Julia Kloos

Valuation of domestic water use in the Middle Olifants sub-basin of South Africa




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Abstract

Valuation of domestic water use in the Middle Olifants sub-basin of South Africa

In South Africa, water is a relative scarce resource that is distributed unevenly geographically and saisonally as well as socially. The Middle Olifants sub-basin of South Africa was chosen as study area, because it is characterized as a very water scarce region - it is counted as the third most stressed basin in South Africa - with a poor and predominantly rural population. Households in former-homeland areas are still disadvantaged and lack access to sufficient and reliable water services. Current water use in the basin leads to overuse of the resource at the expense of domestic and environmental water needs.

For an effective water management that is able to address the South African policy objectives of efficiency in water use, equity in access and benefits as well as long-term sustainability, economic valuation of the different water uses is required. In order to assist policy-makers in reaching these goals, this study contributes to the existing knowledge by providing information on the economic value of water in domestic uses. For this purpose, two separate choice experiments were designed to detect preferences and 'Willingness to pay' for different water service levels and water sources.

Results of a household survey of 475 households provide a clear picture of the different water sources and service levels received by households in the Middle Olifants. Sampled households using basic water sources such as Public taps, Yard connections or Boreholes consume on average only 18.68 liter per person per day, while households with private taps inside their houses consume 78 liter per person per day. To analyze preferences for water services at the household level and to detect households' 'Willingness to pay' for improved service levels, choice experiments were carried out in four villages and one town. Data analysis indicates the presence of preference heterogeneity and, hence, a latent class model was applied, readily dividing households into homogeneous groups according to their preferences. Several distinct classes of households could be found differing significantly in terms of socio-economic characteristics, particularly household income, current water consumption and service levels as well as attitudes towards pricing of water and satisfaction with current water service levels. 'Willingness to pay'-estimates of single water service characteristics of all groups indicate that households are willing to pay higher prices for a better and more reliable water provision. But the amount of money households are willing to spend differs among groups. Price sensitivity was found to be strongly linked to income. With increasing income, price sensitivity of households decreases. This information is helpful for policy-makers to enable the design of water services in the Middle Olifants according to preferences of local households. The increase in 'Willingness to pay' with increasing income shows that subsidies either as income subsidies or lower water tariffs may be useful tools to allow low-income households to pay water bills.

Kurzfassung

Bewertung der Wassernutzung von Haushalten im Flusseinzugsgebiet “Mittlerer Olifant” in Südafrika

Wasser ist in Südafrika eine relativ knappe und ungleich verteilte Ressource - sowohl geographisch, saisonal als auch sozial gesehen. Das Flusseinzugsgebiet “Mittlerer Olifant” wurde als Untersuchungsgebiet ausgewählt, da es als sehr wasserknappes und daher stark gefährdetes Flusseinzugsgebiet gilt. Zudem ist die Bevölkerung im “Mittleren Olifant” überwiegend arm und lebt in ländlichen Gebieten, den früheren “Homelands”. Weite Teile der Bevölkerung sind hier immer noch benachteiligt und erhalten kaum Zugang zu ausreichendem und sauberem Trinkwasser. Die gegenwärtige Wassernutzung im “Mittleren Olifant” durch die verschiedenen Wassernutzer - Haushalte, Landwirtschaft und Bergbau - führt zur Übernutzung, so dass die Versorgung der ländlichen Bevölkerung mit Wasser nicht gewährleistet ist und negative Folgen für die Umwelt und das Flussökosystem auftreten.

Um ein besseres Wassermanagement zu ermöglichen, welches die südafrikanischen politischen Ziele - Effizienz in der Wassernutzung, Gleichheit im Zugang und Nutzen von Wasser sowie langfristige Nachhaltigkeit der Nutzung - beachtet, ist die ökonomische Bewertung aller Wassernutzungen erforderlich. In diesem Kontext ermittelt die vorliegende Studie den ökonomischen Wert von Wasser im Haushaltsgebrauch. Dazu wurden zwei separate Choice-Experimente erarbeitet, mit denen Präferenzen und Zahlungsbereitschaften für verschiedene Wasserquellen und unterschiedliche Wasserversorgungsgrade ermittelt werden können.

Die Ergebnisse der dazu durchgeführten Haushaltsbefragung von 475 Haushalten zeigen ein klares Bild der verschiedenen Wasserquellen und der Güte der Wasserversorgung im “Mittleren Olifant”. Die untersuchten Haushalte, die nur über eine Grundversorgung mit Wasser verfügen, verbrauchen 18,68 Liter pro Tag und Person wohingegen Haushalte, die bereits an einen privaten Wasseranschluß im Haus angebunden sind, 78 Liter pro Tag und Person konsumieren. Da die Analyse der beiden Choice Experimente die Annahmen der Präferenzhomogenität sowie der IID-verteilten Störterme nicht bestätigen konnte, wurde ein “Latent-Class”-Modell zur ökonometrischen Schätzung verwendet. Dieses Modell teilt die Haushalte entsprechend ihrer Präferenzen in homogene Klassen ein. Bei der Klassifizierung konnten auch Haushaltsmerkmale wie sozio-ökonomische Charakteristika - insbesondere Haushaltseinkommen - die gegenwärtige Wasserversorgung, Zufriedenheit mit dieser und Einstellungen zu Wasserpreisen als signifikante Faktoren zur Gruppenbildung aufgedeckt werden. Die geschätzten Zahlungsbereitschaften für Verbesserungen einzelner Merkmale der Wasserversorgung in allen Gruppen zeigen, dass Haushalte tatsächlich bereit sind für eine bessere Wasserversorgung zu zahlen. Wieviel hingegen ist von der Gruppenzugehörigkeit abhängig. Wie sensibel Haushalte auf Preisänderungen reagieren, hängt stark vom Einkommen ab. Mit steigendem Einkommen nimmt die Stärke der Reaktion auf Preisänderungen ab. Diese Ergebnisse sind wichtig für die politischen Entscheidungsträger, da sie hierdurch die Art und Güte der Wasserversorgung den Präferenzen der Haushalte im “Mittleren Olifant” und ihrer Zahlungsbereitschaft anpassen können. Da die Zahlungsbereitschaft mit höheren Einkommen zunimmt, können Einkommensunterstützungen an einkommenschwache Haushalte Zahlungen von Wasserrechnungen begünstigen.

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Abbreviations and variables

AP	Average Price
ASC	Alternative Specific Constant
CE	Choice Experiment
CMA	Catchment Management Agency
CS	Consumer Surplus
CV	Compensating Variation
CVM	Contingent Valuation Method
DWAF	Department of Water Affairs and Forestry
ES	Equitable Share
EV	Equivalent Variation
FBW	Free Basic Water
GDP	Gross Domestic Product
GGP	Gross Geographic Product
GWP	Global Water Partnership
IIA	Independence of Irrelevant Alternatives
IID	Independent and Identically Distributed
IV	Inclusive Value
IWRM	Integrated Water Resources Management
l/dc	liter per day per capita
LC	Latent Class
LR	Likelihood Ratio
MDG	Millenium Development Goals
MIG	Municipal Infrastructure Grant
MNL	Multinomial Logit Model
MP	Marginal Price
NSA	National Services Act
NWA	National Water Act
OAM	Optimal Allocation Model
TCM	Travel Cost Method
TEV	Total Economic Value
VAT	Value Added Tax
WMA	Water Management Area

WSA .... Water Service Authority
WSAM .... Water Situation Assessment Model
WSP .... Water Service Provider
WTA .... Willingness to accept
WTP .... Willingness to pay
WUA .... Water User Association
ZAR .... South African Rand

Chapter 1

Introduction and objectives

1.1 Introduction

Access to improved drinking water has long been recognized as one of the main challenges of development. UN (2000) acknowledges the right to water at the level of the individual, which implies access to a minimum amount of water sufficient to cover basic needs. Progress towards universal achievement of this minimum level of water is associated with substantial health gains and remains a focus on international policy initiatives through the declaration of the Millennium Development Goals (MDGs). One of the targets of the MDGs is to reduce by half the proportion of people that have no sustainable access to safe drinking water by 2015 [UN, 2000].

WHO defines domestic water as 'water used for all usual domestic purposes including consumption, bathing and food preparation' [Howard and Bartram, 2003]. Access to domestic water in developing countries encompasses many forms and varies widely between regions, especially urban and rural areas [Komives et al., 2005]. Households may use unimproved water sources such as rivers or boreholes, they buy water from neighbors, water kiosks or water tanks, have private in-house connections to the water network or collect water from public taps and standpipes. Usually, not only a single water source is used throughout the year but different water sources are combined depending on seasons and other conditions [Statistics-South-Africa, 2007].

Water resources are unevenly distributed in time and space and are found to be increasingly under pressure due to major population changes and increased demand from various water users. Water use worldwide has been growing at more than twice the rate of the 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 [FAO, 2006].

In these water scarce regions, households are found to compete more and more with the agricultural sector, which demands water for food production, and industrial water needs. Water overuse tends to threaten sustainability and to have negative impacts on the environment. In order to sustain water needs from different water users and the environment, a shift towards efficient use of water sources, water allocation strategies that maximize the economic and social returns to limited water resources, and, at the same, time enhance the water productivity of all sectors and ensure environmental sustainability is needed [FAO, 2006].

Optimal water allocation is based on economic valuation and, therefore, economic valuation of water is becoming more and more important for policy-makers which are faced with planning processes in water management and aim to achieve an efficient water allocation. Economic valuation refers to attaching a monetary value to water and water services using specific valuation techniques. Net benefits of different water management alternatives can, hence, be compared to identify the most suitable option [Unesco, 2006].

Various characteristics of water such as physical, cultural, political and economic factors make water special in terms of its valuation. Domestic water use has characteristics of a private good when households have access to a private water connection, but also characteristics of a public good - when water sources are communally used. Existing and functioning markets for water allow for demand estimation using actual prices to value water while especially in developing countries, where domestic water is often not priced, non-market valuation techniques based on 'Willingness to pay' are applied.

The concept of 'Willingness to pay' refers to the amount of income households are willing to give away in order to receive some improvement in circumstances such as an improvement in water services (or avoid a deterioration). But a low 'Willingness to pay' may not necessarily reflect a low preference, but a low ability to pay. Low-income households may have a lower 'Willingness to pay' due to their limited income capacities. In this endeavor, there needs to be a special focus on issues related to low-income households to ensure equity in access to water and on the social impacts of water allocation policies.

In economic terms, water provision can be categorized as a multi-attribute product [le Blanc, 2008]. Water services can be defined by several dimensions: price, quantity, and quality are most commonly referred to [le Blanc, 2008], but also frequency of supply in terms of days and hours, distance of the water source, waiting time and other attributes play a role. Households may receive very different service levels with regard to these attributes [Komives et al., 2005] and may characterize water services from very poor to excellent depending on them. Therefore, these differences in service levels have to be taken into account when water services are evaluated.

As the provision of water services induces costs, cost recovery is regarded as a central element of a sustainable provision of water services, and a precondition for improvement of quality levels and extension of access to improved water sources in rural areas. Therefore, criteria such as financial sustainability and the 'user pays' principle are applied when setting tariffs. Policy-makers widely recognize a basic amount of water that is essential for life and health. Charging all households equally according to the 'user pays' principle would be comparable to denying access a basic amount of water for households who cannot afford paying. In certain cases, people need more water than they are willing or able to pay for, so policies are designed to help the poor satisfy basic water needs and address water security [Unesco, 2006]. Multiple criteria influence policy decisions on appropriate tariff structures. Tariff-setting must balance both costs[1] and value considerations such as 'Willingness to pay'.

Economic valuation is therefore an essential tool for water management in order to identify the value of water at the level of water user groups, but it can also identify differences in valuation within a specific user group. Valuing water use of households by using the 'Willingness to pay'-principle needs consideration of household characteristics - especially income - to be able to avoid negative social impacts of an efficient water allocation.

1.2 Motivation of the study and research questions

Located in a semi-arid region in the North-West of South Africa, available water resources in the Olifants River basin are used by different water user groups like growing industries, especially mines, households living in rapidly and uncontrolled growing settlements, large and small-scale farmers with irrigation activities as well as power plants. It is counted as the third most water stressed basin in South Africa [DWAF, 2004]. The Olifants River is of special ecological importance because it enters Krueger National Park and underlies transboundary commitments with Mozambique [Unesco, 2004]. Severe overexploitation of water resources at the expense of ecological functions and the availability of water for basic human needs already takes place in the Middle Olifants - a sub-basin of the Olifants River basin.

While South Africa already successfully achieved the MDG target of halving the proportion of people lacking access to safe water by 2015[2], still 9 million people mostly in rural areas lack access to water [Unesco, 2006]. Especially the predominant rural population in the Middle Olifants sub-basin is disadvantaged in terms of accessing potable water for domestic purposes [Levite and Sally, 2002,DWAF, 2004]. South African water policy was basically reformed from 1994 onwards and the new water law stands out due to a constitutional right to water in which water is formally recognized as a human right [Constitution, 1996]. In order to ensure this, the national Free Basic Water (FBW) policy was implemented. Water is recognized as an economic (Dublin principles) but also as a social good; access to water is granted for all households (NWA, 1998). At the institutional level, Catchment Management Agencies (CMAs) are established in all Water Management Areas (WMAs). They are responsible for water resource planning and management at the catchment level addressing the new policy goals of equity in access to and benefits from water, economically optimal water uses and long term sustainability including ecological functioning. This is in accordance with the principles that, globally, tend to be seen as best practices of Integrated Water Resources Management (IWRM)[3]. The IWRM-approach has received much attention and it has been one of the most important policy issues for the post-apartheid regime in South Africa. IWRM is a tool to increase water use efficiency, equity in

[1] A discussion of costs in terms of full supply costs, full economic costs and full costs can be found in Unesco (2006).

[2] reduced from 40 percent to 19 percent since 1994.

[3] For a definition of IWRM and important concepts see appendix

access to water and environmental and ecological sustainability [GWP, 2000] and thus suitable to address the South African policy objectives.

Since current water use practices do not meet the objectives, reallocation of water from low to high value uses and in a way that promotes social equity and sustainability is needed. Despite the recognition that water is an economic good, the current prevailing approach to water allocation in South Africa is strongly administrative. In other words, it is based predominantly on the relevant administration (the CMA) to allocate water in order to reach the above policy goals [PDG, 2004]. The water scarcity in the basin makes a detailed planning and management of water resources between the major water user groups - households, industries and commercial farmers - necessary to prevent negative effects of overuse. The prevalent tools, registration and licensing of water users, address water allocation in an administrative way. Before licenses are distributed, a registration process which captures all water users and their current water needs takes place. But it is a rather static approach that cannot capture the effects of some influencing factors or changing prices and does not ensure an economic efficient water allocation.

Due to the complexity of water management caused by physical, economic and socio-economic dependencies, research is required to assist the new institutional settings providing information on economic valuation of all water uses at the catchment level. This study is conducted as part of the project "Integrated Water Resources Management Pilot Project in the Middle Olifants sub-basin of South Africa ('IWRM Middle Olifants')" which aims to provide a modeling tool based on the economic valuation of different water uses in the sub-basin and optimizes water use in a way that ensures equity in access, efficiency and sustainability of water use. The 'IWRM Middle Olifants'-project estimates aggregate demand functions of the most important water users in the sub-basin - households, commercial farmers and mines - and maximizes benefits under considerations of efficiency, equity and sustainability given the available water yield determined by a hydrological model. This yields an optimal allocation of water and the respective shadow prices for the different water users. No reallocation of water could generate higher welfare from the available water resources. Such a modeling tool is useful for the responsible planning institution at the basin-level (CMA) to be in a better position to plan and forecast water demands of all water users when some conditions change and to be able to forecast effects of increasing water prices on demand. As sub-project within the framework of the 'IWRM Middle Olifants' - project, this study has its focus on domestic water use addressing the following research questions:

- What is the current situation of households with regard to access to water? What kind of service levels do households receive at different water sources and how much water do they actually use?
- Which water service attributes do households value most and how much would they be willing to pay for different water services? What are important factors that influence 'Willingness to pay' and how is it connected to their ability to pay?

- What kind of subsidies can help to ensure access to water and payment of water bills by low-income households? How do households value mechanisms used to increase payment rates such as prepaid payment meters?

1.3 Objectives

Specific objectives of this study are:

1. To characterize current access of households to water.

   Collecting household-level data on water sources, distances and waiting times as well as socio-economic characteristics is usually done in the South African Census and the 'Household Survey' by Statistics Services, South Africa (StatsSA). Findings are then presented at the smallest aggregate level of local municipalities and enumeration areas. This snapshot of access to water tends to underestimate the number of households without adequate services because it is based on proximity or use of a water source rather than on the quality and reliability of service that users actually obtain [Komives et al., 2005]. Though two households can be categorized as having access to a public tap, it makes a difference whether water is provided once a week or every day. So far, there is little information on a detailed characterization of water service levels in terms of all important attributes such as frequency of supply, hours of supply and quantities used from each water source that allows describing the situation of households at the catchment level.

2. To analyze preferences and 'Willingness to pay' for different domestic water services.

   A better understanding of the values that households place on important characteristics of water services and the determinants of their economic behavior and choices is necessary to provide policy-makers with important information. Valuation of domestic water services reflects preferences of households with regard to water service attributes and is useful to detect which service attributes provide the strongest utility to households to be improved first. When calculating 'Willingness to pay', factors contributing to heterogeneity of households' preferences need to be considered. It is helpful for water authorities to know how much households are willing to pay for single attributes given households' financial capacities and other characteristics as well as their welfare gains introduced by clearly defined improvements in water services. As water is a continuous good, corresponding quantities and impacts on water demand have to be considered explicitly.

3. To analyze the opportunities of different policy interventions on improving access to water for low-income households.

In the year 2000, the responsibility for water services was shifted to local governments and national government has steadily decreased financial and technical support. Municipalities in the capacity of water services providers are under considerable pressure to become financially self-sufficient and to recover service-related costs from all areas including poor communities [Tissington et al., 2008]. This means that reaching cost-recovery of water services, may come at the expense of low-income households. Knowing 'Willingness to pay' of low-income households given their financial constraints contributes to a better design of water tariffs and subsidization schemes.

1.4 Outline of the study

This research is divided into five chapters. After the introductory chapter 1, chapter 2 presents background information on water use and availability in the study area - the Middle Olifants sub-basin -, the legislative framework of water management as well as the practical implementation of IWRM in South Africa. Chapter 3 focuses on concepts and techniques available for economic valuation of water with special emphasis on non-market techniques and embeds economic valuation into the general consumer theory and welfare theory. Special attention is given to the differences between continuous and discrete data. In this chapter the choice of the appropriate valuation technique is discussed in detail. Chapter 4 presents the procedures, analyses and results of a household survey conducted in the Middle Olifants. Following sampling procedures, structure of the questionnaire and design of the choice experiments, a description of the situation of households with regard to water services quality, water quantity, water use and pricing of water is given. Data analysis with a latent class model aimed at a special consideration of household characteristics such as income, current water services, and attitudes of households in the estimation of 'Willingness to pay'. Chapter 5 concludes the whole study by presenting a summary and discussion of the main findings, addressing policy implications and finally providing suggestions for future research.

Chapter 2

Background of the study

2.1 Olifants River Catchment

The Middle Olifants sub-basin is part of the Olifants River Basin, north of Johannesburg and Pretoria, located in the provinces Limpopo, Mpumalanga and Gauteng as shown in Figure 2.1. The Olifants River Basin constitutes a WMA under the NWA (1998).

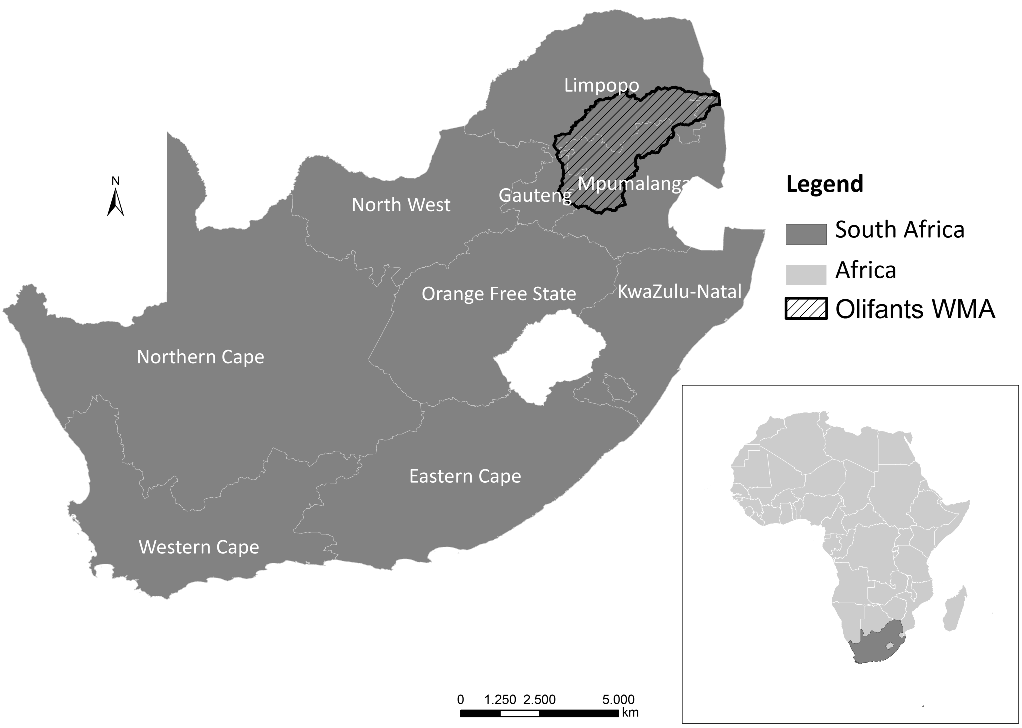

Figure 2.1: Location of Olifants WMA

The Olifants River originates at Trichardt to the East of Johannesburg and flows northwards to enter Mozambique, where it joins the Limpopo River before discharging into the Indian Ocean. The Olifants River Basin is characterized by a semi-arid climate. The mean annual temperature ranges between 14°C in the southwest to more than 22°C in the northeast with an average of 16°C for the basin. Rainfall occurs mainly in summer (from October to March) and varies between 800 to 500 mm in most areas. The mean annual gross evaporation (as measured by Symons pan) ranges from 1 300 mm to 2 000 mm over the whole Olifants [DWAF, 2003a]. The topography of the Olifants basin varies extremely, ranging from approximately 150 meters where it joins the Limpopo River in Mozambique, to over 2,000 meters above sea level in the mountainous region of the northern extension of the Drakensberg Mountains. Most of the basin consists of light hilly terrain separated by ranges of hills and mountains [Ashton et al., 2003]. Concerning demography, the Olifants WMA has a predominantly rural character with 67% of the people classified as living in rural areas. The rural communities are scattered formal and informal villages, localized in the former homeland areas Lebowa, KwaNdebele, Boputhatswana and Gazankulu [DWAF, 2003a]. Former homelands cover only 26% of the area but house 60% of the population [van Koppen, 2008]. As a consequence of past inequities, a large proportion of the basin's population is extremely poor and lacks access to basic services such as clean water and adequate sanitation [Ashton et al., 2003, Levite and Sally, 2002]. Poverty is widespread among the population of the Olifants River Catchment with 32% of all households in the basin having no income at all (excluding governmental grants). Besides, it experiences large-scale migration from rural areas to urban settlements.

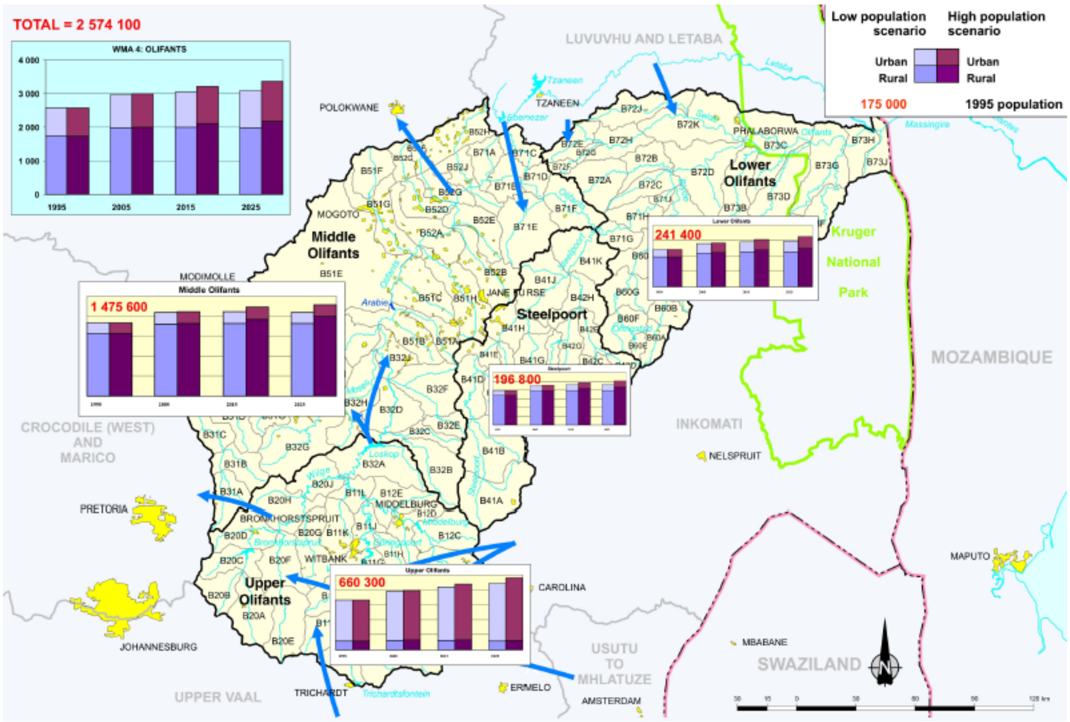

Figure 2.2: Population growth and migration in Olifants WMA [DWAF, 2003a, page 16]

About 45% of the people are unemployed, 43% active in the formal economy, and 12% in informal sectors [Unesco, 2004]. The following economic activities provide employment: mining, power generation, metallurgic industries, irrigation, dry land and subsistence agriculture and eco-tourism. The most important sectors in terms of contribution to the gross geographic product (GGP) are Mining (22.1%), Manufacturing (18.2%), Electricity (15.9%), Government (15.6%) and Agriculture (7%) in the whole Olifants region for the year 1997 (DWAF 2003b).

Only 5% of the gross domestic product (GDP) of South Africa is generated in the Olifants. The public sector accounts for 48% of those formally employed, with mining and agriculture providing 21% and 19% respectively [Unesco, 2004]. Mining activities in the area include coal-mining, mining and processing of flint clay and diamonds, silica and platinum, ferro-chrome, phosphate, copper and associated deposits. The significance of the manufacturing industry can be attributed to the relatively cheap supply of coal, which is particularly contributing to its success [DWAF, 2003a]. Land use - as shown in Figure 2.3 - consists mainly of irrigated and dry land farming and grazing. Close to 44,000 ha[1] (7.5%) of the 585,000 ha cultivable land is currently irrigated [DWAF, 2004].

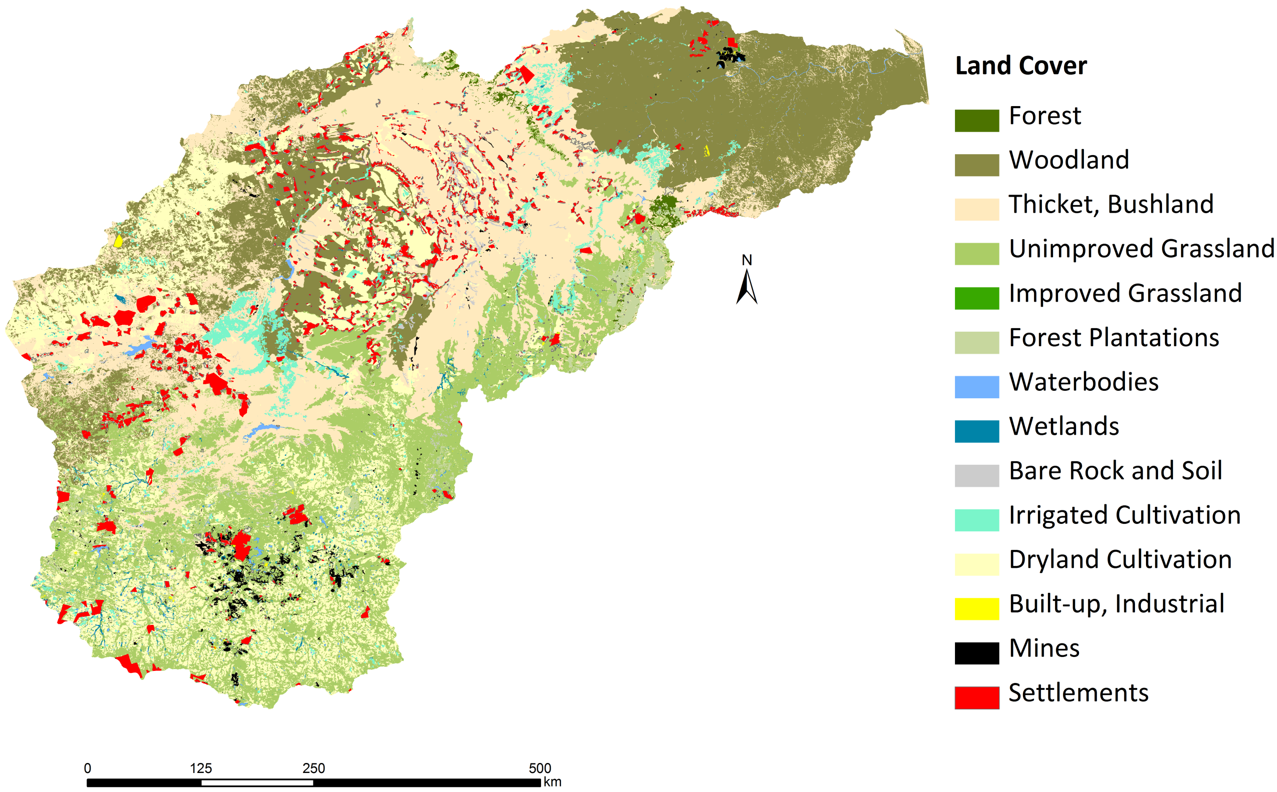

Figure 2.3: Land cover in Olifants WMA [DWAF, 2003a]

However, the specific types of land use are controlled by climatic factors, water availability and land tenure forms. A large proportion of the land in the Olifants basin is under communal or customary forms of tenure, so that the lack of land ownership is considered to be one of the major constraints to proper land use and conservation (Chenje, 2000 as cited in Ashton et al., 2003). Overcrowding and insecure ownership in the smaller communal farming areas - as in

[1] 107,000 ha [Levite and Sally, 2002], commercial and small-scale irrigation: 100,000 ha [Unesco, 2004].

