if the P-values were found to be less than $\alpha=0.05$. The value $\alpha=0.05$ is called the significance level of the test. The ANOVA F-test assumes normality of data. If the data was not normally distributed

[3] StatSoft Inc. (2008)

(which it was in most cases) the non-parametric tests were used. Appropriate tests used in this case were the Mann-Whitney test or Kruskall-Wallis test. These tests also indicated with a P-value of less than $\alpha=0.05$ that the means of the continuous variables differed significantly between the levels of the nominal variables.

To check if the data is normally distributed, the researcher checked the graph of normal probability plots of the residuals. If the dots were pretty close to the red line, it indicated that the data for each group was indeed normally distributed and the ANOVA F-test was appropriate. If it was found to be not normally distributed the non-parametric tests were used. Figure 4.1 is a household size normality test example observed in the analysis. It shows that household size was not normally distributed because the dots deviate quite a lot from the red line, especially at the top, so the researcher did not make the assumption that the household size was normally distributed, and consequently in this case the Mann-Whitney test or the Kruskall-Wallis test was more appropriate. When more than two levels of the nominal variable were involved and when the null hypothesis of equal means is rejected, it was necessary to do a multiple comparison procedure to see which means are different, causing the rejection of the null hypothesis.

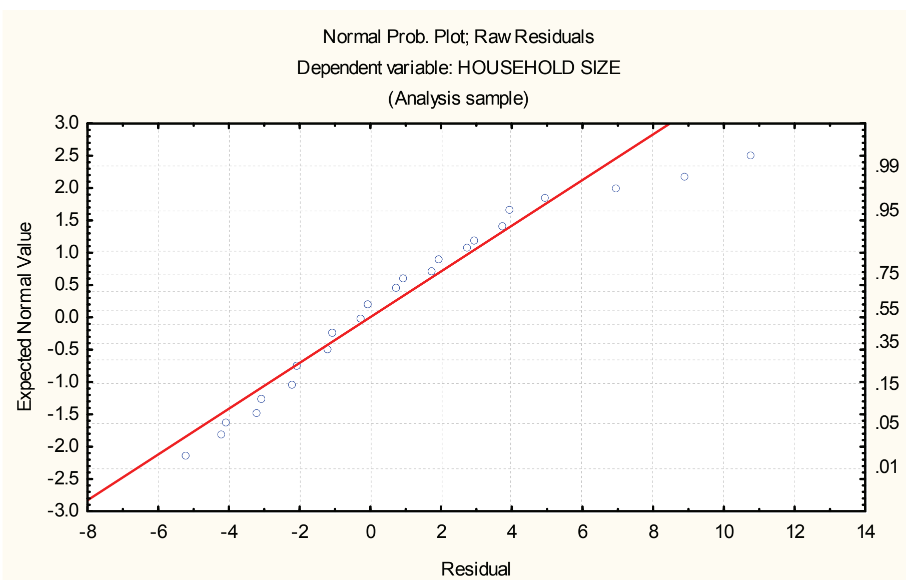


Figure 4.1: Normal probability plots of the residuals for household size

- **Comparing a nominal variable against another nominal variable**

When a nominal variable was compared to another nominal variable, it was done using a contingency table (commonly known as a cross-tabulation). The assumption was that the levels of the one nominal variable do not influence the levels of the other nominal variable, i.e. that the two variables are independent. The method tested whether the influence of the one nominal variable on the other was sufficient to state that the two variables were not independent. This was done by using an appropriate chi-square test like the Pearson's chi-square or the more robust maximum-likelihood (ML) chi-square test.

- **Comparing a continuous variable against another continuous variable**

The comparison of a continuous versus another continuous variable was done using regression and correlation analysis. The independent variable X was chosen as the variable over which the researcher had control or which could be observed with lesser variance than the other variable Y which is called the dependent variable. The researcher needed to determine if the influence of the independent variable X had on the dependent variable Y was significant or not. The t-test is probably the simplest commonly used statistical procedure. To compare the mean of a continuous variable in two different populations, the difference between the two means divided by its standard deviation has a special distribution, known as the "t-distribution". When the difference between the two means is large relative to its standard deviation the t test will be significant.

4.4 Research methods used for agricultural water

Produce growers' associations, commercial farmers, fresh produce markets, Statistics South Africa (2002) and the Limpopo Department of Agriculture were consulted in order to obtain secondary data to use for research preparation. Table 4.1 shows the horticultural area planted and volumes of production in Limpopo. The secondary data revealed that the epicentre of table potato production was Polokwane (Pietersburg), while the epicentre for tomato production was Mooketsi (Letaba area). The table potato hectrage and yield of Polokwane was 2 550 hectares and 71 893 metric tons respectively. The tomato hectrage and yield of Mooketsi was 3 259 hectares and 155 355 metric tons respectively. The

Polokwane and Mooketsi commercial farming areas were thus selected as representative of large scale commercial table potato and tomato farming in this thesis. A list of table potato and tomato farms found within the two representative farming areas was established after contacting and requesting the cooperation of the table potato and tomato farmers for group discussions. The particulars of the selected farmers cannot be disclosed, and aggregates will be used for further analysis in this thesis.

The typical farm information elicitation technique was applied. A total of three group discussions with farmers were conducted in July 2008 to develop data for a typical table potato and tomato farm. The farm questionnaire consisted of 11 sections. Section A solicited information on farm characteristics such as names, address, gender, age, occupation, education, and farm size. Section B contained questions that aimed at assessing typical farm size and structure. Section C was for collecting information on the typical cropping patterns and composition. Section D concentrated on investigating typical farm capital investment information. Section E collected data on typical borrowed capital outlay. Section F investigated gross production value of annual crops for a typical farm. Section G identified expected annual crop costs per hectare for a typical farm. Section H solicited information on crop water requirements and borehole data for a typical farm. Section I dealt with human resources costs, and Section J investigated contingent groundwater use. The last section, Section K, elicited comments and suggestions regarding the groundwater situation, and it also requested respondents to highlight any opportunities and threats regarding groundwater.

Table 4.1: Horticulture area planted and volume of production in Limpopo

District	Crop			
	Table potatoes		Tomatoes	
	Planted (hectares)	Production (metric tons)	Planted (hectares)	Production (metric tons)
Dzanani	0	0	0	0
Ellisras	65	926	22	1260
Giyani	0	0	162	2335
Letaba	128	5100	3259	155355
Messina	278	6501	859	45847
Mhala	0	0	14	420
Mutale	0	0	41	591
Phalaborwa	0	0	46	942
Pietersburg	2550	71893	115	4319
Potgietersberg	575	10299	128	2416
Soutpansberg	865	27418	180	5997
Thabazimbi	4	76	27	572
Warmbad	444	12210	36	2050
Waterberg	270	4746	81	2531
Limpopo Total	**5179**	**139169**	**4970**	**224635**

Source: Statistics SA (2002)

When the typical farm group discussion method was applied, the researcher observed that it had the merit of group dynamics. Discussion with a panel of farmers enhanced reliability of answers. Participants were encouraged to revise their answers in light of the replies of other members of the group. The researchers (facilitators) were in direct contact with the farmer groups all the time, and aimed to finalize each section of the questionnaire by reaching a consensus within the group as the discussions progressed.

This method also had the advantage of making the survey a self-correcting continual process until the survey was completed. It was believed that during such a process the range of the answers would quickly decrease and the group would converge towards the "correct" answer quicker. This was actually observed by the researchers in the discussions.

From the group discussions for the crops, the study established a typical farm for table potato and for tomato crops in the study area respectively. The group discussions provided the following typical data for table potato and tomato farming: farm size and structure, cropping composition and pattern, capital investment, borrowed capital outlay, gross production values, costs and crop water requirements and borehole data.

The typical table potato and tomato data collected facilitated the construction of typical table potato and tomato farm budgets and provided valuation information for a typical tomato and table potato farm. This information was then analysed using LINDO (Linear Interactive Discrete Optimizer) linear programming software to determine the VMP of irrigation groundwater.

4.5 Modelling for domestic and irrigation groundwater

4.5.1 Household water

In the study area, 70% of sampled households were found not only to be currently paying for water, but paying for it at exorbitant rates, while only 30% were getting water for free. By subjecting each member of the sample to a rigorous questionnaire regime, using carefully prepared questionnaires it was possible to determine how a consumer's consumption of water demand varies with the tariff. In South Africa, because the price of water has been historically low, large price increases were postulated in the survey conducted. Experience has shown that when small price increases are postulated the results obtained from the experiment do not yield results that are useful since the change in consumers' behaviour to the price increases are generally muted. In order to gauge the reaction of people to changes in the tariff of groundwater, this study made use of relatively large changes in water tariffs in the CV survey. Thomas and Syme (1988) in a similar study conducted in Australia also made use of large intervals in their CV water price increments.

In a study conducted by Veck and Bill (2000) to estimate the price elasticity of demand in Alberton and Thokoza, the arc elasticity concept was applied. This study adopted the approach used by Veck and Bill (2000) to calculate the arc elasticity of demand, which was used as the measure of households' responsiveness to changes in water tariffs.

- A total bill for the study area was established by summating the water bills of all the households at the current price of water. This total bill was divided by the summated quantity of water used to yield an average unit price of water. Thus, one point on the demand curve was established i.e., the total quantity of water used and the average unit price of water established. This point represented the status-quo position with regard to water usage in the study area. In this study this point was zero whenever water was for free.

- Similarly, three other points on the demand curve for the study area were established from the answers solicited in the CV section of the household survey. Since households generally face exorbitant water rates that prevail in the local water market structure (with extremes to the tune of R200 per kilo-litre (kl) being recorded) the CV elicitation had to take a 'from higher to lower' tariff direction. The first point set in the CV section was R4.65/kl, the second point was when the tariff is reduced to R3.10/kl, and finally the third point was when the tariff is further reduced to R1.55/kl.
- Using the information obtained for the four points, the arc elasticity of demand for water was then determined.

4.5.2 Agricultural water

The information elicited from the typical farm group discussions was used to construct typical farm production budgets. When all other inputs were held constant, the marginal physical productivity of groundwater for each cubic meter of groundwater used on the crops was calculated. The marginal value of each cubic meter is the marginal physical product times the crop price. This procedure is the procedure adopted in this study, and it relies on the assumption that applications of different amounts of groundwater incur the same labour, fertiliser and other non-water input costs. Since these marginal values are not dependent on the economics of crop production, they are not related to fixed or variable costs, but only to the crop selling price and the physical productivity of the groundwater unit. In addition, they reflect the value of at-site irrigation groundwater (Gibbons, 1986).

The procedure applied in this thesis to derive a shadow value of irrigation groundwater was parametric linear programming using the data set derived from typical crop budgets of tomato and table potato crops in the study area. Parametric linear programming was chosen because the procedure can handle more complex problems than budgeting or marginal analysis alone and it provides not only information on the optimal way of allocating resources, but also additional information concerning the value of various resources used in planning (Boehlje and Eidman, 1984). The advantage of parametric budgeting is that it provides a sensitivity analysis that shows how the shadow value of irrigation groundwater (per cubic meter per annum) varies with changes in parameters (which is what happens in reality).

One-price variable programming was conducted for tomato and table potato crops respectively. First the optimum plan at the average price in the required range was computed. Subsequently, critical price levels at which the optimum plan changed were calculated, and the objective function values and VMPs for irrigation groundwater were derived for these price levels. One-resource variable programming was also conducted where the crop yields per hectare were varied. During one-resource variable programming for each level of crop yield, an optimum plan was obtained. Variation in the two parameters provided a map of the shadow values of irrigation groundwater at different producer price and yield levels.

The next three sections of this research mark the unfolding of the results and discussion of this thesis. These sections also commence the answering of the research questions.

CHAPTER 5

GROUNDWATER QUANTITY AND QUALITY

5.1 Introduction

South Africa's National Water Act of 1998 (Act No 36 of 1998) is widely regarded as a pioneer of an international wave of reform in the water sector, including the EU (European Union) Water Framework Directive (EU, 2000) and Mexico's National Water Plan (2001-2006), which embodied a set of guiding principles agreed at the 1992 International Conference on Water and the Environment (ICWE) in Dublin (Calder, 1999; Heathcote, 1998; World Bank, 1993, 2003). The key ICEW principles are (Woodhouse, 2008):

- The River Basin is a natural unit of analysis and management. A holistic approach to water management is advocated, i.e. Integrated Catchment Management.
- Action must be taken at the lowest appropriate level (subsidiarity). This will necessitate the devolution/decentralisation of management.
- Water has an economic value. Economic instruments should be used to encourage efficient use of the resource.
- A participatory approach is advocated – all stakeholders (with particular reference to women) should be involved in the planning and management of water resources.

The purpose of the National Water Act (NWA) is stated as (Woodhouse, 2008):

"To ensure that the nation's water resources are protected, used, developed, conserved, managed, and controlled in ways that take into account:

- Meeting basic human needs of present and future generations.
- Promoting equitable access to water.
- Promoting the efficient, sustainable and beneficial use of water in the public interest.
- Facilitating economic and social development.
- Providing for growing demand for water use.
- Protecting aquatic and associated ecosystems and their biodiversity.

- Reducing and preventing pollution and degradation of water resources.

And, for achieving this purpose, there is need to establish suitable institutions and to ensure that they have appropriate community, racial and gender representation".

With regard to economic use, irrigation agriculture is by far the largest user of water in South Africa, namely 59 percent of the total. Most of this water is also subject to evapo-transpiration and deep percolation, which implies that the return flow is very limited. Households are responsible for 10.2 percent and bulk users 5.8 percent of the total consumptive use of water. To accommodate the diverse and multi-sectoral use of water as a resource, South Africa has a complex water tariff structure (DWAF, 2004a; Grosskopf, 2004 and King, 2002). But this varying structure does allow the government to charge different raw water charges to different water users. This enables the taxing of different water users differently as well (Van Heerden et al., 2008).

Before the NWA was promulgated, landowners were entitled to unlimited groundwater use. The Act rectified this anomaly; however, the practical application of sustainable development concepts in groundwater resource management will be complex. The focus of groundwater management in South Africa, for the foreseeable future will be on equitable allocation for economic development, maintaining resource integrity, and meeting basic human needs. The challenge remains to implement these principles in reality. Management strategies (like WDM) will need to be developed to address the unique characteristics and roles of groundwater. This needs to take place within the context of the socio-economic development paradigm (Pietersen, 2006).

5.2 Water management area 1 [4]

WMA1 is the northern most WMA in the country and represents part of the South African portion of the Limpopo basin. The region is semi-arid, while economic activity mainly centres on livestock farming and irrigation, together with increasing mining operations. Approximately 760 rural communities are scattered throughout WMA1, with

[4] Source: DWAF (2004a)

little local economic activity to support these population concentrations. WMA1 consists of seven sub-catchments which are mostly independent of each other. The seven sub-catchments are the Matlabas, Mokolo, Lephala, Mogalakwena, Sand, Nzhelele and Nwanedzi regions.

- **Matlabas**

This is a dry catchment with non-perennial flow and hence no sustainable yield from surface water. The limited water use in this catchment is mostly from groundwater, which is under-exploited. New allocations can only be made from groundwater or from additional yield which could conceivably be created from construction of farm dams.

- **Mokolo**

From a water resources point of view, the Mokolo key area is the most developed in the WMA and has more surface water available than any of the other key areas in the WMA. Apart form the higher than average rainfall, the large Mokolo dam is situated in this key area, which provides water for a multitude of uses, the most important being the supply to the Matimba power station and Grootgeluk coal mine. There are a large number of farm dams in the Mokolo key area which has effectively moved much of the yield of the Mokolo dam upstream where it is used to supply large areas of irrigation, with an estimated requirement of 68 million m^3/annum (a). There is also a significant amount of irrigation from groundwater in this key area. Groundwater is underutilised and should be the first option to supply increased domestic requirements, provided the water quality is acceptable. Where water of acceptable quality cannot be sourced, additional small dams may be required to supply increased domestic requirements.

- **Lephalala**

The Lephalala key area has limited water resources but surprisingly high water requirements, dominated by the irrigation sector with its water requirements estimated at 33 milliom m^3/a. Irrigation takes place mainly in the higher rainfall upper reaches of the key area where there are a large number of farm dams, while lower in the catchment irrigators make use of water from alluvial aquifers. Nevertheless, the catchment appears to be stressed and no new allocations should be made for irrigation purposes. Additional water for domestic purposes should be sourced from groundwater. The middle reaches of the Lephalala key area are of a high conservation value. Development should be limited in the Lephalala to maintain this important conservation area.

- **Mogalakwena**

This is the catchment with limited surface water resources but large groundwater resources which have already been extensively exploited by the irrigation sector. The water use in this key area is dominated by irrigation with an estimated requirement of 90 million m^3/a. New allocations for domestic use should be sourced from groundwater. New allocations to the irrigation sector are possible from groundwater but this would need to be studied in more detail since there is a risk of over-exploiting the groundwater resources in this area.

- **Sand**

This is a dry catchment with very limited surface water resources. However, it has exceptional groundwater reserves which have been fully and possibly over-exploited. The water requirements are large compared to the rest of the WMA, but again irrigation is the largest water user, with a requirement of 185 million m^3/a. Urban requirements, estimated at 24 million m^3/a, are supplied mostly from transfers in from other WMAs. The catchment is in serious deficit to the over-development of irrigators relying mostly on groundwater and the very sparse surface water resources. This is a very real concern that the groundwater resources has been over-exploited but this will require further study to be confirmed. Compulsory licensing may be required in order to reduce abstractions from groundwater to sustainable levels.

- **Nzhelele**

This is a small area dominated by irrigation, with an allocated area of 4 800ha, but not all of this is currently in use due to insufficient water resources. Uncharacteristically for the Limpopo WMA, there is small area of afforestation, estimated at $31km^2$, but this has only a very limited impact on the water resource of this area. The only significant water use in the area is domestic use by the rural sector. The second largest dam in the WMA, the Nzhelele dam, is situated in this key area and most of the surface water of the key area is derived from this dam while groundwater is also used extensively. The catchment is clearly stressed and this is due to over-allocation and/or over-development of the irrigation sector. This is the current situation before implementation of the ecological reserve. In order to successfully implement the reserve, it will probably be necessary to carry out compulsory licensing, but there is no urgency for this. No new allocations to the irrigation sector are possible at present, while additional allocations for domestic use will have to be sourced from groundwater.

- **Nwanedzi**

This is a small catchment in the north-eastern corner of the WMA, characterised by large areas under irrigation (relative to the size of the catchment) which are estimated to be in the order of 20km^2. The water resources of the key area are limited to that provided by a few small dams and run-of-river, and the catchment is in deficit. This is due to the over-allocation or over-development by the irrigation sector. Figure 5.1 shows the locality of the seven sub-catchments in WMA1.

Figure 5.1: Locality map of the WMA1
Source: DWAF (2004a)

5.2.1 Groundwater quantity situation assessment[5]

The total groundwater use in WMA1 is given in the National Water Resource Situation Assessment (DWAF, 2004d) as 98 million cubic meters per annum (m^3/a). However, new data which recently became available indicates much higher groundwater use. The registered water use gives a total groundwater use of 310 million m^3/a while estimates from the Groundwater Resource Information Project (GRIP) (DWAF, 2004a) gives estimates of between 460 and 550 million m^3/a for the whole Limpopo Province. While there is wide disparity in estimates of groundwater use, it is clear that the use is much higher than previously thought and the question that this now raises is whether or not this large use is sustainable.

The GRIP project has prepared 1:500 000 scale hydro-geological maps of the Limpopo Province. These maps depict the groundwater resources, groundwater quality and development potential, based upon the needs of the end user. The maps provide the level of detailed information that will be useful to engineers and planners when considering groundwater resource development. Overall the available groundwater resources within WMA1 are under-utilised. Even weaker groundwater occurrence areas can provide more than the RDP level of 25 litres per head per day. It is important to note that groundwater is the only remaining water resource in WMA1 that is not fully utilised (with the exception of the Sand Key Area).

In general, groundwater resources are available throughout WMA1, but in varying quantities depending upon the hydro-geological characteristics of the underlying aquifer. Parts of WMA1 are heavily populated and widespread rural communities are a feature of the area which included the old Lebowa and part of the old Venda. The primary source of water to these scattered rural communities is groundwater, which makes groundwater a resource of great strategic importance in WMA1. Nevertheless, according to the registered water use in WMA1, more than 90% of groundwater is used for irrigation.

There is extensive use of groundwater from the deeply weathered and fractures granites north of Polokwane (drainage area A71A) and in the area around Dendron (drainage area

[5] Source: DWAF (2004a)

A72G and A72A) where large abstraction for irrigation and domestic supply occurs. Large abstractions of groundwater also occur in Weipe (drainage area A71L) from the aquifer associated with the Limpopo River.

The mountainous areas of Mokopane are of special interest as far as groundwater is concerned, as this area consists primarily of dolomite and has considerable groundwater resources. The aquifer is however, heavily exploited, both within WMA1 (drainage area A61F) and in the Olifants WMA (drainage area B51E) where Zebedelia Estates abstract significant quantities in an uncontrolled manner. Abstraction along the Rooisloot Valley for irrigation has caused a decline in groundwater levels, as has abstraction in the Dorps River Valley. The Mokopane well-field, with an abstraction of about 3 million m^3/a, is located in a small area in the west of the Dorps River Valley, leading to stress on the aquifer in this area. Abstraction in these areas has resulted in a reduction of groundwater flow down the hydraulic gradient, leading to an impact on downstream users.

In the past not enough resources have been put into siting boreholes scientifically nor have abstractions been managed properly. This led many boreholes running dry and creating the perception that groundwater is not a reliable resource.

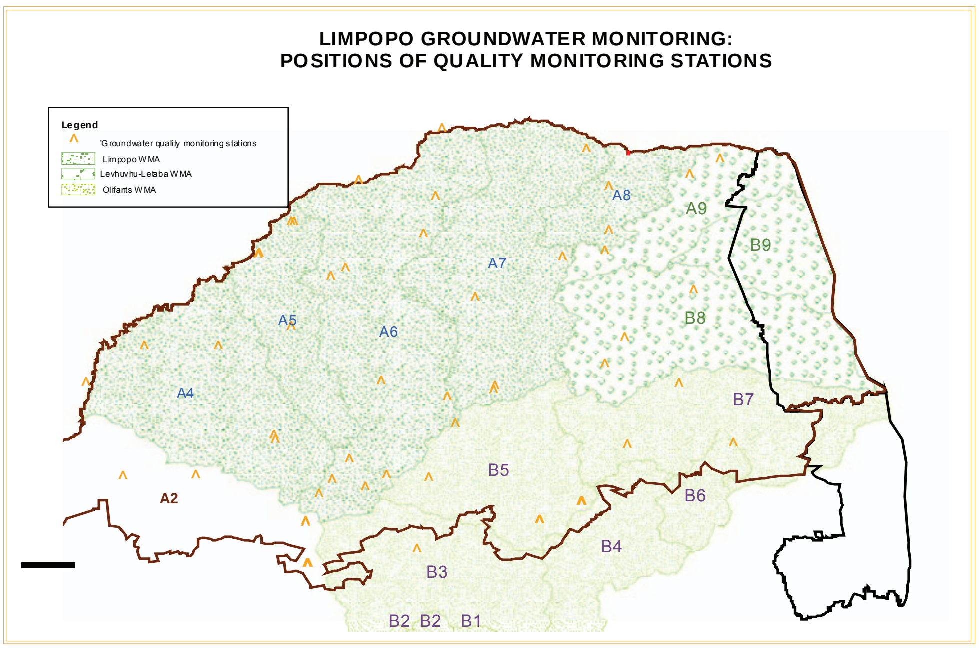
5.2.2 Groundwater – surface water linkage

Groundwater contributes to base flow throughout the catchment via sub surface seepage and springs. The Waterberg and Soutpansberg Ranges are important areas of groundwater recharge and drainage base flow.

The relationship between groundwater, base flow, and river flow is reasonably well understood where hydrographs are available. However, the impact of groundwater abstraction on surface water resources is less well understood and this is an aspect that warrants study. Recharge of the groundwater system from river flow, especially during flood events is important (DWAF, 2004a).

5.2.3 Monitoring and groundwater level trends May 2007 – May 2008[6]

WMA1 consists of secondary drainage areas A4, A5, A6, A7, and A8. And WMA2 consists of the secondary drainage areas A9, B8, and B9 as shown in Figure 5.1. The Limpopo Province's Groundwater Level Monitoring Network is a programme being conducted by DWAF. The Monitoring Network currently consists of 190 monitoring stations (Figure 5.2). The stations record groundwater level fluctuations using borehole readings that are measured at regular intervals in meters (m) below the collar.



MAP 3

Figure 5.2: Limpopo groundwater monitoring – positions of monitoring stations
Source: Verster (2008)

This section describes the results of groundwater level monitoring in WMA1 (WMA2 will be described later).

- **A4 Drainage area (Matlabas, Mokolo Rivers)**

There are no active monitoring stations in this drainage area, but so far four boreholes have been drilled but not yet equipped. The drilling rig had been temporarily withdrawn from this area due to other priorities but it resumed drilling of the ten remaining boreholes in September 2008.

[6] Source: Verster (2008)

- **A5 Drainage area (Lephalala River)**

There is hardly any groundwater level fluctuation indicated by any of the monitoring stations in this drainage area. This signifies a volumetric balance between abstraction levels and recharge rates. Figure 5.3 shows the results of three monitoring stations observed during the research period.

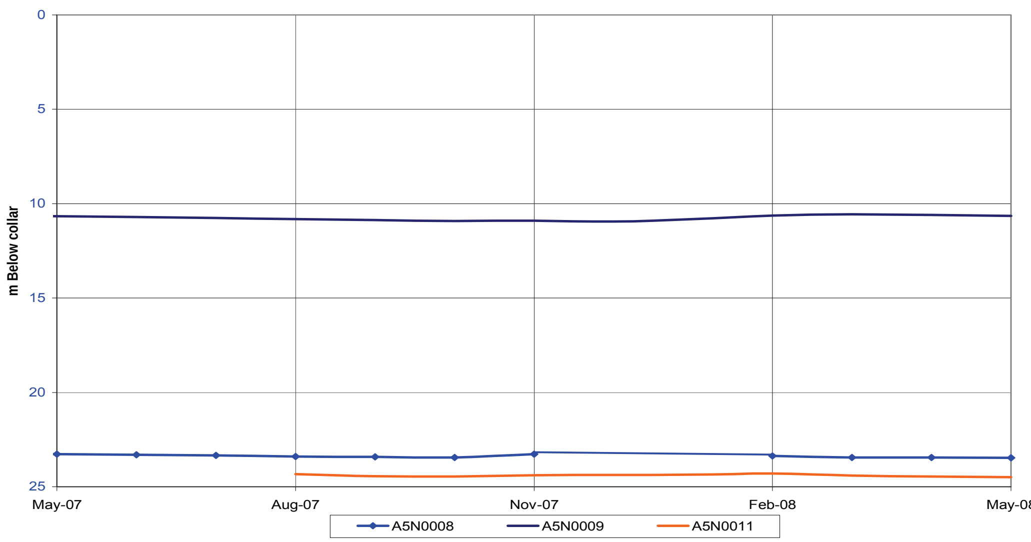


Figure 5.3: Comparison of groundwater level trends at stations in A5 drainage: 1 May 2007 to 1 May 2008 (meters below collar)
Source: Verster (2008)

- **A6 Drainage area (Nile, Sterk, Mogalakwena, and Dorps Rivers)**

Water level trends over the past years vary, but some recharge over the past season is evident in most of the monitoring stations observed in this drainage area, showing that volumetric recharge outweighs abstraction levels. Figure 5.4 shows the results from nine monitoring stations observed during the research period. This can be shown by doing a comparison with previous levels. From October 2007 to May 2008 (beginning to end of the past wet season), overall an average groundwater rise of 1.33m was recorded. This is a rise higher than that recorded for the entire year (May 2007 to May 2008) of 1.17m. Average water levels are slightly higher than the long-term average values and are 3.79m higher than the lowest average recorded (Figure 5.5). Despite the improvement in groundwater levels for most of the area the declining trend over longer term in some areas, especially in areas not closely associated with a river system persists.