Middle Olifants sub-basin - lead to land degradation and is thus an important driver of poverty and declining per capita agricultural production [Ashton et al., 2003].

Almost all irrigation takes place in the commercial farming sector, which is dominated by white farmers possessing 95% of the irrigated area [Levite and Sally, 2002]. Agriculture consists of mainly rainfed crops (e.g. maize) and livestock. Main irrigated crops are Soya beans, cotton, vegetables, citrus, wheat, and tobacco [Unesco, 2004]. The largest proportion of commercial irrigation in all sub-basins can be found in the Middle Olifants, a very large irrigation scheme is located close to the Loskop dam, which is by far the largest reservoir in the basin with a capacity 348 Mio. m^3. Extensive irrigation using groundwater can be found in Springbok Flats at the Zebedelia Estates. Lowering groundwater tables and overextraction in these areas are reported [DWAF, 2004]. A number of abandoned irrigation schemes, mainly small-scale schemes which are currently under reconstruction as poverty eradication initiatives[2].

Water resources and use

Most of the surface runoff originates from the higher rainfall in southern and mountainous parts of the Olifants WMA [DWAF, 2003a]. Rainfall and runoff in the Olifants River Basin show high inter-annual variability and the basin is subject to both floods and droughts. The Olifants River has been known to have zero flow during short periods and a severe drought occurs practically every decade [Unesco, 2004]. Several large dams have been constructed on the Olifants River and its tributaries, and the surface water resources are already highly developed. Table 2.1 gives an overview of the water resources in each sub-basin. Large quantities of groundwater are abstracted for rural water supplies throughout the WMA. The largest use of groundwater occurs in the Middle Olifants sub-basin with the largest share of rural population and where large quantities of groundwater are needed for irrigation [DWAF, 2003a].

Economic development and population growth brought increasing pressure on the water resources. Since available water is limited, intensive competition between the growing water use sectors emerged. Agriculture (57%) is by far the largest water using sector, followed by power generation (19%) and domestic, industrial and mining purposes (19%) [DWAF, 2003a]. Table 2.2 indicates water requirements per user and sub-basin.

Comparing availability and requirements per sub-basin, the water balance of the Olifants WMA reveals a deficit of almost 200 million m^3/a.[3] The 'National Reserve', which includes ecological and human basic needs, cannot be maintained as required and zero flow in the dry season has already occurred in Kruger National Park. In addition to that, severe water quality problems exist in certain areas due to point discharges from industries especially from old and abandoned mines, wastewater treatment works, mine dewatering, irrigation return flows and diffuse sources such as runoff from mining and industrial complexes [Levite and Sally, 2002, Unesco, 2004].

[2] Rehabilitation of Small Holder Irrigation Schemes (RESIS) programme of the Department of Agriculture of Limpopo Province.

[3] Grand total required (973 Million m^3/a) minus grand total available (781 million m^3/a).

Table 2.1: Available water in the Olifants WMA in year 2000 (million m^3/a)

Sub-catchment	Surface water	Ground-water	Return flows (Irrigation)	Return flows (Urban)	Return flows (Mining/ bulk)	Total local yield	Transfers in	**Grand Total**
Upper Olifants	194	4	2	34	4	238	171	409
Middle Olifants	100	70	34	5	1	210	91	**301**
Steelpoort	42	14	3	1	1	61	0	61
Lower Olifants	74	11	5	2	8	100	1	101
Total	410	99	44	42	14	609	172	781

After allowance for the impacts on yield of: ecological component of Reserve, river losses, alien vegetation. This is based on WRSM90 model of the Department of Water Affairs. The model is calibrated using the available information on return flows, water infrastructure etc. [DWAF, 2004].

Table 2.2: Water requirements of the Olifants WMA year 2000 (million m^3/a)

Sub-area	Irrigation	Urban	Rural	Mining/ bulk	Power gen.	Afforestation	Total local requ.	Transfers out	**Grand Total**
Upper Olifants	44	62	6	20	181	1	314	96	410
Middle Olifants	336	15	28	13	0	0	392	3	**395**
Steelpoort	69	3	5	17	0	1	95	0	95
Lower Olifants	108	7	5	43	0	1	164	0	164
Total	557	87	44	93	181	3	965	8	973

As the actual water use figures are missing for most water users, requirements are based on average values and then up-scaled [DWAF, 2004].

Besides, operational problems leading to water shortages in the domestic sector in the Western Highveld area reduced the available potable water.

The Middle Olifants sub-basin with a size of 22,550 km^2 was selected as study area, because it is the most stressed sub-basin of the Olifants WMA with a deficit of 94 million m^3/a and it is characterized by a variety of water using sectors. On the one hand its predominantly rural and historically disadvantaged population reflects strong inequities in terms of accessing water [Levite and Sally, 2002]. Improvements of this situation require allocation of more water to domestic needs. On the other hand growing industrial and agricultural activities driving the economic development in the region have increasing water needs. In the Middle Olifants this problem is the most severe and water shortages already occur locally. National research so far focused on other WMAs [Bate et al., 1999, Louw, 2002, Crafford et al., 2004, etc.] or other parts of the Olifants WMA such as the Steelport sub-basin [Hassan and Farolfi, 2005] leaving a gap that this study tries to fill.

2.2 Water policy development

Under the South African Apartheid Regime, policies in general aimed to provide advantages for few people while excluding the majority of the population. Accordingly, policies for development and management of water resources encouraged a use of water that strengthens economic growth in the country rather than enhances access to water for the mostly black and rural population [Goldin, 2005]. Water rights were provided according to the riparian principle so that right and access to water were linked to property of land. Through a series of land related laws, 87% of South Africa's land was set aside for the white population only [Turton et al., 2004, page 354].

Most municipalities and townships provided water services to residents, but at lower standards to the black population than to the white population. As these inequalities - not only with regard to water - became more and more obvious, withholding of payments (usually monthly flat rates) for water (and other municipal services) by black communities became an effective form of protest against the apartheid regime in the 1980s [McDonald and Pape, 2002]. The government continued to supply water to those communities to prevent the former political tension from resurfacing. Due to this a "Culture of Non-payment" for services evolved in South Africa [King, 2004, Lefebre et al., 2005, Funke et al., 2007]. With introduction of democracy in 1994, improving and equalizing living conditions of the black population were among the main objectives of the new government and, hence, a far-reaching reform process of the whole water sector was striven for. Major stages of water policy development in South Africa were - including constitutional developments - the development of the Water Law Principles (DWAF, 1996), the White Paper on a National Water Policy for South Africa (DWAF, 1997), the National Water Act (1998, the National Services Act (1997) and their implementation through of the National Water Resource Strategy (DWAF, 2002) [de Coning and Sherwill, 2004].

The most important changes of the Water Law Principles

- led to the abolition of riparian water rights and private ownership of water (principles 3 and 4)
- established "environmentally sustainable social and economic benefits" as key criteria for water resources management and allocation decisions (principle 7)
- allowed the use of economic instruments in the management and control of pollution (principle 16)
- stated that "beneficiaries of the water management system should contribute to the cost of its establishment and maintenance" (principle 24) [MacKay, 2003]

These principles were further developed and formulated in the "White Paper on National Water Policy for South Africa". As formal incorporations followed the National Services Act (1997) and the National Water Act (1998) providing the legal framework of water use in South Africa.

The Water Services Act (NSA, 1997) guarantees the right to basic water and sanitation services to everyone. The government is committed to ensure an equal, efficient and sustainable provision of water and sanitation services. It defines roles for the new institutional setting, conditions for the provision of potable water, priority of securing water for drinking purposes against other uses, standards of water quality as well as norms and standards for domestic water tariffs. It promotes user charges to be based on the volume of water used as long as this is possible and to represent full financial and economic costs of water supply [Hedden-Dunkhorst, 2005]. More concrete implementation issues of the WSA (1997) are described in the "Strategic Framework for Water Resources (2003)". This Strategy paper provides steps how to improve water and sanitation services until 2010 and how to finance water provision with a system of subsidies and water tariffs.

The National Water Act (1998) deals with the management of water as a national resource[4]. Herein, water is considered as a national good, fulfilling social and economic functions. It gives comprehensive provisions for the protection, use, development, conservation, management and control of water resources. The new Act acknowledges the role of the environment as well as the virtues of water demand strategies. The NWA (1998) is based on four objectives of equal importance: social equity, ecological sustainability, financial sustainability and economic efficiency. It promotes an Integrated Water Resources Management (IRWM, appendix 5.3) under a decentralized institutional framework. Decision-making falls into the competences of local governments, so that a greater participation in the decision-making processes is possible. The new institutions are Catchment Management Agencies (CMA) and Water User Associations (WUA) which are supposed to ensure an equal and beneficial water use for the benefit of all people by addressing poverty, generate economic growth and create jobs. The Act sets out the following priorities for allocating water:

1. Provision of the 'National Reserve'
2. Meeting international agreements and obligations
3. Meeting water needs for strategic purposes
4. Meeting the needs of general social and economic uses

Priority in water allocation is given to the 'National Reserve', which consists of the 'Ecological Reserve' and the 'Human Reserve' to meet basic human and environmental water needs. The average annual 'Ecological Reserve' for the Olifants WMA is estimated to be 460 million m^3 [Unesco, 2004]. The NWA (1998) provides the legislative framework for a change from so far existing riparian water rights[5] to a system of water licenses. This breaks the linkage between

[4]The actual implementation of the Act is described in the National Water Resources Strategy (NWRS).
[5]Landowners who own land with/adjoining water bodies have the right to use them.

land ownership and water leading to use rights instead of property rights[6]. Water licenses guarantee use rights up to a period of 40 years, but they have to be confirmed every 5 years. The application for a license involves registration of the water user, quantity of water used and purpose of water use. The registration is compulsory for all water users, not receiving their water from any official water service provider or governmental water schemes and are using water for non-domestic purposes [DWAF, 2003b]. Licenses are introduced to facilitate water allocation between the different water users. The Act allows for imposition of water use charges and a restriction of water use to avoid overuse of water resources at the expense of the 'National Reserve'. It furthermore acknowledges the possibility of temporary transfers of water entitlements and therefore creates the opportunity of water markets as allocation strategies.

2.2.1 New institutional settings

Since 1994, the national Department of Water Affairs and Forestry (DWAF) is responsible for water policy. Due to the new Water Acts, decentralization of the management of water resources from governmental to regional and local authorities is taking place. This decentralization process aims at the provision of a sustainable and cost-efficient management and allows for an easier participation of stakeholders in decision-making. Therefore, responsibility is shifted from DWAF to CMAs. Nineteen CMAs have to be established, each responsible for the water management in a WMA. Their tasks are to develop a catchment management strategy, organize the licensing process and guarantee water use rights, impose charges and monitor water quality. At the local level, WUAs as organizations of individual water users are supposed to contribute to the management of water and to ensure the representation of the interests of all water users[7]. According to the NSA (1997), the institutional organization of water and sanitation services is split up into different levels.

At the local level, Water Service Authorities (WSA) and Water Service Providers (WSP) represent the main institutions involved in domestic water provision. Local governments act as WSAs, ensuring access to water and sanitation. WSPs use and manage water reticulation schemes and can be either the WSA itself or outsourced to a private company. Water Boards (bulk water suppliers) deal with the supply of raw water to WSAs or WSPs. WSAs are linked to CMAs by requesting licenses for water abstraction and wastewater discharge and are thus also part of the water management plan.

[6] A property right is the exclusive authority to determine how a water resource is used. Use rights do not require land ownership.

[7] By law each WUA develops and submits water management plans according to quantities needed by the registered and licensed water users. Priority thereby is given to those agricultural uses, that incorporate high value crops and improved irrigation technique [Grove et al., 2006, page 3]. The agricultural sector strategy seeks to provide the framework for improved irrigation efficiency [Hedden-Dunkhorst, 2005].

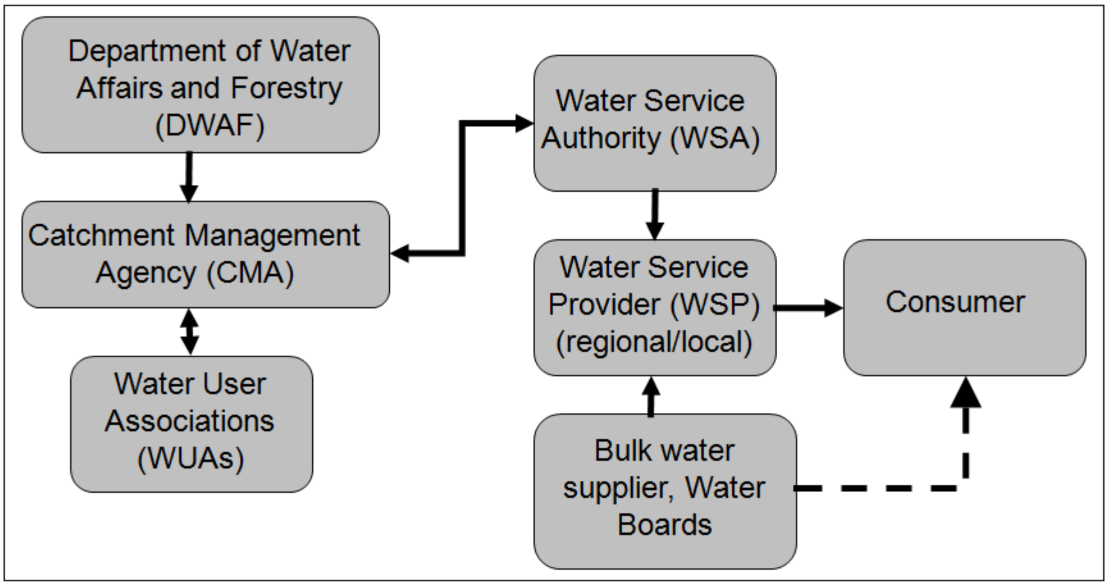

Figure 2.4: New institutional setting in the water sector in South Africa, modified based on [Hedden-Dunkhorst, 2005, page 163]

Lack of income made it impossible for many households to pay their water bills and they could not exercise their right to water. This became obvious to policy-makers in the late 1990s and, hence, the free basic water policy of the South African government was implemented in the year 2000. In order to ensure satisfaction of basic human water needs, a provision with 25 liters per day and capita (l/dc) or, respectively, 6000l/household[8] and month free of charge was introduced. This amount of water is supposed to be provided from a water source in less than 200 meters from the dwelling, at a flow rate of 10 liters/sec and at 98% reliability. Any quantity above the 25 l/dc requires payment.

2.2.2 Water pricing strategies and subsidies in the domestic sector

Water services provision in South Africa lies within the responsibility of the WSAs, Water Boards, Irrigation Boards and community-based organizations (in some rural areas) as described above. Among them, Water Boards provide bulk water supply services to WSAs and limited retail water services directly to mostly rural households. Irrigation Boards are responsible for the supply of water to large-scale irrigation areas. WSAs have the constitutional mandate to provide water services to consumers by purchasing (treated) bulk water from water boards for retail and reticulation. WSAs can be metropolitan cities, local municipalities and/or district municipalities functioning as water retailers. According to the new Acts, all people receiving water above the free-basic water standard, have to pay for water to ensure a non-wasteful water use. Water tariffs are intended to reflect actual values of water, especially, where water is very scarce and demand exceeds supply.

[8]An average South African household was assumed to consist of 8 members.

How the consumer tariffs are composed[9], can be inferred from Figure 2.5. According to NSA (1997) and NWA (1998), a three-tier pricing has to be implemented. First-tier pricing reflects raw water use abstracted directly from the water resource or supplied from governmental waterworks. Second-tier pricing addresses water supplied by Water Boards or Bulk Water Suppliers. The third tier consists of the retail price of water (water tariff), charged by municipalities to end users. A similar three-tier system exists for wastewater comprising sanitation charges, bulk wastewater tariffs and waste discharge charges [King, 2004, DWAF, 2007].

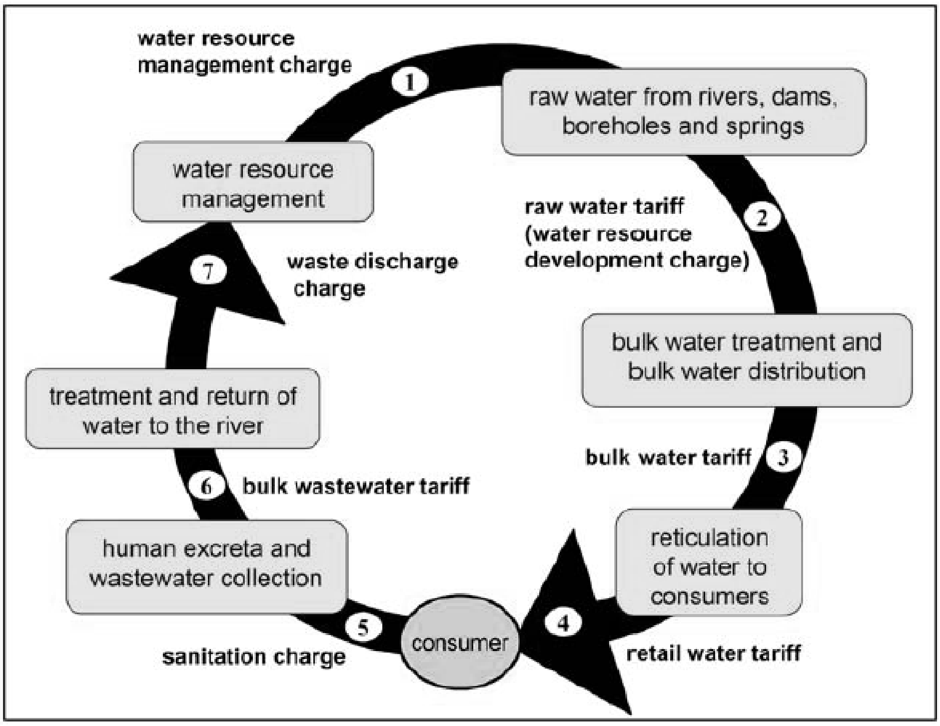

Figure 2.5: Price chain [DWAF, 2007]

The various charges and tariffs in the price chain add up to the retail/consumer tariff. Raw water prices are set by DWAF. This charge addresses objectives of social equity and ecological sustainability. It can be subdivided into the Water Resource Management charge (WRM charge) used for planning, managing, protecting, allocating and controlling water resources as done by CMAs in each WMA and other charges for water resource development to provide better water schemes and a waste discharge charge system. Table 2.3 gives an overview of average raw water charges per province.

Water boards act as intermediaries and distribute raw and potable water over vast distances to the regional supply schemes. They treat raw water and sell the treated water to WSAs/WSPs. Bulk water prices for potable water varied from ZAR 2.52 to 7.13 per m^3 in 2006/2007. Since 2001 increasing block rate tariffs are introduced to achieve equitable access to water (rela-

[9]Price and tariff are distinguished whereas "price" refers the broader market for water and includes aggregated tariffs, while "tariff" means the actual monetary charge to be paid by water users (either for withdrawal from bulk water supply or for water services) [King, 2004].

Table 2.3: Raw water charges per province in South Africa

Province	Average charge for domestic use (ZAR/m^3)	Average charge for irrigation use (ZAR/m^3)
Eastern Cape	0.43	0.04
Free State	0.25	0.02
Gauteng	0.13	0.00
KwaZulu-Natal	0.24	0.05
Limpopo	0.36	0.04
Mpumalanga	0.28	0.02
Northern Cape	0.26	0.01
North West	0.30	0.02
Western Cape	0.22	0.03
South African Average	**0.32**	**0.03**

[DWAF, 2007, page 42]

tively lower prices of the first blocks/free basic water), cost recovery (high-quantity users cross-subsidize low quantity/free basic water policy) and water conservation (high prices for high quantities). So far, according to DWAF (2007) in 60% of the municipalities, all households receive free basic water, in about 20% of the municipalities only certain households under the framework of the indigent policy[10] and in 20% no free basic water is provided. Average water prices are calculated by DWAF (2007) for all provinces and shown in Table 2.4.

Table 2.4: Average tariffs for households in South Africa, population weighted, including VAT

Province	Tariff 0 - 6 m^3 (ZAR/m^3)	Tariff 6 - 20 m^3 (ZAR/m^3)	Tariff 20 - 60 m^3 (ZAR/m^3)	Tariff $> 60m^3$ (ZAR/m^3)
population-weighted average	1.13	5.82	8.43	9.96
volume-weighted average	1.11	5.78	8.16	10.13

The weighted average takes into account the number of households that falls within each block while the volume-weighted approach considers the quantity of water consumed within each block and thus estimated the value of 1 m^3 of water in each block [DWAF, 2007].

Subsidising water services includes - besides municipal tariff schemes with increasing block tariffs and the free basic water policy - transfers from governmental income to cover operation and maintenance costs and infrastructure developments in poor municipalities. Two such subsidy measures are in place in South Africa: The Municipal Infrastructure Grant (MIG) and the Equitable Share. The MIG is a consolidated conditional grant to municipalities aiming to facilitate the eradication of backlogs in basic services (among them, basic water services) and cover the capital costs of infrastructure developments for poor households predominantly. Beneficiaries of the grant are municipal service providers or institutions either used extensively or run by

[10]Indigent policies in municipalities are designed to provide benefits (lower tariffs, grants, free basic water etc.) for those households who qualify due to a household income below a certain threshold.

poor households. The calculation of the MIG is based on a formula that takes into account backlogs with regard to water and sanitation in municipalities, the water and sanitation allocation amount and the total number of backlogs in South Africa [Tissington et al., 2008]. Local Government Equitable Share is an unconditional[11] grant from national government to local government, usually used as the main subsidy for operation and maintenance costs. It is meant to complement the MIG. The amount of money allocated to each municipality is determined by assessing fiscal capacity, fiscal efficiency, developmental needs, poverty and backlogs [Tissington et al., 2008].

Since the quality of water services extremely varies within South Africa due to historical, social and economic reasons, accordingly, retail water prices differ a lot between municipalities. DWAF (2007) states that tariff settings are highly inconsistent throughout the country. Currently, due to cross-subsidies and redistributed tax income, tariffs may sometimes not reflect actual values of water but rather socio-political objectives [DWAF, 2007].

2.2.3 Current status of the water policy reform

As CMAs are the new water management and planning institutions operating at the level of WMAs, they need to be provided with knowledge of the available water resources (locally and seasonally) and of the hydrological cycle and systems and interactions between them at the basin-level to account for the finite nature of water resources. Knowing how much water is available, where and when, is essential to be able to coordinate water demands of the different users. For many WMAs, among them, the Olifants-WMA, DWAF disposes of a substantial data basis concerning hydrological conditions, which can provide a valuable basis for planning purposes. To gather information on the different water users at the level of each WMA, registration of water use and respective quantities (Licensing) was made compulsory.

The decentralization resulted in WMAs and self-organization by CMAs and WUAs to account for the principle of participation in South Africa. In practice it is difficult to address marginalized users, particularly very poor households. But those have to be especially considered to address past inequities in South Africa and make sure that historically disadvantaged groups can participate. So far, not all CMAs or WUAs are operating and even if, many households are unaware of their existence. The new institutions are not yet functioning well, lacking experience[12] and competences and embedding into existing governmental structures. Funke et al. (2007) analyzed the IWRM-approach in the Mhlatuze Catchment in South Africa. They found that too few people are involved in water management at the national and local levels and that fluctuation in positions is high. Then there are still problems in coordination of functions and

[11] Municipalities do not have to report on how they allocate or spend the ES.

[12] While IWRM in South Africa is a key part of national policy on paper, it has yet to be accepted and understood by water managers in practice. Water managers are either unaware of IWRM or are too preoccupied with other tasks to give it full attention [Funke et al., 2007].

competences of local governments and traditional village leaders (Chiefs) [van Koppen et al., 2002]. Adjustment of the tasks and functioning of the newly built institutions is time and labor-intensive [Hedden-Dunkhorst, 2005].

Attaching an economic value to water in different uses enables the allocation of water to the most efficient users. Pricing is a useful instrument to prevent wasteful and inefficient water use. This principle has to be addressed with special consideration of the conditions in South Africa. As described above, water is a basic right in the South African Constitution and therefore access to a basic amount of water has to be guaranteed for free - as it is acknowledged by the free basic water policy - so that ability to pay for water does not influence access to water for basic needs. Still problematic in South Africa is the non-payment culture for water which makes it difficult to implement pricing as an economic tool. This is particularly true due to the fact that prices - if existing - are not well enforced. A special issue in South Africa are inequities resulting from past apartheid regime. Participation in the economic development is not equally distributed among different population groups. Large groups - especially rural households - are still disadvantaged and do not have adequate access to water. The decision-making of WUAs and particularly CMAs involves dealing with complex systems of interactions between multiple biophysical and socio-economic needs and with the promoted equity and sustainability concerns and thus requires high degree of technical and managerial expertise at these levels of decentralization [King, 2004]. According to Hassan and Farolfi (2005) water allocation decisions are currently made on the basis of very limited information on behavioral structures of the different water users [Hassan and Farolfi, 2005]. To better manage water demands, the South African government has implemented tools as water user registration and licensing. But the economic valuation of water in its different uses to ensure water use efficiency is not yet in the focus and data on that is still missing.

2.3 Summary and conclusions

This chapter gives a detailed characterization of the Middle Olifants sub-basin in terms of climatic conditions, population and socio-economic situation of households as well as land-use with a special focus on irrigation and mining activities. Commercial agriculture, mining as well as urban and rural households are the major water using groups that can be found in the Middle-Olifants. A comparison of available water resources and current water use of the different sectors shows that water is highly overused - at the expense of basic human and ecological needs.

Awareness of water scarcity and unequal access to water resulted in a water sector reform in South Africa and a new legislative framework and water-related policies. The new water management approach is characterized by decentralization with newly established institutions and management instruments aiming to ensure equal, beneficial and efficient water use. In this framework pricing of water is a key tool to ensure efficient and non-wasteful water use. The price chains for domestic water use as well as domestic water tariffs are described but also problems with regard to their implementation are discussed. A free basic water policy is introduced to address equity objectives and to ensure access to a basic quantity of water. Increasing block rates are implemented to allow for cross-subsidization of low-quantity users (presumably poor households) by high-quantity (rich) households. To ensure infrastructure development and coverage of operation and maintenance costs by redistributing tax income to poor municipalities, the MIG and ES were designed.

The imbalance between requirements of the NWA (1998) and the WSA (1997) and the current situation in the Olifants River basin necessitates a water management that reallocates water to ensure equity in access and sustainability of water resources and prevent overuse. Therefore, the scarce water must be used in an optimal way: economically efficient use (shift from low value to high value uses) but also social equality in access and sustainability of use.

Economic valuation of water uses is not one of the primary tools applied in water management in South Africa. A deep knowledge on hydrological settings and systems exists, but a detailed economic analysis of water users in terms of an economic valuation of water use at the catchment level as a substantial part of IWRM is missing. How to link economic efficiency to equity and sustainability needs further consideration and research in the Middle Olifants.

Chapter 3

Economic valuation

The economic value of a resource (or a good or service) is based on its scarcity and its contribution to human well-being. Therefore, it is necessary to take a decision about how to make the best out of what is available. 'Making the best' does not only refer to consumptive uses of resources but is also related to their existence or their preservation (due to altruistic or ethical concerns). In order to take a choice, it is important to assess the values associated with alternative uses of a resource or changes in environmental quality. This chapter elaborates on the economic concepts for valuation based on basic consumer theory and welfare economics. Welfare economics allow determining how to allocate scarce resources among potential users in order to meet an individual's or society's needs and to derive valid models for estimation and measurement of economic values. This provides the basis for the estimation of the analysis of the choice experiment using discrete data [Freeman III, 2003].

3.1 Choice behavior and consumer theory

All individuals are consumers of goods and services[1]. From a variety of goods and services, consumers make decisions by comparing different product or service alternatives with each other and select the one that they like most and the quantity they want to consume. In the following section, principles of individual choice are discussed. Following Ben-Akiva and Lerman (1985) consumers' choice process consists of a number of sequential steps [Ben-Akiva and Lerman, 1985]:

1. Definition of choice problem
2. Generation of alternatives
3. Evaluation of characteristics ("attributes") of the alternatives

[1]In the following the terms 'goods', 'commodities' or 'services' are used but the same concepts refer to natural resources.

4. Choice
5. Implementation

In a specific choice problem the following elements have to be defined:

- decision maker
- alternatives
- attributes and attribute levels
- decision rule(s)

In the following the decision maker is a household. Since households may have completely different tastes facing the same choice decision, it is important to explicitly include differences between decision makers in the explanation of choices. Any choice is made from a set of choices, consisting of a finite number of alternatives. These alternatives need to be feasible, realistic and known to the decision maker. The alternatives of the choice set can be either continuous (such as quantities of water, milk, bread and butter in a "commodity bundle") or they are naturally discontinuous such as different transport modes (e.g. train, bus, car) or different water sources (e.g. Private tap, Public Tap, Borehole). The attributes of alternatives give information about the characteristics of an alternative and thus its relative attractiveness. In case of continuous and homogeneous alternatives there can be only one attribute - namely quantity - that is necessary to differentiate between alternatives. For heterogeneous alternatives it is usually more appropriate to use several characteristics, which may be evaluated in a different manner.

To choose one alternative out of a set, alternatives have to be evaluated with respect to their characteristics. Different decision rules can be applied by the households to select the most preferred alternative:

1. Dominance: the alternative is chosen which is better with respect to at least one attribute and no worse for all others. Often, an alternative like that either does not exist or does not lead to a unique choice. But this rule can be used to detect inferior alternatives.
2. Satisfaction: A certain level of satisfaction is assumed for every attribute, so that alternatives with attributes not reaching these thresholds can be eliminated from the choice set. But - again - this rule does not necessarily result in the selection of a single alternative.
3. Lexicographic rules: The alternative is chosen, that contains the highest level of the most important attribute. If still more than one alternative meets this criterion, same applies to the second most important criterion ("Elimination by aspects").

4. Utility: This decision rule assumes that all attributes of an alternative can be summarized into one value of utility ("index of attractiveness"). This value is a function of different attribute levels allowing for compensatory effects between attributes. The individual will choose the alternative with the highest utility as the one having the best combination of attributes and levels.

Using the utility decision rule means that trade-offs between attributes are made. The alternative with the best combination of all attributes is chosen (resulting in the highest utility score). Attributes with undesirable levels can be compensated by others with desirable levels. In case of market goods, price is one of the attributes. People express their preferences through the choices they make, given certain constraints, such as income or available time. Economic consumer theory assumes that people have well defined preferences among alternatives and are aware of them.

Consumer demand theory relates assumptions about preferences with demand for goods [Deaton and Muellbauer, 1980]. A consumer chooses a consumption bundle $Q = \{q_1, q_2, \cdots, q_i, \cdots, q_n\}$, where q_i are quantities of goods i that are commonly assumed to be nonnegative continuous variables[2]. The consumption bundle can consist of any quantities of the goods, but is constrained by the available budget and influenced by the respective prices. For fixed income and prices, the budget constraint is

$$Y \geq \sum_{i=1}^{n} q_i p_i \tag{3.1}$$

where Y is income and p_i are the respective prices. Since many different consumption bundles are possible with a given income, the consumer is assumed to have preferences over alternative bundles i and j, $Q_i \succeq Q_j$. The sign $\succeq$ means that consumption bundle Q_i is at least as good as Q_j. Regarding consistency, preferences for goods are assumed to be transitive[3], complete[4], reflexive[5], continuous[6] and non-satiated[7].

The axioms of transitive, complete and reflexive preferences already ensure a deterministic and consistent preference ordering, but all of them are needed to reduce the consumer's choice problem to the constrained maximization of utility [Deaton and Muellbauer, 1980, Pages 3-28]. The utility function is ordinal, meaning that a preference ranking exists, that orders bundles while it is not possible to assign a specific value to the utility level associated with a specific con-

[2]For goods that are available only in discrete quantities, the theory is essentially the same, but some modifications are necessary and n is the total number of goods considered. Details on discrete choice theory are given in section 3.4.1.

[3]if $Q_i \succeq Q_j$ and $Q_j \succeq Q_k$, then $Q_i \succeq Q_k$.

[4]$Q_i \succeq Q_j \vee Q_j \succeq Q_i$, completeness requires that any consumption bundle can be compared and evaluated by the decision maker.

[5]Preferences are reflexive if for all Q_i, $Q_i \succeq Q_i$ (Q_i is at least as good as Q_i).

[6]Define $A(Q_i)$ for any bundle Q_i as the at least as good as Q_i and $B(Q_i)$ as no better than Q_i set by $A(Q_i) = (Q|Q \gtrsim Q_i)$, $B(Q_i) = (Q|Q_i \gtrsim Q)$. Then $A(Q_i)$ and $B(Q_i)$ are closed and contain their own boundaries for any Q_i in the choice set.

[7]A bundle of goods with a larger quantity of one good will be preferred.

sumption bundle (ordinal utility theory). Preferences can be expressed as indifference curves. Along these indifference curves, consumers are indifferent between all consumption bundles represented by that curve.

Expressing preferences mathematically, a consumption bundle is represented by a scalar value of utility:

$$u = u(\mathbf{Q}) \tag{3.2}$$

where $\mathbf{Q}$ is a vector of quantities ($\mathbf{Q} = q_1, \cdots, q_i, \cdots, q_n$) of n commodities in a bundle.

The utility function needs to be twice differentiable and strictly quasi concave. Maximizing utility (equ. 3.2) subject to the budget constraint ($Y = \sum_{i=1}^{n} q_i p_i$) and solving the first order conditions yields the ordinary demand functions for each of the n commodity quantities:

$$q_i = q_i(\mathbf{P}, Y) \tag{3.3}$$

where $\mathbf{P}$ is a vector of prices ($\mathbf{P} = p_1, \cdots, p_i, \cdots, p_n$). This is a set of n (ordinary, uncompensated) Marshallian demand functions explaining quantity demanded as a function of price and income.

Substituting the optimal quantities into the utility function yields the indirect utility function v, which represents the maximum attainable utility given prices and income[8]

$$v(\mathbf{P}, Y) = u \tag{3.4}$$

Given v is monotonic increasing in income, it can be inverted to yield the expenditure function

$$v^{-1}(\mathbf{P}, Y) = e(\mathbf{P}, u) \tag{3.5}$$

Dual to the maximization problem is expenditure minimization. The individual's problem is to choose $q_1, ..., q_i, \cdots, q_n$ to minimize total expenditures given by the following function

$$e = p_1 q_1 + \cdots + p_i q_i + \cdots + p_n q_n \tag{3.6}$$

subject to the constraint to attain a given (minimum) utility level u^*

$$u^* = u(\mathbf{Q}) \tag{3.7}$$

The solution to the minimization problem is a set of compensated, Hicksian demand functions. The optimal amounts of $q_1, \cdots, q_i, q_n$ depend on the prices of the goods and the required utility level. As prices change, expenditures are adjusted in order to maintain the same level of

[8]According to Roy's identity demand functions can also be expressed in terms or the underlying indirect utility functions $q_i(\mathbf{P}, Y) = \frac{\delta v / \delta p_i}{\delta v / \delta Y}$.

utility. Substituting these demand functions into equation 3.6 yields the expenditure function. Expenditure function and compensated demand function are related via Shepard's Lemma in a way, that the (compensated) Hicksian demand for a good is the derivative of the expenditure function with respect to price:

$$\frac{\partial e(\mathbf{P}, u)}{\partial P_i} = q_i^H(\mathbf{P}, u) \tag{3.8}$$

In uncompensated, Marshall demand functions price and income effects are bundled while in compensated demand functions price effects are isolated. Compensated and uncompensated demand are related via the Slutsky condition, which decomposes the effect of a price change into the substitution effect and the income effect of the price change as follows

$$\frac{\partial q_i^M(\mathbf{P}, Y)}{\partial p_j} = \frac{\partial q_i^H(\mathbf{P}, u)}{\partial p_j} - \frac{\partial q_i^M(\mathbf{P}, Y)}{\partial Y} * q_j^M(\mathbf{P}, Y) \tag{3.9}$$

Usually, consumers' behavior can be observed on markets and from that, demand functions for goods can be estimated instead of directly observing utility functions. Demand functions should contain the same information as the underlying preferences in utility functions: If the integrability conditions are satisfied, a set of demand functions can be integrated resulting in the expenditure function. These conditions require that the Slutsky matrix is symmetric and negative semi-definite [Hurwicz and Uzawa, 1971; Silberberg, 1978; Varian, 1984 as cited in Freeman (2003)]. The expenditure function can then be used to derive direct and indirect utility functions.

This section explained the basic demand theory with a particular emphasis on utility and demand functions and their relationship as these are the central functions used for the valuation of domestic water use in the Middle Olifants. To give explanations on how these functions are linked to the basic welfare concepts and measures is the objective of the next section.

3.2 Definition and concepts

The valuation problem is essentially regarded as a problem of calculating changes in welfare due to alternative uses of scarce resources. The theory of economic valuation is based on individual preferences and choices as explained above. A central assumption for welfare economics is that preferences have the property of substitutability. If the consumption of one good or resource is reduced, a person can be compensated by an increase in another good or resource so that he or she is not worse off than before. The trade-offs that people make, reveal the values that they place on different goods or resources. Values based on substitutability can be expressed in terms of Willingness to pay (WTP) and Willingness to accept (WTA). Values can be placed against any good but usually they are expressed in monetary units.

WTP is the maximum amount of money an individual is willing to pay to experience an improvement or to avoid a deterioration/loss.
WTA is the minimum amount of money an individual would require to voluntarily forgo an improvement or experience a deterioration/loss that would be otherwise experienced/not experienced.

WTP is the amount, that would make an individual indifferent between the alternatives of paying the money and experiencing an improvement/avoiding a loss or not experiencing/avoiding it and keeping the money. WTA is the amount that would make an individual indifferent between the alternatives of forgoing the improvement/experience a deterioration and receiving the money or experiencing the improvement/not experience the deterioration. Though both concepts are based on substitutability, their reference points are different. WTP refers to the absence of goods/resources while WTA is relative to their presence. WTP is constrained by an individual's income since a person cannot pay more than what is earned while WTA is actually unconstrained, so that both measures do not necessarily coincide.

WTP is related to the demand curve, as a demand curve reflects the WTP for alternative quantities of goods. As already mentioned before, the demand curve is the derivative of the utility function and thus indicates marginal utility of an additional unit consumed. This equals the marginal WTP for an additional unit as depicted in Figure 3.1. The total WTP for a given quantity of good is represented by the area under the demand function up to the quantity, to be calculated by integrating the demand function (see Figure 3.1).

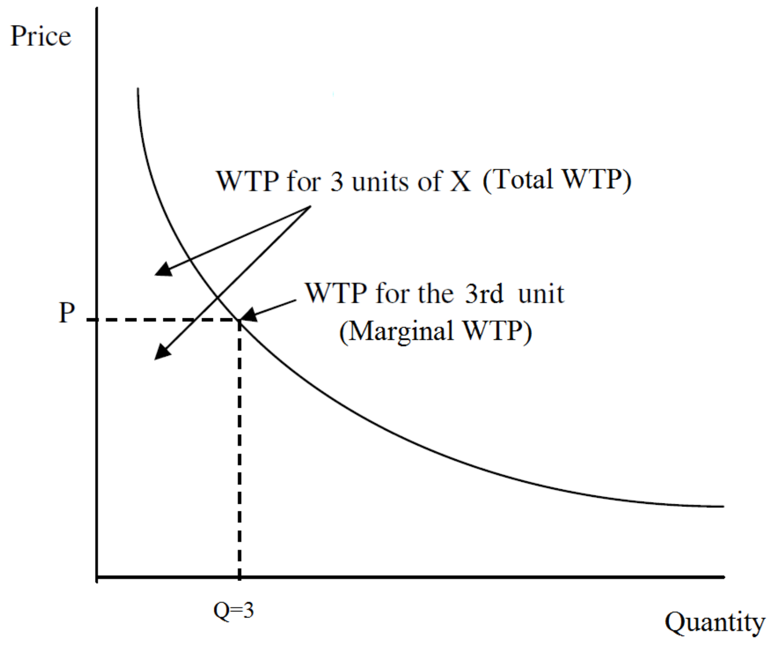

Figure 3.1: WTP and Demand curve

Measuring changes of welfare is mainly used to assess the impact of policy changes or to evaluate quality/price changes of goods or service. Concepts of Consumer Surplus (CS), Compensating

(CV) and Equivalent Variation (EV) and Compensating (COS) and Equivalent Surplus (ES) are used to compare the well-being of a consumer before and after a change. Changes can be either caused by a price change, a change in quality or quantity of a good. Figure 3.2 serves to explain the differences between CS and CV/EV graphically for a price change from p_1^0 to p_1^1 and thus a utility change from u^0 to u^1 in a two-commodity case.

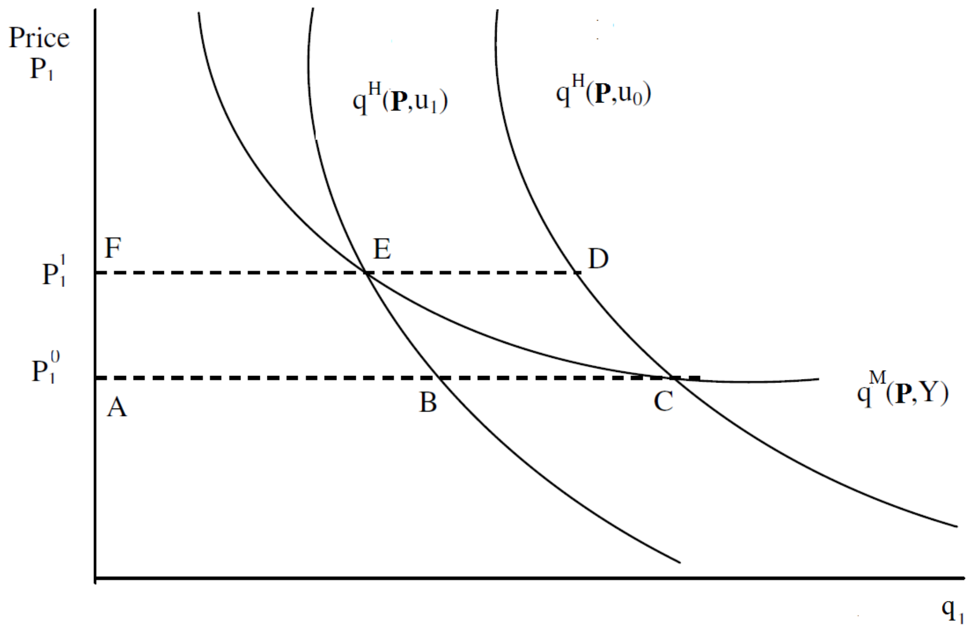

Figure 3.2: Consumer Surplus, Compensating and Equivalent Variation [Braden and Kolstad, 1991, Freeman III, 2003, page 29 & page 58]

The most common measure of consumer welfare is (uncompensated) Consumer Surplus, which constitutes the integral under the Mashallian demand function until the actual price, so it can be described by the area ACEF in Figure 3.2 [Braden and Kolstad, 1991, pages 28-30]. CS is defined as the difference between what consumers would be willing to pay and what they actually pay. But the Marshall demand function reflects both income and substitution effects so that these effects are compounded. CS is not an appropriate welfare measure as it does not provide a potential compensation due to a gain or a loss. CS cannot be defined in terms of the underlying utility function [Freeman III, 2003, page 49]. Despite of that, measures of Consumer Surplus are often used due to the fact that mostly Marshall demand functions are empirically estimated (because researchers observes the reaction to both, income and substitution effects [Braden and Kolstad, 1991]).

The remaining four measures, CV, EV, COS and ES are theoretical refinements of the ordinary Consumer Surplus and represent relevant welfare measures (Hicks 1943 as cited in Freeman 2003, p. 51). They relate to the Hicks demand curve. The following definitions refer to measurements of welfare changes due to price changes. CV describes the (compensating) amount of money, that is necessary to make an individual indifferent between the original situation (before the price change) and the new price situation. CV is often interpreted as the maximum amount of money an individual would be willing to pay for the opportunity to receive a good at a new (lower) price or that he or she has to be paid to make him/her indifferent towards a price increase [Freeman III, 2003]. In terms of the indirect utility function, CV is the solution to

$$v(\mathbf{P}^0, Y) = v(\mathbf{P}^1, Y - CV) = u^0 \tag{3.10}$$

EV asks what change in income at original prices would cause the same change in utility as a price change. Hence, it has been interpreted as the minimum payment that would make an individual indifferent between the old situation and a new (lower) price or the maximum amount an individual would pay to avoid a new (higher) price. EV is the solution to

$$v(\mathbf{P}^0, Y + EV) = v(\mathbf{P}^1, Y) = u^1 \tag{3.11}$$

CV yields income to maintain the utility level u^0 and EV removes the amount of income to reach the same utility as the price change u^1. Figure 3.2 allows to graphically compare CS with CV and EV. CV in Figure 3.2 is the integral under the Hicksian demand function $q^H(\mathbf{P}, u^0)$ and can be described by the area ACDF while EV refers to the area ABEF. Consumer Surplus is considered as an approximation of the CV and EV which are pure income effect measures. For a normal good, CS lies somewhere between compensating and equivalent variation (Willig's Theorem).

COS and ES are measures that are quite similar to CV and EV, respectively. The basic difference between CV/EV and COS/ES is that CV and EV allow quantities to adjust due to price and income changes, while COS and ES restrict quantity adjustments. In most situations, CV and EV are the measures applied because they are based on competitive behavior. But COS and ES are of importance when consumers cannot adjust their purchased quantities of a good. This is often the case when environmental goods are considered which may be consumed in fixed imposed quantities only [Just et al., 1982]. Many policy proposals want to change qualities or quantities of nonmarket environmental goods or services rather than price changes of market goods [Freeman III, 2003] so it is important to know how welfare would change. When explicitly evaluating quantity changes of a good, COS and ES are the appropriate measures[9] [Freeman III, 2003, page 74]. According to Freeman (2003) there are several ways of presenting COS and ES for changes in quantity constraint goods: Considering the indirect utility function, COS is the solution to $v(\mathbf{P}, Y - rq^0, q^0) = v(\mathbf{P}, Y - rq^1 - COS, q^1)$ and ES to $v(\mathbf{P}, Y - rq^0 + ES, q^0) = v(\mathbf{P}, Y - rq^1, q^1)$ with r as the price of the quantity constraint good. The two measures can also be expressed in terms of the expenditure function:

$$COS = e(\mathbf{P}, r, q^0, u^0) - e(\mathbf{P}, r, q^1, u^0) = Y - e(\mathbf{P}, r, q^1, u^0) \tag{3.12}$$

$$ES = e(\mathbf{P}, r, q^0, u^1) - e(\mathbf{P}, r, q^0, u^0) = Y - e(\mathbf{P}, r, q^0, u^1) \tag{3.13}$$

[9] COS and ES are also defined for changes in prices. See Freeman (2003, pages 49-52) for more details.

When $r = 0$ as it is the case for many environmental goods and also for basic water services in study area, the measures can be simplified. The budget lines are horizontal as can be seen in figure 3.3. At the initial position, the individual consumes q^0 and x^0 and reaches utility

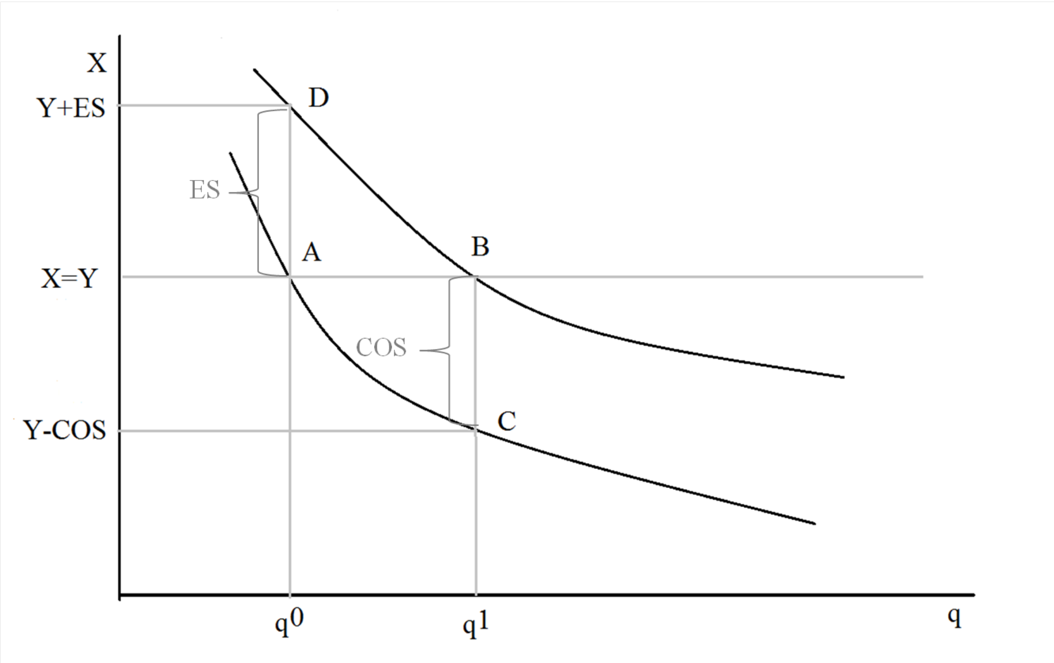

Figure 3.3: Compensating and Equivalent Surplus for a change in q when $r = 0$ [Freeman III, 2003, page 80]

level u^0. This is point A in Figure 3.3. The quantity increase up to q^1 allows to reach utility level u^1, which is represented by point B. Reducing income by COS, pushes the individual to point C at the same quantity level q^1. Here, the individual is not allowed to make any quantity adjustments. Same holds true for ES. As before, the quantity increase enables the individual to reach utility level u^1. If income is increased by ES, the individual could reach the same utility level while holding q constant at q^0 (point D).

3.3 Valuation techniques for domestic water use

As basic water services are provided for free in South Africa and domestic water tariffs may lack enforcement and even not reflect true values, non-market valuation, using either revealed preference or stated preference, becomes necessary. Data from observed market behavior is used for revealed preferences methods. Here, individuals - as actors in a real world - bear the consequences of their choices. Stated preferences methods rely on people's responses to hypothetical questions about their behavior. These methods involve asking people directly about the values they infer. Their responses can then be interpreted as compensating or equivalent measures and, hence, these methods are also called "direct valuation methods". Revealed preferences methods are referred to as indirect methods, because values have to be obtained from behavior.

3.3.1 Revealed preferences methods for domestic water use

Revealed preferences methods can be used to value non-market goods such as e.g. environmental quality or environmental services from observed behavior that is associated to the good to be valued (e.g. visiting a recreation site or buying a house). Revealed preference methods are based on people's behavior in actual market settings and these markets are somehow related to non-market goods to be able to reveal underlying values. The choice of visiting a recreation-site or buying a house is assumed to reveal information about how people value water quality or air quality for example. Commonly used revealed preferences methods are Hedonic pricing, Travel cost method and Averting behavior. Hedonic pricing uses information about how much people pay for houses or other directly purchased goods or services with specific attributes of interest to infer how much they value changes in those attributes. Travel cost methods use information about how much people pay to visit locations with specific environmental attributes. Averting-behavior methods base the estimation of economic values on people's expenditure to avoid negative effects. Among those methods, travel cost method is frequently used to value domestic water services when people have to cover long distances to fetch water as costs of overcoming the distance arise [Osei-Asare, 2005, Banda et al., 2007, e.g.]. Those costs can consist of travel costs but also opportunity costs of time. Though a useful tool for valuing public taps and other water sources, the method cannot infer values for water sources located close to the house that can be accessed without inferring any costs.

3.3.2 Stated preferences methods for domestic water use

Stated preferences methods can be applied to generate values of domestic water use. This section presents methods and their suitability given the conditions in the Middle Olifants. Stated preferences methods are often critized referring to validity problems and biases. After choosing the appropriate method, ways to accommodate for the relevant biases are discussed. Stated preference methods seek to elicit preferences directly by asking individuals about their preferences and their willingness to pay using surveys [Freeman III, 2003]. They typically ask for the maximum willingness to pay for an improvement (= Compensating Surplus) or the maximum willingness to pay to avoid a loss (= Equivalent Surplus) [Freeman III, 2003, page 163] or the minimum amount to accept a deterioration or forgo an improvement. These methods can reflect use as well as non-use values. Freeman (2003) classified stated preferences methods into Contingent Valuation Method (CVM), in which WTP is directly asking for, attribute-based methods[10] and contingent behavior methods, the latter two methods not revealing monetary measures directly. Attribute-based methods require the use of an analytical model, a discrete choice model, that provides a set of parameter weights on the attributes. Usually one of the

[10] This term refers to Holmes and Adamowicz (2003), Freeman (2003) called them "stated choice-methods" [Freeman III, 2003].

attributes is a monetary attribute to calculate WTP, thus measuring WTP is not as straight forward as in CVM. Stated preferences methods in the context of water resources are useful for valuation of improved water services or recreational activities and public goods in general [Mitchell and Carson, 1989], but also for environmental aspects of water resources such as water quality and biodiversity.

Contingent valuation method

Contingent valuation method (CVM) is a survey-based method to determine monetary valuations. An individual's WTP or WTA is measured in a hypothetical market scenario by asking the amount of money (e.g. entrance fees, taxes, meals etc.) a person would be willing to pay for an improvement or willing to accept for deterioration [Freeman III, 2003]. The monetary values obtained are contingent on the hypothetical market scenario and the described good or amenity. The question format may be either a direct question (continuous or open-ended question), an iterative bidding game, Payment cards [Mitchell and Carson, 1989] or a referendum (Yes/No) vote (discrete or dichotomous choice). Utility is allowed to depend on socio-economic variables assumed to influence the trade-off between income and the level of the good or resource.

Attribute-based methods

Attribute-based methods are commonly divided according to the kind of choosing into Choice experiments ('Choose the most preferred alternative'), Ranking experiments ('Rank a set of alternatives from most preferred to least preferred') and Rating experiments ('Give a utility score to each alternative') [Hanley et al., 2001, e.g.]. All of them have their roots in Lancaster's characteristics theory of value [Lancaster, 1966] and random utility theory [Manski, 1977]. Choice experiments (CE) mimic actual market behavior best since respondents usually select only one option out of a set of options e.g. in a supermarket [Adamowicz et al., 1998, Page 189]. Ranking experiments have the advantage that they reveal more information than CEs since rankings provide information on preferences for all options in a choice set - not only for the most preferred option. But rankings are cognitively more demanding than a single choice and also do not reflect the true market situation [Adamowicz et al., 1998, Page 193]. Hanley et al. (2003) sum up findings on limitations of ranking experiments and indicate that choices were found to be unreliable and inconsistent across ranks. Also, subsequent choices may reflect a conditional demand curve since choices are made conditional on the remaining options [Louviere et al., 2000]. In a rating experiment, the respondent is asked to rate different options on a utility scale by assigning the magnitude of utility provided by that option. But despite the appeal of this method in its simple econometric analysis, Adamowicz et al. (1998) do not recommend its use. Ratings have to be adjusted on a common metric scale and respondents need to indicate their status quo utility as a reference for the changes. Respondents are not familiar with the rating situation since it does not reflect an actual market situation. Hanley et al. (2001) state that its rather strong assumptions lead to inconsistent estimates.

In attribute-based models the options to choose from, rate or rank are called "alternatives", and the set of options "choice set". The alternatives differ with respect to their characteristics ("attributes"). Attribute-based methods comprise the following elements [Louviere, 2001]:

- a set of choice sets (usually 2-10), each of them presenting 2 to 4 choice alternatives. Alternatives may be named to reveal information about the kind of alternatives ("Labeled"). In transportation studies, alternatives usually indicate the transportation mode (e.g. car, bus, train) or, in marketing studies, alternatives may be named according to product brands. In contrast to that, alternatives may have uninformative names such as 'Alternative A' and 'Alternative B', in which alternatives comprise only attributes and their relevant levels ("Unlabeled"). The researcher has to choose which approach is more suitable given the particular valuation problem.
- a set of attributes, meaningfully describing differences between alternatives and explaining preferences. Attributes can be part of all alternatives ('generic attributes') or apply to certain alternatives only ('alternative-specific attributes').
- a set of levels of each attribute to represent variation in the respective attribute among the options. Levels may be binary (attribute present/not present), discrete or numerical and the number of levels may vary between attributes.

Levels of attributes are combined into alternatives according to statistical design principles[11]. For valuing water services, respondents can be asked to evaluate sets of water service alternatives that differ with respect to certain service attributes such as frequency of water supply, price and payment method. With this method, respondents are forced to make trade-offs between different attributes and, hence, reflect their preferences. From the trade-offs between attributes/attribute levels, marginal rates of substitution between pairs of attributes and, given price is one attribute, WTP can be calculated.

Contingent behavior method

Contingent behavior method is often used to combine data from stated preferences with data provided from revealed preferences. The method refers to hypothetical questions about how the actual behavior would change if some characteristics of a good/resource/site (instead of their reaction to cost increases) change [Freeman III, 2003]. In a recreation context, respondents are presented with hypothetical scenarios of different site conditions and then asked if they would change their intended number of visits. A recent application of contingent behavior method for valuation of forests in the UK is Christie et al. (2007).

[11] Louviere emphasizes that the statistical design allows for data collection in a way that particular model forms derived from theory can be estimated, which is a clear advantage over revealed preferences (problem of parameter identifiability [Louviere, 2001, Page 17].

Validity and biases in stated preferences methods

Compared to market-based, revealed preferences methods, stated preferences methods have in general the advantage of greater flexibility in eliciting values as they are not restricted to the actual situation. The researcher is able to control the setting and to focus on the specific research interest. A common problem when applying market-based methods is that variables are collinear making it difficult to predict effects of variations in a single variable. This problem can be avoided by specific design principles of stated preferences methods, especially attribute based methods [Louviere, 2001]. However, there is a potential danger that the stated preferences results will not be consistent with real life settings and differ from true preferences due to the hypothetical nature. Hypothetical bias arises because answers to stated preferences questions have no consequences in contrast to real market situations since respondents who state that they would pay are not actually required to pay. The respondent may be trying to influence policy decision by their answers (strategic bias) and/or the respondent may simply be pleasing the interviewer (yea-saying bias reflecting the tendency to agree with proposed payments). Hypotheses regarding hypothetical bias may be tested using assessments of different types of validity[12]. The validity is a measure for the degree a stated preferences study (usually CVM) accurately measures the value it is supposed to measure [Mitchell and Carson, 1989]. It is subdivided into criterion, content and convergence validity[13]. Content validity asks whether structure, objective and design of the stated preferences study is based on economic theory. Convergent validity compares estimates with those generated by a second non market valuation techniques such as travel cost method, different contingent valuation response formats or choice experiments. The more the results of the related methods are correlated, the more validity of them is emphasized [Adamowicz et al., 1998]. Criterion validity tests compare stated behavior in hypothetical contexts and actual behavior using some type of real payment. They have the greatest potential to test for WTP validity [Mitchell and Carson, 1989]. Three general types of criterion validity tests are comparisons of stated preferences responses to behavior in actual markets, responses to behavior in simulated markets involving actual money transactions and to voting behavior in binding public referenda.