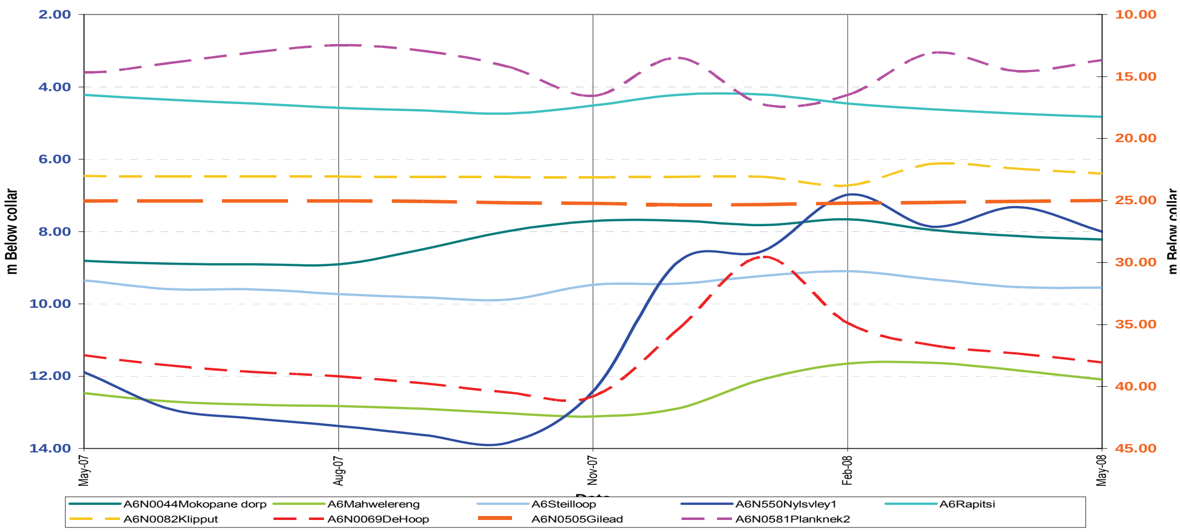


Figure 5.4: Comparison of groundwater level trends at some stations in A6 drainage: 1 May 2007 to 1 May 2008 (meters below collar)
Source: Verster (2008)

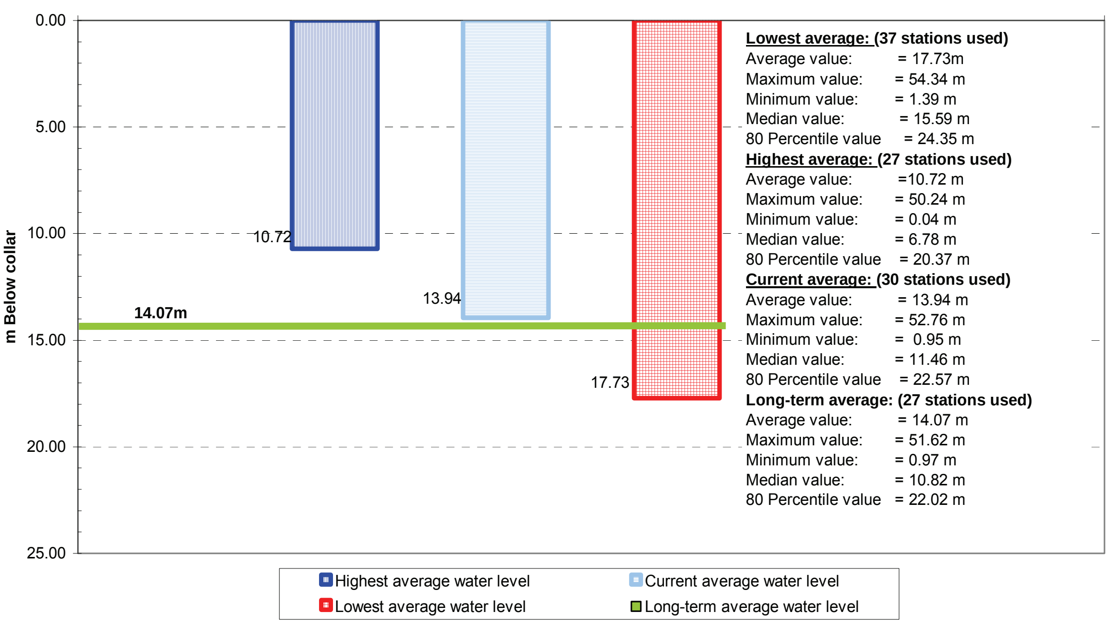


Figure 5.5: Comparison of average current groundwater level depths with highest, lowest and long-term average water level depths in A6 drainage since 1973 (meters below collar)
Source: Verster (2008)

- **A7 Drainage area (Sand, Blood, Diep, Hout, Dwars and Brak Rivers)**

Very little fluctuations can be noted in groundwater levels over the past year, but limited recharge is evident as some stations (Figure 5.6). This can be shown by doing a comparison with previous levels. From October 2007 to May 2008 (beginning to end of the past wet season), overall an average groundwater rise of 0.27m was recorded. Records for the entire year (May 2007 to May 2008) report a recession of 0.53m.

Current average water levels are slightly lower than the long-term average and are 2.54m higher than the lowest average recorded (Figure 5.7). Long-term trends show some corresponding behaviour with that of Drainage A6 but recharge over the past season was less and the current declining trend is more pronounced.

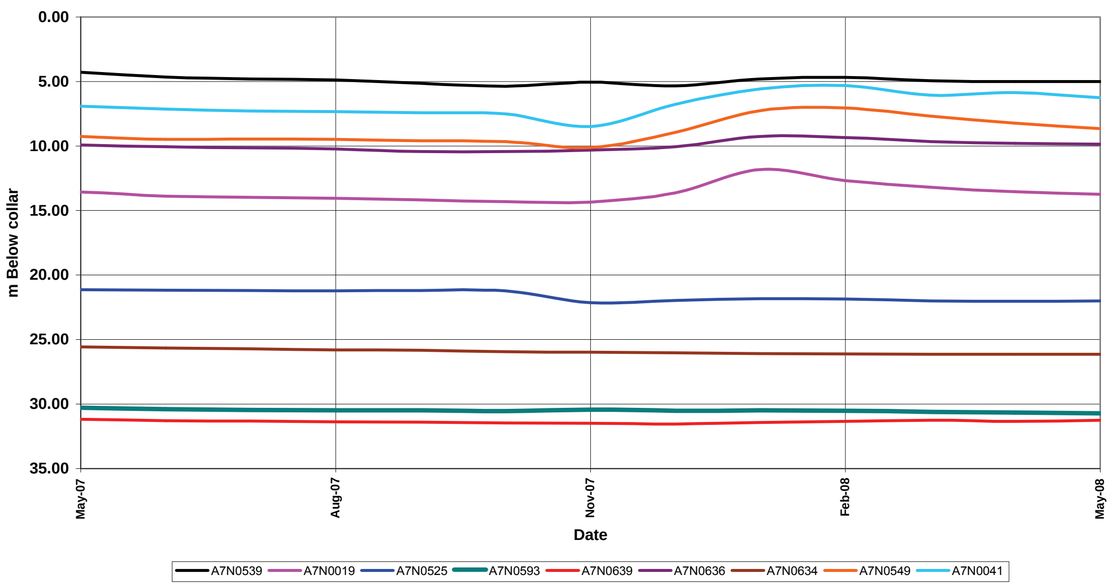


Figure 5.6: Comparison of groundwater level trends at some stations in A7 drainage: 1 May 2007 to 1 May 2008 (meters below collar)
Source: Verster (2008)

- **A8 Drainage area (Nwanedzi, Nzhelele Rivers)**

A slight rise in water levels this past season is evident at some stations (Figure 5.8). This can be shown by doing a comparison with previous levels. From October 2007 to May 2008 (beginning to end of the past wet season), overall an average groundwater rise of 0.85m was recorded. An overall rise of 0.27m was recorded over the past year (May 2007 to May 2008). Unfortunately all monitoring stations are fairly new and no long-term trends can be observed.

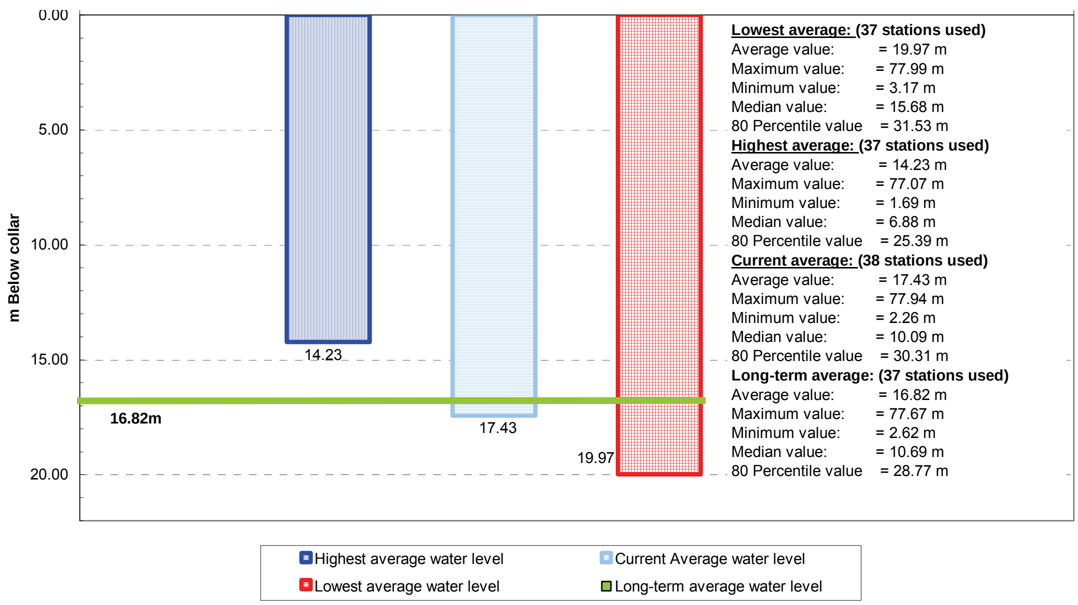


Figure 5.7: Comparison of average current groundwater level depths with highest, lowest and long-term average water level depths in A6 drainage since 1968 (meters below collar)
Source: Verster (2008)

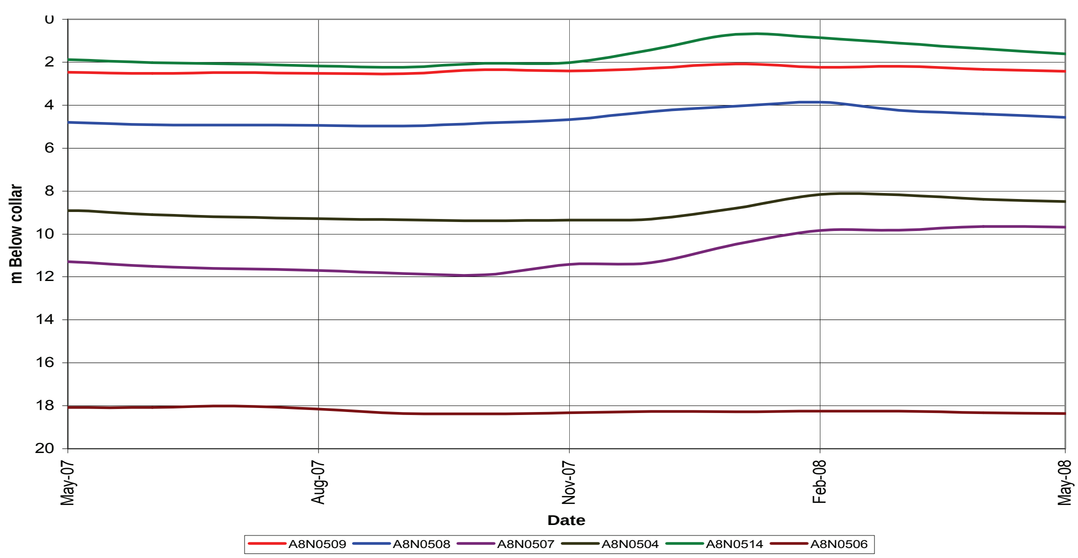


Figure 5.8: Comparison of groundwater trends at some stations in A8 drainage: 1 May 2007 to 1 May 2008 (meters below collar)
Source: Verster (2008)

5.2.4 Groundwater quality situation assessment[7]

Given that many of the rivers in the WMA are either dry or seasonal, about 35% of the water is drawn from groundwater resources. It is important, therefore to consider water quality in terms of both surface water and groundwater.

The water quality in WMA1 is affected by: (a) Pollution from urban areas and informal settlements surrounding urban centres; (b) Contamination of groundwater as a result of high concentration of pit latrines in many rural villages; (c) Impact of mining and industrial activities; (d) Diffuse pollution as a result of agricultural activities.

There are a few large urban centres, Polokwane being the only city of significance. Some of the water quality problems around the town and neighbouring urban areas are a consequence of inefficient management of solid waste disposal sites. Currently DWAF Regional Office is assisting Polokwane Municipality in addressing this issue.

The Limpopo Province has long been considered one of the poorest in South Africa, with a large but widely scattered rural community, mostly settled into medium sized villages. These bring their own water quality management problems, particularly contamination of the very groundwater resources on which they are often dependent. Some of the generic problems related to rural areas are high concentration of pit latrines and poor siting of boreholes. This calls for a very strong programme of planning and management of land use (settlement and stock watering) in relation to the water resource.

As part of the thrust to move out of the poverty cycle, the Limpopo Province is fast expanding its mining interests. Major developments are in Mogalakwena catchment. In addition there are old and closed mines which cause serious pollution, especially to the groundwater resource. The strategy needs to ensure that the integrity of the WMA's water quality is maintained, whilst at the same time not placing undue brakes on economic development. The impacts of irrigated agriculture on the water resource must be recognized. The leaching of fertilizer is a serious problem in the WMA, particularly

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[7] Source: DWAF (2004a)

given the limited surface water and inability of the system to absorb and flush out these excess nutrients. This makes it particularly vulnerable.

Regionally the natural groundwater quality is usually good, satisfies the DWAF water quality guidelines and is suitable for domestic and agricultural supply. The salt content if the groundwater is elevated in some of the dries western areas and, for example, conductivities above 150mS/m occur locally in Karoo strata to the W, NW, N and NE of Lephalala and in the basement rocks in the vicinity of Alldays. Fluoride values above 1.5mg/l are locally present in the groundwater of the Limpopo Mobile Belt rocks and the Nebo granite south-west and west of Mokopane.

5.3 Water management area 2[8]

WMA2 is located adjacent to and shares watercourses with Zimbabwe and Mozambique, and the Limpopo River demarcates its northern boundary. The Kruger National Park (hereafter referred to as KNP) lies along the eastern boundary, and occupies approximately 35% of WMA2. The main rivers in WMA2 are the Luvhuvhu, Shingwedzi and Letaba Rivers, which all flow in an easterly direction through the KNP and into Mozambique before discharging into the Indian Ocean. The Shingwedzi River first flows into the Rio des Elephants River (Olifants River) in Mozambique, which then joins the Limpopo River. The two main tributaries of the Letaba River, the Klein and Groot Letaba, have their confluence on the western boundary of the KNP, whilst the Letaba River flows into the Olifants River just upstream of the border with Mozambique.

The main urban areas are Tzaneen and Nkowakowa in the Groot Letaba River catchment, Giyani in the Klein Letaba River catchment, and Thohoyandou in the Luvuvhu River catchment. The rural population is scattered throughout the WMA. Intensive irrigation farming is practised in the upper parts of the Klein Letaba River catchment, upstream and downstream of the Middle Letaba Dam, and particularly along the Groot Letaba and Letsitele Rivers, as well as in the upper Luvuvhu River catchment. Vegetables (including the largest tomato production area in the country), citrus and a variety of fruits such as bananas, mangoes, avocados and nuts are grown. Large areas have been planted to

[8] Source: DWAF (2004b)

commercial forests in the high rainfall areas of the Drakensberg escarpment and on the Soutpansberg. WMA2 consists of five sub-catchments, namely the Luvuvhu/Mutale, Shingwedzi, Groot Letaba, Klein Letaba, and Lower Letaba regions.

- **Luvuvhu/Mutale**

The gross surface water resource in the Luvuvhu sub-area is estimated to increse from 94 million m^3/a to 156 million m^3/a with the completion of the Nandoni Dam. There is a relatively large groundwater resource in this catchment, estimated to be about 16 million m^3/a. Large scale utilization of the groundwater resource occurs mostly downstream of the Albasini Dam where it is used by irrigators and in the vicinity of Thohoyandou where it is used to supply rural communities. The irrigation requirement of the Luvuvhu/Mutale sub-area is based on the irrigated area of 124km^2 and majority of which is in the Luvuvhu catchment downstream of the Albasini dam. The yield of the Albasini dam is not sufficient to supply all the water requirements of irrigators in the Luvuvhu Government Water Scheme. These irrigators also make use of farm dams and groundwater to supplement their supplies.

- **Groot Letaba**

The contribution of groundwater to available water resources in the Groot Letaba sub-area is estimated to be 12 million m^3/a while the recently completed registration of water use gives the groundwater use as 23 million m^3/a. This groundwater use is mostly downstream of the Tzaneen Dam where it is used to supplement irrigation supplies from surface water during times of drought. In many cases groundwater abstraction takes place close to the river and probably has a direct impact on the surface water flow. The groundwater/surface water dependency needs to be quantified (DWAF, 2004e).

- **Klein Letaba**

The contribution of groundwater to available water in the Klein Letaba sub-area is estimated to be about 9 million m^3/a. This groundwater use is mostly upstream of the Middle Letaba dam where it is used to supplement surface water supplies for irrigation.

Groundwater was also used to supply most of the rural population in the sub-area, but much of this has now been replaced by reticulated supply from the Middle Letaba Dam. The irrigation requirement of in the Klein Letaba catchment is based on an irrigation area of 51km^2. Most of the irrigation water occurs upstream of the Middle Letaba Dam and is sourced from small dams and from groundwater. Irrigation downstream of the Middle Letaba Dam has fallen into disuse apparently due to decreasing assurance of supply as more and more yield of the Middle Letaba is supplied to Giyani and other towns for domestic use.

- **Lower Letaba**

Situated downstream of the Groot and Klein Letaba sub areas and falls entirely within the KNP. This sub-area therefore receives all the water following out of the Groot Letaba and Klein Letaba sub-areas. For all practical purposes, no sustainable yield is derived from runoff in the Lower Letaba sub-area. Water use in the catchment is negligible. The groundwater resource is given in the (DWAF, 2004e) as zero, but this is based on actual groundwater use and is not an indication of the actual potential resource. There are undoubtedly groundwater resources in the sub-area, but these have not been reliably quantified. Game watering and domestic requirements for the rest camps in the KNP are supplied mostly from groundwater. The environmental requirements for the Lower Letaba are important because the river flows through the KNP.

- **Shingwedzi**

This is a head-water catchment which drains into Mozambique. It is situated almost entirely in the KNP. For all practical purposes, no sustainable yield is derived from the surface flow in the Shingwedzi catchment. Water use in the catchment is negligible. By far the largest user of available water resources in WMA2 is irrigation, with other significant users being forestry and rural domestic water use, and transfers out of the WMA. Figure 5.9 shows the locality of the five sub-catchments in WMA2.

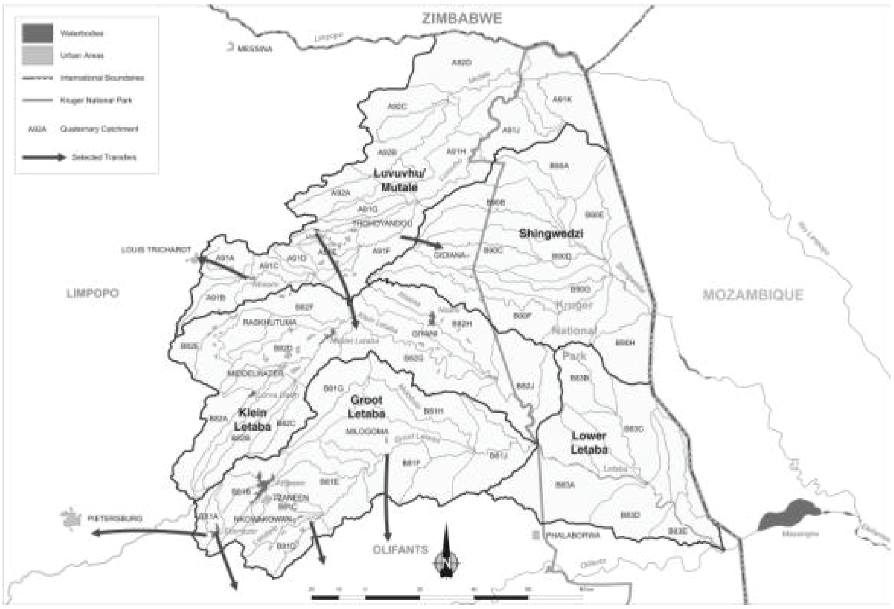

Figure 5.9: Locality map of WMA2
Source: DWAF (2004b)

5.3.1 Groundwater quantity situation assessment[9]

For many water users, groundwater constitutes the only dependable source of water and its utilisation is of major importance in the WMA. A large proportion of the rural domestic and stock watering requirements are supplied from groundwater for most of the rural settlements and villages in the WMA. Groundwater is also used for game watering. Substantial quantities of groundwater are abstracted for irrigation purposes in the upper Luvuvhu river catchment and upstream of the middle Letaba Dam. In total some 15% of all available yield forming the water resources in the WMA is from groundwater.

WMA2 is divided into two sub-areas, namely Luvuvhu/Mutale and Letaba/Shingwedzi. There is a relatively large groundwater resource in Luvuvhu/Mutale sub-area, estimated to be about 16 million m^3/a (DWAF, 2003a). Large scale utilization of the groundwater resource occurs mostly downstream of the Albasini Dam where it is used by irrigators and in the vicinity of Thohoyandou where it is used to supply rural communities. A water use registration conducted by DWAF (2004b) gives the groundwater use in Letaba/Shingwedzi sub-area as 23 million m^3/a. This groundwater use is mostly

[9] Source: DWAF (2004b)

downstream of the Tzaneen Dam where it is used to supplement irrigation supplies from surface water during times of drought. In most cases groundwater abstraction takes place close to the river and probably has a direct impact on the surface water flow. This groundwater – surface water dependency needs to be quantified and the availability of groundwater should be studied in more detail. Over-exploitation of the groundwater resource occurs at some locations in the WMA, notably in the vicinity of Thohoyandou, at Gidiana and possibly downstream of Albasini Dam.

5.3.2 Monitoring and groundwater level trends May 2007 – May 2008[10]

As stated earlier, WMA2 consists of three Drainage areas, namely, A9, B8, and B9.

- **A9 Drainage area (Mutale, Levuvhu Rivers)**

Water levels vary considerably over the area from significant rise as some stations, to no fluctuations at others (Figure 5.10). To see the direction of the trend, a comparison with previous levels was necessary. From October 2007 to May 2008 (beginning to end of the past wet season), overall an average groundwater drop -0.26m was recorded. Overall a very slight rise of 0.08m was recorded over the past year (May 2007 to May 2008) in the area. Monitoring of this Drainage area also started recently and no long-term data is available. Available data indicate very little change in the situation at any station the past three years.

- **B8 Drainage area (Groot, Middel and Klein Letaba Rivers)**

Trends mostly indicate little or no fluctuations over the past year (Figure 5.11). To see the direction of the trend, a comparison with previous levels was necessary. From October 2007 to May 2008 (beginning to end of the past wet season), overall an average groundwater rise of 0.7m was recorded. Overall a rise of 0.14m was recorded over the past year (May 2007 to May 2008) in the area. No long-term data is available but data for about three years is available for some stations and indicate a constant decline the past three years.

[10] Source: Verster (2008)

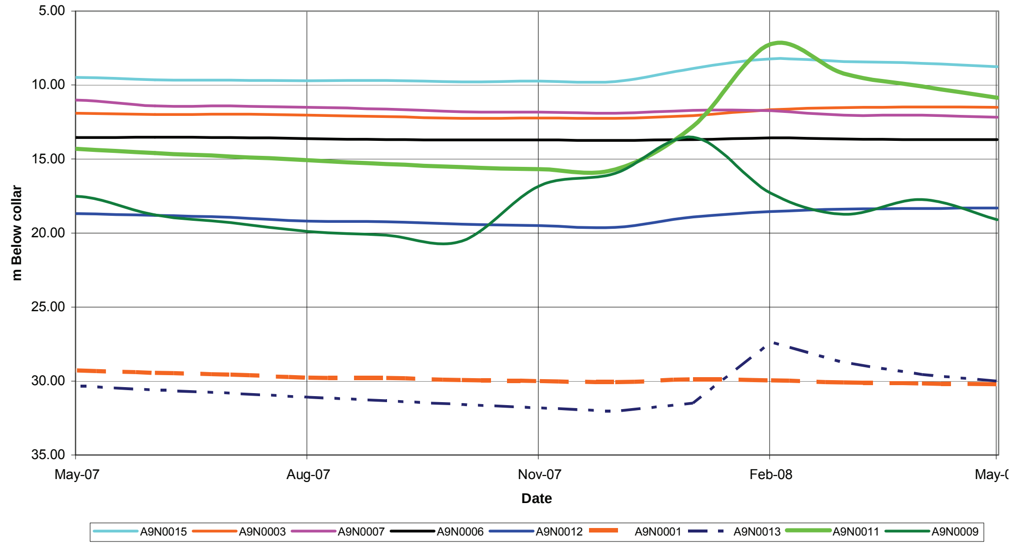

Figure 5.10: Comparison of groundwater trends at some stations in A9 drainage: 1 May 2007 to 1 May 2008 (meters below collar)
Source: Verster (2008)

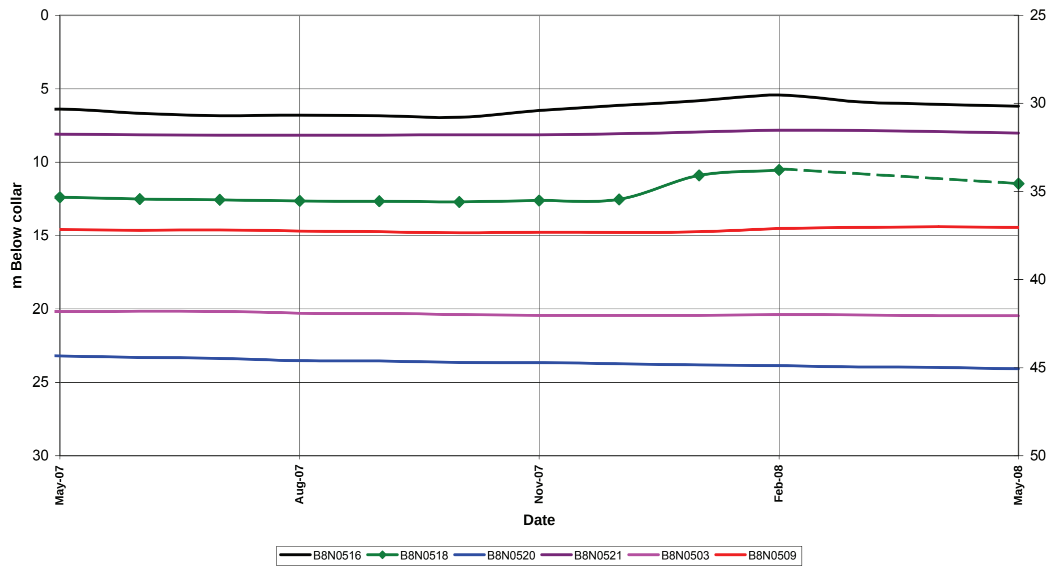

Figure 5.11: Comparison of groundwater trends at some stations in B8 drainage: 1 May 2007 to 1 May 2008 (meters below collar)
Source: Verster (2008)

- **B9 Drainage area (Shingwedzi, Mphongolo Rovers)**

Three of the four stations indicate some rise in groundwater level (Figure 5.12). Comparison with previous levels shows that from October 2007 to May 2008 (beginning to end of the past wet season), a rise ranging from 0.06m to 1.8m was recorded. Over the past year (May 2007 to May 2008) one station indicated a slightly lower level with three stations having higher levels.

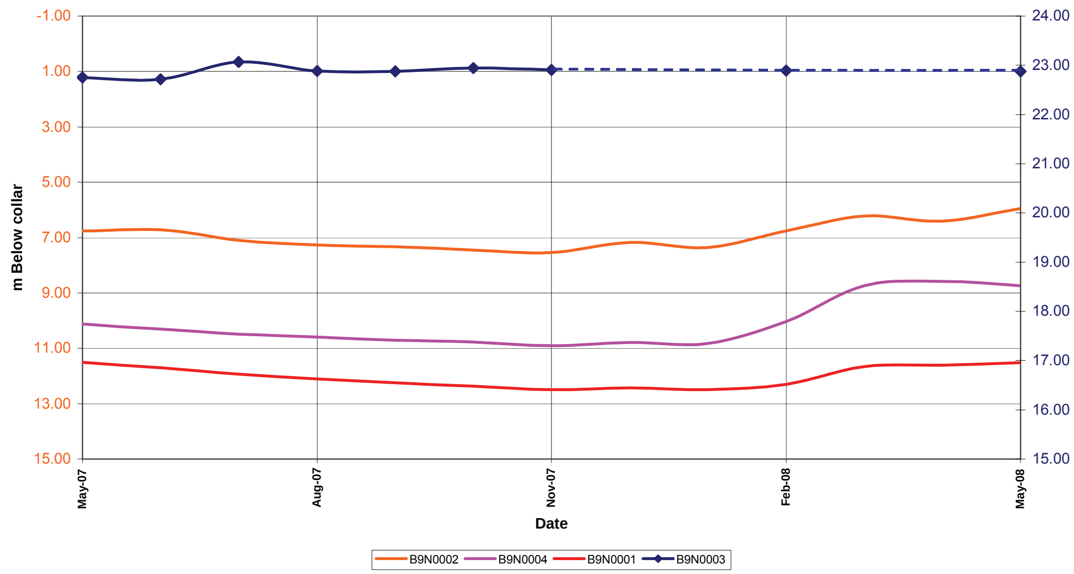

Figure 5.12: Comparison of groundwater trends at some stations in B9 drainage: 1 May 2007 to 1 May 2008 (meters below collar)
Source: Verster (2008)

5.3.3 Groundwater quality situation assessment[11]

The quality of groundwater in WMA2 is generally good particularly in the mountainous areas. Water of high mineral content occurs in some of the drier parts. There are no records of significant pollution of groundwater.

[11] Source: DWAF (2004b)

5.4 Overview of groundwater levels in WMA1 and WMA2[12]

This section looks at areas of noticeable rise, or the lack thereof, in groundwater levels. A prominent feature is the concentration (91%) of stations with groundwater levels rising more than 1m in mostly the upper reaches of major rivers and located relatively close to the rivers (Figure 5.13). These stations are concentrated in the following areas:

- Upper Nile and Nkumpi Rivers;
- Upper to Middle Sand River;
- Upper Letaba River;
- Upper Shingwedzi River;
- Upper Mutale River; and
- The length of the Luvuvhu River.

There are some stations that are not associated with rivers in B3 and B5 Drainages (Springbok Flats) that also showed a rise. These stations are located in areas of high irrigation abstraction and the areas received heavy precipitation the past season which rendered the monitoring stations inaccessible for some time. The area is underlain by basalt and characterized by turf soil (peat). The significant rise in water levels here can be ascribed to the combined result of reduced abstraction due to wet conditions as well as recharge. Also noticeable is the very limited rise in groundwater levels in the western and north-western parts of the Province.

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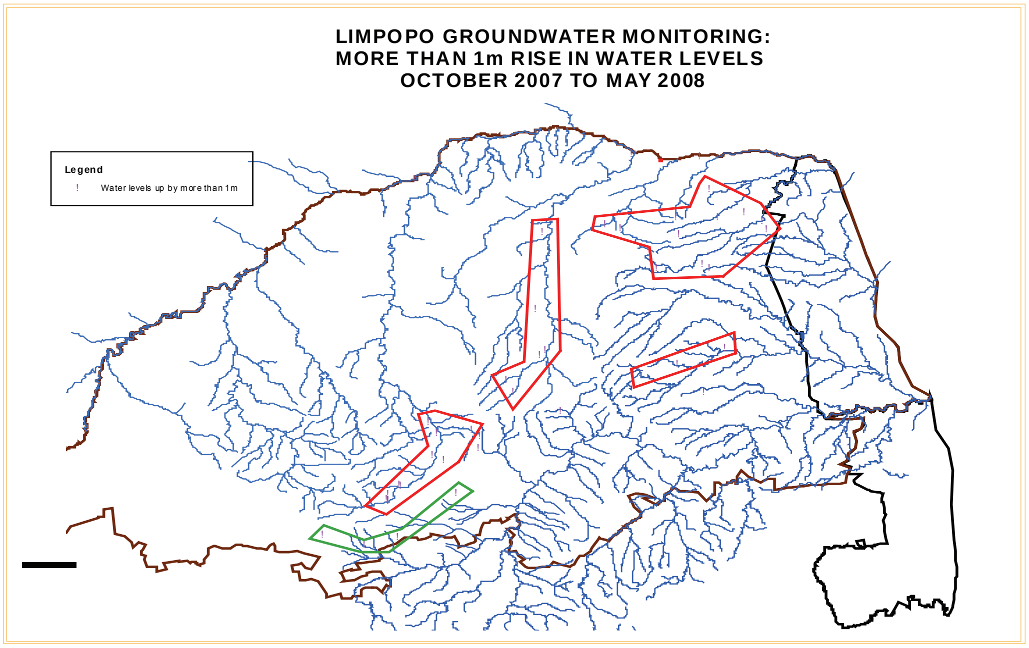
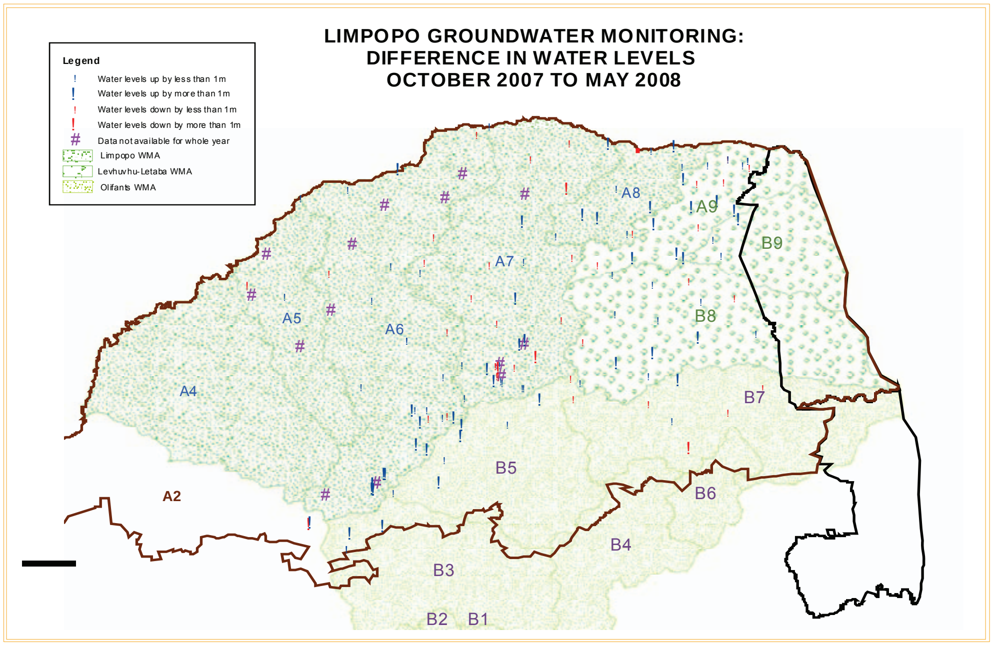
[12] Source: Verster (2008)



MAP 5

Figure 5.13: Limpopo groundwater monitoring: More than 1m rise in groundwater levels: October 2007 to May 2008
Source: Verster (2008)

An overview of the groundwater monitoring process that shows the fluctuations in groundwater levels is shown in Figure 5.12. In concurrence with the picture depicted in Figure 5.14, there is a general rise in groundwater levels in Limpopo Province as shown by the results of the trend analysis conducted by DWAF. DWAF water quality analysis also reveals that groundwater quality in the study area, despite the potential quality threats that are impending, is indeed of good quality hitherto.



MAP 4

Figure 5.14: Limpopo groundwater monitoring: Difference in groundwater levels: October 2007 to May 2008
Source: Verster (2008)

5.5 Summary

This chapter addressed the first hypothesis of this study – "The availability and quality of groundwater in the study area makes groundwater suitable for domestic and agricultural abstraction". The meticulous work conducted by DWAF provides findings that accept this hypothesis. The observed quantity and quality of groundwater in the study area was indeed suitable for abstraction. Albeit this being the case, the need to take heed of caveats highlighted in WDM literature (Brooks, 2007; Nielsen, 2002) becomes even starker for Limpopo Province, in order to maintain and/or even further improve groundwater resource quantity and quality in the wake of ever increasing demand pressures.

The next chapter gives the results and discussion on groundwater use in households of selected rural villages. It also covers the statistical descriptive analysis and statistical inferential analyses pertaining to household groundwater use.

CHAPTER 6

HOUSEHOLDS RESULTS AND DISCUSSION

6.1 Situation of water supply and sanitation service delivery

The Department of Water Affairs and Forestry (DWAF) is the custodian of South Africa's water resources. DWAF seeks to harness South Africa's water resources in the battle against inequality, poverty, and deprivation that continue to plague South Africa (DWAF, 2004e). In recognition of the primary importance of having clean and adequate water supply, the South African government in 2000 introduced the Free Basic Water Policy, which allows for every household to get 6kl of water per month at no cost. This is calculated at 25 litres per person per day for a family of eight (Hall et al., 2006).

According to a Statistics South Africa Community Survey (2007), 78.1% of Limpopo households had access to piped water in 2001, compared to 83.6% in 2007 which shows an improvement in water supply and sanitation. The DWAF Free Basic Water website (November 2008) provides a water service update for Limpopo Province households. It shows that 82.42% of poor households are served a basic water supply at no charge and 80.82% of total households are served a basic water supply at no charge. Tables 6.1 up to 6.4 give information on the water supply and sanitation service situation in Limpopo.

Table 6.1: Free basic water summary of all households and poor households

Households	Total	Poor
Total	1 259 743	753 969
Served	1 018 076	621 397
%	**80.82%**	**82.42%**

Source: DWAF (2008a)

Table 6.2: Free basic water service view of all households served

Total households served					
Service level	**No infrastructure**	**Below RDP**	**At RDP**	**Above RDP**	**Total**
Total	65 141	185 453	337 664	671 486	1 259 743
Served	1 906	183 829	262 684	569 656	1 018 076
%	**2.93%**	**99.12%**	**77.79%**	**84.84%**	**80.82%**

Source: DWAF (2008a)

Table 6.3: Free basic water service view of all poor households served

Total poor households served					
Service level	**No infrastructure**	**Below RDP**	**At RDP**	**Above RDP**	**Total**
Total	40 557	113 651	212 578	387 183	753 969
Served	951	112 354	164 949	343 143	621 397
%	**2.34%**	**98.86%**	**77.59%**	**88.63%**	**82.42%**

Source: DWAF (2008a)

A definition of the data used in the above three tables is given in Table 6.4.

Table 6.4: Free basic water data definitions

No infrastructure	Households have no access to any infrastructure i.e. those people that still drink unsafe water from a dam, spring, river or receives water from vending (e.g. trucking) projects.
Below RDP	Households have access to infrastructure but at a below RDP standard e.g. standpipe over 200m away from dwelling.
At RDP	The infrastructure necessary to supply 25 litres of potable water per person per day supplied within 200m of a household and with a minimum flow of 10 litres per minute (in the case of communal water points) or 6000 litres of potable water supplied per formal connection per month (in the case of yard or house connections).
Above RDP	Households have access to in-house or in-yard water supply connections.
Poor household	A household that has a total income of less than R800 per month.
Served	Household that receives a basic water supply at no charge / for free

Source: DWAF (2008a)

Households in the study area were observed to range between the 'No infrastructure' and the 'At RDP' levels of water service. Only communal standpipes were observed in the survey, and in limited cases the standpipe fell 'in-yard', but the reticulation pattern was that of communal taps. No 'in-house' standpipes were observed.

The communal standpipes were all DWAF installations and all households enjoyed a free basic supply at no charge. In some cases only a minimal charge was paid for repair and maintenance of the system. Although DWAF basic water was free of charge, supply was chronically short in most villages because the pumping infrastructure could not cope with the number of households and as such, a rotation system of water delivery was the norm.

This was observed to be the cause of the existence of an informal local water market that desperate water seekers would rely on in times of water need. Residents with tanks and/or own-boreholes were observed to collect water for speculation purposes, and these agents served as the water suppliers on the informal local water markets.

6.2 A description of household characteristics[13]

6.2.1 Gender

In the survey conducted, of the 106 households interviewed, 58 household were female headed (55%), while 48 were male headed (45%). Mashamba showed the highest proportion of female household heads (68%), while Sereni had the highest male household head proportion (87%).

6.2.2 Age

The mean age of household heads in all villages was 54 years. The youngest (22 years) and the oldest (85 years) were both from Mashamba.

6.2.3 Education level[14]

The average household head was found to be educated up to primary school level. Uneducated household heads were found in all villages of the study area, while the highest level observed was diploma level in Sereni and Kanana.

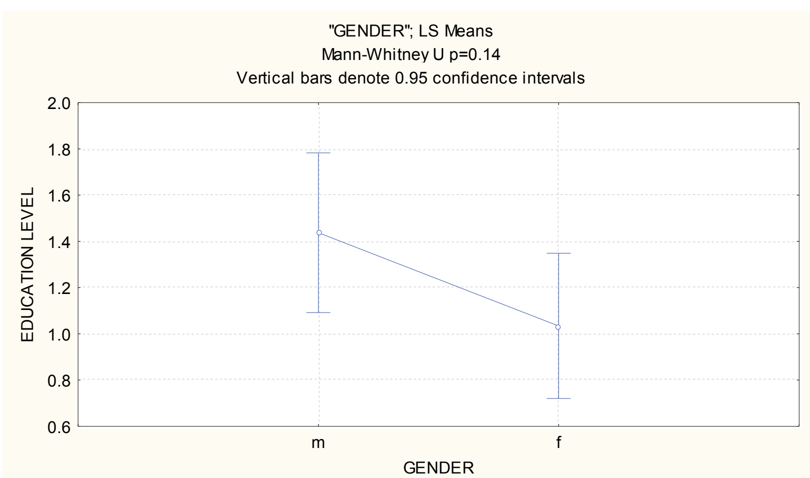


Figure 6.1: Analysis of education level and gender of household head

[13] Figures displayed are based on data collected in WMA1 and WMA2 in July of 2008.
[14] 0=No education, 1=Primary school, 2=High school, 3=Matric, 4=Certificate, 5=Diploma, 6=Degree and above.

According to Figure 6.1, the Mann-Whitney test indicated, with P-value 0.14 that the mean education level of the two genders of household heads did not differ significantly. The influence that age had on education level was found to be significant. A rather strong negative correlation (-0.52) was observed from a regression of education level on age, this signified that older house heads had lower education levels.

6.2.4 Household size

The average family size was found to consist of five members. The biggest family unit (17 members) was found in Mashamba. The single member household was the smallest unit observed in Mashamba, Sereni, Kanana, Gaphago and Leokaneng.

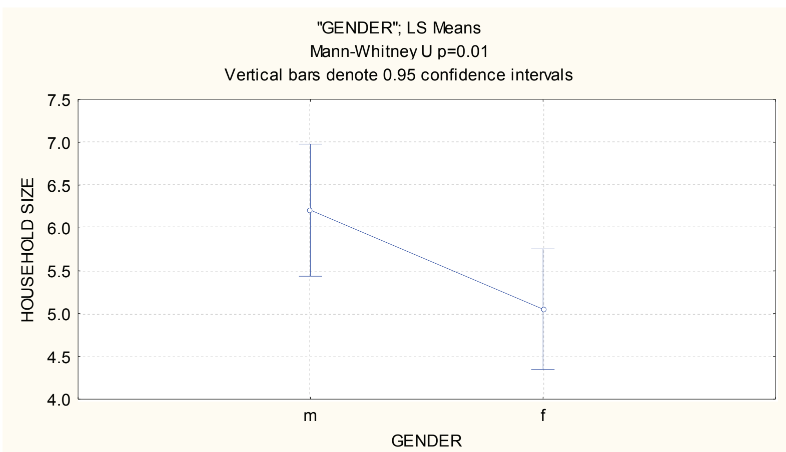


Figure 6.2: Analysis of household size and gender of household head

According to Figure 6.2, the Mann-Whitney test indicated, with P-value 0.01 that the mean household size of the two genders of household heads differed significantly. Male headed households averaged six members compared with female headed households that averaged five members.

6.2.5 Employment status[15]

Village was found to have a significant effect on employment. The highest proportion of employed household heads was in Sereni, while the least was Mohlajeng as shown in

[15] Employment category 0=Unemployed, 1=Retired, 2=Employed.

Figure 6.3. Figure 6.4 shows the distribution of employment categories, where: '0' is unemployed, '1' is retired, and '2' is employed.

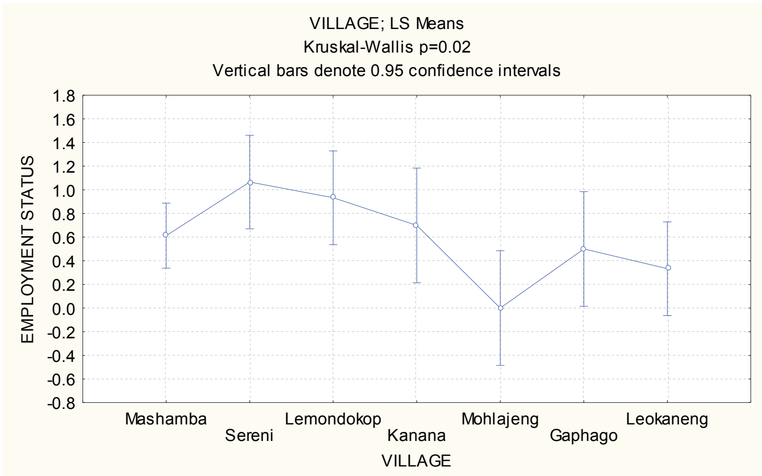


Figure 6.3: Analysis of employment status by village

Figure 6.4: Categorized Histogram: Employment status by village

Gender and education level were observed to significantly influence employment status. The majority of the unemployed were females (68%) and the majority of the employed were males (82%) as shown in Figure 6.5; where '0' depicts females and '1' depicts males. The proportion of less educated people was found to be highest amongst the unemployed category, and least in the employed category as shown in Figure 6.6.

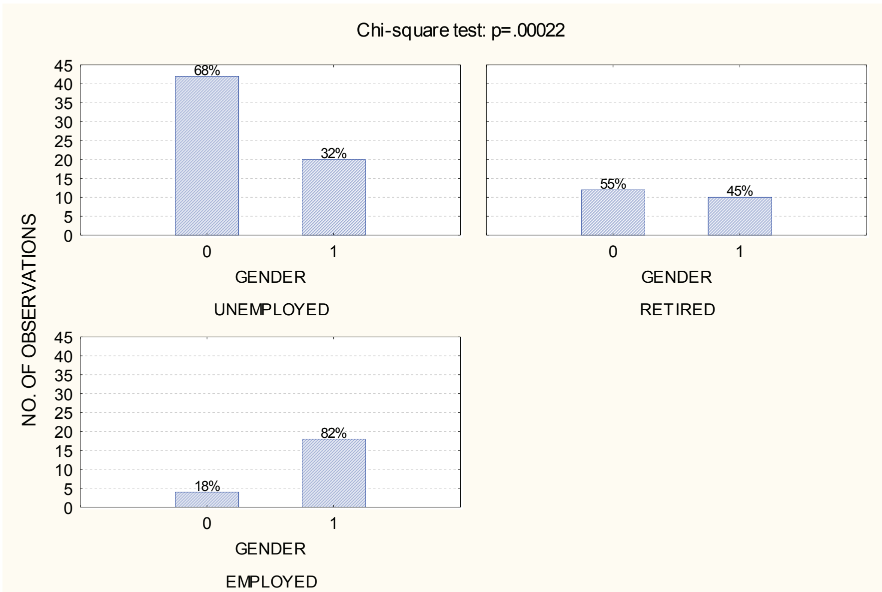


Figure 6.5: Categorized Histogram: Employment status by gender

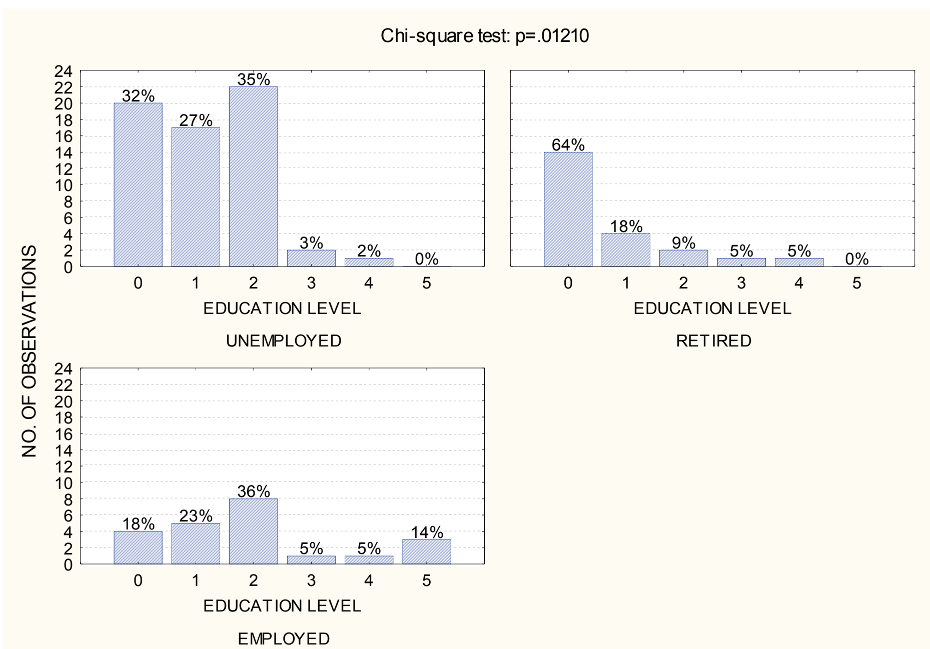


Figure 6.6: Categorized Histogram: Employment status versus education level

6.2.6 Income[16]

The average household income was found to range from R500-R899 per month. The minimum was less than R200 (observed in Mashamba, Sereni, Gaphago and Leokaneng) and the maximum ranged from R9000-R19000 (observed in Kanana).

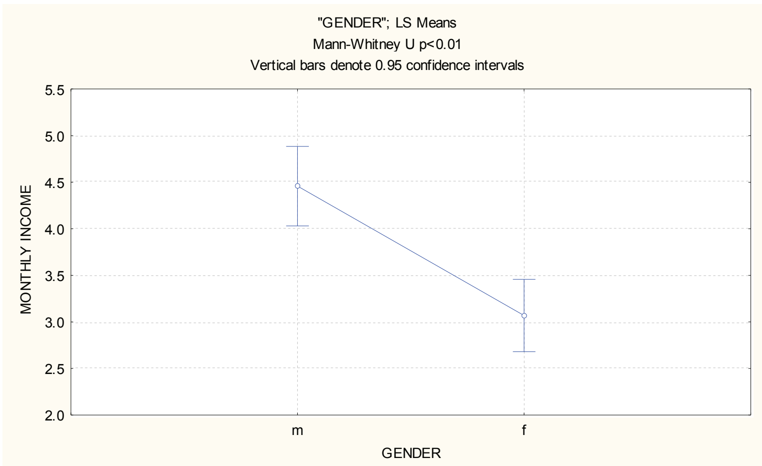


Figure 6.7: Analysis of monthly income and gender of household head

According to Figure 6.7, the Mann-Whitney test indicated, with P-value less than 0.01 that the mean monthly income of the two genders differed significantly. Male headed households averaged R900 to R1399 per month, while female headed households averaged R500 to R899 per month.

The influence that education level had on monthly income was found to be significant. A positive correlation (0.25) was observed from a regression of income on education level, this revealed that more educated household heads had higher monthly incomes levels.

A significant relationship was observed between income and household size. A regression of household size on income revealed a weak positive correlation (0.24). Bigger households therefore had higher household income levels. In spite of this observation, a study by Statistics South Africa on Income and expenditure of households (2000) did not show any conclusive relationship between household size and income levels in Limpopo.

[16] Income category 1=<R200, 2=R200-R499, 3=R500-R899, 4=R900-R1399, 5=R1400-R2499, 6=R2500-R3999, 7=R4000-R5999, 8=R6000-R8999, 9=R9000-R19000, 10=>R20000 per month.

6.2.7 Marital status[17]

No divorced household heads were observed in all the sampled villages. Mashamba was found to have the highest proportion of single household heads (26%), while Kanana and Mohlajeng had none. Lemondokop had the highest proportion of married household heads (93%), with Kanana having the lowest (60%). Kanana had the highest observed proportion of widows and widowers (40%), the least were Sereni and Lemondokop with none at all as shown in Figure 6.8.

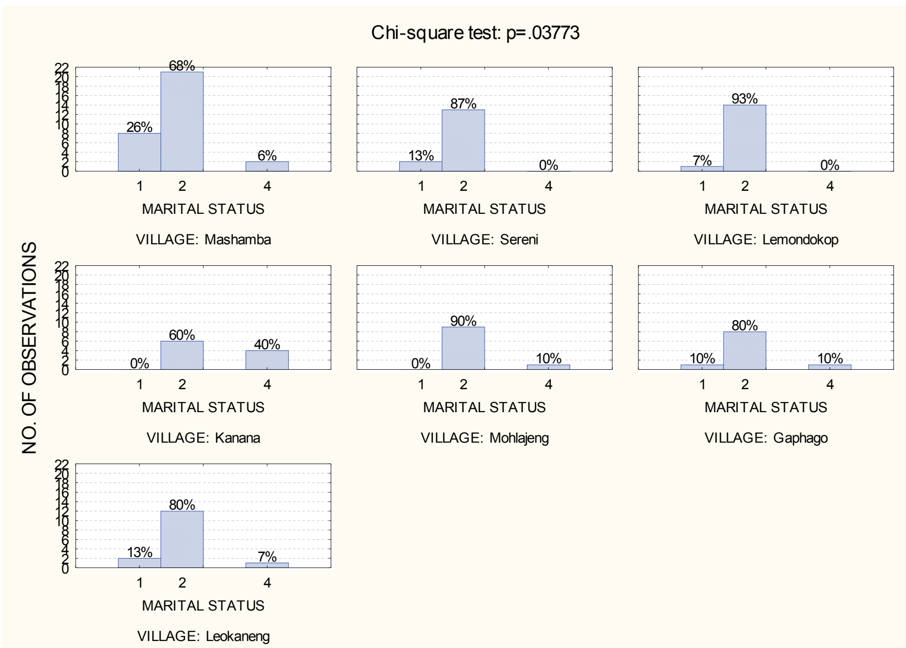


Figure 6.8: Categorized Histogram: Marital status by village

6.3 Groundwater use characteristics and perceptions[18]

6.3.1 Age

Analysis of data revealed that age significantly influenced how respondents viewed the importance of water use for bathing, washing dishes and pots, hand laundry, and washing floors. A negative correlation was found between the importance of water for all these uses and age.