Concerning the validity of choice experiments, some authors compared results from stated choice experiments with those generated by "real" choice experiments, in which at least one of the choices is binding and involves real money transactions. Carlsson and Martinsson (2001) found that marginal WTP for environmental projects in both experiments was statistically equal - but later approaches criticized them for not using an opt-out option in the choice experiment and not calculating total WTP [Carlsson and Martinsson, 2001]. Lusk and Schroeder (2004) found as well that marginal WTP for a change in quality of a private good did not differ statistically, but they found a difference in total WTP. Using a hypothetical CE total WTP

[12] See Veisten (2007) for a current review of validity tests [Veisten, 2007].

[13] According to [Mitchell and Carson, 1989], instead convergence validity, theoretical validity (the degree to which study results are consistent with economic theory) and convergent validity are combined into construct validity.

was significantly higher than when using a real experiment [Lusk and Schroeder, 2004]. Also, Alfnes and Steine (2005) analyzed estimates for a private good such as salmon generated by a stated and a real choice experiment and could confirm findings of Lusk and Schroeder (2004). Total WTP was overestimated in a hypothetical CE while marginal WTP did not differ [Alfnes and Steine, 2005]. Johansson-Stenman and Svedsäter (2003) concluded that marginal WTP for contributions to campaigns is highest when choices are hypothetical, lower in a real choice experiments experiment that follows a hypothetical experiment, and lowest when real-money choices are made directly. Besides, they found in their study that uncontroversial product attributes such as quality are less likely to have a hypothetical bias than attributes reflecting an ethical dimension such as how much to leave for future generations and environmental friendliness[14] [Johansson-Stenman and Svedsäter, 2003]. To sum up these studies, it seems that marginal WTP for a certain non-ethical attribute is less prone to hypothetical bias but still much more research is needed to validate these few findings[15].

'Warm glow' effects - defined as the enjoyment derived by contributors to charities or other good - describe the finding that benefits realized by the beneficiaries and good feelings of giving may have an effect on WTP [Kahneman and Knetsch, 1992]). Strategic bias arises when the respondent provides a biased answer in order to influence a particular outcome. If respondents believe that prices and tariffs actually have to be paid, they may understate their WTP. If individuals assume prices and tariffs or taxes will not have to be paid, they may overstate true values in order to ensure provision of the good or service [Mitchell and Carson, 1989]. Especially in cases of the valuation of public goods, strategic behavior can occur, because once the public good is provided no one can be excluded from its use (incentive to free-ride). However, after many tests, which can be found in the literature, Freeman (1986) (as cited in Hanley (1986)) concluded that evidence of free rider behavior was not found in most CVM studies so far[16]. However, not all, but many of the studies confirmed significant differences between actual (true) and stated (hypothetical) WTP [Arrow et al., 1993, Carlsson et al., 2005, Hanemann, 1994]. Further research is therefore needed to clarify the presence and extent of strategic behavior in stated preferences methods.

Literature on how to classify and name the various biases is quite diverse, therefore the following enumeration of biases does not claim to be exhaustive. Besides the before mentioned biases, embedding effects describing findings that WTP for the same good depends on whether it is assessed on its own or embedded as *part of a package* [Kahneman and Knetsch, 1992, Page 58].

[14] Brownstone and Small (2005) and Isacsson (2007) analyzed the value of travel time and both measured a higher WTP for a reduced travel time in real experiments than in hypothetical experiments. Isacsson supposes this is due to the perceived travel time which is different from actual travel time.

[15] As Alfnes and Steine (2005) point out that it is difficult to really compare results between experimental markets and CE due to a difference in representation of the products to be valued. While experimental markets involve real physical products, CEs define products only over certain attributes which may lead to differences in valuation.

[16] Little and Berrens (2004), List and Gallett (2001), Murphy et al. (2005) review a growing literature focusing on assessments of hypothetical biases in contingent valuation studies.

Studies found that the WTP for one good is equal to the WTP for a more comprehensive good, that comprises the previous good. These findings question the logical consistency of CVM. According to Hanemann (1994), embedding effects can be further split up into scope, sequencing and sub-additivity effects. Scope effects describe the failure of respondents to distinguish differences in the amount or scale of the resource or good to be valued. The sequencing effect reflects the tendency of respondents to indicate different WTP values depending on whether a hypothetical good is offered at the beginning of a list or if it appears at the end. The sub-additivity effect arises when values of the components of a good or resource do not sum to total value. A possible explanation for the presence of sequencing and sub-additivity effects is that they represent substitution effects and diminishing marginal utility, so they are consistent with utility theory [Hanemann, 1994][17]. Strongly related to embedding effects are so-called ordering effects. Ordering effects describe a situation in which the values respondents place on a nested sequence of environmental goods are sensitive to the order in which the goods are presented. Typically, the smallest bundle of goods is valued more highly if presented first than following more comprehensive bundles[18]. In CEs ordering effects are related to the order of attributes or choices in the choice experiment [Olsen et al., 2005].

Framing effects occur when individuals try to cope with their uncertainty about how to value a good by using information from the questionnaire, such as the question's phrasing or the structure of possible responses guiding them in valuation of the good. A classical example of framing effect is described by Tversky and Kahneman (1981) [Tversky and Kahneman, 1981]. In their article, findings differ with respect to a positive or negative framing of the question (save lives = positive frame, minimize deaths =negative frame)[19]. Anchoring bias appears when respondents base their answers on the attribute levels provided in the CE, rather than on their own true preferences (also referred to as "range-bias"). This effect can be either related to monetary or non-monetary attributes. Verlegh et al. (2002) found significant effects of varying attribute levels and their range widths [Verlegh et al., 2002]. Ohler et al. (2000) however did not detect significant effects of varying attribute level ranges on parameter estimates taking scale differences into account [Ohler et al., 2000]. Ryan and Woodsworth (2000) compared WTP with regard to changes in the levels of attributes. Their results indicated a significant impact of varying attribute levels on mean WTP estimates, there was no clear result on the direction of that impact [Ryan and Wordsworth, 2000]. Testing for effects of the monetary attribute, Carlsson and Martinsson (2008) varied only the levels of the monetary attribute, and found a higher WTP of those respondents presented with the higher cost levels [Carlsson and Martinsson, 2008]. Though Hanley et al. (2005) found the same, the difference in WTP was not statistically significant [Hanley et al., 2005].[20]

[17]Whether embedding effects are present is testable [Carson and Mitchell, 1995].
[18]For a recent test of the presence of order effects and a literature review see Clark and Friesen (2008) [Clark and Friesen, 2008].
[19]For an overview of studies conducted on framing effects see [Kuhberger, 1998].
[20]However, Whynes et al. (2004) found evidence for range bias in a contingent valuation study [Whynes et al.,

According to Mitchell and Carson (1989), Payment vehicle bias appears *where the payment vehicle is either misperceived or is itself valued in a way not intended by the researcher*. Further discussion of biases in stated preferences methods can be found in [Bateman et al., 2004, Garrod and Willis, 1999, Mitchell and Carson, 1989].

But despite the before mentioned problems and biases, stated preferences methods have high potential, because they are often the only possible valuation method when markets are absent [Manski, 2000]. Stated preferences methods can describe new goods and design hypothetical markets for non-market goods, and therefore exceed possibilities generated by revealed preferences methods. Well designed surveys can avoid many of the potential biases [Mitchell and Carson, 1989, Manski, 2000].[21]

Within the class of stated preferences methods, many comparisons of CVM-studies and CE-studies have been conducted so far [Boxall et al., 1996, Hanley et al., 1998, Adamowicz et al., 1998, Stevens et al., 2001, Mogas et al., 2006, Christie and Azevedo, 2009]. These studies compared welfare estimates derived from CE and dichotomous CVM or parameter estimates from a preference model to find out whether a common underlying preference structure in both exists. Boxall (1996) found similar welfare estimates when taking into account the number of available substitutes in CVM. Hanley (1998) found welfare estimates of CE to lie within the 95% confidence interval of CVM estimates. Stevens (2000) identified differences in welfare estimates but concluded that further research is needed on that topic. Mogas (2006) compared different specifications of utility in the welfare estimation process and concluded that these specifications cause unequal welfare estimates. Similar welfare estimates could be derived when accounting for interactions between attributes. Christie and Azevedo (2009) compared results of a CE to a repeated CVM-study and their test results showed consistency between CVM and CE in terms of parameter equality, but at the same time the authors found inconsistency in the compensating surplus welfare estimates.

Findings in the literature so far point out that still more research is needed to clarify which factors influence consistency of CE and CVM estimates. Apart from the discussion on consistency and comparability of welfare estimates, there is consent on the advantages and disadvantages of CE over CVM. While CVM approaches the value of a good or resource as a whole, CE methods allow to estimate disaggregated values of the characteristics of a good or resource. In terms of the economic value, CE can easily reflect specific values depending on the attributes chosen. In CVM studies usually nothing is revealed about the different characteristics and components of the good or resource valued, while in CE studies the characteristics are the main focus. With experimental design strategies, collinearity between attributes and attribute levels can be completely eliminated or reduced. It avoids Yea-saying bias likely to exist in dichotomous

2004].

[21] Summing up a lot of discussion of biases in the CVM literature the National Oceanic and Atmospheric Administration (NOAA, 1993) recommended a set of rules when conducting CVM related to compensation for environmental disasters in USA [Arrow et al., 1993].

CVM-studies [Hanley et al., 1998] and also avoids an explicit elicitation of WTP but instead works with expressed choices [Hanley et al., 2001].

CE can in general be seen as a generalization of the CVM approach, because rather than decide on choosing or not choosing one alternative in CVM, individuals are asked to choose between several alternatives, characterized by different attributes [Adamowicz et al., 1998, Page 65]. Due to the usual question design ('How much would you be willing to pay?', 'How much would you be willing to accept?') in CVM studies, whether something is 'good' or a 'bad' is already imposed by the researcher's question while in CEs ('Which situation do you prefer?') all attributes may be freely regarded as 'goods' or 'bads'.

Choice experiments are particularly useful when goods or resources have to valued, which are multidimensional/multi attribute (consisting of lots of different characteristics, which are typically provided in combination with each other) and where the trade-offs between the attributes are of particular interest. It is often more useful for policy-makers to know how specific changes in characteristics of a resource or service alter welfare than the presence or absence of a good as a whole[22] [Hanley et al., 2001, Page 447]. Since water services typically comprise various attributes such as 'Frequency of the Service', 'Quantity' and 'Quality of water provided', 'Reliability of the supply', 'Occurrence of break-downs', 'Distance to water source' etc., they belong to the class of multidimensional goods or services. South African water authorities are generally not able to provide a very good water service at once with regard to all before-mentioned characteristics especially in the rural and poor areas due to the scattered settlements [Tissington et al., 2008]. A realistic situation for respondents as well as policy-makers is therefore not the absence or presence of water services as a whole, but changes/improvements with regard to certain characteristics. Information on how households trade-off different service attributes is very useful to design water services that fit to households' preferences.

CE usually provides the decision-maker detailed information on the good in question covering quite a range of different levels of the good. CE asks for WTP in a more indirect way than the strong "all or nothing" [Hanley et al., 1998] approach of CVM. This is especially an advantage when asking South African households, who received water services for free so far to avoid protest answers or strong "No" reactions, but present them different options so they can directly see the improvements over the current service[23].

For these reasons given the situation of water services in the Middle Olifants, CE was selected as the appropriate method to reflect households WTP for improved water services.

Despite the many advantages, there are few drawbacks compared to CVM or other stated preferences methods. First of all, the method is more cognitively demanding, especially when

[22]It is also possible to generate multi-attribute information with repeated CVM but it would demand much more effort and control of multicollinearity is more difficult [Adamowicz et al., 1998, Page 65].

[23]This is less true for CVM using Payment cards.

many choice sets are presented with a variety of attributes and levels. This can lead to use of rules of thumb for choosing an option instead of solving the complex underlying utility function. The set of chosen options is then found to reflect that preference are unstable[24]. Furthermore, with an increasing number of choice sets that have to be evaluated, learning and fatigue effects may lead to unstable preferences [Bradley and Daly, 1994]. As in CVM studies, results generated with CE are sensitive to the study design. It is important for the researcher to find out all relevant attributes the good or service comprises. Attributes, which influence utility but are not included into the choice experiment will be captured in the constant term or in the error term of the utility function. The levels of the finally chosen attributes, particularly price levels, will strongly impact on welfare estimates [Hanley et al., 2001]. Louviere (2000) advises researchers to spend as much time and effort as possible in the set-up of the choice experiment and to clarify relevant attributes and levels in focus group discussions to be able to make alternatives as realistic as possible[25] [Louviere et al., 2000]. To address these drawbacks in the present survey, the CE was designed as simple and realistic as possible (see section 4.2.3). Not more than three levels were chosen for each attribute to avoid to overstrain respondents. In addition to that, extensive pretesting and focus group discussions have been conducted to identify the relevant levels and attributes of the alternatives[26].

3.4 Extensions of basic theory

This section serves to explain in greater detail the theories and concepts used in the empirical models to analyze choice experiments. After having presented a brief overview of the basic consumer theory for continuous goods in section 3.1, modifications and developments will be presented in this section that allow dealing with discrete goods. Discrete choice theory provides the theoretical basis for the application of Choice Experiments. The choice between alternatives in a choice set of a CE is a discrete choice. Respondents select only one alternative out of a set of alternatives. Hence, the dependent variable is the choice of a certain water service alternative, which can be either "chosen" or "not chosen". The second sub-section presents welfare estimations based on discrete choice models.

[24] Whether standard assumptions on individuals' preferences, such as transitivity, stability of preferences, and monotonicity (see section 3.1) are maintained can be tested, see e.g. [Carson et al., 2001].

[25] Hanley et al. (1998) discuss the assumption inherited in CE that the total value of a good is comprised of the value of its characteristics. This is linked to the above mentioned necessity to incorporate all characteristics of a good in the choice experiment to generate values for them and second whether the "additivity" of the attributes is truly given. This could be possibly tested by comparing welfare estimates of CVM for the utility of a good as a whole and CE for the "added" utility of its characteristics. Evidence from transport studies suggests that the "whole" is valued less than the sum of its part (see e.g. [Foster and Mourato, 2003]).

[26] A comparison of results of CE and CVM was first planned in order to address the issue of additivity of values. But when asking households to value water services using both methods in the same questionnaire, it was realized during pretests and focus group discussions that households are influenced by the CE when answering the CVM-questions. Households adjusted their CVM-WTP estimates with the prices presented in the choice experiment- irrespectively of presenting first CVM or CE. Therefore a true comparison of independent WTP estimates was not possible and the CVM method was left out for the final survey. For further research on this topic, two separate surveys for each method are recommended.

3.4.1 Discrete choice theory

When commodities are consumed in continuous quantities as assumed in the classic consumer theory, demand functions can be derived. But if commodities are consumed in discrete quantities and some or more of the commodities can be zero, "corner solutions" appear which do not allow further calculation of optimal solutions [Ben-Akiva and Lerman, 1985, page 43].

The neoclassical consumer theory assumes that goods are homogeneous and, what matters, is the quantity of each good. A fundamental extension was made in 1966 by Lancaster, who defined utility in terms of the attributes of goods in his "New Consumer Theory" [Lancaster, 1966]. According to that, a consumer does not derive utility from the good as a whole but from the different characteristics (attributes) that a good comprises. So the same kinds of goods are no longer assumed to be homogeneous, but they are allowed to differ in terms of their characteristics. The utility function then consists directly of the utility of the characteristics. This extension is essential for the analysis of choice experiments.

For discrete choices, an alternative way is to analyze preferences directly by the use of utility functions. The decision-making individual is assumed to have consistent and transitive preferences and a unique preference ranking (see above). The utility that an individuum attaches to an alternative can be represented using Lancaster's concept (1966) of defining utility in terms of the characteristics ("attributes") of alternatives. Due to empirical findings, that choice behavior of individuals cannot be predicted deterministically, including probabilistic choice mechanisms explained behavioral inconsistencies in a better way than neoclassical consumer theory. Probabilistic mechanisms can capture both effects of unobserved variation among decision-makers and unobserved attributes of alternatives.

Two different approaches exist that introduce probabilistic mechanisms into choice theory: constant utility and random utility. The constant utility approach treats utility of each alternative as fixed while the decision rule (see 3.1) that the respondent applies is assumed to behave according to a probability distribution function over the alternatives. This idea explained findings of intransitive preferences[27]. In the second approach, random utility as formalized by Manski (1977) and McFadden (1974) based on the work of Thurstone (1927) and Marschak (1960) treated an individual's choice as a realization of a random variable. Randomness can take forms of observation errors regarding an individuals choice or unobserved socio-economic characteristics or taste variation.

[27] A simple constant utility model was derived by Luce (1959). With a certain probability the decision rule does not lead to the choice of the commodity that yields highest utility. It was extended by Tversky's (1972) "Elimination by Aspects" model.

A random utility model will be derived following Train (2003). A decision maker n chooses a certain alternative out of J alternatives. The decision maker obtains a certain level of utility from each alternative. The utility that decision maker n obtains from alternative j is $U_{nj}, j = 1, ..., J$. The decision maker chooses the alternative generating the greatest utility. He chooses alternative i if and only if $U_{ni} > U_{nj}, \forall j \neq i$. The researcher does not observe an individual's utility directly, but some of the sources of utility such as the attributes of the respective alternative x_{nj} and some of the socio-economic characteristics of the individual z_{nj}. The observable part of utility, often called representative utility, can then be defined as follows

$$V_{nj} = V(x_{nj}, z_{nj}), \forall j \tag{3.14}$$

Utility can be split up into an observable and deterministic part V_{nj} and into an unobservable part ϵ_{nj} that is treated as random. The part ϵ_{nj} is defined as the difference between the true utility U_{nj} and the observable part of utility V_{nj}. It is assumed in general that they are independent and additive:

$$U_{nj} = V_{nj} + \epsilon_{nj} \tag{3.15}$$

Since ϵ_{nj} cannot be observed, choices cannot be predicted deterministically but probabilities have to be derived. Therefore the appropriate econometric model is a discrete choice model expressing the probability that one alternative is chosen according to the assumption of utility maximizing behavior of the individual [Train, 2003, page 18]. The joint density of the random vector $\epsilon'_n = \langle \epsilon_{n1}, \ldots, \epsilon_{nJ} \rangle$ is denoted $f(\epsilon_n)$. The probability that individual n chooses alternative i over alternative j is

$$P_{ni} = Prob(U_{ni} > U_{nj}), \forall i \neq j \tag{3.16}$$

In words P_{ni} is the probability that the utility of alternative i is higher than the probability of any other alternative in the choice set given the observed components of each alternative. Replacing and rearranging yields

$$P_{ni} = Prob(V_{ni} + \epsilon_{ni} > V_{nj} + \epsilon_{nj}), \forall i \neq j \tag{3.17}$$

$$P_{ni} = Prob(\epsilon_{nj} - \epsilon_{ni} < V_{ni} - V_{nj}), \forall i \neq j \tag{3.18}$$

Expression 3.18 states that the probability that each $\epsilon_{nj} - \epsilon_{ni}$ is less than $V_{ni} - V_{nj}$. Since ϵ is treated as random also the difference $\epsilon_{nj} - \epsilon_{ni}$ is a random variable. So the probability that each $\epsilon_{nj} - \epsilon_{ni}$ is below $V_{ni} - V_{nj}$ is a joint cumulative distribution [Train, 2003].

Expressing this with the density $f(\epsilon_n)$ results in:

$$P_{ni} = \int_{\epsilon} I(\epsilon_{nj} - \epsilon_{ni} < V_{ni} - V_{nj}, \forall i \neq j) f(\epsilon_n) d\epsilon_n \tag{3.19}$$

$I(\cdot)$ is called indicator function and equals one if $\epsilon_{nj} - \epsilon_{ni} < V_{ni} - V_{nj}$ is true and equals zero if it is not true. The integral is multidimensional over the density of $f(\epsilon_n)$. Equation 3.19 is essential for later interpretation of parameters, because it implies that only differences in utility matter. No absolute levels of utility can be identified. For identification of parameters this means that only those parameters capturing differences over alternatives can be identified. One of the parameters of alternative-specific constants or socio-economic variables has to be normalized and the others are interpreted relative to the normalized one [Train, 2003, page 18ff].

Depending on the specification of the distribution of the random term, discrete choice models are classified into different groups. Logit models can be derived by assuming that ϵ_{ni} is independently and identically (IID) distributed following an extreme value Type I distribution (also referred to as Gumbel-distribution). They are usually split up into binomial (in case of two alternatives) and multinomial (more than two alternatives) logit models. Nested logit models are derived under the assumption of a type of generalized extreme value distribution. Both types of models have a closed form expression for the integral. However, a closed form does not exist for probit and mixed logit models so that it has to be approximated via simulation. Probit models are derived under the assumption of a multivariate normal distribution and for mixed logit models it is assumed that one part of the distribution of $f(\epsilon_n)$ follows IID and one part can follow any distribution specified by the researcher. When the mixing distribution is discrete, the latent class model can arise. The next sections present different, relevant logit models. The discription of the models is mostly taken from Train (2003) and Hensher (2005).

Logit models

In logit models, given IID-error terms, the density and cumulative distribution of ϵ_{nj} are as follows[28]:

$$f(\epsilon_{nj}) = exp(-\epsilon_{nj}) * exp[-exp(-\epsilon_{nj})] \tag{3.20}$$

$$F(\epsilon_{nj}) = exp[-exp(-\epsilon_{nj})] \tag{3.21}$$

From these distributions, the probability that a given individual n chooses alternative i within the choice set C facing J alternatives after algebraic manipulation[29] results in the following

[28] The scale parameter μ cannot be identified in Logit models. One of the properties of the Extreme Value Type 1 distribution is that the error terms of each alternative have the same variance. Variance of the error terms and scale factor are related $\frac{\pi^2}{6\mu^2}$. In order to normalize the unidentifiable scale factor, equivalently the variance can be normalized. Traditionally, the variance is normalized to $\frac{\pi^2}{6} = 1.6$ and thus scale factor μ equals 1. The normalization has to be considered when comparing parameter estimates of Logit to other discrete choice models e.g. Probit models.

[29] see e.g. Train (2003).

closed form expression of the logit model, because the difference between two extreme value variables is distributed logistic

$$P_{ni} = \frac{exp(\mu V_{ni})}{\sum_{j \in C_n} exp(\mu V_{nj})} \tag{3.22}$$

The deterministic component V_{nj} consists of a vector of observed attributes X_{nj} that relate to alternative j as faced by decision maker n and β are coefficients of these attributes (usually linear) as follows

$$V_{nj} = \beta' X_{nj} \tag{3.23}$$

The standard logit model based on equation 3.22 is often referred to as multinomial logit model or conditional logit model. Jones and Hensher (2005) state that both have the same functional form and, hence, the terminology is often used interchangeably. At second glance, however, the multinomial logit model is a special case of the conditional logit model [Hensher et al., 2005a]. The conditional logit model is more appropriate when the choice among alternatives is modeled as a function of the characteristics of the alternatives, rather than (or in addition to) the characteristics of the individual making the choice. Hoffman and Duncan (1988) state that this feature of conditional logit makes it more appropriate for estimating behavioral models [Hoffman and Duncan, 1988]. Therefore, actually the conditional logit (CL) model is used for data analysis of the choice experiments. In the following, the term 'Logit' model is kept referring to both models.

Some important characteristics of the logit model are first its property that P_{ni} is always between one and zero as required for a probability. Second, the choice probabilities for each alternative in the choice set sum up to 1, because the denominator is the sum of the numerators of all choice alternatives. Besides estimating marginal effects which allow for interpretation of the parameters, the ratio of the coefficients can be interpreted in an economical sense as Willingness to pay given one of the coefficients is a price or cost parameter. The relation between the probability of choosing an alternative and its representative utility follows an s-shaped curve ceteris paribus (representative utilities of all other alternatives held constant). This leads to the consequence that increasing the representative utility of alternatives with generally very low or very high utility will not alter the probability of choosing that alternative much. But when representative utilities are relatively similar among alternatives, changes of representative utility of one alternatives have a greater effect on choice probabilities.

The first important assumption of this model is that v is assumed to provide homogeneous utility across the population. In terms of the parameter vector β the relative importance of the included attributes is equal for all individuals in the sample. That's why β does not have an index n as in equation 3.23 [Louviere et al., 2000, page 38]. Respondents may value attributes differently, depending on their demographic and socio-economic characteristics. High-income classes may value prices as less important than low-income classes do. When tastes vary according to the attributes observed in the choice experiment, a logit model can reveal the sources of this variation as long as they are known to the researcher. Heterogeneity across respondents can be covered to some extent by including socio-economic interactions into the utility function. However, other sources of taste variation that do not vary systematically in the choice experiment can influence choices in addition to that. These influences cannot be analyzed with logit models, but other models such as probit or mixed logit models can include random taste variation. The second important assumption in the context of logit models is the property of independence of irrelevant alternatives (IIA) resulting from the behavioral implication of IID error terms. The ratio of the two logit probabilities of alternative i and k depends on the alternative i and k - no other alternative of the choice set influences the relation:

$$\frac{P_{ni}}{P_{nk}} = \frac{\frac{e^{V_{ni}}}{\sum_j e^{V_{nj}}}}{\frac{e^{V_{nk}}}{\sum_j e^{V_{nj}}}} = \frac{e^{V_{ni}}}{e^{V_{nk}}} = e^{V_{ni}-V_{nk}} \tag{3.24}$$

That means the odds of choosing alternative i over k in a choice set with 3 alternatives is independent of the third alternative m. In practical choice settings, the IIA-property may be unrealistic when introducing a third alternative with similar attributes. In case of two similar alternatives it is very likely that the error terms are correlated. Then, the ratio of probabilities for two alternatives will change by adding the third alternative to the choice set[30]. The IIA-property means also a proportional substitutability between alternatives. In case the level of an attribute of alternative i is improved, the probability of choosing alternative i rises. This leads to a decrease of the probability of choosing any other alternative by the same percentage for each alternative. Whether the IIA-property holds in an empirical setting is testable by a Hausman-McFadden test [Hausman, 1978].

When the IIA-property assumption cannot be maintained, models need to be considered that can deal with correlated error terms. Therefore models based on other distributions resulting in less restrictive assumptions on correlations among error terms were developed. Some frequently used models will be presented in the following.

Nested logit models

Nested logit models relax the IIA assumption to some extent and allow for correlation between unobserved factors over certain alternatives. It was first derived by Ben-Akiva (1973) and later shown to be a generalization of the GEV model by McFadden (1978). The nested logit model relaxes the IID assumption between different groups of alternatives while preserving it within these groups. Similar alternatives are grouped together, when their error terms are correlated and thus they share common unobserved factors. Identifying these groups is the major challenge of the nested model. Grouping alternatives in a nested form has nothing to do

[30] See famous “red bus-blue bus” example of Train (2003, page 19)

with any behavioral belief or any hierarchical choice process. It is only done for accommodating similarities between error terms of alternatives [Hensher et al., 2005a]. Let the set of alternatives j be partitioned into K nonoverlapping subsets denoted $B_1, B_2, \ldots, B_K$ and called nests. The tree structure of a nested model consists of at least two levels. The upper level comprises composite alternatives (nests B), which entail one or more elemental alternatives (i) (see Figure 3.4). The utility that person n obtains from alternative j in nest B_k is as before $U_{nj} = V_{nj} + \epsilon_{nj}$.