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[17] The categories 1, 2, 3, and 4 stand for single, married, divorced, and widow or widower respectively.
[18] Figures and tables displayed are based on data collected in WMA1 and WMA2 in July of 2008 (unless otherwise indicated).

6.3.2 Education level

Education level was found to significantly influence respondents' perception of the importance of water use for washing dishes and pots, and for hand laundry. In both cases a positive correlation was observed, revealing that more educated people view water use for these two services as being critical, most probably because of higher health consciousness.

6.3.3 Marital status

Marital status was found to significantly influence respondents' perception of the importance of water use for cooking, drinking, hand laundry, and willingness to pay for water. A positive correlation between all these uses except hand laundry (which showed a negative correlation) and the state of being married was observed. This is most likely because the married in most cases have more family obligations, and are likely to regard water use for these services more importantly than the single headed households in order to achieve family goals. The married will more likely have dependents to provide for, and were observed to be more willing to pay for water.

6.3.4 Household size

Household size was found to significantly influence how importantly respondents' regard water use for cooking, drinking, bathing, cleaning dishes and pots, gardening, outside cleaning of fowl runs etc., livestock watering and household total monthly usage of water, as well as responsiveness to water tariff changes. Bigger family units are likely to invest more in food security through gardening and animal husbandry than smaller units. In addition bigger family units will use more water per month, and as such will be more sensitive to tariff changes than smaller family units that use less water per month. Larger family units were found to naturally be more concerned with bathing water because of the higher volumes of water needed on a daily basis, hence they held bathing water with more importance than smaller households.

6.3.5 Employment

There was a statistically significant difference in the importance of water for cleaning dishes and pots between the employment categories. The importance of water for dishes and pots was higher amongst the employed than the unemployed. This could be because the employed were found to be more educated in this study, and as such were more likely to be more health conscious in the kitchen.

6.3.6 Income

Income was found to be significantly correlated to the importance of water for car washing and household monthly water usage. In both cases a positive correlation with income was observed. The better off could afford to use more water than lower income households. Albeit, the difference in per capita water consumption across income levels was found to be insignificant (P-value = 0.06). Table 6.5 shows the average per capita monthly water consumption by village. The highest per capita monthly water consumption was 922.00 litres per person per month in Gaphago village (which reported much better water availability), while the lowest per capita monthly water consumption was 546.00 litres per person per month in Lemondokop village (which reported a worsening of water availability). The overall mean per capita monthly water consumption for the study area was 761.00 litres per person per month or 25 litres per day.

A statistically significant, but weak negative correlation was observed between prioritising groundwater preservation and income level. As income level rose there was a reduction in willingness to preserve groundwater. The lower income respondents were presumed to prioritise preserving groundwater because for starters their ability to pay for water was presumably lower than that of the higher income respondents, and they are more likely to be thrifty when using groundwater.

Table 6.5: Per capita water consumption by village

Village	Mean per capita monthly water consumption (litres)	Mean per capita daily water consumption (litres)
Gaphago	922.00	30.20
Loekaneng	840.00	27.50
Mohlajeng	810.00	26.60
Kanana	805.00	26.4
Mashamba	728.00	23.9
Sereni	675.00	22.10
Lemondokop	546.00	17.90
Total	**761.00**	**25.00**[19]

6.3.7 Gender

A significant difference in the volume of water used for hand laundry and for gardening was observed between the two genders. Women (denoted by 0) were found to use more water on average per month than men (denoted by 1) as shown in Figures 6.9 and 6.10. This according to the researcher was because men were not as involved in these tasks as much as women, so naturally used less water than women.

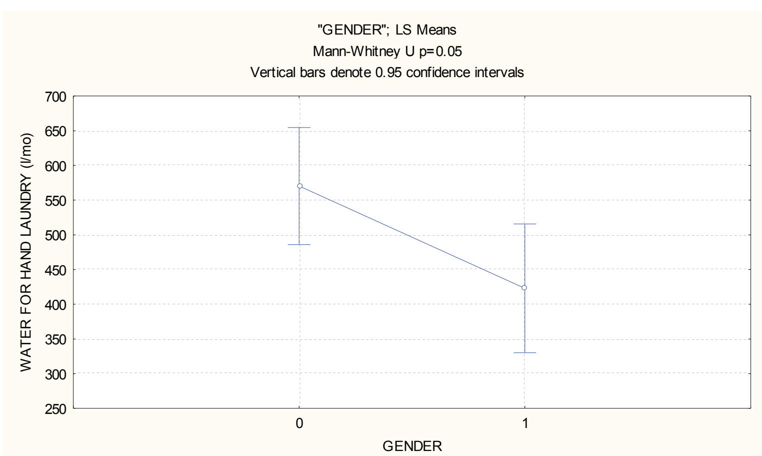

Figure 6.9: Analysis of water used for hand laundry and gender

[19] The infrastructure necessary to supply 25 litres of potable water per person per day supplied within 200m of a household and with a minimum flow rate of 10 litres per minute (in the case of communal water points) indicates service level to be 'At RDP' level by DWAF standards.

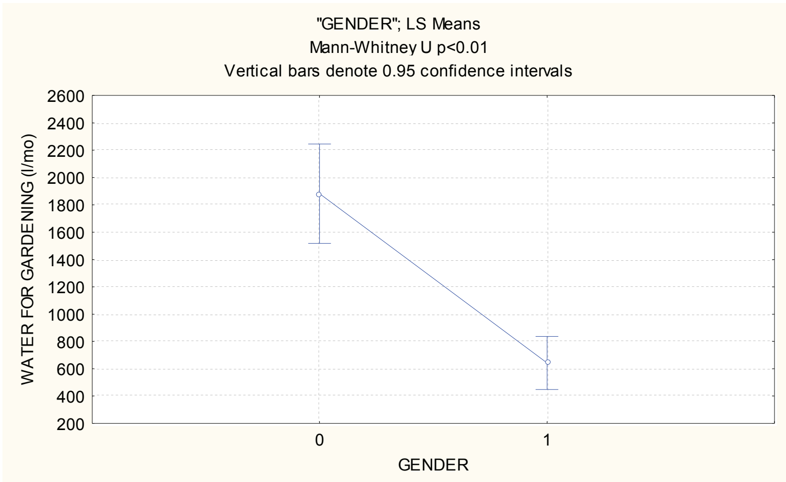

Figure 6.10: Analysis of water used for gardening and gender

6.3.8 Villages and groundwater perceptions

A question was included in the Household Questionnaire to evaluate the level of importance that households attached to the different ground water uses. A sliding scale from one (not important at all) to 10 (extremely important) was used to assign a weight to responses. Table 6.6 shows the importance of groundwater uses. Drinking, cooking and bathing were the three extremely important groundwater uses, while machine washing, toilet flushing and showering were not important at all to households. The latter three were not important at all in the study area because all the sampled households did not own functional flushing toilets, showers, or washing machines. This section addressed two research questions of this study – “What are the current main uses of groundwater?” and “What are the priorities of rural households in terms of groundwater uses?”.

Table 6.6 shows that households prioritise water for drinking, cooking, bathing, dish washing, hand laundry, washing floors, gardening, and for livestock watering in descending importance respectively. Water for outside cleaning and car washing was found to be of very limited importance. Water for toilet flushing, machine laundry, and showering was not important at all in the study area.

Table 6.6: Importance and priority of groundwater uses

Groundwater use	Importance mean weight	Weight description	Rank
Drinking	9.99	Extremely important	1
Cooking	9.99	Extremely important	1
Bathing	9.50	Extremely important	3
Dish washing	8.50	Quite important	4
Hand laundry	8.40	Quite important	5
Washing floors	6.80	Important	6
Garden watering	2.67	Limited importance	7
Livestock watering	2.25	Limited importance	8
Outside cleaning	1.40	Very limited importance	9
Car washing	1.40	Very limited importance	10
Machine laundry	1.00	Not important at all	11
Toilet flushing	1.00	Not important at all	12
Showering	1.00	Not important at all	13

6.3.8.1 Cooking

A statistically significant difference in the volume of water used for cooking per household was observed between villages (see Figure 6.11). Sereni village on average used the most water per month for cooking (400l/mo), while Gaphago used the least water for cooking (120l/mo). The mean monthly water usage for cooking was 260l/mo. The researcher observed that villages differed in their food consumption patterns, in villages like Sereni, traditional pap was consumed nearly with every meal and as such more water was needed for food preparation in Sereni than in other villages.

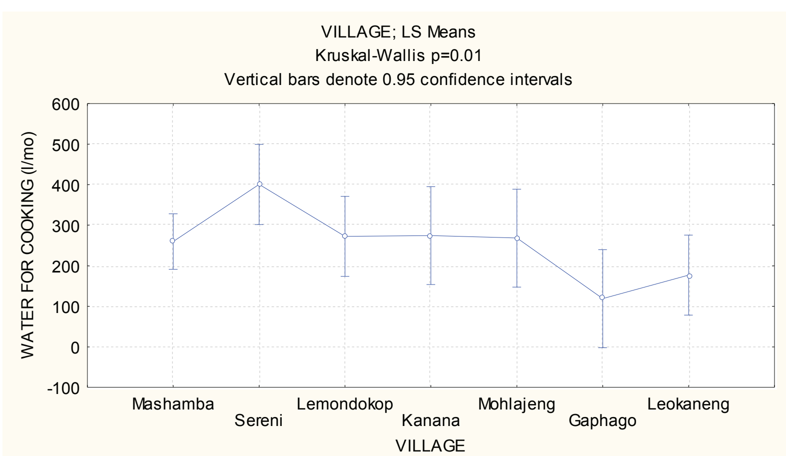

Figure 6.11: Analysis of water used for cooking per household by village

6.3.8.2 Hand laundry importance[20]

Perception of the importance of water for hand laundry was observed to be significantly different between villages (see Figure 6.12). Kanana village was found to value this service the least, while Leokaneng valued water use for hand laundry the most. This was explained by difference in water availability seeming to influence attitudes towards water use from village to village. The water availability situation in Kanana was reported to have become much worse over the past five years, while in Leokaneng the situation over the past five years was reported to have improved.

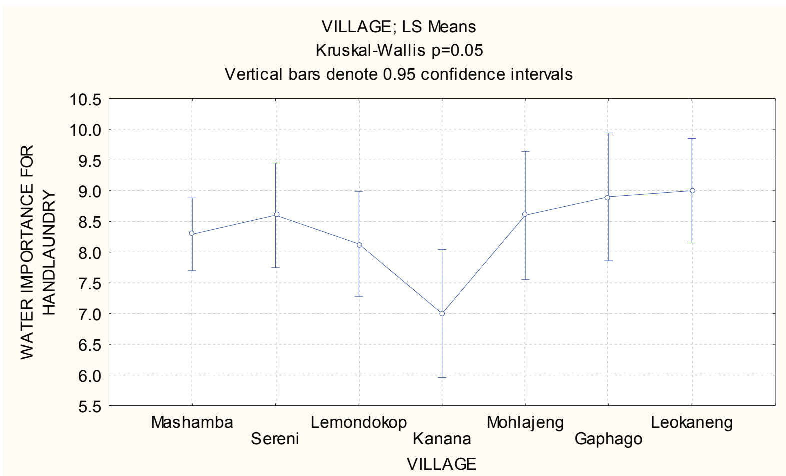

Figure 6.12: Analysis of water importance for hand laundry and village

6.3.8.3 Cleaning floors

The perception of the importance of water for cleaning floors was found to differ significantly between villages (see Figure 6.13). Due to the dire water situation in Kanana, the value of water for this use was the least. The highest value was observed in Mashamba. The researcher observed that in Mashamba household aesthetics were of paramount cultural importance, and elaborate paintings and designs on building facades were quite common.

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[20] Importance of water uses was measured on a 10 point sliding scale from 1=Not important at all to 10=Extremely important.

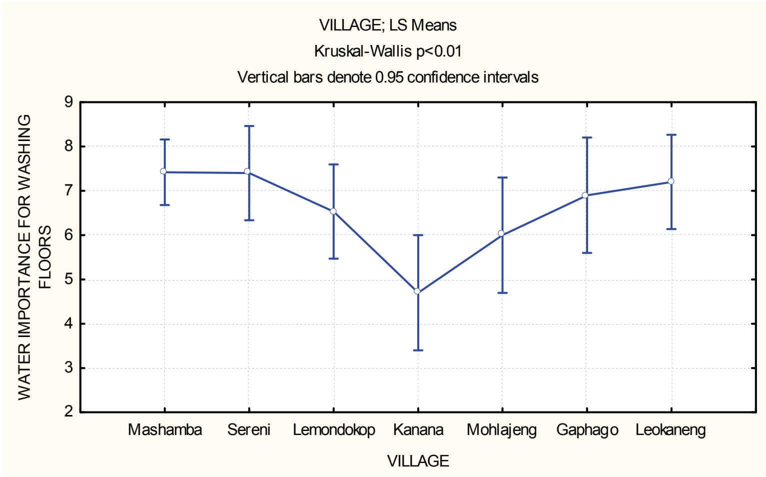

Figure 6.13: Analysis of water importance for washing floors and village

6.3.8.4 Dishes and pots

A statistically significant difference in the volume of water used for dish washing was observed between villages (see Figure 6.14). Generally WMA2 villages (Mashamba, Serani, and Lemondokop) used more water for dish washing than WMA1 villages (Kanana, Mohlajeng, Gaphago, and Leakoneng). Difference in local people's customs, culture, intergroup relations, social organization, gender relations, and social structure by regions in Limpopo could possibly have a direct bearing on issues of groundwater use. These findings are consistent with those of Rathgeber's (1996).

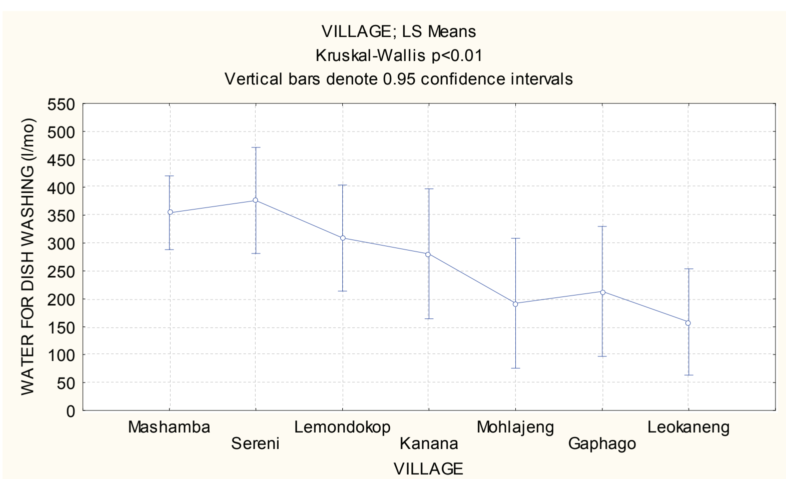

Figure 6.14: Analysis of water used for dish washing and village

6.3.8.5 Toilet flushing

Table 6.7 shows households by type of toilet facility in Limpopo and South Africa. The comparison shows that in Limpopo 49% of households used pit latrines without ventilation, compared to 22.3% nationally. 22.8% of households in Limpopo did not have toilets compared to 13.3% nationally. 16.0% of households in Limpopo had flush toilets in the dwelling compared to 50.0% nationally. Households in Limpopo that had pit latrine toilets with ventilation accounted for 8.1%, compared to 5.6% nationally.

Table 6.7: Households by type of toilet facility, Limpopo and SA, 2001

Type of toilet	**Limpopo**		**South Africa**	
	N	**%**	**N**	**%**
Flush toilet in dwelling	200 585	16.0	5 887 550	50.0
Flush toilet (with septic tank)	25 062	2.0	350 939	3.0
Chemical toilet	16 313	1.3	227 331	1.9
Pit latrine with ventilation	101 391	8.1	655 989	5.6
Pit latrine without ventilation	613 715	49.0	2 626 008	22.3
Bucket latrine	8 370	0.7	464 581	3.9
None	285 760	22.8	1 569 225	13.3
NA	33	0.0	1 011	0.0
Total	**1 251 229**	**100.0**	**11 782 635**	**100.0**

Source: Statistics South Africa, Population Census (2001)

The Household Questionnaire included a question eliciting information on how important households perceived water use for toilet flushing. 100% of the surveyed households perceived water for toilet flushing as not being important at all because all of them did not own flush toilets but instead had pit latrines only.

6.3.8.6 Distance to water source[21]

According to a Statistics South Africa Provincial Profile for Limpopo (2004), of the households in Limpopo, 30.7% had piped water in the yard, which was higher than the percentage for South Africa (29.9%). Approximately 23% of households in Limpopo had piped water on a community stand at a distance greater then 200 meters from the dwelling compared to 12.1% nationally. 15.4% of households in Limpopo had piped

[21] Distance category 1 = <100m, 2 = 100m-499m, 3 = 500m-1km, and 4 = distance > 1km to water point.

water on a community stand at a distance less than 200 meters from the dwelling compared to 10.5% nationally. Only 9.9% of households in Limpopo had piped water inside the dwelling, which is much lower than the percentage of South Africa (32.4%). 6% of households used water from a river or stream compared to 6.2% nationally (Statistics SA 2004).

A question was included in the Household Questionnaire to determine households' water source, and how far it was from their homestead. The village was observed to significantly influence distance to water source. Figure 6.15 shows the distance to water source by village.

Lemondokop on average covered the greatest distance in search of water (on average 100m to 499m) due to a very poor water availability situation precipitated by borehole breakdowns. Villagers had to get water from the river (more than 200m from most households) or to rely on vending (e.g. trucking) projects that delivered water on a weekly basis. This village was observed to range between the 'No infrastructure' and the 'Below RDP' level of water service. Mashamba villagers were also observed to cover distances in excess of 200m from their households in search of water, although the water insecurity situation was not as acute as that of Lemondokop. The water unavailability in Mashamba was worse in the new stands where water reticulation had not yet been installed. The water service level in Mashamba was 'Below RDP' level.

No water availability problems were observed in Mohlajeng village, it was also observed that villagers here travelled the least in search of water (less than 100m). Kanana, Gaphago, and Leokaneng villages travelled within 200m to a standpipe; hence they all fell within the 'At RDP' bracket.

Significant difference in distance to water source was observed between abuse aware and unaware respondents. Respondents that travelled longer distance in search of water tended to be more aware of the likelihood of groundwater abuse, while respondents that travelled shorter distances for water tended to be unaware of the likelihood of groundwater abuse. This could possibly be ascribed to poor water availability forcing people to acquire survival strategies and groundwater knowledge in order to prevent deterioration of their already poor water access (see Figure 6.16).

Households that owned boreholes were significantly closer to the water source than those without boreholes as shown in Figure 6.17. Hence, borehole ownership significantly reduced travel distance to water sources in the study area. Whether households paid for water or enjoyed free water was found to be significantly different at differing distances to water source. Figure 6.18 shows that when the distance to the water source was greater, water was paid for. When distance to water source was shorter, water was generally free.

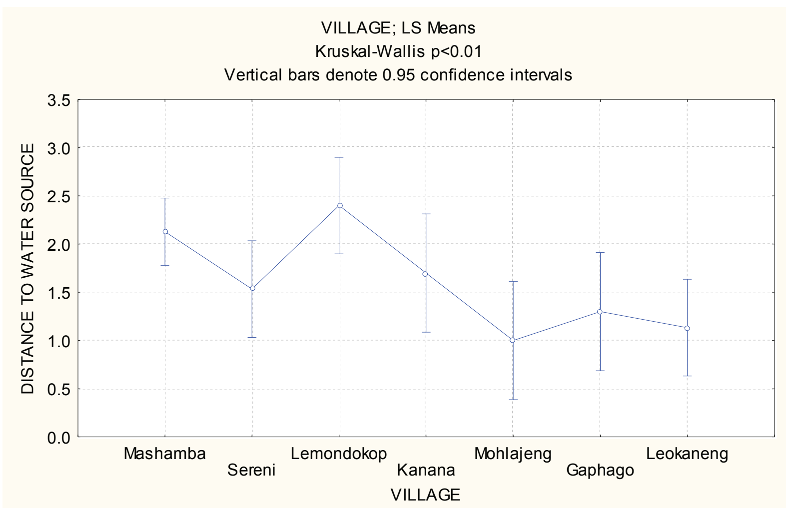

Figure 6.15: Analysis of distance to water source and village

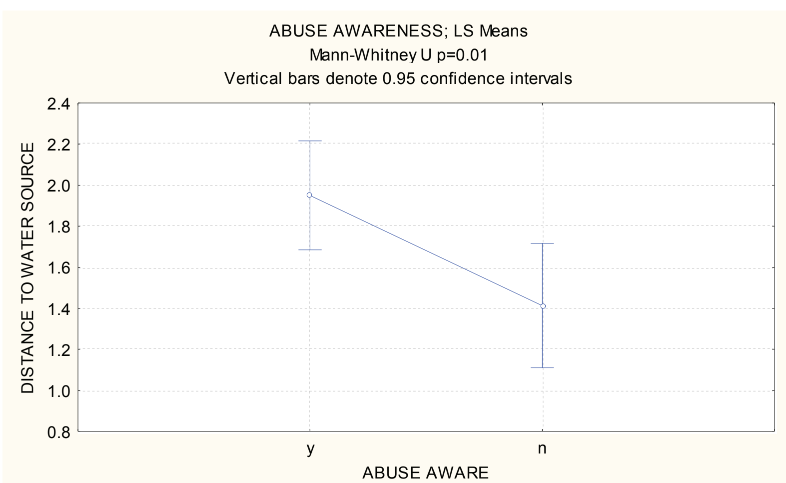

Figure 6.16: Analysis of distance to water source and abuse awareness

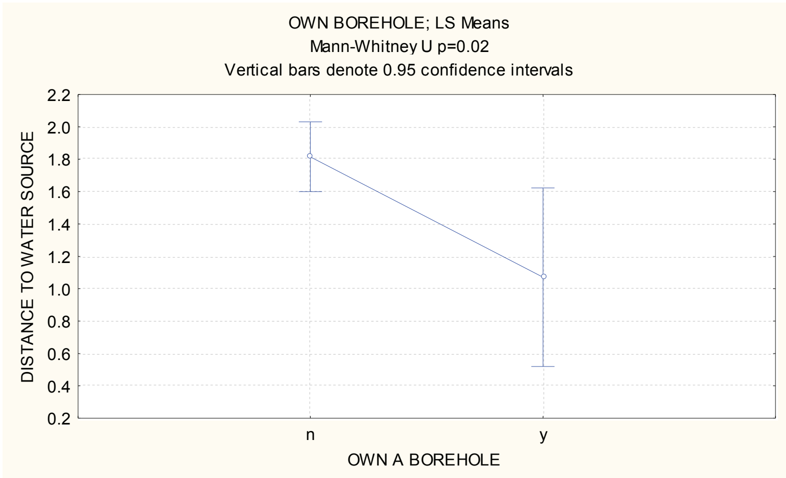

Figure 6.17: Analysis of distance to water source and borehole ownership

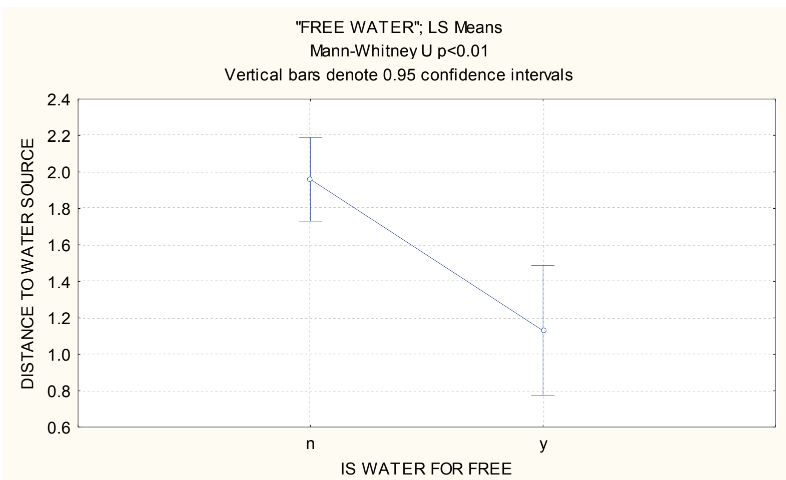

Figure 6.18: Analysis of distance to water source and payment for water

6.3.8.7 Responsiveness to tariff changes

This section addresses part of the second hypothesis of this study – "Rural water consumption can be significantly influenced by changing the groundwater tariff". It investigates how responsive household water consumption was to hypothetical tariff change. The researcher observed that in the study area, households relied on DWAF communal standpipes (which in a few instances fell within household yards) for water. These communal standpipes supplied borehole water on average once per week (for a few hours only) in Mashamba, Lemondokop, Kanana, and Gaphago; twice a week in Sereni; and on a daily basis in Mohlajeng and Leokaneng villages. Water from the

DWAF communal taps was not levied directly, but villagers paid a minimal fee (about R5.00) per month for repair and maintenance of the reticulation system.

In most of the villages, water supply could not satisfy demand due to inadequate water delivery infrastructure, which resulted in the existence of a thriving informal local water market. The same water pumping infrastructure was used to feed different sections within most villages on alternating days; hence supply had to be rationed as these sections had to share the same inadequate infrastructure. This was the reason why the water taps could not run daily in most of the villages.

Households that owned water tanks were observed to hoard water from the communal taps for resale and households that owned boreholes on their premises were also involved in water selling; hence, these two entities were responsible for supplying water on the informal local water market. The observed unit of water sale on the informal local water market was commonly the 25 litre plastic container, which was on average sold for R1.00. For ease of comparison with other studies, the standard kilo-litre (kl) unit of water was used in this study. Hence, the observed average water price of R1.00 per 25 litres of water translated to R40.00 per kl of water. This tariff was found to be rather exorbitant when compared to DWAF recommended tariffs for Limpopo. In Limpopo the recommended DWAF domestic water tariff for 6-20kl monthly water usage ranges from R1.55 to R6.16 per kl (DWAF, 2007).

Contingent Valuation (CV) using Willingness to Pay (WTP) was used to derive a value per kl of piped water. This WTP was contingent upon improved WSS to the households. The prevailing average tariff on the informal local water market (R40.00 per kl) was the starting point of the WTP elicitation. The end point of the WTP elicitation was R1.55 per kl – the recommended minimum DWAF domestic water tariff for Limpopo (DWAF, 2007). CV using WTP hence elicited households' responsiveness to tariff change over the range from R40.00 to R1.55 per kl of water.

According to Figure 6.19, villages were observed to be significantly different in how their households responded to change in water tariff. Despite there being a statistically significant difference in responsiveness between village households, all the villages were observed to be overall unresponsive to tariff change because all the observations were nearly perfectly inelastic (elasticity was approximately zero).

This finding led to the rejection of the hypothesis – “Rural households’ water consumption can be significantly influenced by changing the groundwater tariff”. Table 6.5 showed that per capita daily water use in the study area was 25 litres per capita per day. The infrastructure necessary to supply 25 litres of potable water per person per day supplied within 200m of a household and with a minimum flow rate of 10 litres per minute (in the case of communal water points) indicates service level to be just “at RDP” level by DWAF standards (DWAF, 2008a). This level is the minimum water requirement and households seemed to be comfortable to remain at this level of groundwater use. In some instances humans have chosen to inhabit areas that are less well endowed with water. This means that they have had to evolve a set of coping strategies over time, inadvertently becoming what Descartes referred to in 1637 as “masters and owners of nature” (Anscombe and Geach, 1954).

Sereni on average was observed to increase water use comparatively the most, followed by Mohlajeng, Gaphago, and Lemondokop (in descending order respectively) at the contingent lower water tariffs. A seemingly irrational observation was made where Lekaneng, Kanana, and Mashamba households said they would reduce water use (with increasing magnitude respectively) if the contingent water tariff was reduced (please note this does not necessarily mean they will use more water at a contingent higher tariff). Upon further enquiry into this seemingly irrational behaviour, villagers were found to attach an extrinsic value (the extrinsic value includes non-use values such as bequest or existence values, in addition to mere intrinsic values) to the groundwater resources in their respective areas and viewed using less groundwater at a lower tariff as being “morally right”. They espoused a feeling of moral responsibility for their groundwater resources and they were conscious of the possibility of imposing an externality on fellow users if they over-used groundwater.

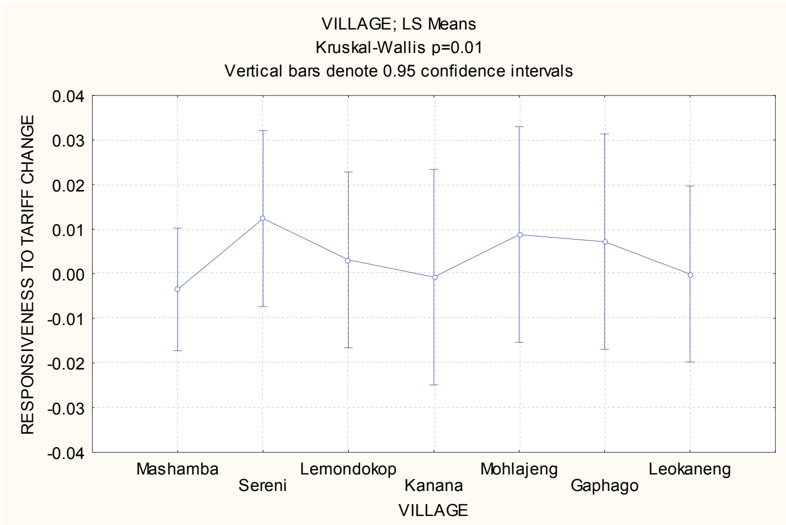

Figure 6.19: Analysis of responsiveness to tariff change and village

6.3.8.8 Awareness about groundwater abuse

A question was put in the Household Questionnaire to observe whether respondents knew that over use or abuse of groundwater aquifers can destroy aquifers. Analysis revealed that a significant difference in awareness about groundwater abuse was observed between villages. Mashamba showed the highest awareness of abuse level, while Mohlajeng was least aware of the danger of groundwater abuse (see Figure 6.20). This observation was also tied in with a significant difference observed between education levels and awareness of groundwater abuse. The respondents that were aware were significantly more educated than those that were not aware, as shown in Figure 6.21.

There was a significant difference in water payment between groundwater abuse-aware and abuse-unaware respondents (see Figure 6.22). Of the respondents who were aware of the dangers of groundwater abuse, 78% paid for water and 22% did not pay for water. Of the respondents who were not aware of the dangers of groundwater abuse, 61% paid for their water and 39% did not pay for water. Comparatively, more respondents paid for water in the groundwater abuse-aware category than in the groundwater abuse-unaware category. This indicated that respondents that paid for water were generally more conscious of the value of water, and the possibility of it getting abused.

A significant difference in groundwater abuse awareness was observed at differing reported water availability (measured on a sliding scale from 1 = Much worse to 10 = Much better) situations in the study area over the past five years. Respondents tended to be aware of the dangers of groundwater abuse in cases of worsening water availability. In cases where the water situation was better, respondents were generally unaware of the likelihood of groundwater abuse. Experience being the best teacher, water stressed respondents were probably more conscious of the possibility of losing groundwater resources and the potential threats to groundwater resources (see Figure 6.23).

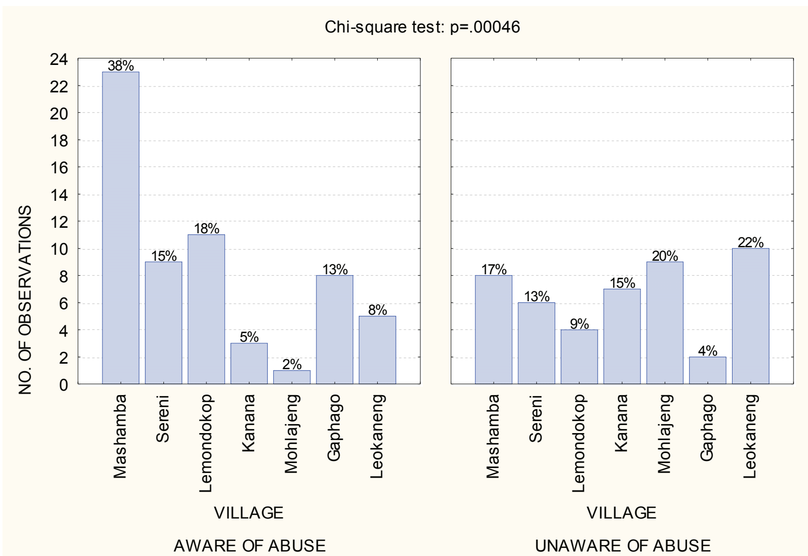

Figure 6.20: Categorized Histogram: Awareness of abuse versus village

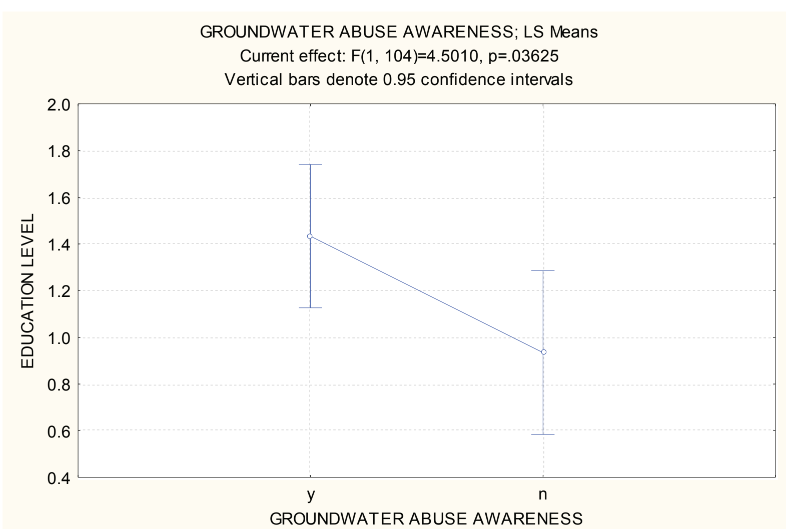

Figure 6.21: Analysis of education versus awareness of groundwater abuse

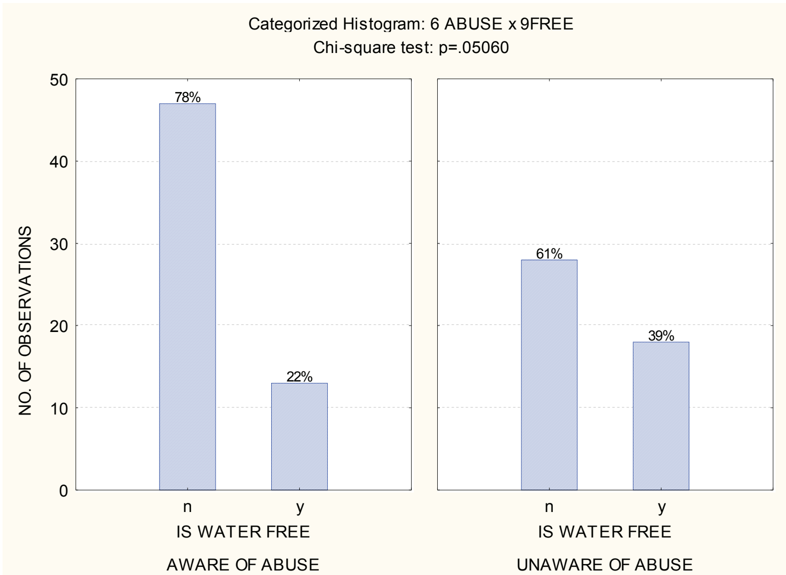

Figure 6.22: Categorized Histogram: Awareness of abuse and payment for water

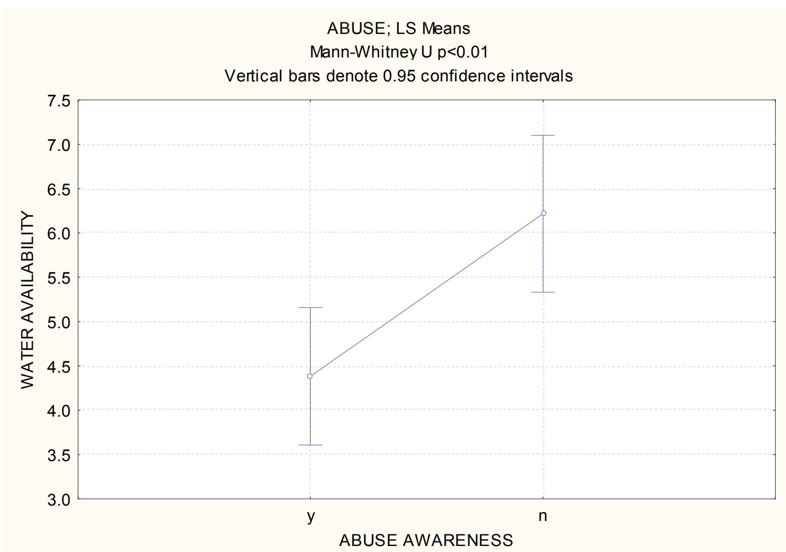

Figure 6.23: Analysis of awareness of abuse and water availability

6.3.8.9 Current water fee

A question was put in the Household Questionnaire to find out whether households paid for water and if so, what tariff households paid for water. Results revealed that villages statistically differed significantly in the fee they paid for water on the informal local water market (DWAF tap water was not levied). Figure 6.24 shows that in villages where water availability was a problem the fee was generally higher than in areas of better water availability (refer to Section 6.3.11.1 for village water availability). Lemondokop reported the highest average tariff (R83.33 per kl), while Leokaneng enjoyed the average lowest tariff (R8.00 per kl). The overall average tariff was R40.00 per kl of water on the informal local water market.

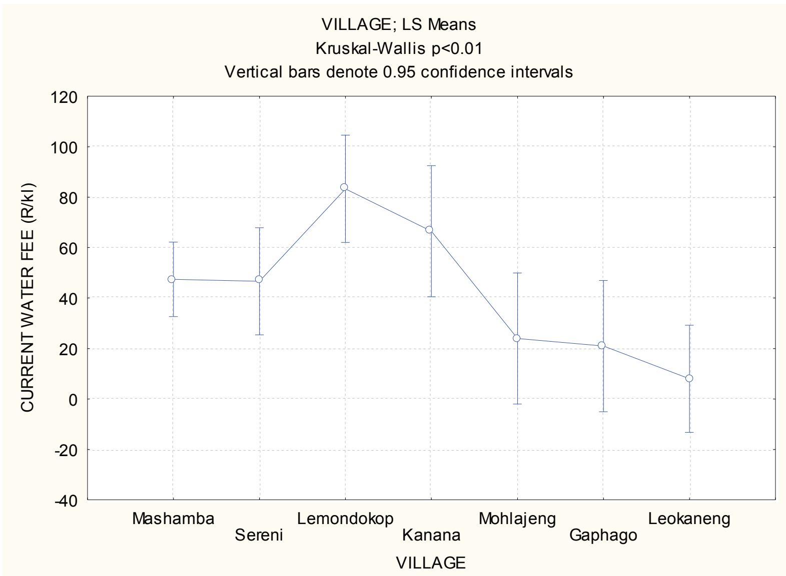

Figure 6.24: Analysis of current water fee and village

6.3.9 Borehole ownership

A significant difference in borehole ownership was observed between payers and non-payers of water. Of the 75 respondents that paid for water only 4% of them owned a borehole, while 96% did not own a borehole. Of the 31 respondents that did not pay for water, 35% of them owned a borehole, while 65% did not own a borehole. Borehole owners relied on their own boreholes for water and so did not have to buy water; hence, borehole ownership could possibly be cost cutting in the study area.

The difference in borehole ownership between villages was found to be significant. Leokaneng had the most of reported boreholes in the study area (57%), while Mashamba, Sereni and Lemondokop had none as shown in Figure 6.25.

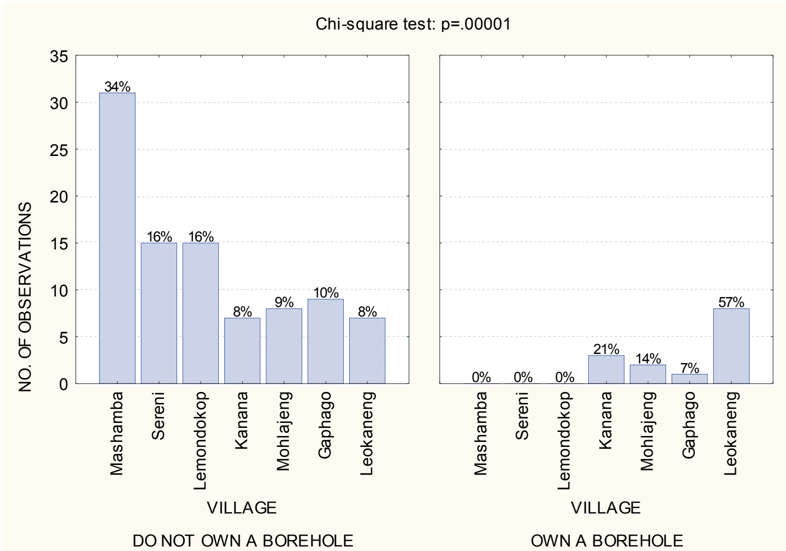

Figure 6.25: Categorized Histogram: Own borehole ownership and village

Water availability was found to differ significantly between borehole owners and non-owners. Better water availability was associated with borehole ownership, while poorer water availability was associated with non-ownership of a borehole (see Figure 6.26).

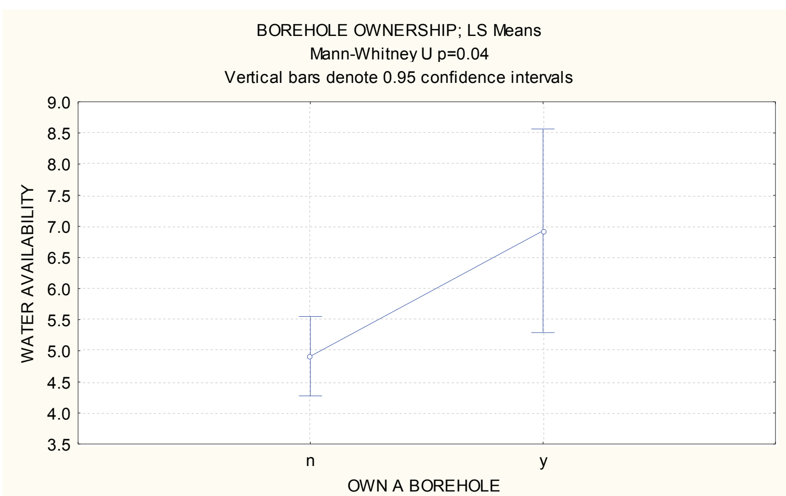

Figure 6.26: Analysis of borehole ownership and water availability

There was a statistically significant difference in total monthly water usage between borehole owners and non-owners as shown in Figure 6.27. Borehole owners on average used 5.3kl of water per month, while non-borehole owners used 3.5kl per month, showing that borehole owners had more latitude for higher monthly water use than non-owners.

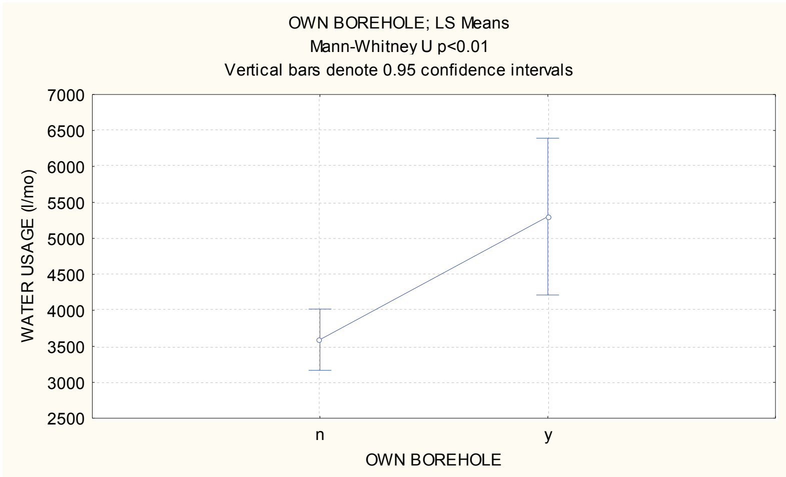

Figure 6.27: Analysis of water usage and borehole ownership

6.3.10 Willingness to pay for groundwater

This section addresses part of the second hypotheses and the third research hypotheses – "Rural households are willing to pay for improved groundwater supply and sanitation" and "Rural household groundwater has a utility value, and this value can be determined by contingent valuation".

A question was included in the Household Questionnaire to determine the level of household WTP for satisfactory groundwater delivery. The difference in households' WTP for water was not found to be statistically significant. A key finding made though, was that households were indeed willing to pay for satisfactory groundwater delivery. The highest observed WTP was R3.46 per kl of water in Kanana village (which reported much worse water availability). The lowest observed WTP was R1.77 per kl of water in Gaphago village (where no water availability problem was reported). The overall mean WTP for satisfactory household groundwater supply and sanitation for the study area was R2.28 per kl of groundwater. Table 6.8 highlights the WTP observations made.

The findings led to the acceptance of the hypotheses - "Rural households are indeed willing to pay for improved groundwater supply and sanitation" and "Rural household groundwater has a utility value, and this value can be determined by contingent valuation". Households' WTP for water service improvements shows that it is possible to recover part of the costs of improved groundwater supply and sanitation. The WTP value of household groundwater represents the utility value (economic value in use) that the consumer places on household groundwater.

Table 6.8: Household Willingness to Pay (WTP) for water by village

	WTP (R/kl)		
Village	**Mean**	**Std. Dev.**	**Std. Error**
Mashamba	2.32	1.65	0.30
Sereni	1.84	1.47	0.38
Lemondokop	2.67	1.72	0.44
Kanana	3.46	1.36	0.43
Mohlajeng	2.20	0.95	0.30
Gaphago	1.77	1.75	0.55
Loekaneng	1.84	1.47	0.38
Total	**2.28**	**1.57**	**0.15**

A significant difference in average willingness to pay was observed between groundwater abuse aware and abuse unaware respondents as shown in Figure 6.28. Aware respondents were willing to pay on average R2.65 per kl of groundwater, while abuse unaware respondents were willing to pay R1.80 per kl of groundwater. This was possibly because the abuse-aware were willing to contribute more towards the preservation of groundwater resources.

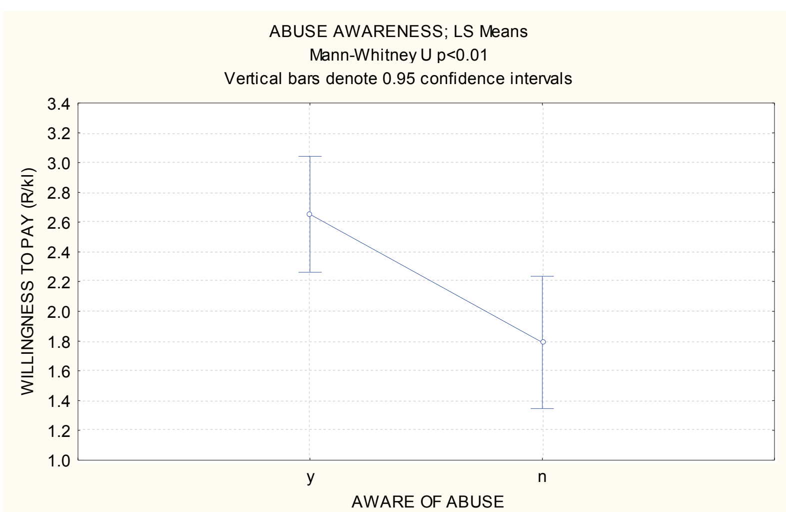

Figure 6.28: Analysis of willingness to pay and abuse awareness

6.3.11 Groundwater availability and groundwater quality[22]

The household survey conducted in this study solicited information on people's perceptions on change in groundwater availability and groundwater quality over the past five years (2004 to 2008).

6.3.11.1 Groundwater availability

This section addressed a part of the second hypothesis – "Rural households are enjoying satisfactory groundwater supply and sanitation". The average opinion observed in Mashamba village (south-east of Makhado) was that water availability had become worse over the past five years. In Sereni village, (south-east of Mashamba) groundwater availability was reported to be slightly worse. In Lemondokop village (south of Sereni) respondents remarked that groundwater access had become worse over the past five years. These villages are all in WMA2. Survey results in WMA1 show that the situation of groundwater access in one village, namely Kanana village was now much worse. The researcher observed that the worsening of water access in these four villages was a result of inadequacy of pumping and water distribution equipment which had to be over-stretched across households, as well as thefts, and breakdowns of water pumping infrastructure. Intermittent water supply a few days per week and only for a few hours was the common state of affairs in these villages. This should not be ascribed at all to excessive groundwater abstraction that results in groundwater level drawdown, but solely to insufficiency of water pumping and reticulation infrastructure.

Of the three remaining villages in WMA1, Mohlajeng and Leokaneng reported much better water availability, while Gaphago reported better water availability over the past five years. The apparent reason for this contrast in results with the earlier four sampled villages was ascribed to better groundwater supply as a result of repair and maintenance of water infrastructure. All four villages in WMA1 are located south-west of Dendron. The observations made as regards water availability showed that rural households are not enjoying satisfactory groundwater supply and sanitation and hence, the rejection of the

[22] Groundwater availability and quality were measured on a sliding scale from 1 = Much worse to 10 = Much better over the past five years (2004-08).

part of the second hypothesis – “Rural households are enjoying satisfactory groundwater supply and sanitation. The majority of the villages (four out of seven) under study were suffering from erratic water supply, while only three villages enjoyed reliable water access.

Lemondokop had to get water from the river (more than 200m from most households) or to rely on vending (e.g. trucking) projects that delivered water on a weekly basis. This village was observed to range between the ‘No infrastructure’ and the ‘Below RDP’ level of water service. Mashamba villagers were also observed to cover distances in excess of 200m from their households in search of water. The water unavailability in Mashamba was worse in the new stands where water reticulation had not yet been installed. The water service level in Mashamba was judged to be ‘Below RDP’ level.

Mohlajeng villagers travelled the least in search of water (less than 100m) because no water availability problems were encountered. Kanana, Gaphago, and Leokaneng villages travelled within 200m to a standpipe; hence they all fell within the ‘At RDP’ category. Water availability was found to be a major driver of water price. A significant difference in whether water was free or paid-for was observed at differing water availability levels. Figure 6.29 shows that people generally paid for water when water availability was poor, while in better water availability situations water was generally free.

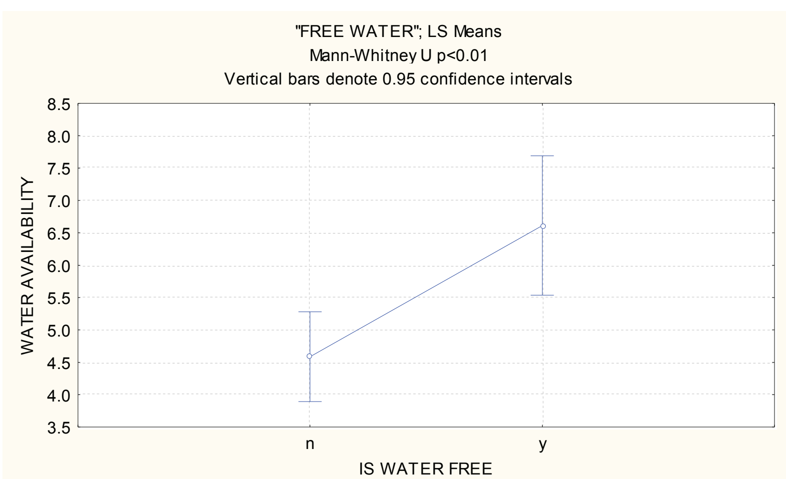

Figure 6.29: Analysis of water payment and water availability

Observed results revealed a statistically significant but weak positive correlation between water quality and quantity (see Figure 6.30). This was explained by the fact that depleted groundwater reserves are generally more vulnerable to contamination than well recharged and healthier reserves.

The importance of water for hand laundry, and cleaning floors was found to have a significant but weak positive correlation with the availability of water (see Figures 6.31 and 6.33). In areas of better water availability, these services emerged in importance since the primary water uses (like drinking and cooking) would have been satisfied by the sufficient water volumes available. In areas of worse water availability, these services failed to emerge in importance since the available water could probably only satisfy the primary water needs.

Observed results revealed a statistically significant and strong positive correlation between distance to water source and water availability (see Figure 6.33). The more available the water was, the less the travel distance that was needed to acquire it.

Observed results revealed a statistically significant but weak negative correlation between willingness to pay and water availability (see Figure 6.34). The more available water was, the lower was the willingness to pay for it, indicating that in times of poor water availability situations, demand could drive the water price higher.