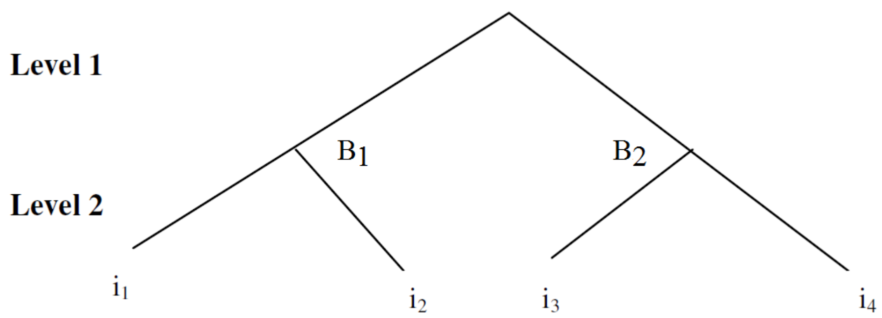

Figure 3.4: Branches in nested logit model, adapted from Hensher et al. (2005)

The nested logit model assumes that the vector of unobserved utility $\epsilon_n = \langle \epsilon_{n1}, \ldots, \epsilon_{nJ} \rangle$ has a cumulative distribution

$$exp\left(-\sum_{k=1}^{K}\left(\sum_{j\in B_k} e^{\left(-\frac{\epsilon_{nj}}{\lambda_k}\right)}\right)^{\lambda_k}\right) \tag{3.25}$$

which is a type of a GEV-distribution. Here, $j \in B_k$ means for all j elemental alternatives in B_k. The parameter λ_k is a measure of the degree of independence in unobserved utility among the alternatives in nest k. The higher the value of λ_k, the greater the independence and the less the correlation [Train, 2003, Page 79]. In nested logit models, the ϵ_{nj} within nests are correlated, so that for any alternatives j and m in nest B_k, ϵ_{nj} is correlated with ϵ_{nm}. But for alternatives of different nests, the unobserved portion of utility is still uncorrelated. According to this distribution, the following choice probability for alternative $i \in B_k$ arises:

$$P_{ni} = \frac{e^{\frac{V_{ni}}{\lambda_k}}(\sum_{j\in B_k} e^{\frac{V_{nj}}{\lambda_k}})^{\lambda_k - 1}}{\sum_{l=1}^{K}(\sum_{j\in B_l} e^{\frac{V_{nj}}{\lambda_l}})^{\lambda_l}} \tag{3.26}$$

The IIA-assumption holds within each nest but not across nests. The choice probability can be presented in a different way, that is more readily interpretable than equation 3.26. Utility can be decomposed and written as $U_{nj} = W_{nk} + Y_{nj} + \epsilon_{nj}$ for $j \in B_k$, where W_{nk} depends only on variables that relate to nest k. These variables are different for the nests but do not vary over alternatives within each nest and Y_{nj} depends on variables that describe alternative

j, so they may vary over alternatives within the nest. The reason for doing this decomposition, is that the nested logit probability can then be written as the product of two standard logit probabilities. The probability of choosing alternative $i \in B_k$ is then the probability that an alternative within nest B_k is chosen and the probability that the alternative i is chosen given that an alternative in B_k is chosen:

$$P_{ni} = P_{ni|B_k} P_{nB_k} \tag{3.27}$$

In the above equation, $P_{ni|B_k}$ is the conditional probability of choosing alternative i given that an alternative in nest B_k is chosen, while P_{nB_k} is the marginal probability of choosing an alternative in nest B_k. The conditional and marginal probabilities take the from of logits, as follows:

$$P_{ni|B_k} = \frac{e^{\frac{Y_{ni}}{\lambda_k}}}{\sum_{j \in B_k} e^{\frac{Y_{nj}}{\lambda_k}}} \tag{3.28}$$

$$P_{nB_k} = \frac{e^{W_{nk} + \lambda_k IV_{nk}}}{\sum_{l=1}^{K} e^{W_{nl} + \lambda_l IV_{nl}}} \tag{3.29}$$

where $IV_{nk} = ln \sum_{j \in B_k} e^{\frac{Y_{nj}}{\lambda_k}}$. Composite and elemental alternatives in one nest/group are linked via the concept of expected maximum utility. Expected maximum utility consists of an expectation of the utility derived by observed and unobserved factors. The term $\lambda_k IV_{nk}$ is the expected utility that decision maker n receives from the choice among the alternatives in nest B_k. So the utility (and thus the choice) of a composite alternative does not only depend on its own utility but also on the expected maximum utilities of all its elemental alternatives [Hensher et al., 2005a, page 484]. This linkage mechanism is most commonly referred to in the literature as 'Inclusive Value' (IV) or 'log sum' since it is equal to the natural logarithm of the denominator of the MNL/CL model for the elemental alternatives.[31]

The Nested Logit Model is designed to capture choice problems where alternatives within nests are correlated. Correlation across nests cannot be handled by the Nested Logit Model. The possibility to group alternatives into well separated nests to reflect their correlation is necessary for application of nested logit models. The elemental alternatives can again be split up into nests depending on the choice problem at hand (2 level, 3 level and 4 level models are commonly used). Other models belonging to Generalized Extreme Value models are the cross nested logit allowing alternatives to belong to more than one nest ('overlapping nests'), as introduced by Vovsha (1997), Bierlaire (1998), and Ben-Akiva and Bierlaire (1999). For alternatives with a natural order, the 'Ordered GEV' was developed by Small (1987). In ordered GEV models, the correlation in unobserved utility between any two alternatives depends on their proximity in the ordering. Some other developments are the 'Paired combinatorial logit' by Chu (1981, 1989) and the generalized nested logit model by Wen and Koppelman (2001) as cited in Train (2003).

[31] For more details on choice probabilities of nests and elemental alternatives see Ben-Akiva and Lerman (1985).

Mixed logit

Mixed logit models are very flexible model that can approximate any random utility model (McFadden and Train, 2000). The mixed logit model can fully relax IIA and account for heterogeneity by allowing for random taste variation, unrestricted substitution patterns, and correlation in unobserved factors over time [Train, 2003].

A straightforward derivation of mixed logit model is based on random coefficients as presented by Hensher (2005). The utility of an alternative j for respondent n is

$$U_{nj} = \beta_n' X_{nj} + \epsilon_{nj} \tag{3.30}$$

The parameter vector β_n does now have an index n. That means, that β_n is a vector of coefficients for person n representing the individual tastes or preferences. The coefficients vary over decision makers in the population. Parameters and error term ϵ_{nj} are not observed and have to be estimated statistically. In order to relax IIA assumption, additional stochastic elements are introduced to β_n, that may be correlated across alternatives.

$$\beta_n = \beta + \delta_k' z_n + \eta_{nk} \tag{3.31}$$

where z_n is observed data specific to the individual and, from now on, index k refers to attributes (1 to K). Two different random parts exist in equation 3.30 and 3.31. For random term η_{nk}, the researchers needs to specify a distribution for the coefficients and estimates the parameters of that distribution while the random term ϵ_{nj} is assumed to be IID over alternatives and does not depend on individual data. Any general distribution such as for example normal, lognormal, triangular or gamma can be assumed for η_{nk} and an IID Extreme Value Type I for ϵ_{nj}. The joint density of $[\eta_{n1}, \cdots, \eta_{nK}]$ is $f(\eta_{n|\Omega z_n})$. The elements of Ω are the underlying parameters of the distribution of β_n.[32] The conditional probability of the choice of alternative i can then be calculated for a given value of η_n

$$L_{ni}(\beta_n | X_n, \eta_n) = \frac{exp(\beta_n' X_{ni})}{\sum_j exp(\beta_n' X_{nj})} \tag{3.32}$$

This is the logit model since the remaining error terms ϵ_{ni} are IID. But in contrast to logit models, additional information is captured in η_n, that influences the choice outcome. When

[32]The mixing distribution is mostly assumed to be continuous, but it can also be discrete when taking a finite set of distinct values. Suppose β takes M possible values labeled $b_1, ..., b_M$ with probability s_m that $\beta = b_m$. In this case, the mixed logit becomes the "latent class model" that is explained in the next section.

integrating equation 3.32 over all values of η_n weighted by its density yields the unconditional probability of choosing alternative i as follows

$$P_{ni}(X_n, z_n, \Omega) = \int_{\beta_n} L_{ni}(\beta_n|X_n, \eta_n) f(\eta_n|z_n, \Omega) d\eta_n \tag{3.33}$$

The probability density originates from the random component in β_n ([Hensher, 2003, Train, 2003]. The name "random coefficients" model mentioned above refers to the fact, that elements of β_n are specified as random parameters instead of fixed ones, so having mean and standard deviation[33]. The standard deviation reflects the degree of heterogeneity associated with the respective attribute, because β_n allows for respondents to have different parameters. The challenge is to identify the underlying distribution correctly since the distribution is usually unknown. The integral does not have a closed form solution so it has to be approximated via simulation. For each set of parameters Ω, values of β_n are drawn from the respective distribution and used to calculate equation 3.33. The resulting mean after R draws is the approximated choice probability

$$\hat{P}_{ni} = \frac{1}{R} \sum_{r=1}^{R} L_{ni}(\beta_n^r|X_n, \eta_n^r) \tag{3.34}$$

The simulated $\hat{P}_{ni}$ are inserted into the log-likelihood function to yield simulated log-likelihood. So far, index t for the choice situation was ignored. The specification can be generalized to allow for repeated choices by each respondent (Panel data, see Train (2003, pages 149-151)). Considering cross elasticities in mixed logit models, these are no longer restricted to be equal for all alternatives since IIA is not given. The ratio of mixed logit probabilities $\frac{P_{ni}}{P_{nj}}$ depends on all data, also attributes of alternatives other than i or j.

The first applications of mixed logit models were done by Boyd and Mellman (1980) and Cardell and Dunbar (1980) and more recent applications are Revelt and Train (1998), Layton and Brown (2000) both assuming normal and log normal distributions of the random parameters and Greene et al. (2005) and (2006) assuming uniform and triangular distributions.

Latent class models

Latent class (LC) models aim at dividing the population into groups with similar preferences. These models are a technique to identify groups in a population with homogeneous intra-group characteristics and heterogeneous inter-group characteristics. Belonging to a group or "class" with specific preferences is probabilistic and can be based on socio-economic characteristics such as income or attitudes and perceptions. LC models were originally used in marketing

[33] The name "mixed logit" reflects the fact, that the choice probability is a mixture of logit with $f(\eta_{n|\Omega z_n})$ as mixing distribution.

research [Kamakura and Russell, 1989, Gupta and Chintagunta, 1994, Swait, 1994] and are quite common in social sciences and psychology[34].

Also other techniques for classification exist such as cluster analysis and factor analysis. Several comparisons between cluster or factor analysis and LC models were conducted in the literature. Morey et al. (2006) compared LC approaches to both, cluster and factor analysis [Morey et al., 2006]. Thacher et al. (2005) and Aldrich et al. (2007) compared cluster analysis and LC models and found similar results with both methods [Thacher et al., 2005, Aldrich et al., 2007]. Nonetheless, advantages of the LC approach are that group membership is probabilistic while in cluster analysis it is usually deterministic[35]. The number of latent classes can be detect with statistically sound methods, using Information Criteria. Thacher et al. (2005) concluded that LC is more advantageous as response probabilities and conditional probabilities are more appealing [Thacher et al., 2005].

The specific latent class model described in the following has been adapted to deal with discrete choice data [Swait, 1994]. McFadden (1986) introduced the idea of latent variables as they may contribute to the understanding of choice behavior [McFadden, 1986]. Group membership in LC models is unobserved and regarded as "latent". Preferences of respondents captured in the same class are more closely correlated than preferences of respondents in different classes. Co-variation among observed variables is then supposed to be caused by the latent variable. The LC model assumes - once it is controlled for class membership - that preferences are independent. McFadden (1986) suggested to combine data from choice models with data on socio-economic characteristics, attitudes or perceptions of the respondents [McFadden, 1986]. In most situations it is very likely that respondents choose differently due to their attitudes, perceptions, experiences, social influences and so on. While mixed logit models allow heterogeneous preferences for all respondents (preferences are treated as being "unique" for each individual), latent class models sort individuals with similar preferences into homogeneous groups.

LC models belong to the family of finite mixture models [Titterington et al., 1985]. Respondents are assumed to come from a population that is a mixture of S unobserved classes, so that it is necessary to unmix the sample by identifying the stochastic structures leading class membership and behavior of each individual [Wedel and Kamakura, 2000]. The ratio of each class in the population is usually not known a priori but has to be estimated. As the mixing distribution is finite compared to a continuous distribution for mixed logit model, with number of groups of a latent class model approaching sample size, the use of a random parameter mixed logit model is motivated. Several authors compare LC and mixed logit models with each other but could not find superiority of one over the other model [Hensher and Greene, 2002, Scarpa et al., 2005, Provencher et al., 2002]. A more recent paper by Shen (2009) actually found a better performance of the LC model compared to the Mixed Logit model based on data on

[34] Standard references are for example Titterington et al. (1985), Bartholomew and Knott (1999), and Wedel and Kamakura (2000).

[35] One exception is fuzzy clustering which probabilistically assigns class members, but his method is complex and uncommon [Morey et al., 2008].

transportation mode choice [Shen, 2009]. Anyway, the LC model has the advantage over the mixed logit model that it is a semiparamteric approach and therefore no specific assumption about the distributions of parameters is necessary. The idea of latent variables allows addressing heterogeneity in preferences so that preferences in each "latent" class are homogeneous while between classes they are heterogeneous.

Classes can be profiled according to socio-economic variables or attitudes of the respondents to be able to explain differences in preferences and choices. Socio-economic and other variables can be either added after estimation (post-hoc) or simultaneously with estimation in hybrid approaches[36] [Wedel and Kamakura, 2000, page 145].

The latter approach - how to simultaneously classify respondents according to their characteristics and choice behavior into homogeneous groups ("classes") of the population - is the preferable approach. The latent class model will be used to analyze choice experiments, in which each individual is asked to evaluate a sequence of choice tasks. Index $t(n)$ is introduced for a specific choice task of respondent n following Ruto and Scarpa (2008). Assuming the existence of S classes in the population and that individual n belongs to class s, the utility of alternative i can be calculated as follows

$$U_{nit|s} = \beta_s' X_{nit} + \epsilon_{nit|s} \tag{3.35}$$

X_{ni} is a vector of observable attributes associated with alternative i and individual n. Utility parameters β are now class-specific. Assuming that IIA holds within classes (so $\epsilon_{ni|s}$ is distributed IID Extreme Value Type I) the joint logit probability of a set of choices $T(n)$ made by individual n, conditional on being in a given class becomes now

$$P_{T(n)}|s = \prod_{t(n)}^{T(n)} \frac{exp(\mu_s \beta_s' X_{nit})}{\sum_{j \in C} exp(\mu_s \beta_s' X_{njt})} \tag{3.36}$$

For each class a unique parameter vector β_s is estimated and the scale parameter μ_s is allowed to vary between classes.[37] How to separate individuals into appropriate classes is explained by the class membership likelihood function 3.37. Classification variables influencing membership such as socio-demographic variables, attitudes and perceptions or other motivational factors (so called "covariates") Z enter the model, so that classes are simultaneously built upon choice preferences and covariates. The class-membership likelihood function M for respondent n belonging to class s can be calculated as follows:

[36] An iterative approach is to first sort each respondent deterministically or probabilistic (e.g. with help of fuzzy clustering) into one class and then, secondly, to estimate the parameters of the choice models.

[37] It can be helpful to test hypotheses with respect to parameter and scale equality across segments. Swait and Louviere (1993) point out that studies, that identified significant between-segment parameter differences may actually be measuring scale (i.e. variance) differences. That would mean that some segments are more variable than others while the trade-offs class-members made are actually the same [Swait, 1994].

$$M_{ns} = \delta_s Z_n + \zeta_{ns} \tag{3.37}$$

Assuming ζ_{ns} to be IID Extreme Value Type I across individuals and classes, the probability of respondent n belonging to class s is given by:

$$H_{ns} = \frac{exp(\alpha\delta_s Z_n)}{\sum_{s=1}^{S} exp(\alpha\delta_s Z_n)} \tag{3.38}$$

with δ_s as class specific parameters, Z_n as covariates of the respondent and α as scale parameters representing the scale across the class membership functions. The class-specific parameters express the influence of the covariates on probability of belonging to a class. The unconditional joint probability of a set of choices $T(n)$ for individual n follows by combining the conditional probability with the segment membership probability by means of taking the expectation over all the S segments [Ruto et al., 2008]:

$$Pr(T(n)) = \sum_{s=1}^{S} H_{ns} P(T(n)|s) \tag{3.39}$$

The log-likelihood function to be maximised is the sum over individuals N of the log of the expectation over classes of the joint probability of the sequence of T choices

$$lnL = \sum_{n=1}^{N} \sum_{i \in C} IlnPr(T(n)) \tag{3.40}$$

where I is the indicator variable for the observed choice. Equation 3.40 will then be estimated in order to receive the parameters δ_s and β_s[38]. The choice made by respondent n is assumed to be independent given class membership. This is equivalent to the axiom of local independence, that means variables within a class are assumed to be independent. In latent class models IIA assumption holds true within each class, because the number of classes is increased until IIA is maintained. This is due to the fact, that fewer classes would not yield the predicted choices between alternatives consistent with observed choices in the sample[39] [Vermunt and Magidson, 2005, page 13].

However, the latent class model cannot be estimated unless the number of classes S is given[40]. To detect the appropriate number of classes, Information criteria are used instead of likelihood ratio tests. Likelihood ratio tests cannot be applied because the test-statistic is not asymptoti-

[38] The scale parameters μ_s and α are not identifiable and can only be estimated when constraining the parameters β to be equal over all classes. So they are commonly assumed to equal one [Boxall and Adamowicz, 1999, 426].

[39] The information criteria would indicate a higher number of classes.

[40] S is discrete while maximum likelihood estimation required the parameter space to be continuous and estimates to lie within the interior of the space [Swait, 2007].

cally χ^2 distributed [Wedel and Kamakura, 2000, page 91]. Since log-likelihood value decreases with increasing number of classes, the information criteria usually include penalty terms. The most commonly used information criteria are Akaike Information Criterion (AIC), Modified Akaike Information Criterion (MAIC or AIC3), Bayesian Information Criterion (BIC), Consistent Akaike Information Criterion [Vermunt and Magidson, 2005, page 46]. The BIC is regarded as a quite conservative criterion pointing usually at a smaller number of classes than the others. But despite the usefulness of the information criteria, the objective of the study and the interpretation of the class membership parameter estimates need also taken into account when determining the appropriate number of classes [Scarpa and Thiene, 2005, Hynes et al., 2008, Ruto et al., 2008].

3.4.2 Welfare theory in discrete choice models

Calculation of changes in welfare must take into account the discreteness of choice data, because in contrast to continuous goods, discrete goods are only available in certain quantities or can even be consumed either all or nothing [Small and Rosen, 1981, page 111]. Due to the quantity restrictions, welfare measures of COS and ES are appropriate [Just et al., 1982]. Small and Rosen (1981) show that welfare measures in discrete choice may be expressed similar to continuous choices by integrating the area under the (Hicks) demand function. While this is a useful result if data is available to estimate demand functions, stated preferences methods do not usually generate demand curves [Small and Rosen, 1981, Bockstael et al., 1991, page 125, page 260]. Observing the outcome of a choice between different goods or services results in the knowledge which good or services is preferred, but it doesn't tell anything about how much of the chosen good or service is consumed. The quantity consumed is usually not considered as a characteristic of a good but as the result after choosing it. When observing the choice outcome over some time period, it is possible to measure how often a specific good was chosen given a certain price to get a demand function. Hensher (2005) proposed a method of analyzing revealed preferences over a certain time period for example in the context of recreation areas [Hensher et al., 2005a]. Bockstael et al. (1991) state for the use of discrete choice models in recreation demand that the total number of trips in a season cannot be explained with discrete choice models only. The structure of a discrete choice model focuses at explaining choices among different alternatives with varying attributes [Bockstael et al., 1991]. For recreation demand models combining revealed preferences (number of trips actually undertaken) and stated preferences data allows for the estimation of a single continuous demand function for all trips which is added to the random utility model. This makes a proportional allocation of the total number of recreation trips to each recreation alternative possible[41]. Guadagni and Little (1983) and Keane (1997) analyzed different combinations of brand and package size, so they

[41] For applications see [Hausman et al., 1995].

also incorporated an aspect of quantity into their models but did not regard multiple purchases of packages and did not estimate demand functions [Guadagni and Little, 1983, Keane, 1997].

As explained above, estimation of demand functions will be quite challenging in many applications. Fortunately, estimation of COS in discrete choice random utility models does not depend on demand functions, because instead utility functions can be used directly. This development was attributable to Small and Rosen (1982) and Hanemann (1982). The unconditional indirect utility function measures the utility gained by a utility maximizing consumer facing given prices, attributes and income. Therefore the representative utility v can be interpreted as an indirect utility function.

In the context of conditional logit models, the change in welfare based on a 'before-' and 'after'-scenario can be calculated as follows

$$E(COS) = \frac{1}{\gamma}[ln \sum_{i=1}^{J} e^{V_{ni}^1} - ln \sum_{i=1}^{J} e^{V_{ni}^0}] \tag{3.41}$$

where V_{ni}^0 and V_{ni}^1 are the utilities before and after the change and γ is the marginal utility of income ($\gamma = \frac{dU}{dY}$), often represented by the price coefficient multiplied with -1. These changes can imply changes in attribute levels (e.g. improvements in water services quality), removing alternatives (e.g. closure of sights or removal of products from the market) or introducing new, not yet existing alternatives with known attributes [Bockstael et al., 1991]. McFadden (1999) extended equation 3.41 when income effects are present [McFadden, 1999]. This is the case when e.g. interactions between the price attribute and the income variable are included into the utility function in order to detect price sensitivity with respect to income[42]. But according to Train (2003), when the evaluated goods or services are sufficiently small in terms of total household income, income effects can be neglected.

When the choice set includes a single 'before' and 'after'-policy option, equation 3.41 reduces to

$$E(COS) = \frac{1}{\gamma}[ln(e^{V_n^1}) - ln(e^{V_n^0})] = \frac{1}{\gamma}[V_n^1 - V_n^0] \tag{3.42}$$

For changes in a single attribute k to (usually referred to as marginal willingness to pay) the following formula applies:

$$WTP = -1(\frac{\beta_k}{\beta_{price}}) \tag{3.43}$$

which is equivalent to the ratio of the two marginal utilities. In order to get aggregated welfare of the whole population, the average COS of the sample can be multiplied by the population size [Bockstael et al., 1991].

[42] For more information on welfare calculations when income is nonlinear see [Morey and Rossmann, 2003, Dagsvik and Karlstroem, 2005].

For calculating welfare measures in other discrete choice models, equation 3.41 has to be modified. Application of equation 3.41 in the latent class model necessitates the use of the class-specific coefficients and assignments of individuals to classes. The class-specific welfare change can be calculated as follows:

$$E(COS_{n|s}) = \frac{1}{\gamma_s}[ln \sum_{i=1}^{J} e^{V^1_{ni|s}} - ln \sum_{i=1}^{J} e^{V^0_{ni|s}}] \tag{3.44}$$

By weighting class membership and multiplying equation 3.44 with $\sum_{s=1}^{S} H_s$, the welfare change of the whole sample can be assessed [Boxall and Adamowicz, 2002, page 438].

3.5 Summary and conclusion

The purpose of this chapter was to present the theoretical background necessary for the analysis of the discrete choice data as generated from the choice experiments. First, the basic choice situation of a consumer choosing from various alternatives was defined. Consumer demand theory relates preferences with demand for goods in terms of quantities and prices. From this, demand functions can be estimated which allow for estimation of welfare changes using concepts of Consumer Surplus (CS), Compensating Variation (CV), Equivalent Variation (EV), Compensating Surplus (COS) and Equivalent Surplus (ES). These concepts provide the basis of economic valuation of water. Then economic valuation techniques applicable to the valuation of domestic water use are presented and discussed with regard to their usefulness to the valuation problems and to the objectives of this study. Stated preferences methods are able to elicit preferences and willingness to pay for different water sources and water services in cases where neither prices nor metered connections exist. The choice experiment method was chosen, because it is well-suited for the conditions in the Middle Olifants. Since the level of water services and the available water source vary, the choice experiment method can explicitly account for differences in water services. CEs are in general preferable in situations where goods or services are multidimensional and values of attributes of goods and services have to be considered. Due to their hypothetical nature, stated preferences methods are often subject to criticism with regard to the validity of the resulting values. For this reason, common biases but also ways to alleviate them were presented and discussed. The section closes with providing details on discrete choice theory and assumption underlying the different models arising from that. Special attention was given to the calculation of welfare changes with discrete data, which does not rely on demand functions but is based directly on utility functions that can be used to measure COS.

Chapter 4

Analysis of domestic water services

4.1 Literature overview

A number of non-market valuation studies of domestic water services were conducted so far using a variety of valuation methods such as Travel Cost Method, Contingent Valuation Method and Choice Experiments. Among them, important studies applying choice experiments for water services were done by Hensher et al. (2004), Nam and Son (2004), Hope and Garrod (2004), Hope (2006), MacDonald et al. (2005), Scarpa et al. (2005), Yang et al. (2006), Snowball et al. (2008) and Kanyoka et al. (2008).

Hensher et al. (2004) conducted a series of choice experiments to value domestic water services in Canberra, Australia. The attributes they used were related to service interruptions (frequency, timing and duration of interruptions as well as information provided during an interruption and price) in the first CE and waste water services in the second. Respondents were willing to pay for service improvements such as reducing the number and frequency of interruptions and overflows, having interruptions on weekdays later in the day and receiving notices on service interruptions. Estimated mean marginal WTP for a reduction in frequency of interruptions varied depending on the frequency of interruptions from AUS$ 9.58 for monthly interruptions to AUS$ 113.20 for an interruption once in ten years. To reduce the length of the interruptions to 24h respondents were willing to pay AUS$ 4.38 and for a reduction to one hour interruption only even AUS$ 54.75 monthly.

Another Australian study was conducted in Adelaide by MacDonald et al. (2005) with similar choice experiments and attributes related to the frequency and duration of household water supply interruptions, notification options (letter, phone call, in-person visit) and alternative water supply options during the interruption (none, from a central location, delivery of bottled water). The authors included two additional options, a status quo and a “don’t know”-option and found only frequency, duration of interruptions and price to be significant. Annual WTP varied depending on the model specification from AUS$ 1.10 - AUS$ 4.40 for a decrease in the duration of interruptions and from AUS$ 6.00 - AUS$ 15.40 for a decrease in the frequency of interruptions.

Yang et al. (2006) conducted a choice experiment in Sri Lanka and presented different service options (private tap, minigrid, public stand post) that varied with regard to four attributes - price, quantity, safety and reliability. They found that households have diverse preferences for the service attributes and heterogeneity was reflected by means of a mixed logit model. By including interactions between a dummy variable (Poor household) and the attributes of the CE, poor households were identified to have a lower ability to trade-off income and better water services.

Nam and Son (2005) compared choice experiment and contingent valuation methods for valuing domestic water quality and water pressure in Ho Chi Min City in Vietnam. They split up the sample into households already connected to the water supply system, who stated their willingness to pay for good water quality and high pressure using contingent valuation method, and households not connected, who were asked to choose between the status quo situation and other water supply options based on a choice experiment. The choice experiment was based on the attributes "Water Quality", "Water Pressure" and "Price". Nam and Son (2005) found that the amount that households are willing to pay for a better water supply is significantly higher than their current water bill and costs of various coping strategies (like collecting water, treating and storing it or buying it from vendors) and that water quality was by far the most important attribute compared to water pressure.

Water valuation studies conducted in South Africa so far, used mainly contingent valuation method, travel cost method or combinations of both [Goldblatt, 1999, Veck and Bill, 2000, Banda et al., 2007]. Goldblatt (1999) showed a frequency distribution of WTP in cents per 25 liter and for monthly payment in ZAR/month. The majority of respondents chose a monthly payment between 10 and 30 ZAR/month. Veck and Bill (2000) estimated price elasticity for urban households to lie between -0.12 and -0.14 using contingent valuation method. Banda et al. (2006) asked collective tap water users and river water users in the Steelport sub-basin of the Olifants River basin respectively about their WTP for improved water quantity and quality. Collective tap users stated to be willing to pay ZAR 4.03/m^3 for an improvement in both and River water users ZAR 6.15/m^3. The same authors compared these results in a study applying Travel Cost method and found lower WTP-estimates of improved water quantity and quality. Resulting consumer surplus of Collective tap users was ZAR 2.91/m^3 for an improvement in both service attributes and that of River water users was ZAR 4.34/m^3 [Banda et al., 2006].

More recently, four studies were conducted to detect preferences for different water service attributes or water sources using choice experiments. Hope and Garrod (2004) and Hope (2006) presented households with different water sources, water quantities, water quality, stream-flow failure and productive uses of domestic water but they did not aim at estimating WTP and thus did not include price as an attribute [Hope and Garrod, 2004, Hope, 2006]. Snowball et al. (2008) analyzed preferences using a choice experiment in Grahamstone West in South Africa focusing on WTP towards water quality issues, breakdowns and water pressure [Snowball et al., 2008]. In a recent publication, Kaniyoka et al. (2008) applied a choice experiment and estimated WTP for the attributes "Quantity", "Frequency", "Quality", "Price", "Productive uses" and "Water source" [Kanyoka et al., 2008].[1] They split their sample into households with access to a private tap and households without access to a private tap and analyzed differences in WTP with regard to actual water consumption and household income. Important findings of their study are that price sensitivity decreases with increasing income and that - when private taps are available - frequency of supply is less important for households already consuming more water. A summary of the studies and their respective findings on WTP is given in the appendix, Table A.1.

Applications of the LC model to value water services were developed by Hope (2006) and Scarpa et al. (2005). Hope (2006) identified two distinct classes of households. Scarpa et al. (2005) conducted two choice experiments analyzing preferences for so called "Service factors" comprising "Area flooding by sewage", "River quality", "Nuisance from odour and flies", "Cost of service" presented in the first experiment and "Water amenities for recreation", "Quality of bathing water" and "Cost of service" in the second. Results of a mixed logit and a LC model indicate the presence of heterogeneous preferences, the LC model points to four distinct groups - covariates for class membership not included. Distributions of posterior WTP estimates for the different service factors were estimated. The authors concluded that, the use of a LC model is favored due to the fact that this segmented information potentially is more appropriate for water companies since it offers readily interpretable heterogeneity in terms of the classes which mixed logit does not [Scarpa et al., 2005].

The following chapter will contribute to the literature since it provides an extensive analysis of the current water service levels that households receive and their valuation of different water sources such as Private Taps, Public Taps and Private Boreholes and water service levels with regard to quantity of water, availability per week and other service characteristics (hours of supply, distance of water source etc.). Especially the quantity aspect is rather new in the application of choice experiments[2].

Prepaid meters

As already mentioned in Section 2.2.2, a culture of non-payment for communal services evolved in South Africa. To improve cost-recovery, electricity suppliers started to address that problem by introducing a system of prepayment meters for electricity. With a prepaid metering system,

[1] As the study was published one year after data collection of this study, it confirms the choice of some of the relevant attributes in this study as a completely independent research team found some similar attributes (Frequency, Quantity and water source).