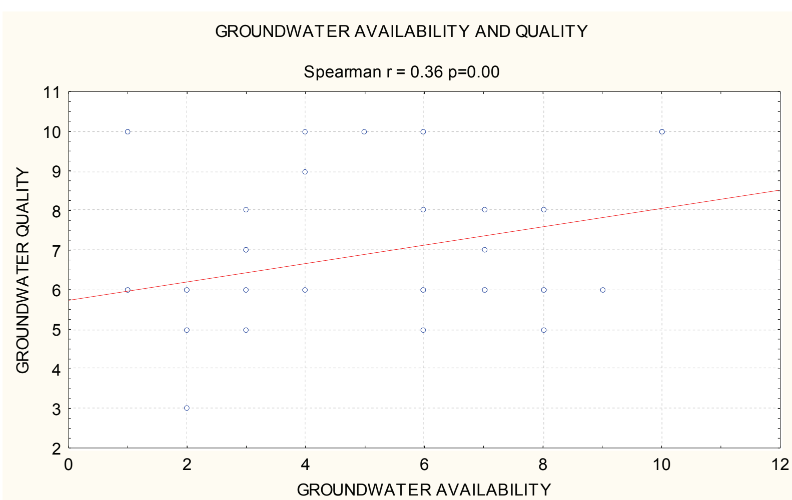

Figure 6.30: Analysis of groundwater quality and availability

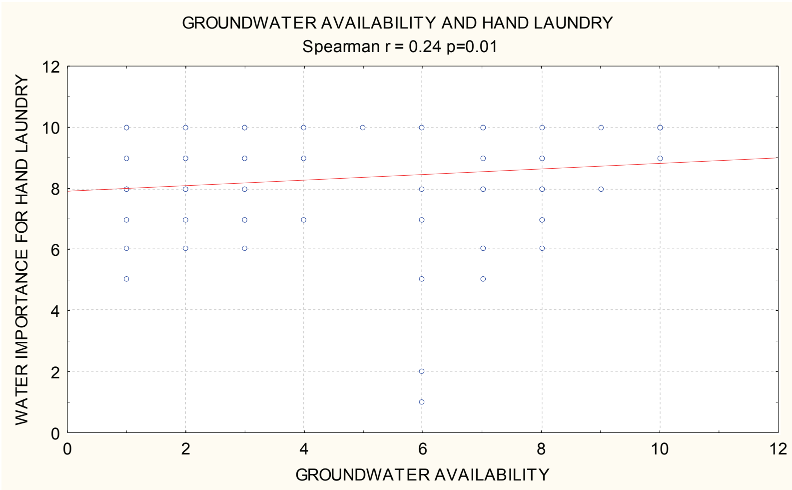

Figure 6.31: Analysis of water importance for hand laundry and water availability

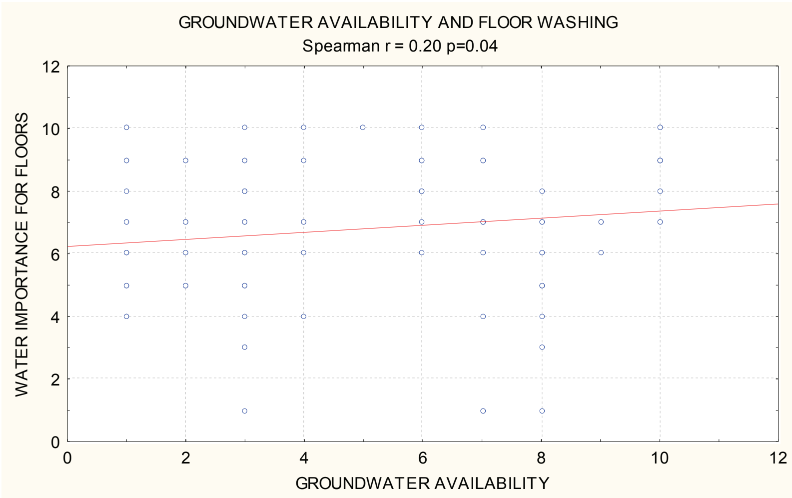

Figure 6.32: Analysis of water importance for floor washing and water availability

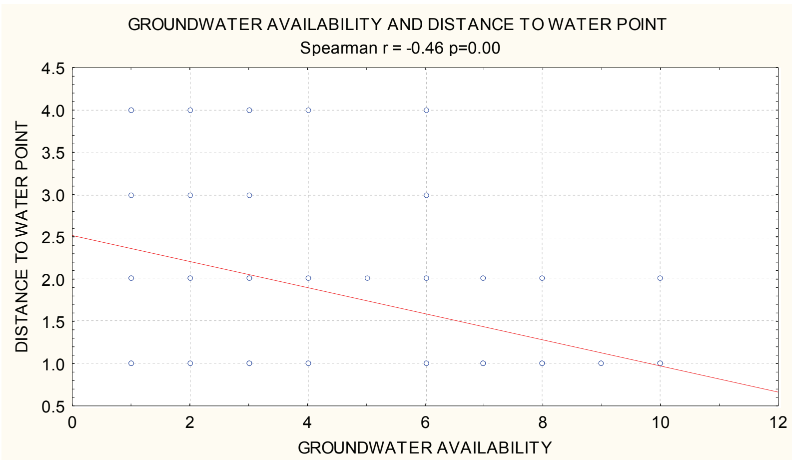

Figure 6.33: Analysis of distance to water point and water availability

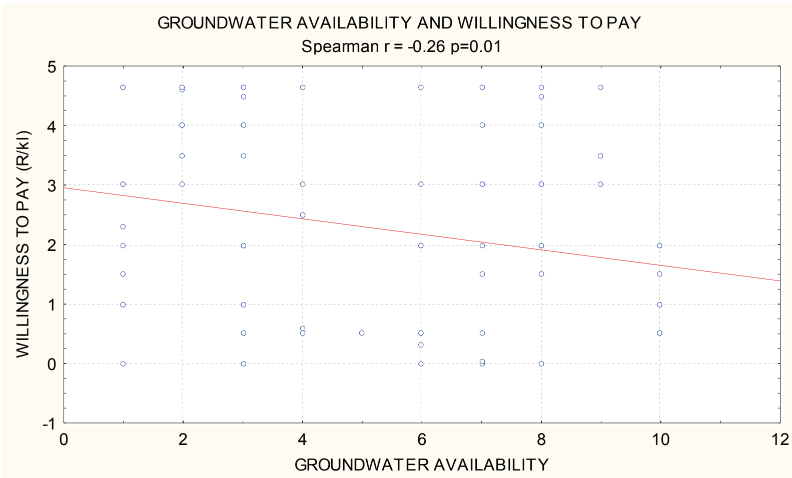

Figure 6.34: Analysis of willingness to pay and water availability

6.3.11.2 Groundwater quality

A rather strong positive correlation was observed to be significant between water quality and the importance of water for bathing, dish washing and cleaning floors (see Figures 6.35 to 6.37). Mashamba, Mohlajeng, Gaphago, and Leokaneng villages on average reported better water quality over the past five years. Sereni, Lemondokop, and Kanana villages remarked that that water quality had remained the same. Overall, the water quality in the entire study area was observed to have remained the same, being of potable quality. This observation resonates with results in DWAF Internal Strategic Perspective (2004).

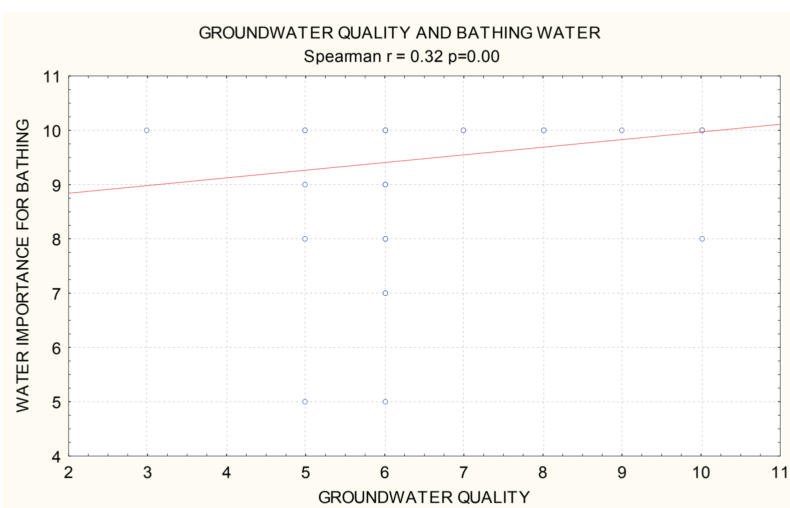

Figure 6.35: Analysis of water importance for bathing and water quality

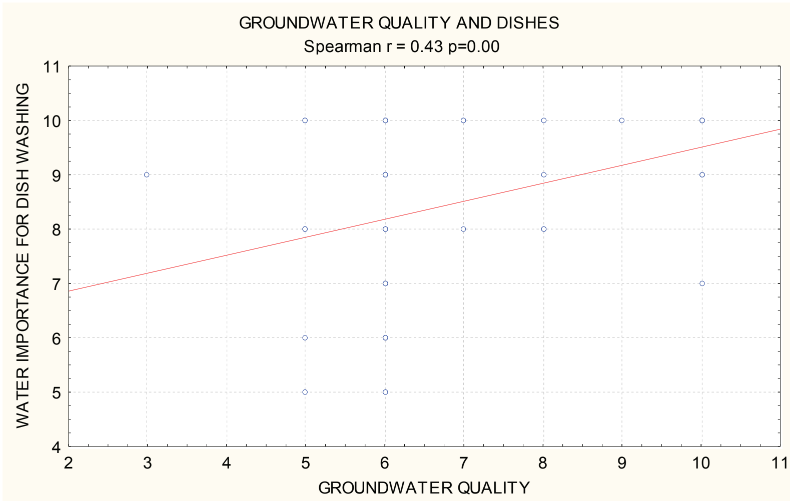

Figure 6.36: Analysis of water importance for dish washing and water quality

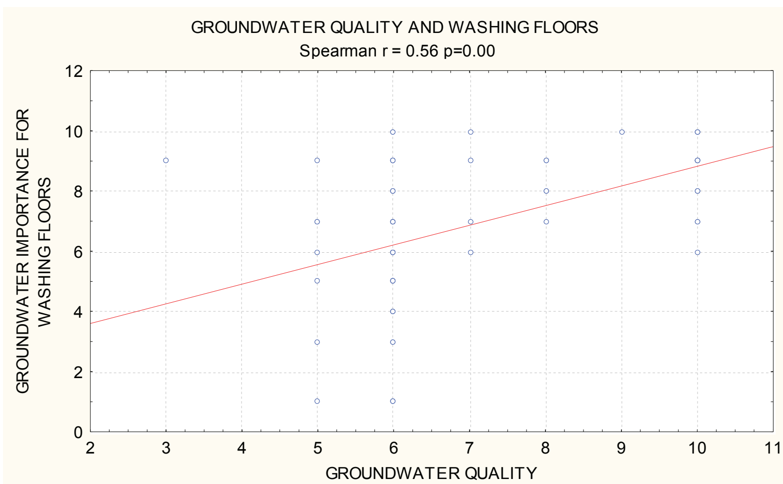

Figure 6.37: Analysis of water importance for washing floors and water quality

6.3.12 Importance of groundwater and priority to preserve groundwater[23]

A significant and very strong positive correlation was observed between the importance of groundwater and the priority of preserving groundwater resources (see Figure 6.38). This observation presumably revealed that households that viewed water to be of high importance also prioritised groundwater's preservation.

A positive correlation was also found between the importance of water for bathing and the importance of groundwater in general (see Figure 6.39). Bathing water was found to

[23] Scales of groundwater importance used were 1=Not very important, 2=Somewhat important, 3=Very important. Scales of groundwater preservation priority used were 1=Somewhat lesser importance and 2=Very top priority.

be among the most voluminous water uses; hence, naturally it commanded much importance from the observed households.

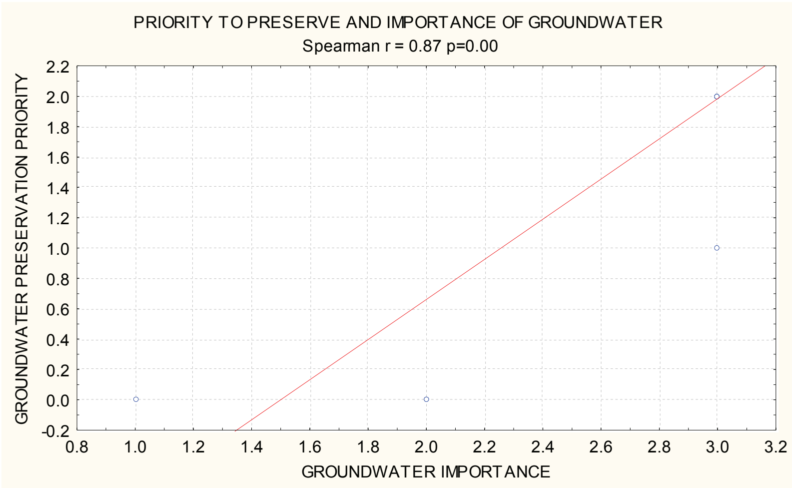

Figure 6.38: Analysis of preservation priority and importance of groundwater

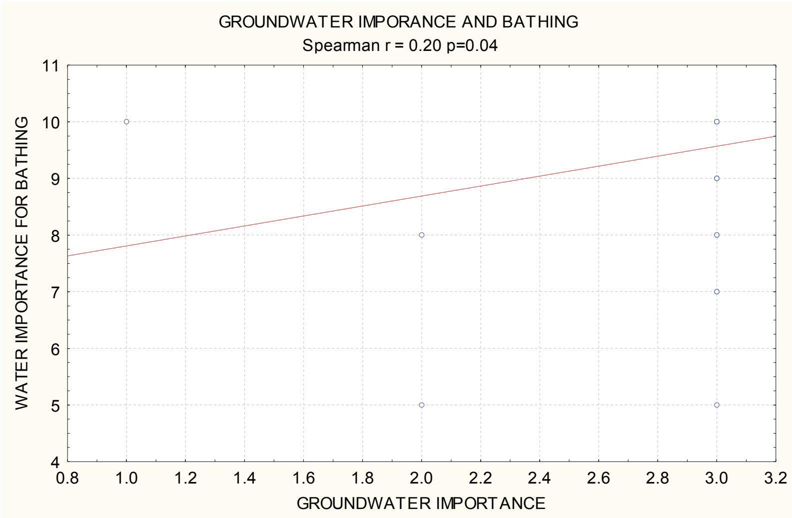

Figure 6.39: Analysis of water importance for bathing and groundwater importance

6.4 Summary

This study observed that most households were female headed (55%), and as such, any policy intervention in the area of groundwater should represent female headed households fairly in order to be more effective. Women constitute the majority of the unemployed, and their average monthly incomes were found to be lower than their male counterparts. In spite of this, women were found to be more involved in gardening. Hence, interventions that are women-oriented like irrigated garden projects would contribute to empowering women and improving food security in Limpopo.

It was observed that there was a correlation between education levels and being aware of the threat of groundwater abuse. A higher education level (also correlated with being employed) was also found to be correlated with valuing groundwater services like dish washing and laundry, probably because the more educated are more health conscious. This finding concurs with a finding that households with heads that are more educated use more water because they are better informed on the health benefits of using sufficient water by Nyong and Kanaraglou (1999) in a study in Katarko rural village (Nigeria). The elderly and the less educated valued dish washing, laundry, bathing and washing floors less than the younger respondents and the educated respectively. In this regard, awareness campaigns at household level should be undertaken to raise levels of awareness in order to protect groundwater resources and to inform villagers on the importance of groundwater services for them to appreciate the resource more.

Married people as well as bigger household units tended to value household water services more than the single and smaller units respectively. It therefore shows that household goals may be adversely affected in situations of water scarcity and as such, it is of high importance for groundwater to be made available satisfactorily at household level.

Higher income households were found to value water for car washing more than the poor. They were also found to consume more water per capita per month, and they prioritised preservation of groundwater less than the poorer households. Rising block tariffs are a sensible suggestion to address this scenario in order to protect the poorer, penalize the higher water consumers, and preserve groundwater resources.

The more water stressed villages were found to appreciate groundwater services more than the villages which were better endowed with groundwater resources. The more water stressed were also more aware of the threat of potential groundwater abuse than the less water stressed. The former have probably evolved to appreciate and value water more than their less water stressed counterparts. The former villages were also observed to travel greater distances on average to access water, and they were found to pay for their water, while those that got water nearer generally enjoyed free water. Borehole owners were found to travel shorter distances to get water than non-borehole owners. The less water stressed should be informed on the issue of groundwater importance, and more borehole exploration will help to reduce travel time and cost to get water. In general the more water stressed areas paid higher water tariffs than the less water stressed areas.

Borehole ownership was found to guarantee water availability, and owners generally did not buy water, except in instances of borehole breakdowns. Borehole owners also consumed more water per capita per month, which shows that they had access to more water per capita than non-borehole owners.

Table 6.9 represents the results of a local municipality (LM) water tariff survey conducted by DWAF (2006). All the tariffs are VAT inclusive. The survey focused on LMs as the lowest building block from where the national average tariffs were calculated according to three different methods: (i) The mathematical average adds the tariffs of all municipalities within each block and then divides the sum by the total number of municipalities. This represents the average tariff among the municipalities/institutions, regardless of their size. (ii) The population-weighted average considers the number of people affected within each LM and within each tariff block. This reflects the typical rates paid by a household for each block considering the fact that fewer use the higher blocks due to limited affordability. (iii) The volume-weighted average considers people and their service levels, thus representing the average value of 1kl of water used in each of the blocks.

Table 6.9: Domestic water tariffs - Limpopo provincial perspective

Perspective	Tariffs								
	6-20kl (incl. VAT)			20-60kl (incl. VAT)			>60kl (incl. VAT)		
	Avg R	Min R	Max R	Avg R	Min R	Max R	Avg R	Min R	Max R
Limpopo	3.51	1.55	6.16	3.93	1.61	6.93	5.24	3.00	8.97

Source: DWAF (2007)

In the surveys for this thesis households were found to be generally willing to pay for satisfactory groundwater supply and sanitation. The average village WTP was R2.28 per kilo-litre. In the villages Mashamba, Sereni, Lemondokop, Kanana, Mohlajeng, Gaphago, and Leokaneng the village average WTP was R2.32, R1.84, R2.67, R3.46, R2.20, R1.77, and R1.84 per kl respectively. This indicates that indeed rural households are willing to pay for a groundwater supply and sanitation of acceptable standards. Intervention to improve the water situation could therefore be self-sustaining relying on funds generated from reasonable tariffs. Respondents that were aware of the threat of groundwater abuse were willing to pay more than their unaware counterparts. The DWAF survey of Limpopo recorded a minimum tariff of R1.55/kl to a maximum of R6.16/kl for the first tariff block (after free basic water). The average WTP value of groundwater recorded in this thesis was R2.28/kl, which falls within the range of Limpopo tariffs for the first tariff block.

According to GWP's IWRM (2000) charging for groundwater is applying an economic instrument to affect behaviour towards conservation and efficient groundwater usage, to provide incentives for demand management, ensure cost recovery and to signal consumers' WTP for additional investments in groundwater services. The WTP value of rural local municipal groundwater determined using contingent valuation in this thesis is therefore well supported by DWAF standard groundwater charging calculations and stands as rational signal of consumers' WTP for additional investments in groundwater service provision. Rural households were generally found to be unresponsive to tariff change in the study area, probably due to the influence of exceptionally high groundwater prices on the informal market.

Water availability and quality were observed to be correlated in this study, in this regard; ensuring groundwater recharge could possibly maintain good water quality. As water availability improved, secondary water services such as laundry and cleaning floors emerged in importance after the primary uses like drinking and cooking had been satisfied. A negative correlation between water availability and travel distance to water and WTP was observed. The easier water is to access, the less people were willing to pay for it.

Water quality was found to be associated with groundwater service importance, the better the water quality the more the respondents appreciated its service use. In this regard, ensuring good water quality could keep people conscious of the importance of water. The importance of groundwater was found to be associated with prioritizing groundwater preservation and its use for bathing. Lower water availability was found to be associated with paying for water, while better availability was associated with free water. As such, groundwater availability has strong economic connotations in Limpopo.

This chapter addressed the three parts of the second hypothesis of this study – "Rural households are enjoying satisfactory groundwater supply and sanitation", "Rural households are willing to pay for improved groundwater supply and sanitation" and "Rural households' groundwater consumption can be significantly influenced by changing the water tariff". It also addressed the third hypothesis – "Rural groundwater has a utility value that can guide the formulation of domestic groundwater tariffs for water demand management". The significant socio-economic linkages that were observed to revolve around household use of groundwater in Limpopo were also highlighted.

CHAPTER 7

AGRICULTURE RESULTS AND DISCUSSION

7.1 Introduction

While 13% of South Africa's land can be used for crop production, only 22% of this is high-potential arable land. The most important limiting factor is water availability. Rainfall is distributed unevenly across the whole country, with most inland areas prone to drought. More than 50% of South Africa's water is used for irrigation agriculture, with about 1.3 million hectares under irrigation (South Africa Information, 2008).

Many farms use groundwater (artesian or bore), but while measuring water use is relatively easy, the monitoring thereof is bad and the quality of the data is weak. While water is a scarce commodity, it is forestry and irrigation agriculture that can do most to reduce the demand for water (Van Heerden et al., 2008).

The demand for water for crop irrigation has a number of important characteristics, such as season, location, and the quality requirements and effects. While natural stream flows usually fluctuate, the demand for irrigation water extends throughout the growing season. The quality of irrigation water can affect crop yields, for example, high salinity levels may preclude production of many crops other than salt tolerant ones. The water quality effects on irrigated agriculture are numerous, but probably the most important dimension of irrigation water demand is quantity (Gibbons, 1986).

7.2 Value of agricultural water

The decisions on water demand on a typical farm illustrate some of the basic principles of the demand for irrigation water (Gibbons, 1986). In this thesis the approach chosen to determine the shadow value of irrigation groundwater was to use typical whole farm budget data for tomato and table potato crops in the study area. These typical whole farm budgets were then incorporated into a linear programming (LP) model in order to determine the shadow value of irrigation groundwater. Typical whole farm budget information solicited from the different farmer group discussions was aggregated by crop type into typical whole farm budgets that represented typical tomato and table potato production in the study area. These typical whole farm crop budgets then provided the basis for the LP model. As suggested by Williams et al. (2008), the typical whole farm budgets were constructed on a per hectare basis and then scaled up to cover the respective typical farm sizes in hectares.

In each budget directly allocatable costs (associated with the production of the crop) were deducted from gross production value (GPV), namely items like plant material, fertilizer, sprays and chemicals, irrigation costs, harvesting costs and labour directly allocatable to the product, which determined the margin above specified costs. From margin above specified costs, general farm costs like depreciation, insurance, repairs and maintenance, administration costs, fuel and electricity, and others were deducted to determine net farm income (NFI). The reward to irrigation groundwater was calculated as the residual value that remained after all factors of production had been fairly remunerated at a predetermined rate. The LP model derived the shadow values of irrigation. This variable was the important parameter in determining the shadow value of irrigation groundwater, which was the core of this study. This same approach was used by Williams et al. (2008).

Typically farms in the study area practise monoculture in conjunction with annual arable-land rotation, this is done to prevent pest and disease build up in the fields. In a year when the land is not used to grow the typical crops, cucurbits (squash, pumpkin, cucumber, gourd, watermelon and cantaloupe family) are grown or the land is turned into leyland (land where grass grows) amongst various options depending on management decisions. In this study only the typical crops were studied, and while the rotational activities were found not to be typical (differing form farm to farm), only the hectrage under the typical crop was used to determine VMPs of irrigation groundwater.

7.3 Capital investment

From farmer group discussions and secondary data it was possible to draw up budgets of the capital investment on each typical crop farm. The Standard Bank (2005) and Boehlje and Eidman (1984) formed the important guidelines used during the capital investment analysis procedures in this thesis. The valuation of waterworks, buildings, kraals, dams, fences and other fixed improvements, as well as vehicles, machinery and equipment differs for periods of high inflation and periods of low inflation. In periods with low inflation, assets are valued at cost prices less accumulated depreciation. In periods with high inflation, assets are valued at replacement value less accumulated depreciation. Replacement value was used in this study.

7.3.1 Fixed improvements

Depreciation on fixed improvements is usually calculated on a straight-line basis according to the following formula:

Annual depreciation = (Replacement - Salvage values)/Expected lifetime *(Eqn. 7.1)*

The annual depreciation will therefore be the same for every year of the expected lifetime of the asset. Accumulated depreciation is equal to the annual depreciation multiplied by the age of the fixed assets. Half-life was assumed to be the current age of all fixed improvements. The half life depreciated replacement value of fixed improvements was used to calculate the investment in fixed improvements in this thesis.

7.3.2 Moveable assets

The declining balance method is generally used to calculate depreciation on purchased vehicles, machinery and equipment (moveable assets). A fixed percentage of the asset’s value is written off each year, which means that the asset is depreciated more rapidly during the beginning years, as is often the case in practice. The half life depreciated replacement value of moveable assets was used to calculate the investment in moveable assets. Table 7.1 shows the declining balance rates used to calculate depreciation; Archer et al. (2008) was consulted for expected lifespan of moveable assets. Before the depreciation was calculated, the depreciation rates were first calculated by means of the following formula (The Standard Bank, 2005):

Annual rate of depreciation = 200/Expected lifetime *(Eqn. 7.2)*

Table 7.1: Rates of depreciation using the declining balance method and expected lifespan of moveable assets

Asset	Rate (%)	Lifespan (years)	Half life (years)
Bakkies	25	8	4
Trucks (lorries)	20	10	5
Tractors	17	12	6
Forklifts	17	12	6
Trailers	10	20	10
Implements (except ridgers)	20	10	5
Ridgers	14	14	7
Fertilizer spreaders	25	8	4
Gypsum spreaders	25	8	4
Boom sprayers	20	10	5
Potato sorters	20	10	5
Power generators	10	20	10
Electric cables	20	10	5
Center pivots	8	25	12.5
Mother lines	13	16	8
Branch lines	13	16	8
Pipes (laterals)	25	8	4
Centrifugal pumps	13	16	8
Booster pumps	13	16	8
Irrigation engines	13	16	8

A summary of the capital investment in a typical tomato and table potato farm in Mooketsi and Polokwane farming areas respectively is given in Table 7.2.

Table 7.2: Capital investment of a typical tomato and table potato farm in Mooketsi and Polokwane farming areas respectively (July 2008)

Capital investment	Tomato (R)	Table potato (R)
Land	**1 280 000.00**	**1 600 000.00**
Fixed improvements:		
Management housing	646 250.00	-
Worker housing	446 050.00	33 000.00
General farm buildings	2 263 839.50	1 372 800.00
Fencing	110 850.00	-
Total	**3 466 989.50**	**1 405 800.00**
Moveable assets:		
Vehicles	348 160.00	229 376.00
Tractors	490 410.00	216 137.00
Machinery	472 346.00	946 175.81
Total	**1 310 916.00**	**1 458 448.33**

Fixed and non-allocatable costs of typical tomato and table potato farms in Mooketsi and Polokwane areas respectively is given in Table 7.3. The annual fixed costs on fixed improvements included repairs and maintenance (R&M) and insurance, charged at 1% and 0.6% per annum respectively. Annual costs on moveable assets included insurance costs and housing and maintenance facility costs charged at 0.6% and 2% respectively. The interest cost of capital was calculated at an interest rate of 10%, which reflected the status quo in South Africa at the time of study (July 2008). All depreciation and asset current values were calculated as at the half life age.

Table 7.3: Fixed and other non-allocatable cost items of typical tomato and table potato farms in Mooketsi and Polokwane areas respectively (July 2008)

Fixed and non-allocatable costs per annum	**Tomato (R)**	**Table potato (R)**
Interest:		
Land	128 000.00	160 000.00
Fixed improvements	346 698.95	140 580.00
Moveable assets	248 039.48	389 620.64
Working capital (10% of half of TVC)	7 031.85	3 508.85
Depreciation:		
Fixed improvements	158 480.70	115 020.00
Moveable assets	245 278.92	311 339.81
General:		
Annual costs on fixed improvements	77 698.24	34 734.17
Annual costs on moveable assets	100 945.35	91 138.23
Entrepreneurial salary	700 000.00	700 000.00
Permanent worker salary	327 309.00	84 000.00
Electricity (not directly allocatable)	21 664.00	15 000.00
Administration	50 720.00	45 000.00
Tractor (not directly allocatable)	5 192.00	2 500.00
Rent inter company	24 780.00	-
R&M of vehicles, machinery and equipment	144 488.00	68 330.00
R&M of troughs and cripps	833.33	1 500.00
Water tax	12 000.00	5 000.00
R&M of fences	4 000.00	3 333.00
Banking costs	40 000.00	29 000.00
Phone	8 000.00	13 000.00
Fuel (not directly allocatable)	240 000.00	189 500.00
Other non-allocatable costs	36 490.80	11 443.10
Total	**2 927 650.62**	**2 413 547.80**

7.4 Compiling typical whole farm crop budgets

When estimating the value of water which is subject to a derived demand, farm crop budgets are an essential building block as they can be used to estimate the maximum revenue share of the water input to the production process. The total revenue derived from crops less non-water related input costs represents the maximum amount the farmer could pay for water and still cover costs of production. As such, it represents the value of water at the current usage level (Williams et al., 2008).

As mentioned earlier, typical farm budgets were derived from farm budget information solicited from the farmer group discussions. Tables 7.4 and 7.5 present summaries of the tomato and table potato typical farm budgets that formed the data set supplied to the LP model that was used in determining the VMP of irrigation groundwater in this study.