[2] See Corsi (2007) for a discussion of the missing links between valuation studies and the resulting quantity demanded [Corsi, 2007].

the use of electricity requires ex-ante payments. Due to the public acceptance of that system, also prepaid meters for water were installed. Some pilot projects were undertaken - among others - in Stratford Four, a district in Orange Farm in 2002/03 and in Phiri, Soweto, in 2003/04. In urban areas, prepaid meters are installed at private water connections, while in rural areas they were found to regulate access to public taps. Motivation of introducing prepaid systems came from several conditions. First of all, supplying electricity or water in remote areas requires a lot of personnel to deal with billing, meter reading, connecting and disconnecting. Second, in many rural and poor areas general infrastructure is missing and unemployment rates are high. Households neither have bank accounts nor fixed addresses for sending the bills to and due to low education levels even understanding the bill may be difficult [Tewaria and Shah, 2003].

Prepaid meters thus allow a much better cost-recovery at significantly lower service and administration costs. In combination with the free basic water policy, prepaid meters can guarantee access to the basic amount of 6 m^3 per household per month, and at the same time ensure payment for any amount of water consumed additional to that. Tokens are frequently used as payment method, as they can be entered either directly as a paper card or they contain a number that has to be entered into the meter. Prepaid water meters have several advantages for service providers as well as consumers but are often critized with respect to equity issues. The associated benefit for consumers is that a better understanding of water use and related prices can be achieved due to the direct relation between payment and use. This provides a strong incentive to save water. Furthermore, it helps control expenditure for water and budgeting since no debts can be made [Tewaria and Shah, 2003, Marah et al., 2003]. A negative impact on consumers are costs devoted to buying the tokens, which can be particularly high in remote areas with little infrastructure. Running out of money directly leads to disconnection from the system. A reduced water use due to lack of income has (probably) led to cholera outbreaks in Madlebe in KwazuluNatal in 2002/2003, because households had to fetch water at unimproved water sources [Tewaria and Shah, 2003]. In politicized areas, households hardly accepted prepaid meters since they regard them as a tool to control communities and to cut poor households from accessing water - as in Phiri, Soweto, where households have brought the issue of prepaid meters to trial[3]. However, a study conducted by Water Research Commission (2003) showed that the majority of responding households accepted and supported the use of prepaid meters [Marah et al., 2003].

Due to the contradictory findings on acceptance of prepaid water meters in South Africa, the extent to which households in the Middle Olifants accept prepaid meters was therefore chosen to be part of the analysis.

[3] Johannesburg High Court adjudged their criticism and confirmed that free basic water is not regarded as sufficient to cover basic water needs by many (especially urban) households. In October 2009, the constitutional court however confirmed the lawfulness of prepaid meters [Constitutional-Court, 2009].

4.2 Data and survey design

A household survey was conducted from August to November 2007 to provide the data basis for analysis of domestic water services in this chapter.

4.2.1 Sampling design

In order to ensure representativity of the sample, stratified random sampling was applied. The database of the National Department of Water Affairs and Forestry (DWAF) provided information on main domestic water sources in all villages and towns in the Middle Olifants sub-basin. This database allowed a stratification into urban and rural areas as well as main water sources (see Table 4.1)[4]. In total, 475 households were interviewed. With this sample size, a sufficient number of observations for each alternative of a CE and for each block exists.

Table 4.1: Stratified sampling

	in Percent		Number of households		
Main water source	Rural	Urban	Rural	Urban	Limpopo
Private taps inside the house	14%	51%	43	85	18%
Yard connection / Private Tap on-site	24%	30%	74	50	15.5%
Public tap / communal stand pipe	42%	14%	130	24	40.1%
Other water sources	20%	5%	61	8	15.3%

Source: Data for "Limpopo" is taken from the Community Survey 2007 [Statistics-South-Africa, 2007]. Data for "Urban" and "Rural" from DWAF database.

According to the database of DWAF, 65% of the villages and towns in the Middle Olifants were classified as rural areas and 35% as urban areas. Accordingly, the total sample size was split up into 309 rural households and 166 urban households.

In order to select survey sites that represent a high diversity, local municipalities of the Middle Olifants sub-basin were divided into municipalities with good, medium and bad access to tap water services based on data from Census (2001) [Statistics-South-Africa, 2001].

[4] Hensher et al. (2005) described sampling procedures in the context of choice experiments [Hensher et al., 2005a].

Good water services: $<$ 60% of the population has access to tap water
Medium water services: 30-60% of the population has access to tap water
Bad water services: $>$ 30% of the population has access to tap water

Source: own definition

Selecting randomly one municipality for each water service level according to the above definitions resulted in the choice of the following municipalities: Polokwane Municipality (good water services), Lepelle Nkumpi Municipality (medium water services) and Fetakgomo Municipality (bad water services). The only urban area in these municipalities is the town Lebowakgomo in Polokwane Municipality, which was thus chosen to represent urban inhabitants. Finally, four villages were randomly chosen from all villages in the selected municipalities.

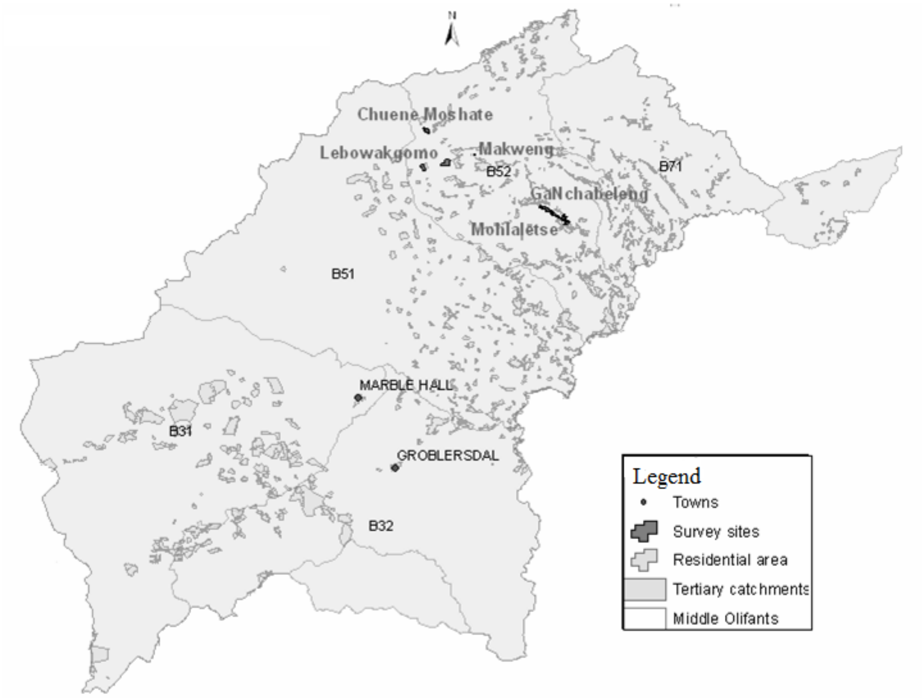

Figure 4.1: Survey sites, own presentation

An evaluation of the representativity of the study with regard to socio-economic characteristics such as household income, education and household size by comparing the figures to official statistics is rather difficult. The Statistical Service of South Africa ('StatsSA') collects data based on administrative boundaries such as municipalities and not based on hydrological boundaries such as river basins. However, a comparison of the survey statistics with Household data from Limpopo Province, which has the largest share of the Middle Olifants, is provided in the appendix, Table A.2. The sample does not represent the different income and education classes perfectly. But since Limpopo Province is the poorest province in South Africa and Gauteng Province, which also lies partly within the Middle Olifants is the richest one, it is credible to assume that income and education levels may be higher in the Middle Olifants than in Limpopo only.

4.2.2 Questionnaire design

The study setting and wording of the survey questionnaire forms a vital part of any choice experiment. CE studies are context-specific, meaning that the results are strongly related to the study's circumstances. The context of a CE as provided by the questionnaire is critical, in order to estimate the true values respondents hold for the resources under consideration.

The questionnaire is based on different sections: one section about socio-economic characteristics of the household, two sections about water service characteristics and water usage, one part about attitudes towards pricing of water and the choice experiment. The first section aimed to provide an overview of the household and its members including questions on age, education, average income and income sources. The part on water services was needed to get a clear picture of the current water service levels provided to the household. Questions on water source, water availability, quantities used, reliability of the service, distances and sufficiency as well as overall satisfaction with the service were asked. The choice experiment was placed in the middle of the questionnaire for two purposes. First, it should be ensured, that households are already familiar with the interviewer and that they are aware of their current water service situation in order to be able to evaluate the new proposed service levels in the CE. Second, since the choice experiment is quite cognitively demanding, households are not yet tired of answering questions. The remaining part of the questionnaire consisted of detailed questions on household water use, indoor and outdoor water use and other water related activities (e.g. irrigation and livestock). After that households were asked to choose among several statements concerning the pricing of water to reveal their attitude towards pricing and a ranking of the most important service attributes. Finally, a complete profile of household expenditure for food and non-food items was developed. Answering all questions and the choice experiment took on average 1 hour.

4.2.3 Design of Choice experiments

In order to design a choice experiment three design stages have to be passed through [Louviere, 2001].

Stage 1: Problem definition

The stage of problem definition aims at clarifying how to construct the choice experiment in a way that it includes the main elements that influence choice behavior[5]. It is essential to be aware of all elements that influence choices to mirror the choice situation in a realistic

[5]Before defining the choice problem, it must also be decided upon which type of value will be addressed by it- use-values, non-values, option values etc. In this context of water service alternatives only use-values will be analyzed. The value one wishes to identify influences the selection of the relevant attributes for the choice construction [Holmes and Adamowicz, 2003].

fashion. An important part in the choice construction process is the identification of the relevant alternatives from which the respondent is supposed to choose the preferred one. When the set of feasible choice alternatives differs among households, it has to be clarified whether all choice situations can be reflected in a single CE or whether the development of specific CEs adapted to the conditions would be preferable. In the Middle Olifants, domestic water sources are quite diverse, but not all possible water sources provide meaningful options for all households. Households already having a private in-house connection do not use public taps or boreholes. For them, these alternatives would be unrealistic and thus not chosen. For households using basic or even unimproved water sources, choices between different water sources are meaningful and feasible. Mostly, households in urban areas have private tap connections. They also tend to experience better service levels in terms of availability of water and quantity accordingly. To be able to design CEs with meaningful alternatives and attribute levels, the sampled households were split into two groups:

Choice Experiment I (unlabeled experiment): Households having private taps inside the house and households having yard connections in urban areas
Choice Experiment II (labeled experiment): All households not in Choice experiment I

Source: own definition

A question that arises in this context is whether to present the alternatives in a labeled form or in an unlabeled generic form (see Section 3.3.2). A choice experiment without labels or names attached to each alternative does not carry any additional information - the alternative is only described in terms of the attributes and levels (e.g. Option A, B, C). A labeled choice experiment however, provides itself information to the respondent by giving names to the alternatives (e.g. brand names). According to Blamey et al. (2000) the preferred approach depends on the objective and the nature of the choice but in general labeled choice sets are preferred when meaningful labels exist and willingness to pay estimates for the different options shall be derived [Blamey et al., 2000, pages 283-284].

Discussing the relevant attributes/characteristics of water services in focus group discussions, it turned out that some of them are related to specific water sources only. According to the objective to come up with willingness to pay estimates depending on the water source, a labeled CE was chosen for those household of the choice experiment (CE 2), in which different water sources form the alternatives. Households having private taps or private yard connections experience much better water service levels, so that the only credible options for them were to choose between different service levels of private tap connections. In this CE, a single water source as an unlabeled option was presented, but at varying service levels (CE 1).

The set of alternatives (different Private Tap-alternatives in CE 1 or Private Tap, Public Tap and Private Borehole in CE 2) is called a “choice set”, which needs to fulfill three requirements in order to allow for the discrete choice framework:

- Mutual exclusivity: From the individual's point of view, the alternatives must be exclusive so that respondents can only choose one of the alternatives. Restricting the alternatives to be the "main water source" fulfills this condition.
- Exhaustiveness: All possible alternatives have to be included into the presented choice set. For the CEs in this study, not all possible water sources have to be included in the choice set, but the ones for which a price can be credibly imposed on the water service.
- Finiteness: the number of alternatives must be finite.

For households in CE 1, constructing meaningful options is rather straight forward since only one water source is involved. In CE 2, from all possible water sources in the Middle Olifants such as private and public taps (using piped water), boreholes (either private or public), wells, springs, rivers, canals, rain water, water tanks and water vendors, only the alternatives private and public taps as well as private boreholes were selected as separate alternatives. Since one of the attributes for each alternative should be price in order to be able to calculate willingness to pay estimates, only those alternatives could be selected for which a price can be credibly imposed. Public boreholes were not used in the sampled villages and focus groups stated not to be willing to pay for using them. Households combine different water sources depending on accessibility or season. However, the choice experiment allows only one choice so water sources were restricted to main water sources. Public vendors hardly represent the main water source and could be excluded for that reason. Private taps can be located either inside the dwelling or inside the yard (yard connection). Both types are regarded as 'tap water' and households appreciate it not to walk to the water source. When using to communal/public taps, households do not differentiate much between a yard connection and taps inside the house as long as the tap is located close to their dwelling. Therefore, they were not included as separate options (tap water inside and yard connection), but captured in the attribute "Distance" with the levels 'inside dwelling' and 'inside yard'.

After deciding on the different alternatives and water sources in the CEs, relevant characteristics and attribute levels of them have to be discussed. Attribute levels were selected according to the following principles

- plausible and realistic
- actionable
- levels must allow for trade-offs between attributes
- fit to requirements of policy-makers
- as simple as possible [Holmes and Adamowicz, 2003]

Drawing on the results of expert interviews, focus group discussions and pretests, the following attributes were identified:

- FREQUENCY (in days per week): Households stated during focus group discussions for CE 1 that they do not have access to water every day. Water is often not provided on weekends or at peak times during the week. Households selected for CE 2 are located in municipalities in which it is common to supply water to villages in a rotation systems [Kanyoka et al., 2008]. Only on certain days in a week a village receives water, on sample average three times per week.
- RELIABILITY (in hours) during the 'water days' is an issue because households receive water sometimes only 3 hours per day, sometimes not at night, not during weekends (depending on the storage capacity of the municipal reservoirs) or do not even know exactly when water is available and when it will be finished. Results of the pilot study of CE 2 showed that all attribute levels for reliability were insignificant. Households do not really trade-off between frequency and reliability due to the low frequency-levels in general. Choosing how many days per week water is provided influences choices strongly so that levels of reliability in hours were not included in the choice. For households of CE 1 especially during peak times on weekdays and weekends the water can be cut. Accordingly, reliability is an important concern besides the - relatively higher - frequency of water supply per week.
- CONSUMPTION (in liter per person per day). While all households considered in CE 1 had private and metered connections, households of CE 2 have to fetch water with 25 - sometimes 20-liter - canisters, even when having a yard connection. Though water is not measured in liters, households are able to count the canisters they collected or the drums they filled.
- DISTANCE: The distance between water source and house is subject to a wide variety. Households may be located very close to a public tap, so that they can use hose pipes to fill their water tanks/drums instead of carrying the water while others may have to walk even far distances carrying the water. Presenting households three different distances (close by, 2-5 minutes and 7-10 minutes walking time) allowed to capture the effects of distance for the "Public tap" - alternative. Distance can also refer to the alternative "Private Tap" - as (usually several) private taps can be either inside the house or on the yard around the house.
- WAITING TIME (in minutes). Households in Ga-Chuene developed rotation systems for the order to access the public tap when water is provided and, hence, waiting time

was close to zero. But in other villages waiting time was definitely considered as an issue, because households had to wait for more than 5 minutes per trip. Waiting time is considered as an important characteristic of public taps that may influence people's decisions in many villages and was therefore included in the choice experiment.

- PUMP: Almost all boreholes in the study area were equipped with hand pumps. In order to know to what extent the effort of pumping water matters to the household it was decided to test for it by using either hand pump or motor pump as attribute levels.
- PAYMENT METHOD: Households in Lebowakgomo have to pay their water bills, which they receive from the municipality once a month while households in the villages do not have to pay for the water provided by the municipality. Systems of prepaid payment meters were implemented in some other areas in South Africa to facilitate cost-recovery in provision of water services, but not in the study area.
- PRICE: Payment vehicle used in the study was price in ZAR/m^3 in CE 1 and $cents/25$ liter in CE 2. As quantity of water is an important factor, households of CE 1 already pay for their water use and are therefore familiar with a price per cubic meter. Households of CE 2 do not pay for their current water services, but 17% of them spend money for buying water from neighbours. Based on the prices they pay for buying water and on willingness to pay indicated during the focus group discussions, price levels were set.

The number of attribute levels selected in the choice experiment influences the ability to reflect the underlying utility curve. The more attribute levels the researcher includes, the better the estimated curve fits the real one [Hensher et al., 2005a, page 107]. But since more attribute levels always increase the sample size and make the experiment more complex for the respondent, there's a trade-off between simplifying the experiment and approximating the utility function as close as possible.

Stage 2: Experimental design

The foundation for any choice experiment is the experimental design, a specialized statistical procedure [Hensher et al., 2005a, page 100]. *An experimental design is the plan of running an experiment* [Kuhfeld, 2005] and deals with the combination of different attribute levels into choice sets. Rather than setting levels and attributes randomly or purposely, an experimental design helps decide which levels of attributes to combine into alternatives of a choice set. A full factorial design is a design in which all possible combinations of levels of attributes are enumerated. This has the advantage that all attribute effects can be statistically estimated since they are truly independent. Usually, these kinds of designs result in a quite high number of choice sets to be asked (high sample sizes or many choice sets per respondent) and thus exceed available financial means, cognitive capabilities of respondents and lead to fatigue effects. To reduce the design size either the number of levels has to be minimized (e.g. so called end-point design with only two levels [Louviere, 2001]) which comes at the expense of assuming a linear relationship of the utility derived by different levels of the same attribute (also referred to as 'path worth utilities') or fractional factorial designs are applied in which only some of the combinations are evaluated. Instead of selecting randomly a particular subset of the full factorial, sampling methods were developed leading to designs with desirable statistical properties. Two main approaches used in marketing research are:

- orthogonal fractional factorial designs, which generate designs with statistically independent (uncorrelated) attributes
- optimal fractional factorial designs, which maximize the amount of information about the coefficients that can be extracted from a design while minimizing correlation between attributes

Optimal designs ensure statistical efficiency, but may not completely erase all correlations between attributes while orthogonal designs guarantee no correlations but may not represent the most statistically efficient design available. Which one to use depends on the belief of the analyst about the most important property of experimental designs, because both possess advantages and disadvantages [Rose and Bliemer, 2005]. Besides the concept of orthogonality and efficiency, balance in a design is of particular interest. In a balanced design, each level of an attribute appears equally often. Imbalance increases the variances of the coefficients and decreases their efficiency [Kuhfeld, 2005, page 50]. An orthogonal design that is both orthogonal and balanced is at the same time optimal and 100% efficient. In the calculation of the efficiency of a design usually D-efficiency[6] is selected and used as criteria because it is fast to calculate and not influenced by the coding [Kuhfeld, 2005]. The higher the efficiency the more a design tends to orthogonality and balance. These measures are not meaningful in absolute terms but relative to a (hypothetical) orthogonal design. An important concept necessary for the development of experimental designs is the understanding of main and interaction effects. The term "effects" means the impact of a certain attribute level on choice. A main effect is the influence of each attribute level on the choice variable irrespective of all other attributes and can be estimated as the coefficient respective variable level (see Section 4.4). An interaction effect describes the influence of one attribute on choice dependent on the level of a second attribute. A two-way interaction thus is the coefficient of two interacted attributes $x_1 * x_2$ [Hensher et al., 2005a, page 116]. In full factorial designs all possible effects (main effects, two-way interactions, three-way interactions etc.) can be estimated independently, they are not confounded with each other. Using fractional factorial designs produces confoundments between some of these effects. Estimating a 'Main effects only'-design reduces the required number of choice sets often dramatically but comes at the expense of assuming all interactions to be statistically insignificant

[6]For more information on how to calculate D-efficiency and other efficiency measures, see Kuhfeld (2005).

and equal to zero. When suspecting some interactions to be significant, it is possible to include exactly at least selected interactions into the design. Although this is desirable, in more complex experimental designs with selected two-way or higher interactions or some infeasible combinations of levels orthogonality cannot be maintained, because a suitable orthogonal and balanced design simply does not exist. In these cases efficient non-orthogonal designs (with slight correlations between attributes) have to be used. To develop the experimental design of the two CEs applied in this study, the statistical software package SAS 9.1 was used to generate two optimal experimental designs including selected two-way interactions. Orthogonal designs were not available for neither of the CEs due to the inclusion of two-way interactions and the complexity of the CEs.

CE 1: Full factorial: 65, D-efficiency: 97.55 %, Choice sets: 12, Selected two-way interactions: PRICE x FREQUENCY, PRICE x CONSUMPTION.
CE 2: Full-factorial: 236,196, D-efficiency: 93.45 %, Choice sets: 54, Selected two-way interactions: FREQUENCY*PRICE, DISTANCE*PRICE for alternative “Public tap”, PUMP*PRICE for alternative “Borehole”.

Source: own designs using SAS 9, following [Kuhfeld, 2005]

Each respondent was asked to make six choices out of six choice sets presented to him/her. In total, 1620 choices were made in CE 2 and 1224 choices in CE 1. The presence of multicollinearity in the experimental design was tested for using the method of auxiliary regressions [Gujarati, 1997]. In order to analyze the influence of the attributes statistically, they have to be coded. The kind of coding affects the capability to estimate linear or non-linear effects of the attributes. A linear effect is revealed when the influence on utility between moving from the first to the second level and moving from the second to the third level of an attribute is equal. Using a design code (first l level of attribute is coded as 0, second as 1, third as 2 and so on) or an orthogonal coding (first level -1, second 0, third 1, which must always sum to 0) imposes the estimation of a linear effect because a single parameter per attribute is estimated. Non-linear effects allow for a change in the slope when moving from one attribute level to the next. The increase in utility when moving from a bad to a medium level of an attribute may be higher than the increase when moving from a medium to a good level[7]. Dummy and effects coding allow for the estimation of non-linear effects through the creation of several variables per attribute. Hence, more than one parameter for an attribute can be estimated (see Table 4.2). In the presence of three levels, two variables have to be created. In dummy-coding, the level not represented by a variable acts as the base level to which the variables can be compared. This allows on the one hand a straight-forward interpretation of the coefficients, but on the other hand it leads to the consequence, that effects generated from the base level and effects captured in the overall constant of the utility function cannot be separated from each other.

[7]For more details on linear and non-linear effects see Hensher (2005).

Table 4.2: Dummy and Effect coding

Attribute Level	Variable 1	Variable 2
Effects coding		
High	1	0
Medium	0	1
Low	-1	-1
Dummy coding		
High	0	1
Medium	1	0
Low	0	0

Source: Hensher et al. (2005)

Effects coding however solves this problem by coding the base level as -1 and therefore allows independent effects of the constant and the base level. For the reasons of better interpretability of coefficients and the fact, that the constant is not needed for calculation of market shares (as in many marketing studies), dummy-coding can be safely applied.

Stage 3: Refinement

In order to test the selected alternatives, attributes and attribute levels for the choice experiment, a pilot study with 40 sampled households was conducted and analyzed. According to its results, the refined and final attributes and levels for CE I can be found in Table 4.3.

In an ideal situation all relevant attributes influencing the choice of the respondent are selected and the unobserved part is just “pure noise”. This situation rarely applies because the number of attributes and levels that can be included into the choice experiment is limited by the respondent’s cognitive capacity. The more attributes and levels are included the more difficult it is to make trade-offs between all of them. Given the facts, that most of the sampled households live in rural areas and are not used to a high degree of abstraction in their daily life three levels per attribute was regarded as suitable.

Hypothetical bias in CE

Concerning the likelihood of occurrence of any of the biases described in Section 3.3.2, many biases, which relate to the sequential provision of goods do not play a role in this study. However, hypothetical biases[8] was considered as an issue due to the valuation of public water services such as public taps. In the context of water services, respondents might behave strategically and overstate their true WTP in order to ensure an improvement in public water services. Strategic biases in terms of a desired discrepancy between stated and true WTP arise because individuals do not fear any cost or penalty associated with this discrepancy [Pearce and Moran, 1994, Page

[8] The existence and the range of hypothetical bias reduces the validity of households preferences, and hence the estimated WTP-values. Hypothetical biases was often found in CVM studies [Little and Berrens, 2004, List, 2001, Murphy et al., 2005].

Table 4.3: Alternatives, respective attributes and levels of CEs

CE 1 Attributes	Private Tap inside the house	CE 2 Attributes	Private Tap	Public Tap	Private Borehole
FREQUENCY (days of supply per week)	5-6-7	FREQUENCY (days of supply per week)	3-5-7	3-5-7	/ (7)
CONSUMPTION (in liter per person per day)	50-100-150	CONSUMPTION (in liter per person per day)	35-50-65	15-25-35	15-25-35
RELIABILITY (hours of supply per day)	12-18-24	DISTANCE (in minutes)	Inside - on-site	Close to dwelling- 2-5 min.- 7-10 min.	Always On-site
PRICE (in ZAR/m^3)	5-6-7	PRICE (cent/25 liter canister)	100-110-120	40-50-60	40-50-60
PAYMENT	Monthly-every 6 months- prepaid	PUMP	/	/	Hand pump - motor pump
		WAITING TIME (in minutes)	/(0)	0-5-10	/(0)

50]. Additionally, compliance effects may also play a role since respondents are aware that payment for any kind of municipal service is socially desirable.

To test for hypothetical bias in the current setting, no actual market-based method could be used in order to compare WTP-estimates. As simulated markets and public referenda were not feasible given the complexity of the introduction of improved water services, tests of the actual presence of hypothetical bias using criterion validity was not possible. Fortunately, several techniques exist in the literature to ameliorate hypothetical bias using uncertainty adjustments or cheap talk (as introduced by Cummings and Taylor (1999)) and also other methods. Cheap talk is an ex-ante calibration technique in which the researcher attempts to elicit unbiased responses by providing explicit information about the problem of hypothetical bias. Ex-post uncertainty adjustments can range from adding a “don’t know”-option to qualitative (“fairly sure” or “absolutely sure”) or numeric scales (Likert scale in which 1 = very uncertain and 10 = very certain) reflecting the degree of uncertainty of the respondent after having stated his or her willingness to pay. While uncertainty adjustments in combination with choice experiments were considered as being too cognitively demanding and mentally challenging for the predominantly rural population in the Middle Olifants, cheap talk was used in order to mitigate hypothetical bias. Overall, most studies found that cheap talk effectively reduces WTP for the goods in question, particularly when valuing private goods [List, 2001], while Aadland and Caplan (2003) and Lusk (2003) discovered that cheap talk seems to decrease WTP of specific sub-groups only [Aadland and Caplan, 2003, Lusk, 2003]. Other studies such as Brown et al. (2003) and Murphy et al. (2005) concluded that cheap talk has an effect on those respondents who are presented with bid levels in the higher end of the bid range in dichotomous choice or referendum CVM surveys while in others find cheap talk did not significantly lower respondents’ WTP as e.g. in Carlsson and Martinsson (2006). Fewer studies were conducted analyzing the effect of cheap talk in choice experiments particularly. Among them, Carlsson et al. (2005) and List et al. (2006) identified a lower marginal WTP using cheap talk as a method to effectively reduce hypothetical bias . But List et al. (2006) feared that internal consistency might not be ensured using cheap talk[9]. Other methods addressing hypothetical bias are the introduction of a consequential script in which respondents are reminded that the outcome of the study is relevant for policy makers [Bulte et al., 2005, Mitchell and Carson, 1989, page 155] and a so called opt-out reminder, recalling that respondents are not forced to choose [Ladenburg et al., 2007].

In the present study, hypothetical bias was addressed by combining different approaches which were found effective in the literature as recommended by Murphy et al. (2005). *It is likely that a number of factors affect hypothetical bias and therefore no single technique will be the magic bullet that eliminates this bias* [Murphy et al., 2005, page 337]. A short and simple cheap

[9] In a recent working paper, Do and Bennett (2007) used a short, neutral cheap talk script and found WTP to be reduced only for those people living far away from the proposed improvement, a finding similar to the one of List and Lusk for CVM studies.

talk script was used to avoid overstating WTP. The consequential script reminded respondents that the outcome of the survey will be presented to policy makers in Pretoria. To make sure that respondents take enforcement of payments seriously, payment obligation was emphasized by the hypothetical introduction of a fine for non-payment. The opt-out option was explicitly explained and presented in every choice to give respondents the chance to state their non-WTP. With respect to the already cognitively quite demanding and time-intensive choice experiment, the script was designed as short and simple as possible. Mitchell and Carlsson (1989) concluded that meaningfulness of the study and the appropriateness of the chosen method is much more relevant for the success of the study than the possibility of hypothetical biases. Therefore, the main objective of the current study was to design the choice experiment as realistic and applicable as possible and, by doing that, to minimize the occurrence of hypothetical bias.

The following script was used in the survey:

Please choose as if you have to pay the price. Carefully remember how much income you earn. People often tend to overstate what they would pay, so please only choose an option when you really would pay the price. The outcome of this survey is presented to the government which will then decide about an improvement of water services. When the government decides for the improvement, a fine of R500 will be introduced in case of non-payment. When you do not want any of the presented options, you can choose to keep your current water services which are provided for free.

It would have been best to test the influence of the combined approaches by doubling the sample size, splitting it and comparing the marginal WTP of respondents presented with the script to those without. But due to the set-up of the experiment and the resulting experimental design, a large sample size was already needed to ensure reliable parameter estimates. Doubling the sample size was not feasible due to financial and time constraints so a comparison has to be left for further research.