The values of irrigation groundwater determined in this study represent its at-site VMP (value of marginal product associated with irrigation groundwater for a crop on a unit land area). This is the value used in irrigation investment evaluations in order to allocate water to its most economically efficient agricultural use. For the at-source (raw water) value, the delivery costs of moving water from the source to the site of use (crop field) must be deducted. It follows therefore that groundwater has a higher VMP at-site than at-source.

The LP model used in this research made use of the information furnished in Tables 7.2, 7.3, 7.4 and 7.5. Deductions were made on the GPV to get the margin above specified costs. The reward to irrigation groundwater was calculated as the residual value that remained after all factors of production had been fairly remunerated at a predetermined rate. The LP model derived the shadow values of irrigation groundwater.

Table 7.4: Margin above specified costs for a typical tomato farm in Mooketsi faming area (July 2008)

Item	Per hectare
Return over variable costs:	
Typical production scale (ha)	60
Projected yield (kg/ha)	88 333.00
Projected price (R/kg)	2.89
Gross production value (R)	254 988.89
Directly allocatable costs:	**(R)**
Land/soil preparation	2 094.00
Plant material/seed	6 526.00
Fertilizers	15 000.00
Pesticides	7 105.00
Herbicides	227.00
Disease control	766.81
Fungicides	3 450.07
Other chemicals	5 000.00
Consultation/research fees	65.00
Contract labour	19 000.00
Fuel	973.00
Hired transport	14 916.00
Insurance and licence	237.00
Marketing costs	12 824.00
Packaging	17 759.03
Repair and maintenance (e.g. trellis)	172.00
Tyre costs	0.10
Trellis (fruit)	3 154.00
Irrigation system (surface)	201.00
Irrigation system (subsurface)	63.00
Irrigation electricity	12 000.00
Tractor (other costs)	6 072.00
Twine	2 400.00
Harvesting	10 500.00
Other allocatable costs	132.00
Total directly allocatable costs	**140 637.01**
Margin above specified costs	**114 351.88**

Table 7.5: Margin above specified costs for a typical table potato farm in Polokwane farming area (July 2008)

Item	**Per hectare**
Return over variable costs	
Typical production scale (ha)	50
Projected yield/ha (kg)	50 000.00
Projected price/kg (R)	2.11
Gross production value (R)	105 350.00
Directly allocatable costs:	**(R)**
Land/soil preparation	3 400.00
Plant material/seed	6 088.38
Fertilizers	7 829.11
Pesticides	380.31
Herbicides	866.05
Disease control	2 584.47
Fungicides	1 350.07
Chemicals (If above 4 not divisible)	3 238.00
Consultation/research fees	65.00
Contract labour	4 420.00
Wages and salaries	2 959.00
Fuel	3 209.00
Hired transport	11 320.29
Insurance and licence	257.11
Marketing costs	1 800.00
Packaging	2 160.00
Repair and maintenance	1 389.90
Tyre costs	0.32
Irrigation system (surface)	189.00
Irrigation system (subsurface)	77.00
Irrigation electricity, water and maintenance	3 762.00
Tractor (other costs)	5 032.00
Harvesting	7 700.00
Other allocatable costs	100.00
Total directly allocatable costs	**70 177.00**
Margin above specified costs	**35 172.99**

7.5 Linear programming for the shadow value of irrigation groundwater

The farm enterprise budget combined with LP is the most favoured approach in valuing agricultural water (Nieuwoudt et al., 2004), and LP can be used to estimate the marginal values of irrigation groundwater on a typical farm. Generally speaking, LP approaches will be found where it is possible to put forward a multi-crop typical farm where different crops have differing water-use efficiencies and crop substitution is feasible. However, it is also possible, as in this thesis, to use the technique with single crop farms. A programming model of a typical farm situation is usually specified to maximise net return to the residual claimant (the irrigation groundwater resource) subject to constraints on irrigation groundwater and other farm resources (Burt, 1964; Bowen and Young, 1986; Bernardo et al., 1987; Chaudhry and Young, 1989).

7.6 A parametric approach in linear programming

An implicit assumption of the LP model used in this thesis was that irrigation groundwater was being used optimally. This implicit assumption was arrived at using primary and secondary observations concerning groundwater use in the study area. An irrigation groundwater constraint was included in the LP model. The LP model did not vary the water constraint level, so ideally the entire LP analysis was conducted at an optimal groundwater application rate per hectare. The farming system in the study area was not diversified; therefore a simplistic single commodity farm LP model was developed. As a result of the above mentioned factors that otherwise could have deducted from the essence of the LP modelling, a parametric approach to LP was adopted in this thesis in order to make the LP results dynamic and more informative for groundwater management policy analysis. The advantage of using parametric LP was that uncertainty was incorporated in the LP model to see the effect of different producer prices and yield levels due to uncertainty. Another advantageous feature of incorporating a parametric approach in LP was the ability to find the mapping of the optimal solution on the space of the parameters in a computationally efficient manner (Pistikopoulos et al., 2007). This method gives results that are more practical and that apply to real world agriculture.

The matrix for the parametric approach is the same as for LP. The only difference is that one or more parameters in the matrix are allowed to vary. The technique is therefore referred to alternatively as variable resource or variable price programming. In the former, one or more of the constraints are allowed to vary, so that a series of optimum plans is produced over a range of say, farm areas or capital availability (Barnard and Nix, 1979). In this thesis crop yield level was the variable resource in tomato and table potato production. In the latter, one or more of the prices are allowed to vary so that similarly a series of optimal plans is provided for a range of prices for one or more products (Barnard and Nix, 1979). This thesis also conducted variable price programming for the two respective crops. In the parametric approach the level of the variable is altered continuously over a complete range (Barnard and Nix, 1979).

One-price variable programming was conducted for tomato and table potato crops respectively. The price of one product was varied over a given range. It was necessary to have a separate production-harvesting activity and a separate selling activity for the product (say tomato) because it was not enough to have a single combined 'produce and sell' activity. First the optimum plan at the average price in the required range was computed. Subsequently, critical price levels at which the optimum plan changed were calculated, and the objective function values and VMPs for irrigation groundwater were derived for these price levels. By this means a series of tomato and table potato price ranges were obtained, at each of which a given production plan of the respective crop remained optimal. Beyond each critical price level the optimal crop irrigation groundwater shadow value increases. This is depicted in Figures 7.1 and 7.3 for typical tomato and table potato crops respectively. The lines drawn between any two adjacent producer price points are straight because of the linearity assumption. The positive slope denotes rising marginal value products of irrigation groundwater as crop producer prices per hectare increase.

In addition to one-price variable programming, variable yield programming was also conducted where the crop yields per hectare were varied. During variable yield programming for each level of crop yield, an optimum plan was obtained (Barnard and Nix, 1979). This was repeated until the VMP of irrigation groundwater exceeded acceptable norms (see Section 7.7) in one variable change direction, and in another direction until the VMP of irrigation groundwater became zero, indicating that irrigation groundwater had become surplus to the availability of other resources. Intermediate plans were found from plotting the resulting 'key' plans as shown in Figure 7.2 and 7.4 for typical tomato and table potato crops respectively. The lines drawn between any two adjacent key points, where the crop yield levels change, are straight because of the linearity assumption. The positive slope in this case also denotes rising VMPs of irrigation groundwater as crop yields per hectare increased.

An assumption made during the variable yield programming was that TVC would invariably vary with variation in yield levels. In typical tomato and table potato farming, the TVC per kg of yield was calculated to be R1.59 and R1.40 respectively. It follows therefore that in the parametric LP model, the coefficient of the activity of production and harvesting for each crop changed as yield levels changed, in order to realistically represent what is observed in practical agriculture.

When using the concept of VMP of irrigation groundwater to determine its economic value in agriculture, there is no 'single' derived shadow value for irrigation groundwater per se. The shadow value will vary from crop to crop and it will also vary at different constraint levels of the production activities for a single crop. This is the basis for using a parametric approach in the determination of the shadow value of irrigation groundwater in this study. The table potato and tomato shadow values derived where found to be different, naturally as a result of the totally different production processes between the two crops. In addition, for each crop producer price (R per kg) and yield (kg per ha) were found to be important parameters that influenced the shadow value of irrigation groundwater. Shadow value of irrigation groundwater was observed to rise with rising producer prices and rising yields. This observation supports the argument that irrigation groundwater should be allocated efficiently to its highest value uses. When the VMP of irrigation groundwater is high, it implies that the opportunity cost of foregoing that choice is also high, and a higher VMP justifies the allocation of precious irrigation groundwater more than situations having a lower VMP of irrigation groundwater.

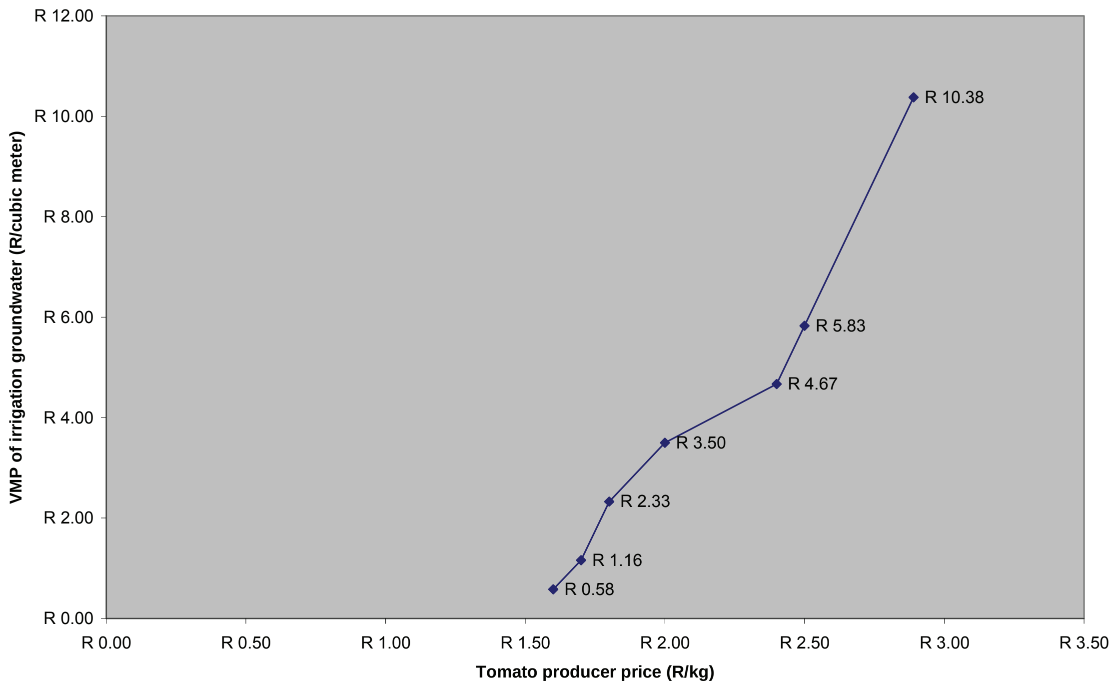

Figure 7.1: VMP of irrigation groundwater vs. producer price for a typical tomato farm in Mooketsi area (at a constant yield of 70 000kg/ha) July 2008

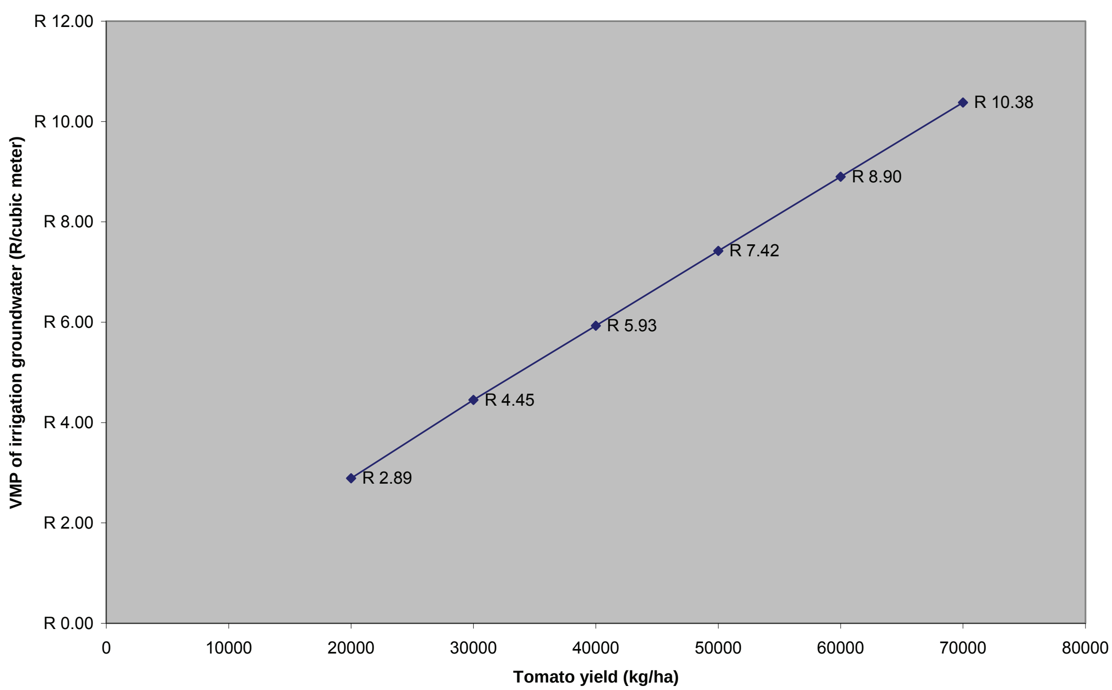

Figure 7.2: VMP of irrigation groundwater vs. yield per hectare in a typical tomato farm in Mooketsi area (at a constant price of R2.89/kg) July 2008

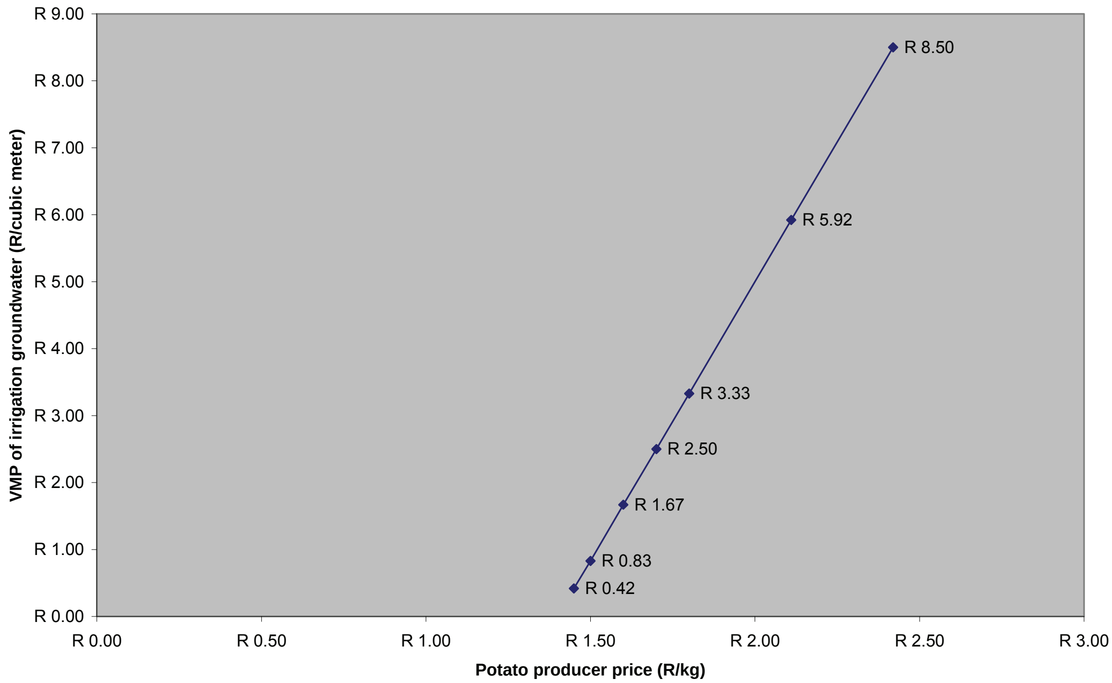

Figure 7.3: VMP of irrigation groundwater vs. producer price for a typical table potato farm in Polokwane area (at a constant yield of 50 000kg/ha) July 2008

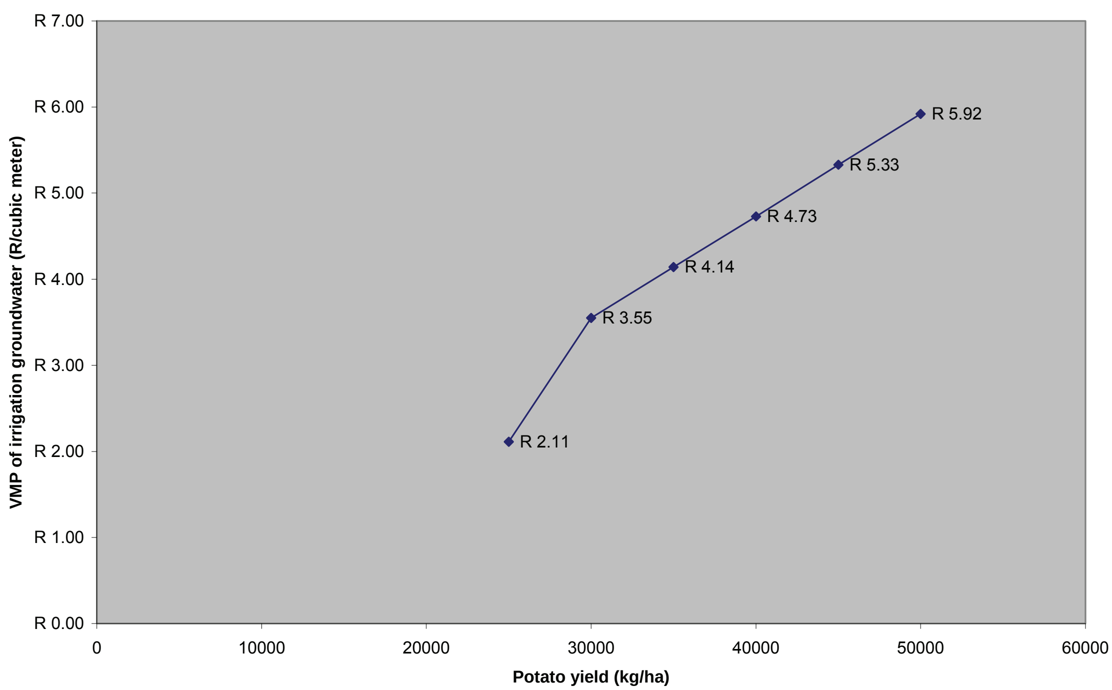

Figure 7.4: VMP of irrigation groundwater vs. yield per hectare in a typical table potato farm in Polokwane area (at a constant price of R2.11/kg) July 2008

The detail given in Tables 7.6 constitutes a summary of Figures 7.1 to 7.4; it presents the results of the LP model used in this thesis. The 'variable' column represents the parametric element of the LP, where prices and yields were varied for tomato and table potato production respectively. The 'constant' column shows the parameter that was held constant in that particular parametric LP analysis. The dual price represents the shadow value (VMP) of irrigation groundwater per cubic meter per annum. The last column represents the value of the objective function which is the reward to irrigation groundwater in this model. When the objective function value is negative, it reflects that the typical producer may produce at that constraint level in the short-run, but he may not be able to produce in the long-run. A negative objective function value means that the farmer can cover the TVC, but may not be able to cover the total costs of production. A positive objective function value shows that the farmer is able to cover his total costs at that level of production.

7.7 Other water valuation research in South Africa

In this thesis the VMP of water was specifically for groundwater, the VMP shown below are for surface water but they were included to give a general guide of the magnitudes of VMP of water as an economic good. Williams et al. (2008) used enterprise budgets and linear programming, or enterprise budgets with crop water production functions for derived demand in agriculture to simulate water demand curves in the Greater Letaba area. The water demand schedule was derived by regarding the whole study area as a single farm containing five crops under consideration, in the proportions in which they were found to be present. The VMP of water was seen to vary from R0.50/m^3 to some R2.50/m^3. Conradie (2002) constructed LP models for 16 model type farms in Fish-Sundays River Scheme, marginal value for water ranged between R0.0003/m^3 and R0.2115/m^3.

Hosking et al. (2002) reported that water rights in the Sundays River trade for about R0.22/m^3. Louw (2002) developed a positive mathematical programming model to study the impacts of water markets in the Berg River basin and the capitalized marginal value of water differed from as low as R0 to as high as R20.00/m^3 within the sub-sectors of the basin. Bate et al. (1999) studied the trading of water in the Crocodile River basin and observed a capitalized value of water between R0.18/m^3 and R0.22/m^3 (Nieuwoudt et al., 2004). Selected agricultural WTP capital estimates calculated by various researchers in South Africa for water in Rands at 2000 price levels include: Backeberg (1996) – Vaalharts Scheme at R1.60/m^3; Armitage (1999) – Lower Orange River at R0.28/m^3; and Engelbrecht (2001) – Sundays River and Fish Rivers at R0.22/m^3 and R0.148/m^3 respectively (Hoskings and Du Preez, 2004).

Table 7.6: Linear programming shadow values of groundwater in typical tomato and table potato farms in Mooketsi and Polokwane areas respectively (2008)

Crop	Variable	Constant	VMP (R/m^3/a)	Reward to groundwater (R/a)
Tomato	R2.89/kg	70 000kg/ha	10.38	689 746.50
Tomato	R2.50/kg	70 000kg/ha	5.83	-948 253.50
Tomato	R2.40/kg	70 000kg/ha	4.67	-1 368 257.00
Tomato	R2.00/kg	70 000kg/ha	3.50	-1 788 254.00
Tomato	R1.80/kg	70 000kg/ha	2.33	-2 208 254.00
Tomato	R1.70/kg	70 000kg/ha	1.16	-2 628 254.00
Tomato	R1.60/kg	70 000kg/ha	0.58	-2 838 254.00
Tomato	70 000kg/ha	R2.89/kg	10.38	689 746.50
Tomato	60 000kg/ha	R2.89/kg	8.90	155 746.50
Tomato	50 000kg/ha	R2.89/kg	7.42	-378 253.50
Tomato	40 000kg/ha	R2.89/kg	5.93	-912 253.50
Tomato	30 000kg/ha	R2.89/kg	4.45	-1 446 254.00
Tomato	20 000kg/ha	R2.89/kg	2.89	-1 980 254.00
Table potato	R2.42/kg	50 000kg/ha	8.50	628 932.20
Table potato	R2.11/kg	50 000kg/ha	5.92	-146 067.70
Table potato	R1.80/kg	50 000kg/ha	3.33	-921 067.80
Table potato	R1.70/kg	50 000kg/ha	2.50	-1 171 068.00
Table potato	R1.60/kg	50 000kg/ha	1.67	-1 421 068.00
Table potato	R1.50/kg	50 000kg/ha	0.83	-1 671 068.00
Table potato	R1.45/kg	50 000kg/ha	0.42	-1 796 068.00
Table potato	50 000kg/ha	R2.11/kg	5.92	-146 067.70
Table potato	45 000kg/ha	R2.11/kg	5.33	-323 567.70
Table potato	40 000kg/ha	R2.11/kg	4.73	-501 067.70
Table potato	35 000kg/ha	R2.11/kg	4.14	-678 567.80
Table potato	30 000kg/ha	R2.11/kg	3.55	-856 067.80
Table potato	25 000kg/ha	R2.11/kg	2.11	-1 033 568.00

It can be observed that quite a number of the water valuation researches for surface water obtained VMP results for surface water that were less than R1.00/m^3. However, a deviation from this below R1.00/m^3 ballpark is observed in other research work such as findings by Williams et al. (2008), Louw (2002), and Backeberg (1996) that all got VMPs that were higher than R1.00/m^3.

The results obtained in the valuation of surface water in other research work may generally be comparable to the VMPs for irrigation groundwater in this thesis at lower producer prices and yield levels per hectare. As these two parameters are raised, the results found in this thesis tend to concur with the results showing a higher VMP of water such as those found by Louw (2002) in a study of the impacts of water markets in the Berg River basin and with the results of Williams et al. (2008) in a study of the value of water in the Greater Letaba area of Limpopo. The VMPs of groundwater determined in this thesis could thus arguably serve as an acceptable guide for tariff estimation for agricultural groundwater. As stated in the literature review, shadow values should be used as a guide for the value of groundwater during tariff determination because of the limited role played by market forces in the allocation of groundwater. Market prices upon which to base groundwater-related resource allocation decisions are seldom available (Young, 1996).

7.8 Summary

This chapter sought to address the fourth hypothesis – "Irrigation groundwater has a shadow value that can guide the formulation of agricultural groundwater tariffs for water demand management", and the fifth hypothesis "Higher crop prices and yields imply higher shadow values of groundwater and lower crop prices and yields imply lower shadow values of groundwater in agriculture". The literature reviewed gave support and encouragement for proceeding with the use of LP to determine the shadow value of irrigation groundwater in typical tomato and table potato farms. Following the modelling approach outlined in the agricultural methodology section of this study, it proved possible to derive the reward to irrigation groundwater and shadow value of irrigation groundwater using parametric LP. The shadow value of irrigation groundwater was found to vary as a result of producer price changes and yield level changes that are usually encountered in everyday agricultural production. The results displayed in Table 7.6 led to the acceptance of the fourth and fifth hypotheses – "Irrigation groundwater has a shadow value that can guide the formulation of agricultural groundwater tariffs for water demand management" and "Higher crop prices and yields imply higher shadow values of groundwater and lower crop prices and yields imply lower shadow values of groundwater in agriculture".

In typical tomato production, the shadow value of irrigation groundwater was found to range from R0.58 to R10.38 per m^3/annum for producer price changes from R1.60/kg to R2.89/kg, and from R2.89 to R10.38 per m^3/annum for yield changes from 20 000kg/ha to 70 000kg/ha. In typical table potato production, the shadow value of irrigation groundwater was found to range from R0.42 to R8.50 per m^3/annum for producer price changes from R1.45/kg to R2.42/kg, and from R2.11 to R5.92 per m^3/annum for yield changes from 25 000kg/ha to 50 000kg/ha.

The value of an additional unit of irrigation groundwater can be expressed by the VMP. The VMP is critical in utilising the groundwater resources in an economically efficient manner. For instance reallocation of irrigation groundwater use will promote society's income if groundwater has greater efficiency of use (VMP) in one area than in another.

The results of the parametric LP were found to be generally comparable to those of previous researches on surface water valuation at lower levels of the variable parameters (see Section 7.7). However, it should be noted that low price and yield levels can only be sustained in the short-run because the farmer cannot cover total costs, at higher price and yield levels, the farmer can make a profit and therefore long-term policy considerations for agricultural groundwater valuation should only consider the higher VMP values, at which the objective function value is positive. At parametric levels when the farmer makes a profit (which is the goal of most rational farmers), the VMPs calculated in this thesis are generally higher than those of most water valuation research.

As the magnitude of the variable parameters rose, the VMPs of irrigation groundwater only became comparable to those obtained by Louw (2002) in the Berg River Basin, and to a lesser extent those obtained by Williams et al. (2008) in the Greater Letaba area. The parametric LP model was successful in determining the shadow value of irrigation groundwater applied in typical tomato and table potato production in the study area. A noteworthy point in this field is that in the real world crop producer prices and crop yields are not static, but are quite dynamic being susceptible to everyday vagaries due to a plethora of factors like market forces, institutional conditions, biological factors, natural disasters and managerial capacity amongst others.

The shadow value of irrigation groundwater will inevitably change due to variability in pricing and output parameters in practical agriculture and it is therefore important for agricultural economists to determine irrigation groundwater shadow values that cater for parametric change. Calculating a single (static) VMP for irrigation groundwater does not furnish sufficient information to policy-makers as to how a situational change will impact on determined shadow values. Effective groundwater management policy should be able to forecast and predetermine the effects due to dynamics that are inherent in practical everyday agricultural production.