4.3 Water use, services and prices

This section presents descriptive results of the questions related to socio-economic characteristics of households, water services and water use as well as satisfaction with current water services. Since income is expected to have an important influence on willingness to pay for water services, special attention is given to income levels and income distribution in the Middle Olifants. The analysis of water use habits focuses on, besides purely domestic purposes, productive uses of water and especially constraints to irrigation of crops and domestic irrigated vegetable gardens.

4.3.1 Socio-economic situation of households

Table 4.4 gives an overview of the socio-economic characteristics of the average household of each sub-sample. A χ^2 - test was used to analyze whether the socio-economic variables differ significantly between those households interviewed in CE 1 and those in CE 2.[10]. According to the results of the χ^2-test, there is a relationship between socio-economic characteristics and being in a certain choice experiment. Sampled households of CE 1 are less often females, smaller average household size, average income exceeds that of CE 2 and better educated respondents. These findings are related to the fact that CE 1 includes households living mainly in urban areas and CE 2 those living predominantly in rural areas[11]

Figure 4.2: Urban and rural area, Source: own pictures, 2007

The average household income of households of CE 2 is with about ZAR 1600 per month remarkably consistent with findings of other studies in rural Limpopo [Kanyoka et al., 2008]. 43% of the sampled households in CE 2 depend solely on governmental grants, such as pensions or child grants, sometimes disability grants. These grants are part of the South African Social Security System, based on the Social Assistence Act (1992). They are provided on a means-tested basis for households with a household income below a certain threshold and do not require any financial contributions made prior.

Child grants of ZAR 190 per child younger than 14 apply if (in the year 2006)

- in rural areas: income less than ZAR 1100 per month
- in urban areas (informal house): income less than ZAR 1100 per month

[10] Certain preconditions have to be fulfilled in order to use a Chi^2-test, otherwise test results are not reliable:

- the expected frequency in each cell of the cross table needs to be at least 5
- the number of cells should exceed 5
- the χ^2-test is especially suitable for variables that are nominal scaled

[11] This is due to the stratified sampling according to main water source.

Table 4.4: Socio-economic characteristics of households and respondents

Characteristic	Description	CE 1	CE 2
Gender of respondent*	male	30.3%	23.1%
	female	69.7%	76.9%
Household size*	mean	4.4036	4.7037
	st.error	0.04497	0.04849
Age of respondent*	Mean	34.6350	39.5492
	St.err.	0.42943	0.44271
Income of household*	Mean	6843	1632.38
	St.err.	144.19	65.19
Income of household (incl.governmental grants)*			
	Mean	7031	2532
	St.err.	139.90	02259
Income classes incl. governmental grants			
	ZAR 0-799	7%	13.1%
	ZAR 800-1199	7.2%	21.2%
	ZAR 1200-1799	3.4%	19.2%
	ZAR 1800-2499	5.5%	9.8%
	ZAR 2500-4999	12.3%	16.8%
	ZAR 5000-9999	42.7%	14.5%
	ZAR $\geq$ 10000	22.4%	5.4%
Education of respondent*	no schooling	7.1%	17.3%
	Primary school	5.1%	15.3%
	Secondary school	56.4%	56.9%
	university degree	31.4%	10.5%
Residential area	Urban	80%	10%
	Rural	20%	90%

Source: own survey, 2007 *$\chi^2 \leq 0.01$.

- in urban areas (formal house): income less than ZAR 800 per month

Old age grants of ZAR 940 (in the year 2008) are also coupled to certain income and asset thresholds. They apply to woman ($\geq$ 60 years) and man ($\geq$ 63 years), when they earn less than ZAR 1962 (single) and ZAR 3642 (married) per month. These conditions are frequently met for the sampled households in rural areas in CE 2. Take-up rates of grants are quite low in case of child grants (only 20% in 2001). Since 85% of the pensioners live together in households with non-pensioners, the old age pensions are substantially benefitting to all household members [Samson et al., 2003].

Including governmental grants into the calculation of total income available to a household increases average household income in CE 2 to ZAR 2532. But despite the presence of governmental support system, still 13% of the households have less than ZAR 799 and 34.3% have less than ZAR 1199. Different classifications of "poor" households exist worldwide. A frequent classification for South Africa is that households with an income of less than ZAR 800 per month are regarded as being "Poor" (according to DWAF). DWAF (2004) indicate that 70% of the rural population of the Olifants CMA are classified as living in poverty, but it is not indicated whether they refer to the poverty line of ZAR 800 and whether governmental grants are already included in the calculation of poverty. Van Koppen (2008) stated that 30 % of the population in the Olifants CMA do not have any income at all [van Koppen, 2008]. Ignoring governmental grants, just as much of the sampled households in CE 2 were found to have no income at all.

The high standard errors show a high variability of incomes among households. To have a closer look at the income distribution, various income distribution or inequality measures exist in the literature. One very common approach to measuring inequality graphically are Lorenz curves. A Lorenz curve plots the cumulative share of households against the cumulative share of income that accrues to those households. When income is perfectly distributed, the Lorenz curve is a straight line. When the income distribution is unequal, the Lorenz curve will lie below the line of perfect equality. As presented in Figure 4.3, one can see that inequality is present in the data. For example, 20% of the households of CE 2 have only 3% of the income.

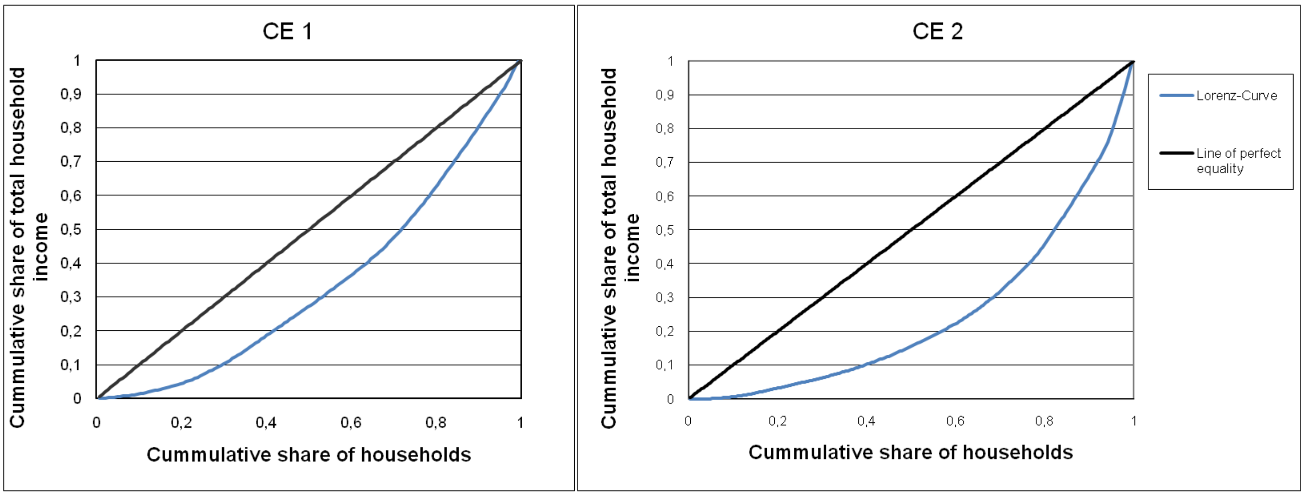

Figure 4.3: Lorenz curve, left: CE 1, right: CE 2, Source: own survey, 2007

The Gini-coefficient is perhaps the best known inequality measure and can be derived from the Lorenz curve. It is defined as the mean of absolute differences between all pairs of individuals for some measure. In order for the Gini-coefficient to be an unbiased estimate of the true population value, it should be multiplied by $\frac{n}{(n-1)}$ where n is the total number of observation. Mathematically, the Gini-coefficient varies between zero and one, although in reality values usually range between 0.20 and 0.30 for countries with a low degree of inequality and between 0.50 and 0.70 for countries with highly unequal income distributions. The Gini-coefficient resulted in 0.556[12] for the income distribution of the households with basic water services (CE 2) and 0.474 for the mostly urban households of CE 1 in the Middle Olifants. The Gini-coefficient of the Middle Olifants is lower than the national Gini-coefficient for South Africa of 0.72 in 2005[13] [Statistics-South-Africa, 2006]. This is likely caused by the fact that it is not calculated for the sample as a whole and that the Middle Olifants is a rather poor area with less high-income households as they can be found in other areas of South Africa.

Respondents of the choice experiment were defined as household members of at least 16 years, who are familiar with the household budget and the water sources. Figure 4.4 displays the relationship of the respondent to the Head of the Household.

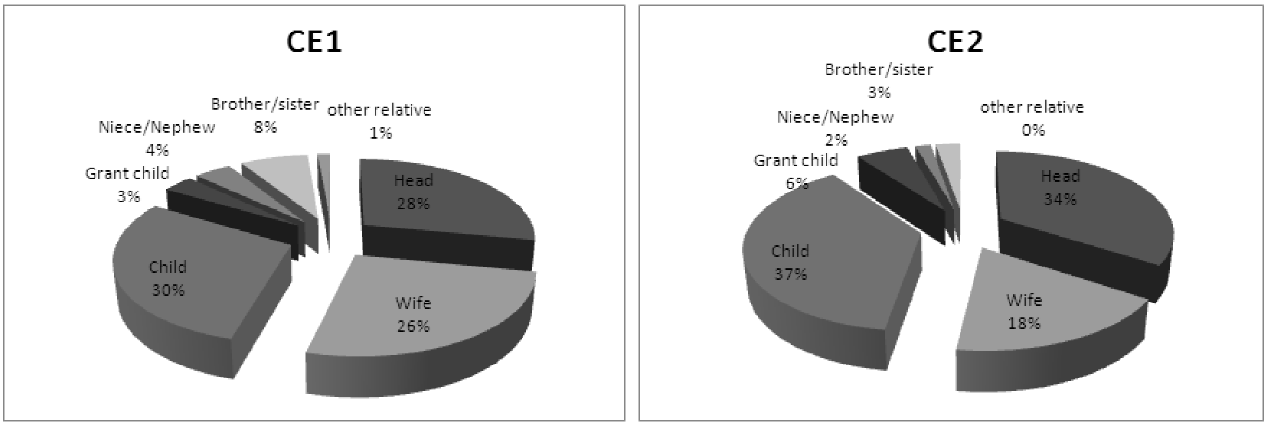

Figure 4.4: Relationship of respondent to Head of Household, Source: own survey, 2007

52% of the households of CE 2 are female-headed. Especially in rural areas in South Africa, many households are headed by women and those are also more likely to be poor. Hope et al. (2003) state that 60% of the female-headed households in South Africa live in poverty, while the corresponding figure for male-headed households is 31% (in 1998) [Hope et al., 2003]. Corresponding to that, female-headed households of the sample have a significantly lower income than male headed households[14]. Therefore, governmental support systems might have to be better targeted towards an empowerment of female-headed households in particular.

Results of questions concerning the current access to water in terms of main water source (see Figure 4.5), frequency of water availability per week, hours of water running per day of supply and occurrence of break downs of water sources are presented in Table 4.5.

[12] The Gini-coefficient for income excluding governmental grants was calculated as 0.596. A comparison the Gini-coefficients and the Lorenz-curves shows a positive effect of governmental grants on enhancing equity. But still, many households do not benefit from the grants, because they are not aware of them, cannot register or grants are just too low to contribute to a more equal income distribution.

[13] The Gini-coefficient is based on disposable income (from work and social grants), which is comparable to the income used to calculate the Gini-coefficient of the sampled households.

[14] Man-Whitney-test: Z-value=-8,877, p-value=0.000.

Table 4.5: Water service levels in the Middle Olifants

Water source	Description	Private Tap inside	Yard connection	Public tap	Other sources	Total
Frequency of supply per week*	never know	7.32%	3.45%	21.79%	14.75%	12.26%
	1 day	0.81%	18.13%	25.64%	11.48%	15.10%
	2 days	0.00%	28.49%	17.31%	4.92%	13.79%
	5-6 days	56.91%	21.44%	23.08%	8.20%	29.73%
	7 days	34.96%	28.49%	12.18%	60.66%	29.11%
Hours of water per day of supply*	$\leq$ 12 hours water per day	6.68%	51.48%	45.67%	17.46%	32.06%
	12 to 23 hours water per day	56.48%	23.33%	30.21%	22.22%	34.74%
	24 hours water per day	36.83%	25.19%	24.12%	50.79%	33.20%
Break-down of water source*	once in a month and more often	4.1%	3.48%	26.5%		
	once in a year	21.42%	20.75%	31.61%		
	almost never	74.49%	75.76%	41.94%		
Hose connection	Yes			28%		
	No			72%		
Connect to public tap in:	Fixed order			5.60%		
	Rotating order			10.10%		
	First come, first serve			83.10%		
	Other			1.10%		
Trips to fetch water per day				3.36 (0.0695)		
Waiting time	no waiting time			25%		
	< 2 min			12%		
	2 - 5 min			20%		
	5 - 10 min			8%		
	10 - 30 min			24%		
	30 min - 1 hour			8%		
	more than 1 hour			3%		

*Significant difference between water sources: $\chi^2 - test, p - value \leq 0.01$, Standard error in brackets, Source: own survey, 2007

Figure 4.5: Main water sources, left: River, at the bottom: Public tap; right: borehole, at the bottom: yard connection, Source: own pictures, 2007

Table 4.5 reflects differences in service characteristics between the water sources. Regarding frequency of water supply in days per week, less than 1 Percent of the households having a private tap inside their houses receive water only once a week. For households using yard connections and public taps about 18% and 26% respectively can access the water source only once a week. The majority of the households with a private tap inside their house receives water 5-6 days a week and about one third even every day per week and the water is flowing between 12 and 23 hours per day, with one third receiving it 24 hours. Only 12% of households with access to public taps receive water every day. Households using yard connections or public taps are supplied less often, most of them receive their water less than 11 hours per day. Households using “Other sources” can access water in 50% of the cases 24 hours per day. This is related to the fact, that 65% of these households use river or canal water and the remaining ones use groundwater which can be accessed usually every day. With regard to the likelihood of break downs of the respective water source, private tap users do not have severe problems with breakdowns, since three quarters of the households indicated that they almost never experience break downs. But with regard to public taps, the problem of break-downs is more severe. As much as 10% of those households indicated to experience break-downs once a week. A χ^2-test was used to analyze whether the variables “Water source” and “Frequency of supply per week”, “Hours of supply per week” and “break-down of water source” are independent of each other or whether there is a relationship between the variables. According to the results of the χ^2-test, there is a relationship between the quality of the service and the type of water source.

4.3.2 Water use habits

This section refers to households of CE 2 only as it was impossible for households of CE 1 to quantify water use for each domestic purpose. Most households use the same water source for all domestic (indoor) purposes. White et al. (1972) as cited in Howard and Bartram (2003) suggested that these types of usages can be defined in relation to general domestic water use:

- Consumption: drinking and cooking
- Hygiene: including basic needs for personal, cloths washing and domestic cleanliness
- Amenity use (for instance car washing, lawn watering and outdoor uses) [Howard and Bartram, 2003].

WHO estimates the daily minimum of drinking water depending on age, climatical conditions and activity to lie between 1 and 3.7 liters [Howard and Bartram, 2003, page 5]. According to WHO (2003), 7.5 liters per capita per day can be calculated as the basic minimum of water required for drinking and cooking. According to Figure 4.6 water used for drinking and cooking purposes sums up to 112 liters per week and household, for an average household of 4.7 persons, this means a daily use for drinking and cooking of 3.7 l/dc. This indicates that the more rural households in the Middle Olifants with access to more basic water sources use less water for their drinking and cooking needs than what is recommended. But the figure is in-line with other studies conducted in Africa. Thompson et al. (2001, as cited in Howard and Bartram (2003, page 9)) show that in East Africa only 4.2 liters per capita per day were used for both drinking and cooking for households with a piped connection and even less (3.8 liters per capita per day) for households without a connection. A study in rural Ghana reflected average water use for drinking and cooking to be as little as 1.7 l/dc given a household size of 8.5 persons in the dry season [Osei-Asare, 2005, page 40, 52].

Households in the Middle Olifants use 10.5 l/dc for personal hygiene followed by 6.1 l/dc used for washing cloths and cleaning the house and dishes. Studies in Kenya, Tanzania and Uganda suggest that the quantities of water used for bathing (including hand washing) and washing of clothes and dishes is sensitive to water service levels according to Thompson et al. (2001). When fetching water from outside the house, an average of 6.6 l/dc is used for cleaning dishes and washing clothes and 7.3 l/dc for bathing. Households with a private tap use on average 16.3 l/dc for washing dishes and clothes and 17.4 l/dc for bathing. The figures of the households of the Middle Olifants lie therefore well within the ranges of the other African studies.

Re-use of water occurs in one third of the households. The re-used water mostly originates from rinsing and bathing water.

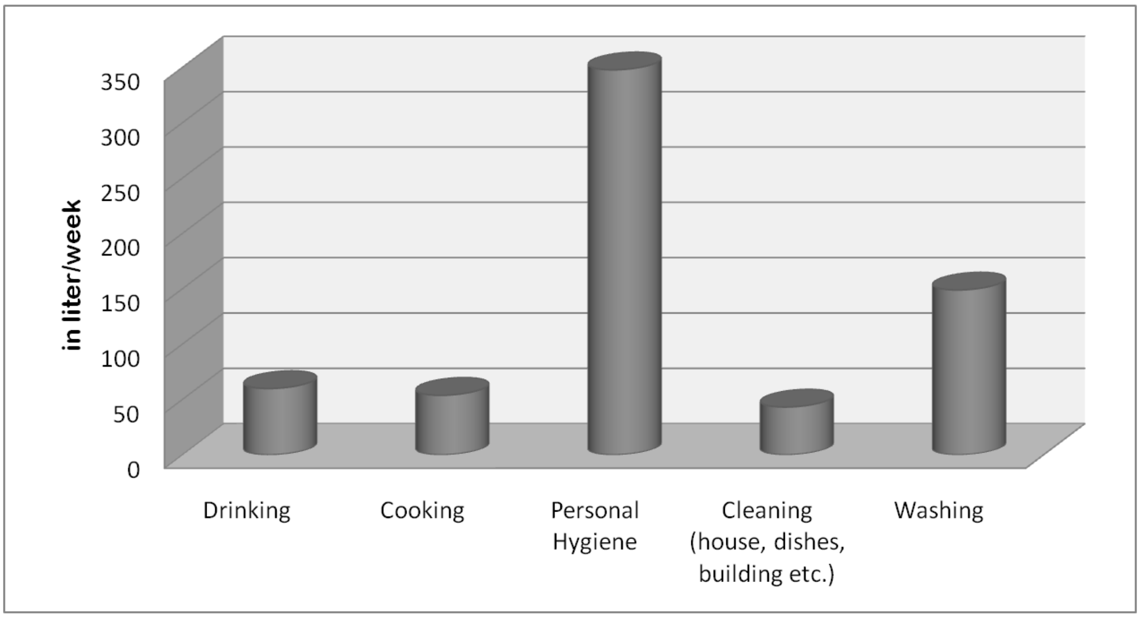

Figure 4.6: Average weekly household water consumption by indoor purpose, Source: own survey, 2007

4.3.3 Water quantity

Households of CE 2

Average consumption of households using basic water services is 18.68 (0.2182) liter per person per day and 2585.88 (46.3241) liter per household per month (Standard error in brackets).

Differences in water use per season could not be calculated since the survey was conducted during dry season and households were not able to estimate how much their average consumption would change. In many cases, the water storage capacity determines the quantity of water used and this does not change over seasons. But in other studies, water use is found to increase during the rainy season [Osei-Asare, 2005, page 50, e.g.] and therefore, average consumption per year may be higher. The mean of consumption differs significantly with respect to the water source according to a Kruskal-Wallis-test[15] ($\chi^2 = 70.83, p \leq 0.001$). Paired comparisons using a Mann-Whitney-U-test indicate that average consumption differs between all water sources significantly[16]. Average consumption is lowest for Public Taps which is likely to be related to the time and effort spend to fetch water. Other sources comprise boreholes and river/canal water. These water sources provide water in general on a daily basis. The total amount of water used for domestic purposes is comparable to other studies in other African countries and rural settings [Osei-Asare, 2005, Kanyoka et al., 2008]. Kaniyoka et al. (2008) estimated the average daily water use per person to lie between 13-25 l/dc in Limpopo Province which is very close

[15]Normality of the variable "CONSUMPTION (l/dc)" was rejected by a Kolmogorov-Smirnoff test and P-P plots and therefore, a non-parametric test has to be used to compare means.

[16]Yard Connection& Public Tap: $Z = -8.144, p \leq 0.001$; Yard connection& Other sources: $Z = -2.851, p \leq 0.01$; Public tap& Other sources: $Z = 4.756, p \leq 0.001$.

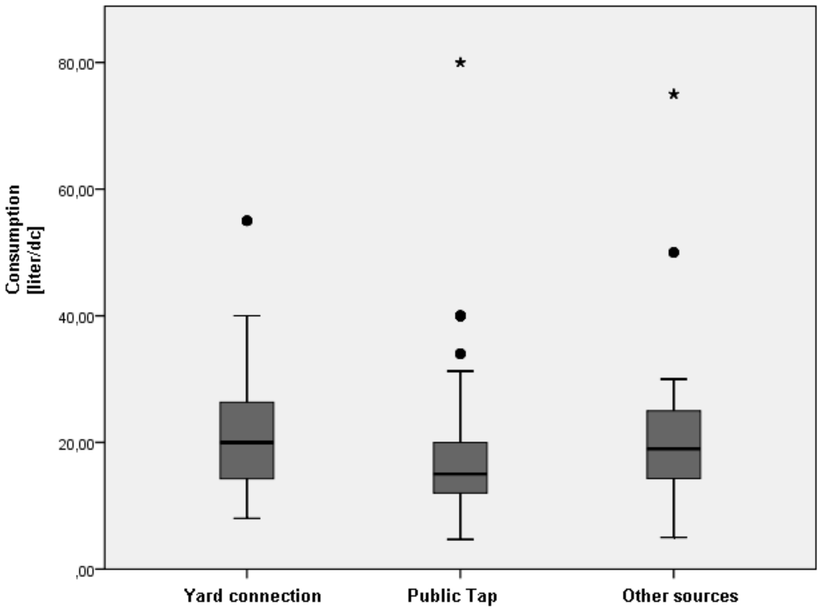

Figure 4.7: Average consumption by water source per capita per day, Source: own survey, 2007

to the figures above [Kanyoka et al., 2008]. Perez de Mendiguren Castresana (2003) estimated consumption for the village Bushbuckridge to lie on average between 21 and 22 l/dc depending on water source [Perez de Mendiguren Castresana, 2003]. The boxplots of each water source in Figure 4.7 present the distribution of the consumption graphically. The median of the water consumed from each water source is represented in the box as well as 50% of the values between the 25% and 75% percentile. As “other sources” represent boreholes and river water in most of the cases, this finding suggests that the greater availability of groundwater and river water can offset the higher effort associated with pumping or walking distance. Public taps, however, have a limited availability and water has to be fetched, so less water can be used on average.

The findings on consumption reveal that households using basic water service do not fully make use of their free basic water of 25 l/dc, they even fall below the estimated minimum amount of 20 l/dc of water to for basic health protection by WHO. As the basic level of supply should be regarded as a minimum quantity of water, WHO recommends to increase levels of service to yard connections and a quantity of 50 l/dc [Howard and Bartram, 2003]. However, 62.5% of the households in CE 2 indicated to receive always or mostly enough water to satisfy their domestic needs. But for the remaining 37.5% the water was not enough to cover their domestic needs. It is expected that the situation of households will aggravate since 42% of the households indicated that their water needs will increase during the next year. To cope with the limited quantity of water that is available, almost all households of CE 2 reuse their water, mainly for outdoor purposes such as gardening activities and irrigation of fruit trees as presented in Figure 4.8.

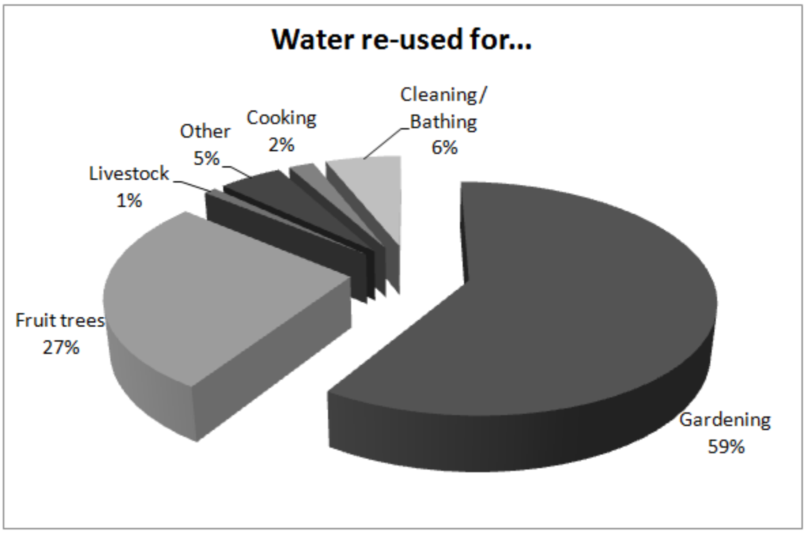

Figure 4.8: Water re-use, Source: own survey, 2007

Water storage is a strategy to enhance water availability and to cope with the few days of supply per week. Concerning water storage capacity, almost all sampled households without private in-house connections have some kind of water storage equipment. Common are tanks with a capacity of 200-300 liters and small canisters with usually 20 or 25 liter capacity. Tanks are used to store water since it is (usually) not provided every day, or 24 hours (see Table 4.5) while canisters are used to fetch water from public taps or yard connections and also for storage purposes. An average household owns 2.3 (st.err. 0.04) tanks with an average capacity of 278 liter (st. err. 9.40) at a cost of ZAR 223 (st.err. 8.20) each, 2.5 canisters with an average capacity of 24.77 liters (st.err. 0.08) at a cost of ZAR 12.62 (st.err. 0.43). Rarely, very large tanks with a capacity of 1000 liters are used. Households spend on average ZAR 544.77 for tanks and canisters (without expenditure for large tanks).

Figure 4.9: Tank and Canister, own pictures, 2007

Households of CE 1

The sampled households having access to private taps inside their houses or as yard connections in urban areas experience much better service levels. Not surprisingly, their average consumption of water of 10.35 m^3/month (St.err. 0.083) exceeds by far the consumption of households using basic water services. Calculating the average water use per day of an average household of 4.4 members results in a daily water use of 78 l/dc. Figure 4.10 shows that the majority of the households falls within the category of 6-10 m^3 per month while only about 5% of the households use more than 20 m^3 per month. Even 15% of the households fall within the free basic water category, but since Lepelle Nkumpi Municipality does not provide free basic water to households in Lebowakgomo, they also pay for their water as long as they are not registered as indigent. Lepelle Nkumpi Municipality provides free basic water only to poor households in the framework of their indigent policy [Lepelle-Nkumpi, 2008]. About 90% of the households equipped with private taps stated that they have sufficient water to cover their domestic water needs. About 7.5% of the remaining households have sometimes problems to receive enough water and only 2.5 % state that they have regularly not enough water to cover their needs. Here, the water services situation of households in terms of quantity of water is much better than that of households with basic water services.

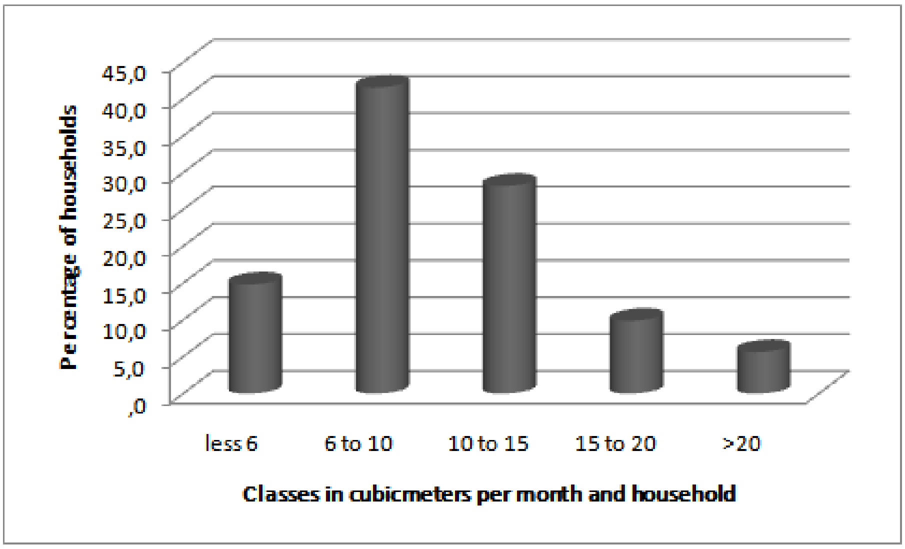

Figure 4.10: Percentage of households falling into different classes of water consumption (in m^3/month), Source: own survey, 2007

4.3.4 Pricing of water

Basic water services

Though households are entitled to a free amount of 25 l/dc by the free basic water policy, they are found to pay fixed charges for basic water services in some villages in Limpopo Province. Kaniyoka et al. (2008) describe that households in some villages pay a fixed amount, mostly ZAR 10 per month for maintenance of the water related infrastructure to the municipality [Kanyoka et al., 2008] but households in the sampled village in this study do not have to pay any water-related charge to the municipality. But they had to pay a connection fee when being equipped with a private yard connection. The amount, households paid varied between ZAR

90 and ZAR 2,500. For installations of private boreholes, households paid between ZAR 1,000 and ZAR 10,000. None of the households stated to have taken out a loan as all paid cash. Water vending is common in South Africa. Perez de Mendiguren Castresana (2003) observed that households pay between ZAR 0.25 and ZAR 2.50 per 25-liter-canister in Bushbuckridge municipality. This is equivalent to ZAR 8-10 per m^3 which is a higher tariff than that faced by households with private tap connections. About 16% of the sampled households indicated to buy additional water from neighbours/vendors and spend on average ZAR 25 per month. Many of the households paid flat rates, so they could use as much water as they wanted.