CHAPTER 8

GENERAL CONCLUSIONS AND POLICY IMPLICATIONS

This study has offered critical and detailed information that can be used to address current groundwater resource management problems faced by policy-makers and decision-makers. Groundwater policy could be either supply or demand oriented but this thesis has stated from the onset that supply-side groundwater management strategies perform unsatisfactorily in addressing current efficiency and equity driven objectives. The observed quantity and quality of groundwater in the study area showed that the resource is indeed suitable for responsible abstraction, and the only way to preserve this precious resource in this desirable state is by enacting economically and socially sound demand management policies, more so in the wake of ever increasing groundwater demand pressures.

Water supply management capabilities for expanding the water supply by means of dams, diversion projects, or extraction from aquifers may have been nearly exceeded yet demand management policies such as valuation and pricing strategies are still under-utilized in many parts of the world. WDM comprises a variety of measures and instruments which enable water managers to control the demand for water – yet most countries focus only on one or two aspects. A few countries in southern Africa have multifaceted WDM strategies. It should be clear that the problems of groundwater demand management problems are complex in nature and the only way to address them is by making use of multifaceted approaches that combine groundwater valuation strategies with pricing strategies to achieve effective WDM.

It should be noted that value and charges (tariffs) are two different things; concern has been voiced over the social consequences of "the economic good" concept: How would this affect poor people's access to groundwater especially after it has emerged that some of the world's poorest people are paying some of the world's highest prices for water. Such poor coverage of water supply and sanitation (WSS) was also observed in this study. To avoid confusion over this concept there is need to distinguish clearly between valuing and charging for groundwater. The value of groundwater in alternative uses is important for the rational allocation of groundwater as a scarce resource (using the "opportunity cost" concept), whether by regulatory or economic means. On the other hand, charging for groundwater is applying an economic instrument to affect behaviour towards conservation and efficient groundwater usage, to provide incentives for demand management, ensure cost recovery and to signal consumers' WTP for additional investments in groundwater WSS services.

Rural households were generally found to be unresponsive to tariff change in the study area, probably due to the influence of exceptionally high groundwater prices on the informal market. Households generally consumed groundwater at the RDP level, and seemed satisfied to maintain this recommended minimum water allowance. This unresponsiveness of consumption patterns to tariff change should not be capitalized upon, but rural households should be protected via targeted pricing policy.

It has been observed that when there is no water to expand water supply and sanitation systems, the first to suffer are the poor who live in rural areas, informal settlements and slums. Because these communities are often unconnected to water systems, they find themselves obliged to pay high unit prices for trucked water, and to make do with lower and insufficient water quantities of uncertain quality. A revelation made in this thesis is that groundwater is crucial for both production and domestic uses in rural households, and rural households are indeed willing to pay for improved groundwater supply and sanitation at tariffs that are much in line with DWAF charges, which also apply to urban water users. This shows that the utility value of domestic groundwater in rural areas is quite comparable to the utility value in urban areas.

The magnitude of the WTP signal that rural households gave undoubtedly allows cost recovery for the supply authority in just as much the same way as urban households' signal would, and as such, nothing stands in the way of providing improved groundwater supply and sanitation to rural households in Limpopo. At present the rural households are not enjoying satisfactory groundwater supply and sanitation and yet are paying tariffs that are extremely exorbitant by DWAF standards. Rural WDM measures must confront actual water use practices on the ground, and not be restricted to formal water sector organizations and official institutions which are often inaccessible to the poor. In rural areas the level of poverty was found to be quite high, therefore WDM should be identified and placed in the context of rural development strategies and not in the direction of “the economic good” concept.

Groundwater has a value as an economic good; many past failures in groundwater demand management are attributable to the fact that groundwater has been and is still viewed as a free good, or at least that the economical value of groundwater has not been recognized. In a situation of competition for scarce groundwater resources, such a notion may lead to groundwater being allocated to low-value uses and provides no incentives to treat groundwater as a limited asset. In order to extract the maximum benefits from the available groundwater resources there is a need to change perceptions about groundwater values and to recognize the opportunity costs involved in current allocative patterns. The marginal value is critical in utilising the groundwater resources in an economically efficient manner. For instance reallocation of use will promote society’s income if irrigation groundwater has greater economic efficiency of use (VMP) in one area than in another.

Irrigation agriculture accounts for 62% of water use in South Africa. Although there are areas where water use is highly efficient, there are significant losses in many distribution and irrigation systems, whilst substantial improvements can be achieved in others. Efficiency gains in the irrigation sector will make much groundwater available for other uses like the ecological reserve. In the wake of irrigation groundwater intra and inter-sectoral competition rising, it is of monumental importance for policy-makers to use the shadow value of irrigation groundwater as a signal of the opportunity cost of alternative use. WDM measures in irrigated agriculture can also improve efficiency of groundwater distribution systems and the efficiency of farm groundwater use. The groundwater saved can increase the delivery of groundwater for other uses like rural WSS, urban WSS, industry, and the environment amongst others, without requiring new groundwater supply.

Policy-makers should allocate groundwater to its most productive uses after evaluating sector determined shadow values of groundwater use, such as the shadow values calculated for irrigation groundwater in this thesis. Also recommended in this thesis is the need for a sensitivity analysis when determining irrigation shadow values. It goes without say that dynamic policy recommendation that takes into cognizance parametric changes will yield more robust groundwater demand management results than static recommendations that try (in vain) to a give utopian solutions. Rational allocation of groundwater as a scarce resource (using the "opportunity cost" concept), by economic means will be enhanced if water authorities can predict the implications on the marginal value of irrigation groundwater that are brought about by producer price changes and/or yield level changes amongst other agricultural parameters. WDM valuation and pricing methods should take on a multi-faceted and dynamic approach, where variables are assessed in a holistic fashion (not individually) if societal well being is to be enhanced.

Economic valuation and correct pricing are helpful measures in identifying opportunities to increase irrigation groundwater net value and designing policies that encourage farmers and water authorities to improve social net benefits (wellbeing). Therefore it is necessary to face farmers with the real economic value of groundwater depending on the prevailing parametric situation. It means appropriate economic values of irrigation groundwater for different crops should be taken into account, so that precious groundwater will be used for the most profitable crops. The most important management implication of this study is the reallocation of groundwater among user sectors in the Limpopo region. A multifaceted approach balances economic efficiency and social equity considerations for the net benefit of society.

Policy-makers need to take note of caveats such as food security, poverty alleviation, catering for the disadvantaged and the poor members of society amongst other extrinsic considerations when valuation and pricing methods for groundwater are incepted, so as to enhance the wellbeing of society. This can be done by taking insightful information on the economic value of groundwater in domestic and agricultural uses such as that proffered in this thesis, and using it to develop targeted WDM strategies in South Africa.

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APPENDICES

Appendix 1: Household questionnaire

QUESTIONNAIRE FOR GROUNDWATER-USE-INFORMATION ELICITATION IN LIMPOPO PROVINCE HOUSEHOLDS

Hello, I'm ………………………………. of Stellenbosch University in Western Cape. We are talking to a cross-section of households in the Limpopo and Luvuvhu/Letaba Water Management Areas about how much **groundwater** benefits are worth to them. The study is specific to groundwater, so I will begin by asking you:

What is the main source of your household water?

Ground	Surface	Don't know

If it is groundwater, proceed with the interview.

If it is surface water, thank them for their time and discontinue the interview.

If they do not know, the interviewer should make observations to verify the main water source. If there is evidence that shows it to be groundwater, continue the survey. But if it is surface water, thank them for the time and discontinue the survey.

Your views will be used to help policy makers make informed decisions.

First let me begin by saying that most of the questions have to do with **your** attitudes and opinions, and there are no right or wrong answers.

This interview is completely confidential; your name will never be associated with your answers.

I hereby certify that this is an honest interview taken in accordance with my academic needs only.

………………………………… ………………………..
Interviewer's Signature Date

Section A: Respondent and Household Information:

Household address ……………………………
……………………………
……………………………

Post Code ……………………………

Local Municipality ……………………………

District Municipality ……………………………

Contact Phone No. ……………………………

Water Management Area

Location of interview

Limpopo	Luvuvhu/Letaba

………………………………………………………

Date or interview ………………. Time: Started ……..

Ended ………

Length of interview ……………

1a) Name of respondent ………………………………………

b) Relationship to household head ………………………………………
(If not the household head)

c) Name of household head ………………………………………
(If not the respondent)

d) Gender of household head

M	F

e) Age of household head on 01-01-2008

f) Highest education level obtained by household head (tick)

None	
Grade no. (if matric not completed)	
Matric	
Certificate	
Diploma	
Degree	
Postgrad.	
Other (specify)	
Don't know	

g) Marital status of household head (tick)

Single	Married	Divorced	Widow	Widower

h) Number of adults (18 years plus) living in this household (including domestic workers) ………….

i) Number of children (17 years and less) living in this household (including those of domestic workers) ………..

j) Profession (job) of household head …………………………………

k) Income of household per month (tick)

<R200	
R200-R499	
R500-R899	
R900-R1399	
R1400-R2499	
R2500-3999	
R4000-R5999	
R6000-R8999	
R9000-R19000	
R20000+	

Or if the monthly income is unclear, interviewer ask:

l) Annual household income ± R……………………

Section B: The importance of groundwater

Please select the most appropriate response by marking an 'X' over your choice.

2. How has groundwater availability changed over the past five years?

1	2	3	4	5	6	7	8	9	10

←Much worse Much better→

Please comment why you say so

…………………………………………………………………………………………
…………………………………………………………………………………………

3. How has groundwater quality changed over the past five years?

1	2	3	4	5	6	7	8	9	10

←Much worse Much better→

Please comment why you say so

…………………………………………………………………………………………
…………………………………………………………………………………………

4. How important to you personally is a goal of preserving groundwater reserves and maintaining stream flow discharges from groundwater? Is it very important, somewhat important, or not very important to you?

a) Very important
b) Somewhat important
c) Not very important
d) Don't know

If the answer to Question 4 is "a)", ask Question 5:

5. You said a goal of protecting stream flow and groundwater reserves is "very important" to you. Would you say it is one of your very top priorities or is it of somewhat less importance to you?

a) Very top priority
b) Somewhat lesser importance
c) Don't know

Ask everyone

6. Groundwater is indeed a renewable resource if used responsibly, but do you know that the over use or abuse of groundwater aquifers can destroy aquifers?

Y	N

Tell everyone:

It has been observed in several instances around the world that mismanagement of groundwater aquifers can cause a loss in services emanating from groundwater aquifers.

7. Please tell me how important the following household services attributable to groundwater are to you:

a) Cooking

1	2	3	4	5	6	7	8	9	10

←Not important at all Extremely important→

b) Drinking

1	2	3	4	5	6	7	8	9	10

←Not important at all Extremely important→

c) Bathing

1	2	3	4	5	6	7	8	9	10

←Not important at all Extremely important→

d) Showering

1	2	3	4	5	6	7	8	9	10

←Not important at all Extremely important→

e) Toilet flushing

1	2	3	4	5	6	7	8	9	10

←Not important at all Extremely important→

f) Washing dishes and pots in sink

1	2	3	4	5	6	7	8	9	10

←Not important at all Extremely important→

g) Washing clothes in bath

1	2	3	4	5	6	7	8	9	10

←Not important at all Extremely important→

h) Washing clothes in washing machine

1	2	3	4	5	6	7	8	9	10

←Not important at all Extremely important→

i) Washing floors and windows

1	2	3	4	5	6	7	8	9	10

←Not important at all Extremely important→

j) Watering the garden

1	2	3	4	5	6	7	8	9	10

←Not important at all Extremely important→

k) Washing the car

1	2	3	4	5	6	7	8	9	10

←Not important at all Extremely important→

l) Cleaning outside e.g., patios, fowl runs, etc.

1	2	3	4	5	6	7	8	9	10

←Not important at all Extremely important→

m) Livestock watering

1	2	3	4	5	6	7	8	9	10

←Not important at all Extremely important→

n) Other (specify)
………………………………………………………………………………..
………………………………………………………………………………..

1	2	3	4	5	6	7	8	9	10

←Not important at all Extremely important→

Section C: Groundwater consumption for indoor and outdoor use

8. Water consumption profile

a) Please tell me with regard to your **daily** activities, on average how many of the following do you estimate all members of your household (including domestic workers living on property) use:

Water consumption for INDOOR use with regard to:

Daily activity for:	Unit	Number	Litres/measure
i) Cooking	No. of jugs/pots?		
ii) Drinking	No. of jugs?		
iii) Bathing	No. of times?		
	How full?		
iv) Showering	No. of times?		
	Avg. time per shower?	min.	
v) Toilet flushing	No. of times?		
vi) Washing dishes and pots in sink	No. of times?		
	How full?		
vii) Other (specify)	No. of times?		
	No. of buckets?		

b) Please tell me with regard to **average weekly** or **monthly activities** of all members of your household, how many of the following do you estimate you use:

	No. of times per….		How full?	No. of bkts. per week or mo.?	Size in litres?
	Week?	Month?			
i) Washing clothes in bath					
ii) Washing clothes in washing machine					
iii) Washing floors and windows					

c) Water consumption for **OUTDOOR** use:

	Using hosepipe	Using buckets
Average weekly activities	Times in min. per week?	No. of buckets per week?
i) Watering the garden		
ii) Washing the car		
iii) Cleaning outside		
iv) Other (specify)		

d)(i) Do you have a borehole(s) on your premises?

Yes		How many	
No			

If they have borehole(s) go to Question 8(d)(ii)
If they do not have borehole(s) on their premises go to Question 8(e)

(ii) Average capacity of borehole(s)   ………. litres per hour

(iii) Average usage per month   ………. hours per month

(iv) Is the borehole(s) your only water source?

Yes			
No		What is your other water source?	

e)   Where do you get your water, and how far is it (in m or km)?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

f)   What proportion of your water sources do you use for indoor and outdoor use?

	Borehole	**Other source (specify)**
Indoor use	%	%
Outdoor use	%	%
Total		

Section D: Contingent Valuation

9. Total household water consumption

Indoor water usage:	**Water Use**	**Monthly volume used (L)** *[Calculate from Q8. Multiply daily by 30.5 and weekly by 4]*
	Cooking	
	Drinking	
	Bathing	
	Showering	
	Toilet flushing	
	Washing dishes in sink	
	Clothes in bath	
	Clothes machine wash	
	Floors and windows	
	Other (specify)	
	SUB TOTAL: INDOORS	
Outdoor water usage:	Watering the garden	
	Washing the car	
	Cleaning outside	
	Other (specify)	
	SUB TOTAL: OUTDOORS	
TOTAL HOUSEHOLD MONTHLY WATER USAGE		

(a) Is all the water you currently use per month for free?

Y	N

If Question 9(a) is "No", what rate are you paying at present? ………………….

(b) Present water usage profile:

[Interviewer calculate current bill and tell the respondentl]

Present water price (R/KL)	Present total monthly water usage	Present monthly water bill

Please remind everyone

The purpose of the next set of questions is not intended to change the current water payment set up (be it free or not). We would kindly like to know how your water use behaviour would change if the set up did change.

(c)(i) **If the price of water were raised from the present tariff to the minimum tariff (R1.55/KL) of the 6KL-20KL/month water-use-block for Limpopo Province, would you change your water consumption?** *[See Appendix 1]*

[Interviewer calculate and state where the new bill will stand to the respondent]

New water price (R/KL)	Total monthly water usage **(present)**	New monthly bill based on the minimum tariff for Limpopo Province
R1.55/KL		

Yes, would change water usage 1 [Go to Question 9(c)(ii)]

No, would not change water usage 2 (Go to Question 9(d)(i)]

(c)(ii) If YES, note 'New total average water usage' and 'New monthly water bill'

[Interviewer discuss how respondent will change water usage. Use Table in Question 9(c)(ii) to make sensible adjustments to water use]

If NO, note same figures from (c)(i)

New water price (R/KL)	New total monthly water usage **(if facing the minimum tariff)**	New monthly bill based on the minimum tariff for Limpopo
R1.55/KL		
Interviewer please note where water will be saved:		

(d)(i) **If the price of water were raised by 100% from R1.55, would you change your water consumption?**

[Interviewer calculate and state where the new bill will stand to the respondent]

New water price (R/KL) (100% increment on minimum tariff)	Total monthly water usage **(present)**	New monthly bill based on 100% increment on minimum tariff
R3.10/KL		

Yes, would change water usage 1 [Go to Question 9(d)(ii)]

No, would not change water usage 2 (Go to Question 9(e)(i)]

(d)(ii) If YES, note 'New total average water usage' and 'New monthly water bill'

[Interviewer discuss how respondent will reduce water bill. Use Table in Question 9(d)(ii) to make sensible adjustments to water use]

If NO, note same figures from (d)(i)

New water price (R/KL) (100% increment on minimum tariff)	New total monthly water usage **(if facing 100% increment on minimum tariff)**	New monthly bill based on 100% increment on minimum tariff
R3.10/KL		
Interviewer please note where water will be saved:		

(e)(i) **If the price of water were raised by 150% from R1.55, would you change your water consumption?**

[Interviewer calculate and state where the new bill will stand to the respondent]

New water price (R/KL) (150% increase on minimum tariff)	Total monthly water usage **(present)**	New monthly bill based on 150% increase on minimum tariff
R4.65/KL		

Yes, would change water usage 1 [Go to Question 9(e)(ii)]

No, would not change water usage 2 (Go to Question 10]

(e)(ii) If YES, note 'New total average water usage' and 'New monthly water bill'

[Interviewer discuss how respondent will reduce water bill. Use Table in Question 9(e)(ii) to make sensible adjustments to water use]

If NO, note same figures from (e)(i)

New water price (R/KL) (150% increase on minimum tariff)	New total monthly water usage **(if facing 150% increment on minimum tariff)**	New monthly bill based on the minimum tariff for Limpopo
R4.65/KL		
Interviewer please note where water will be saved:		

(f) If a household uses more than 6KL per month, what is the highest amount of money per kl of groundwater that you would be willing to pay?

…………………………

Section E: Restrictions and limitations

10. Are there any restrictions or limits to your daily, weekly or monthly water use? If there are any, please specify:

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

Section F: General comments regarding groundwater use in your area

11. Please kindly make any comments or suggestions regarding groundwater:

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

12. Please highlight any opportunities or threats regarding groundwater:

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

CLOSING: Thank you for your precious time and cooperation. God bless you!

Appendix 2: Agriculture questionnaire

QUESTIONNAIRE FOR GROUNDWATER-USE GROUP DISCUSSION IN AGRICULTURE

Hello, I'm ………………………………. of Stellenbosch University in the Western Cape. We are having group discussions with farmers in the Limpopo and Luvuvhu/Letaba Water Management Areas about their use of **groundwater** for irrigation. The study is focusing on groundwater, so I will begin by asking you:

What is the general water use profile for a typical farm?

Water source	Percentage	Irrigation system used	Remarks on the water sources
Groundwater			
Surface water			
Other (specify)			

Your views will be used to help policy makers make informed decisions. Most of the questions have to do with **your** knowledge about crop production, and there are no right or wrong answers.

The results of the group discussion are completely confidential; your names will never be associated with your answers.

I hereby certify that this is an honest group discussion taken in accordance with my academic needs only.

………………………………… ………………………..
Interviewer's Signature Date

Location of group discussion ……………………………………………………
Date or interview ………………. Time: Started ……..
Ended ………
Length of interview ……………

Section A: Actual Farm Information
Respondents and Farm Information *(Assuming five representatives)*

	1	2	3	4	5
Farm name					
Farm respondent's name					
Occupation (e.g., Owner, Manager)					
Gender (M/F)					
Age on 01-01-08					
Highest education level					
Permanently live on the farm (Y/N)					
Farm address					
Local Municipality					
District Municipality					
WMA (Lim=1, Luv=2)					
Phone No.					
Actual Farm size (ha)					

Section B: Farm size and structure of a typical tomato or potato farm in this area

Size of a typical farm in this area (ha)

Total farm-land profile (ha) and value (R):

Land perspective		Hectares	Bare-land value	Value of water right	Bareland and water right value if not separable
Irrigated land:	Field crops				
	Pastures				
	Vineyards				
	Orchards				
Dryland:	Field crops				
	Pastures				
	Vineyards				
	Orchards				
Veld					
Wasteland					
Other (specify)					
Total					

Is land typically owned or rented:

Current market value of typical farm (land and fixed improvements) (R)

What will a fair rental value of this typical farm be? (R)

Section C: Cropping composition and pattern of a typical tomato or potato farm in this area

	Crop A	Crop B	Crop C	Crop D	Crop E
Main crops grown (all crops)					
Area (ha)					
Dryland (ha)					
Irrigated (ha)					
Cultivars grown					

Perennial crops only:	Crop A	Crop B	Crop C
Name of crop			
Age of first crop (years)			
Age of full crop (years)			
Replacement age (years)			

Annual crops only:	Crop A
Name of crop	
Number of crops grown/yr	

If one crop planted per season, fill first column only and if more than one crop, fill the next columns:	If only 1 crop	If more than 1 crop grown 1st crop	2nd crop	3rd crop	4th crop	5th crop
Planting date						
Cultivar/Variety						
Hectares planted						
Groundwater availability (V bad, Bad, Good or V Good)						
Other water availability (V bad, Bad, Good or V Good)						
Specify the other water source						

	Crop B
Annual crops only:	
Name of crop	
Number of crops grown/yr	

If one crop planted per season, fill first column only and if more than one crop, fill the next columns:	**If only 1 crop**	**If more than 1 crop grown**				
		1st crop	**2nd crop**	**3rd crop**	**4th crop**	**5th crop**
Planting date						
Cultivar/Variety						
Hectares planted						
Groundwater availability (V bad, Bad, Good or V Good)						
Other water availability (V bad, Bad, Good or V Good)						
Specify the other water source						

Section C (cont.): Cropping composition and pattern of a typical tomato or potato farm in this area

Recommended crop rotation per annum for typical farm

	C R O P S											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year 1												
Year 2												
Year 3												
Year 4												
Year 5												

Section D: Capital investment for a typical tomato or potato farm in this area*											
Description	**Quantity**	**Current**	**Floor**	**Present bldg**	**Rplcmt**	**Lifespan**	**Present age**	**Salv**	**Depr.**	**R&M**	**Insurance**
		value (R)	**area (m^2)****	**cost (R/m^2)****	**value(R)**	**(yrs)**	**(years)**	**value(R)**	**/yr(R)**	**/yr(R)*****	**/yr(R)*****
Non farming imprvmts:											
Homestead											
Other housing:											
Managers											
Foremen											
Labourers											
Other staff											
General farm buildings:											
Garages											
Sheds											
Storage rooms											
Workshop											
Other (specify)											
Orchards/Vineyards:											
Dryland: fruit											
Irrigated: fruit											
Other (specify)											
Water supply:											
Boreholes											
Cement dams											
Contours, canals & furrows											
Earth dams											
Main irrigation lines (sub-soil)											
Troughs & crips											

Windmills											
Fencing:											
Border fences											
Interior fences											
Other											
Miscellaneous:											
TOTAL											
* Some of the annual costs could be specified here if not specified under Other Costs in Section G											
** Only if replacement value is not known											
*** Cost not capital invested											

Section E: Borrowed Capital Outlay of a typical tomato or potato farm in this area

Anticipated Size of Bond:

Long term bond:	Value (R)	
	Period (yrs)	
	Interest (%)	
	Years remaining	
Mid term bond:	Value (R)	
	Period (yrs)	
	Interest (%)	
	Years remaining	

Percentage of short-term capital financed by:

Bank Overdraft	
Co-op Account	
Other (specify)	

Interest on short-term capital:

From Bank Overdraft	
From Co-op Account	

Section F: Gross production value of annual crops for a typical tomato or potato farm

	Crop A
Crop name:	
Hectares planted:	
Hectares harvested:	

Gross production value:

Grade composition	**Price (R/t)**	**Yield (t/ha)**
Grade A		
Grade B		
Grade C		
Grade D		

OR

Yield (t/ha)		
Average produce price (R/t)		

	Crop B
Crop name:	
Hectares planted:	
Hectares harvested:	

Gross production value:

Grade composition	**Price (R/t)**	**Yield (t/ha)**
Grade A		
Grade B		
Grade C		
Grade D		

OR

Yield (t/ha)		
Average produce price (R/t)		

Section G: Annual Crop Expected Costs per Hectare for a typical tomato or potato farm in this area

Directly Allocatable Costs (R/ha):

	Crop A	Crop B	Crop C	Crop D	Crop E	Crop F	Crop G	Crop H
Name of crop (e.g. Table, Seed or Industrial Potato; or Can, Sauce or Export Tomato etc.):								
Casual labour								
Casual supervision								
Consultation fees/Research								
Contract labour								
Drainage system								
Fertilizer								
Fuel								
Fungicides								
Hail nets								
Herbicides								
Hired transport								
Insecticides								
Insurance								
Irrigation system (surface)								
Irrigation system (subsurface)								
Irrigation water								
Irrigation electricity								
Marketing costs								
Mulches								
Organic fertiliser								
Other allocatable costs								
Other soil nutrients								
Other pest control costs								

Plant material / Seed								
Packaging								
Repairs & maintenance (e.g. trellis)								
Soil preparation (establishment)								
Trace elements								
Trellising (fruit)								
Other (specify):								
TOTAL DIRECTLY ALLOCATABLE COSTS								

Other Costs (R/ha):

Pemanent Labour	
Licences and Assurances	
Electricity	
Water	
Administration	
Entrepreneurial salary	
Banking costs	
Other costs (specify):	
TOTAL INDIRECTLY ALLOCATABLE COSTS	

Section H: Typical Farm Crop Water Requirements and Borehole Data for a typical tomato or potato farm in this area

Borehole Data

No. of farm boreholes:												
Average borehole yield (m^3/hour):												
Months:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Usage per month (hours)												
m^3 of groundwater used per month												
Maximum possible m^3 of groundwater per month												

How has groundwater availability changed over the past five years?	1	2	3	4	5	6
		←Much worse			Much better→	
Please comment why you say so						
How has groundwater quality changed over the past five years?	1	2	3	4	5	6
		←Much worse			Much better→	
Please comment why you say so						

How has the water table changed in depth over the past five years (m)?

Water table depth five years ago (m)	
Present water table depth (m)	

Section I: Farm human resource costs for a typical tomato or potato farm in this area

Crop A

Crop name:														
Months:		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Casual labour:	Labour days reqd.													
Contract labour:	Labour days reqd.													
Permanent labour:	Labour days reqd.													

Crop B

Crop name:														
Months:		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Casual labour:	Labour days reqd.													
Contract labour:	Labour days reqd.													
Permanent labour:	Labour days reqd.													

Crop C

Crop name:														
Months:		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Casual labour:	Labour days reqd.													
Contract labour:	Labour days reqd.													
Permanent labour:	Labour days reqd.													

Crop D

Crop name:														
Months:		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Casual labour:	Labour days reqd.													
Contract labour:	Labour days reqd.													
Permanent labour:	Labour days reqd.													

Section J: Contingent groundwater use for a typical tomato or potato farm in this area

Are you currently paying a levy for your water? Y/N

If yes, payment per cubic meter (R)

If the water levy changed, how would your water use profile change?

% Levy change	**% change in water use**
20% increase	
50% increase	
100% increase	
20% decrese	
50% decrease	
Free water	

Are there any restrictions or limits to groundwater use in this area? Y/N

If there are any, please specify:

Section K: General comments regarding groundwater use in your area:

Please kindly make any comments or suggestions regarding groundwater:

Please highlight any opportunities or threats regarding groundwater:

CLOSING: Thank you for your precious time and cooperation. God bless you!