Households using private taps

All households using private taps were interviewed in the municipality of Lepelle Nkumpi. Households connected with private taps are supposed to pay basic charges for water services and sewerage services and a unit price per cubicmeter of water (ZAR 4.80 in 2007). Increasing block rates were not yet implemented.

During expert interviews conducted with water service officers in Lepelle Nkumpi Municipality, it became apparent that non-payment of bills is a problem in Lebowagkomo. Cut-offs from the water connection in case of non-payment are not enforced. Only two households in the survey indicated that they have been disconnected from the water supply system. The situation of non-payment can be seen in Figure 4.11. Sampled households were asked whether they pay their bill completely, partly or not at all and whether they refuse to pay for water services in general.

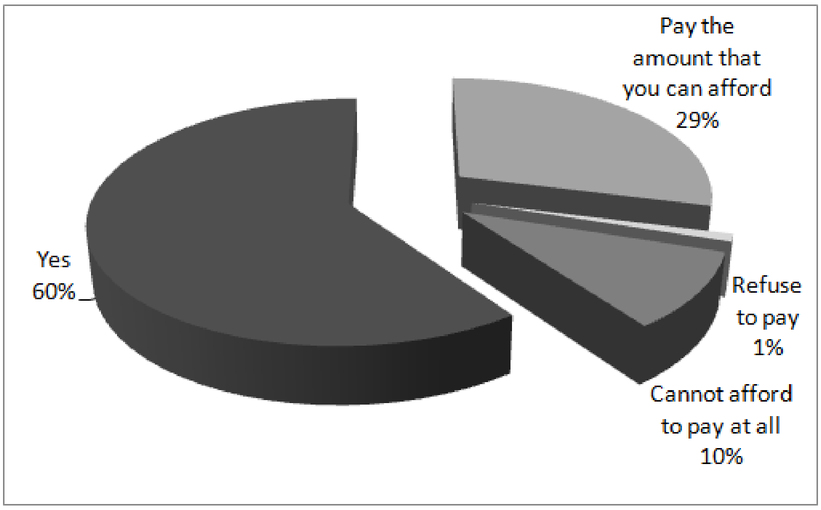

Figure 4.11: Payment of water bills, Source: own survey, 2007

While more than half of the interviewed households pay their bills as requested by the municipality, 29% indicated that they cannot afford to pay the full amount and 10% that they cannot pay at all. Only 1% stated to refuse to pay at all irrespective of affordability. Comparing the mean incomes for those who pay for water and those who claim to have a limited ability to pay indicates that those who pay the bill completly have on average nearly twice the income of those who cannot afford to pay. The formal application of a Man-Whitney U-test to compare the means between the two groups confirms that average income of those households who cannot afford to pay (Mean income: ZAR 4851/month) is significantly lower than the average income of households who pay (Mean income: ZAR 8653/month)[17]. With an average income of about ZAR 4800 per month, households definitely do not fall within the support of the indigent policy of Lepelle Nkumpi municipality and do not benefit from free basic water. Given that households indicated not to be able to pay the usual water bill, this finding suggests reconsidering the income threshold of the indigent policy.

4.3.5 Productive uses of water

Very little is known about water use for productive activities of the households in the Middle Olifants although multiple uses of water are known in South Africa [Hope et al., 2003]. Initially, the 25 l/dc of water were calculated based on the fulfillment of domestic purposes only - productive uses of water within a household were ignored. But the government recognized that water has to fulfill multiple uses composed of domestic and productive water uses [DWAF, 2006] and begins to acknowledge this in its 'Water for Growth and Development Strategy'[18] [van Koppen, 2008].

A study done by Perez de Mendiguren Castresana (2003) in Bushbuckridge in South Africa aimed at analyzing the kind of household production using water, quantifying the water demand for each production, and assessing whether people are able to pay for their water. Using a comparative village-case study approach the dominating productive uses in rural water consumption were found to be vegetable gardens, fruit trees, building of houses, beer brewing and livestock keeping [Hope et al., 2003, Perez de Mendiguren Castresana, 2003].

- Gardening: Gardening refers to any activity in the garden that is not necessarily related to food production but to any planting activity.
- Irrigation: Vegetable gardens are small portions of land used to grow vegetables such as tomatoes, cabbage, lettuce, and pepper, in the winter; and rainfed field-crops such as maize in the summer. They are normally located within the individual homestead and irrigated with domestic water. Households usually posses a number of fruit trees, which provide shade and have aesthetic value as well as giving fruits. The most common types

[17] Normality of the variable "Income" was rejected by a Kolmogorov-Smirnoff-test and P-P plots and therefore, a Man-Whitney-U-test was used to compare means between two groups: Households, that pay bill completely& Households that cannot afford to pay completely/at all: Z = -13.642; p=0.000.

[18] This strategy focuses less on water-related infrastructure but recognizes that water is an essential input for every aspect of existence, food, shelter, energy, recreation. It emphasizes a water management that promotes economic growth, alleviates poverty and contributes to a more equal distribution of water and sanitation infrastructure.

of fruit trees are mango, litchi, banana, paw-paw, avocado, guava and peach in the region. However, trees will survive long periods without water, particularly if they are adult, so a less reliable supply is needed than for vegetables gardens [Perez de Mendiguren Castresana, 2003].

- Livestock: The source of water for cattle is often outside the village (cattle dams, rivers and springs), but especially when water is as scarce as in the dry season, additional water from the domestic water supply system is needed to keep livestock alive [Perez de Mendiguren Castresana, 2003].
- Business: This term refers to any commercial water related activity. Households use for example water for brick making which they can sell.

Asking for the respective quantities needed per activity (see Table 4.6), the author concluded, that an additional amount of 40 l/dc to the basic free water is needed to support these production activities. A calculation of gross margins per liter of water for each activity revealed the lowest returns to water for the most frequent uses of goat keeping and vegetable gardens.

Table 4.6: Type of household production, respective water requirements (l/dc) and gross margins (ZAR/year/capita) in Bushbuckridge Municipality

Household production activity	Water requirements (l/dc)	Gross margin (ZAR/ year and capita)
Vegetable gardens	1.2 - 12.6	7 - 58
Fruit trees	2.2 - 8.5	11 - 66
Cattle	14.5 - 16.4	113 - 131
Goats	1.4 - 2.0	11 - 18
Brewing	0.05 - 0.09	142 - 339
Building of houses	3.1 - 1.3	18 - 33
Ice block	0. 12	33
Total	23.3 - 40.4	361 - 653

[Perez de Mendiguren Castresana, 2003]

As presented in Figure 4.12, water used for business seems to play a very small role for households in the Middle Olifants. But water for gardening activities and irrigation is an important outdoor use for many households. Irrigation for domestic food production can help to improve food security in rural areas. Therefore the government supports rural areas by distributing agricultural starter packs for domestic and communal food production to poor households. Due to the potential benefits of domestic food production, it is interesting to find out what hinders most households from crop irrigation and installation of small vegetable gardens.

Figure 4.13 displays the reasons, why households do not irrigate vegetables. As major obstacle for food production, missing water is indicated in 30% of the cases. Almost 40% of the households using water for productive purposes had to re-use their domestic water for those

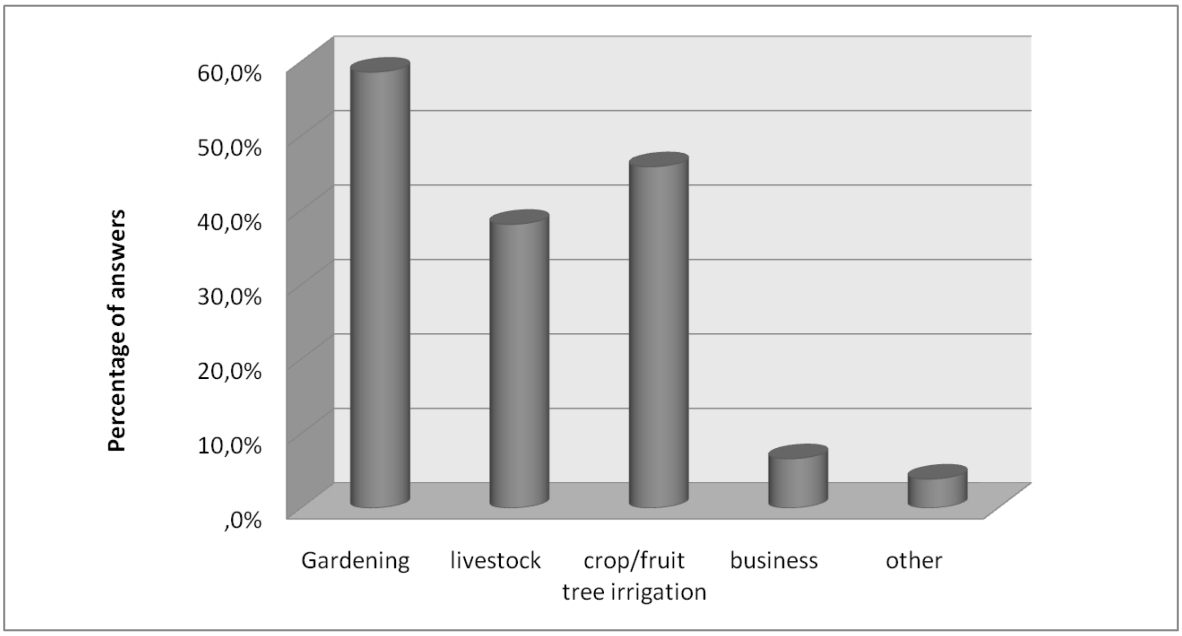

Figure 4.12: Productive uses of water in the Middle Olifants, multiple answers permitted, Source: own survey, 2007

outdoor purposes. Also Hope et al. (2003) recognized that without a regular and reliable water supply, irrigation of crops and vegetable gardens are strongly constraint. In their survey in the Luvuvhu catchment, Limpopo Province, respondents stated not to collect water explicitly for vegetable gardens or irrigation activities [Hope et al., 2003, page 108].

Round about 20% of the households lack suitable land for agricultural production and 8% are just too old for planting. About 18% of the sampled households do some kind of irrigation activity. An increase in food production in rural areas as aimed for by the government can only be reached when water availability is increased as well. Households can hardly fulfill all their domestic needs and can therefore not allocate any domestic water for irrigation activities.

Water requirements for productive uses of water from the sampled households turned out to be around 5 l/dc for livestock (several goats and chicken), which are supplied from domestic water sources[19]. Not enough observations on water requirements for irrigation or vegetable gardens could be made to calculate a reliable number.

4.3.6 Satisfaction with current level of service

Levels of satisfaction with basic water services were elicited by asking the respondents to score their overall satisfaction by assigning a satisfaction rank from five different levels (1= very satisfied, 2=satisfied, 3=neutral, 4=dissatisfied and 5=very dissatisfied). Results are presented

[19]For donkeys and cattle, households supplied about 50 l/dc from domestic water supply system when rivers are dry or for other reasons. But only few households indicated to own cattle or donkeys.

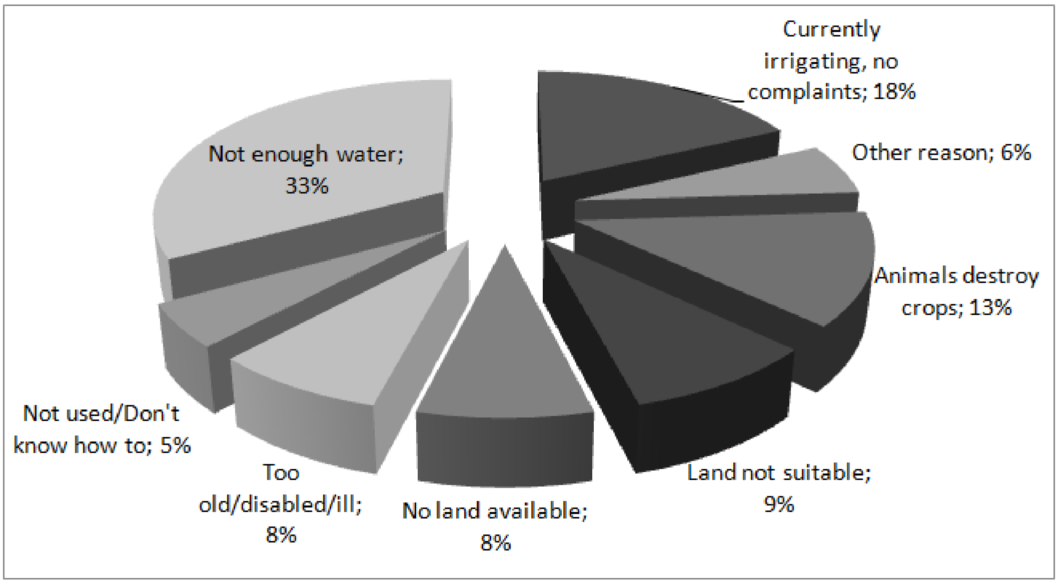

Figure 4.13: Problems with irrigation in the Middle Olifants, Source: own survey, 2007

in Figure 4.14. Average satisfaction score is 3.2088 (St. err. 0.02401). Therefore, households are between neutral and dissatisfied with respect to their current water service levels.

4.4 Preferences and Willingness to pay for in-house connections

In the following section, results of the choice experiment dealing with the alternative "Private Tap inside the house" (CE 1) are presented. The design of CE 1 and the finally selected attributes were already presented in Table 4.3. A Wald-test of linear restrictions was conducted in order to check whether the influence of the coefficients of attributes can be represented best in a linear way or whether nonlinear effects are present [Hensher et al., 2005a]. For example, moving from a consumption of 50 up to 100 l/dc may not be equally advantageous as moving from 100 to 150 l/dc. The categorical attribute[20] "PAYMENT" captures always non-linear effects. According to the results of the Wald-tests, the numerical variable "CONSUMPTION"[21] reveals nonlinear effects. To capture these effects, dummy coding was used. The estimated coefficients are to be interpreted relative to the normalized base-line level, which is always fixed to be the first (lowest) attribute level. Dummy coding was selected because it allows for an easy and straightforward interpretation of the coefficients and, later on, the willingness to pay- estimates. The price attribute as well as "FREQUENCY"[22] and "RELIABILITY"[23] are design-coded with the actual numerical attribute-levels.

[20]A categorical attribute refers to an attribute that can be separated into mutually exclusive categories/levels.
[21]Wald-test ($H_0 = \beta_1 - \beta_2 \neq 0$), CONSUMPTION $\chi^2 = 0.78$, p-value= 0.3756.
[22]FREQUENCY: $\chi^2 = 38.29$, p-value= 0.0000.
[23]RELIABILITY χ^2 =49.75, p-value=0.0000.

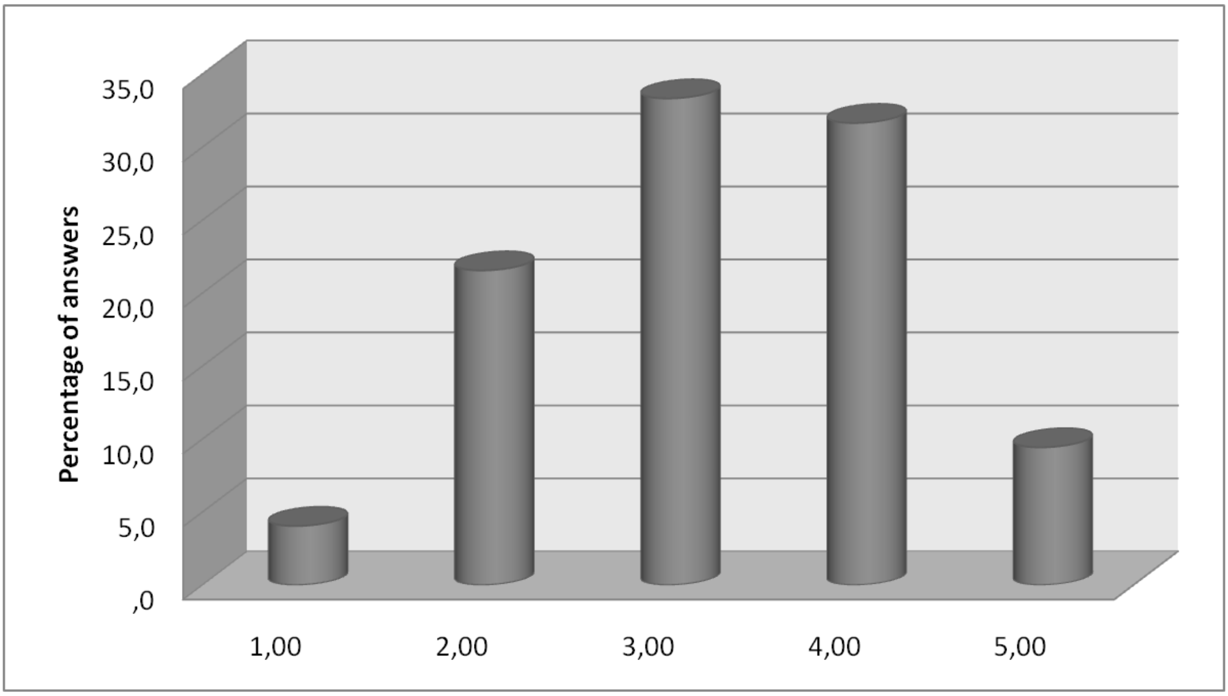

Figure 4.14: Satisfaction with current water services from 1= very satisfied to 5= very unsatisfied, Source: own survey, 2007

4.4.1 Conditional logit model

First, the results were analyzed using a conditional logit (CL) model [McFadden, 1974]. This model is often described as the workhorse-model for discrete choice analysis [Train, 2003, Louviere et al., 2000]. Although demanding strong assumptions, the model can still often be found in the literature and might outperform sophisticated discrete choice models in terms of prediction capabilities [Provencher and Bishop, 2004, Provencher and Moore, 2006]. Hensher et al. (2005) advise to spend time exploring the results provided by the CL-model since many statistically significant effects remain in advanced models [Hensher et al., 2005a].

The CL model - as presented in the appendix in Table A.3 - is overall statistically significant by means of a likelihood ratio test comparing an unrestricted model to a restricted, base model of constants only. Whether the IIA-assumption holds true was tested using a Hausman-test and Wald-test of nested specifications [Hausman and McFadden, 1984] (for more details on the Hausman-test and other tests of IIA, see appendix Section 5.3). If IIA holds, the model estimated on all choices should be the same as a model estimated on a sub-set of alternatives (e.g. excluding one option). According to the Hausman-test, IIA is not maintained with $\alpha = 0.05$ when excluding alternative a. Alternative a is always presented as first choice in the choice set and may thus have a stronger effect on choices than the other options.

The coefficients of the attributes are - as expected - positive for the attributes “FREQUENCY”, “CONSUMPTION” and “RELIABILITY” and negative for the attribute “PRICE”. A higher Frequency of supply of water per week increases utility while a higher price decreases utility gained by the respondent. With respect to “PAYMENT” both attributes are negative but “every 6 months” is not significant and should not be interpreted further. The attribute “Prepaid” indicates that a negative utility is provided by prepaid payment systems. Alternative specific constants (ASC) can be included to capture all systematic unobserved effects in order to represent the average effect on utility of all factors not included in the model. Besides, including ASCs makes maintenance of the IIA-assumption more likely [Blamey et al., 2000]. In this model, no ASC was included, first, due to the use of dummy coding, the ASC is perfectly confounded with the base level of the dummy-coded attributes and cannot be interpreted properly. Second, including alternative-specific constants in an unlabeled experiment would not make sense for its interpretation since the unobserved effects should be the same over all alternatives. Whether or not to include a generic constant in an unlabeled discrete choice model depends on the context of the choice experiment, the availability of the “opt-out” option and other factors [Blamey et al., 2000]. But adding the same constant to all alternatives is here not regarded as influencing choice probabilities among options and therefore no constant (neither alternative-specific nor generic) was included. Selected two-way interactions between attributes (PRICE x FREQUENCY, PRICE x CONSUMPTION) accounted for in the experimental design were not found to be significant and, hence, excluded from the model.

Since the assumption of IID-error terms - as tested by a Hausman-test (see appendix, Table A.3)- cannot be maintained, the random error components of utility are not uncorrelated between choices and do not have equal variances. So coefficients and WTP-estimates are not reliable. A more advanced model needs to be considered which does not impose the strong assumption of IIA. Using a nested model for an unlabeled choice experiment would only make sense from a behavioral point of view by separating the “opt-out” option from the other options. Then, a decision can be reflected whether to choose any new alternative or stay with the current supply on a first step. Unfortunately, such a nested logit specification was not feasible or in line with economic theory (IV parameter > 1) [Hensher and Greene, 2002] (see Section 3.4.1). The nested model would allow to relax IIA to some extent but does not explicitly incorporate heterogeneity among respondents. In general, it is difficult to analyze heterogeneity in the context of choice experiments with several choice tasks per respondent and random utility models since an individual’s characteristics do not vary over choice sets. Same applies to revealed preferences data, when a respondent makes several choices over time. Income, gender and other variables likely to influence preferences stay the same over choices. Therefore including these variables directly into the utility function would make them drop out. The CL-model assumes homogeneity of preferences. Irrespective of any socio-economic variable or attitude, all respondents are supposed to have the same preferences. Imposing homogeneity of preferences on all respondents is a rather strong assumption since it is very likely that preferences differ between high income and low income respondents or between respondents that are very environmentally concerned and those who are not. To allow for heterogeneity to some extent in CL models, the following approaches are usually applied: [Boxall and Adamowicz, 2002]

- interacting socio-economic variables with attributes and including them directly into the utility function. Interacting these variables with attributes prevents them from being dropped out since the attribute varies over choice sets.
- dividing respondents into sub-samples (e.g. low income - high income) and estimating utility functions for each sample separately

It is suggested in the literature that introducing interactions to capture heterogeneity can simultaneously decrease correlation among choices and thus may lead to maintenance of the IIA assumptions. Interactions between socio-economic factors and attributes were added to the CL-model, see appendix Table A.5. Since income is likely to influence price sensitivity it was included as the interaction"INCP" (INCOME X PRICE) and found to be significant. Respondents with a higher income have a lower price-sensitivity. When interacting the age of respondents with price "AGEP" (AGE X PRICE), the negative sign indicates that older respondents are more price sensitive than younger ones, but this interaction was not yet found significant at the 10% level. The interaction "SUMP" reveals the tendency that respondents stating that everyone should pay for their water have a lower price-sensitivity. Again, this interaction is not yet significant. Adding interactions to the model increases model fit significantly according to the results of a likelihood ratio test (LR)[24]. Comparing the WTP-estimates of the CL model with interactions (see appendix, Table A.6) to the one without (appendix, Table A.4) reflects a lower WTP for all attributes when correcting for some heterogeneity. The decrease in WTP is strong, especially for the attributes "FREQUENCY" and "CONSUMPTION". Including interactions reveals that heterogeneity among households is present in the data and that it impacts substantially on the WTP-estimates.

But using the approach of an CL model with interactions requires a-priori selection of interactions and adding more interactions increases the probability of introducing multicollinearity [Louviere, 2001]. As the assumption for the CL model is still not maintained, mixed logit models (and also probit models) and LC models explicitly account for heterogeneity, but in different ways (see Section 3.4.1).

Latent class models accommodate for the systematic variation by dividing the sample into homogeneous groups. These models are more flexible than the approaches of CL models because they do not restrict the choice to be explained by one function - the utility function - but allow for explanation through covariates directly. They are also especially useful when neither the number of classes nor the membership of respondent to a class are known a-priori, since these can be determined statistically [Kontoleon and Yabe, 2006].

For the case of valuing water services, many characteristics will be evaluated in a similar way: A higher frequency of water and a water source closer to the house are always preferred, so the

[24] $\text{LR}=-2(-1015.8545+1006.5569)=18.5952_{3d.o.f.}$.

direction of the influence should be common. But of course whether this influence is strong or not can differ between individuals. Regarding the service attributes it is likely that some of them might "cluster" [Scarpa et al., 2005], respondents choosing a high frequency may also choose a high reliability since they prefer having water available as often as possible.

A second reason for using the LC model is that the population is readily divided into homogeneous classes. For policy recommendations this classification is helpful, since policies can be designed for different classes of people. Especially when socio-demographic variables are important factors influencing class membership, knowing a person's socio-demographic variables helps to understand his or her preferences and likelihood to choose certain goods or services over others.

Besides the question which model to use best to account for heterogeneity, the choice of variables likely to influence preferences is important. In the growing literature on latent class models two general ways of using covariates can be detected: Some studies use one variable that they suspect to be most important for grouping such as e.g. Ruto and Scarpa (2008), who used the variable "purpose of cattle keeping" as the only covariate and Hynes et al. (2008), using "kayak handling skills" as covariate. When one variable can be suspected to account for a lot of observed heterogeneity among preferences, this approach is advisable. But when preferences are likely to be caused by various factors, several covariates were used [Hu et al., 2004, Kontoleon and Yabe, 2006, Rudd, 2008]. In these studies mostly either attitudinal/psychometric or socio-economic or data of both was used. Provencher and Moore (2006) argued that adding attitudinal data to covariates is very valuable for explaining choices [Provencher and Moore, 2006]. Therefore in the present study both socio-economic and attitudinal data will be used as covariates. In addition to that, variables describing the current water service are also suspected to cause heterogeneity.

4.4.2 Latent class model

Latent class models do not necessitate selection of variables but allow for inclusion of all important variables. These variables serve to explain group membership of households in groups with homogeneous intra-group preferences. The variables suspected to influence class membership are presented in Table 4.7.

The variable "Household size" is defined as the number of all household members living in the household for at least 5 days per week. "Total household income" comprises total formal income, informal income, governmental grants such as child grants or pensions, remittances and other sources of income. The variable "Satisfaction" indicates whether a household is overall satisfied with the current water services. The variable "Acceptance" measures a household's attitude towards pricing of water. The household was supposed to choose the most preferred

Table 4.7: CE 1 - Covariates

Variable	Definition
Socio-economic variables:	
Household size	Number of members of household
Age	age of respondents
Gender	1=male
Income	total income of household including grants and remittances
Water demand:	
Quantity	Quantity of water in l/dc
Service	Service index of current water service
Bill	1= household pays bill regularly
Perceptions:	
Satisfaction	Satisfaction with current water service, 1=overall satisfied
Acceptance	Stated acceptance of pricing of water, measures a household's attitude towards pricing of water
Importance	1=price indicated as being the most important attribute

statement out of four statements indicating that (1) the government should pay for all the water (2) the government should pay for a basic amount of water (3) households should pay for water from private taps (4) all households should pay for water. The variable "Importance" reflects the most important attribute of the choice experiment as indicated by the household. Including all covariates, latent class models up to six classes were estimated using equation 3.40. Table 4.8 gives an overview of the model statistics which revealed the best model fit for all alternative specifications.

Table 4.8: CE 1 - Model statistics

Classes	LL	BIC(LL)	AIC(LL)	AIC3(LL)	Class.Err.	$R^2(0)$	R^2
1	-1015.8545	2071.9000	2047.7089	2055.7089	0.0000	0.1886	0.1389
2	-975.6927	2087.0301	2005.3853	2032.3853	0.0411	0.2405	0.1928
3	-928.5606	2088.2197	1949.1212	1995.1212	0.0365	0.2929	0.2475
4	-891.0381	2108.6284	1912.0762	1977.0762	0.0302	0.3186	0.2757
5	-868.8922	2159.7904	1905.7844	1989.7844	0.0681	0.369	0.3284
6	-838.7088	2194.8774	1883.4177	1986.4177	0.0421	0.3612	0.3202

Determination of the optimal number of classes requires a balanced assessment of information criteria. Since the log-likelihood decreases steadily with an increasing number of classes, information criteria provide help for determining the appropriate number of classes. The BIC criterion is lowest for the one-class model while the AIC3 criterion suggests use of the 4-class model. Though at a lower rate, AIC keeps decreasing. In order to examine whether the 4-class model significantly improves model fit, conditional bootstrapping was conducted with 500 draws. The test-statistic is defined as $-2(LL_s - LL_{s+1})$ with s as the number of classes to be tested. The estimated bootstrap p-value is defined as the proportion of bootstrap samples with a larger -2LL-difference value than the original sample [Vermunt and Magidson, 2005]. With $p = 0.000$ the 4-class model improves model fit significantly. But despite the usefulness of the information criteria, the objective of the study and the interpretation and significance of the class membership parameter estimates should be considered when selecting the appropriate number of classes [Scarpa and Thiene, 2005, Ruto et al., 2008]. Hynes et al. (2008) chose a 6 class model according to BIC while AIC3 and AIC pointed towards a model with nine classes which they perceived as simply too numerous. In the study done by Ruto et al. (2008), the information criteria suggest models with 7 to 12 classes, but they decided for a 3-class model since this provides a straightforward interpretation of the classes by the covariate. Since the 1-class model is the same as the CL-model, which was already rejected, and many parameters are significant and interpretable, results of the 4-class model as suggested by AIC3 will be used in the following.

The LC-model can estimate class sizes of the different classes. The four-class model results in the following class sizes: Class one has the largest share with 39% of the households, class two of 34%, class three of 9% and class four of 18%. Table 4.9 presents the estimated coefficients of the attributes and covariates respectively of the 4-class model. The Wald(=)-statistic indicates whether the coefficients vary significantly between groups. According to Table 4.9 preference heterogeneity with respect to all attributes is present in the data. The results as presented in Table 4.9 show, that classes differ with respect to some covariates as well. The influence of the covariates for class one is normalized to zero, so that the remaining parameters of classes two, three and four have to be interpreted relative to class one.

Choices of class one members are significantly influenced by the attributes "FREQUENCY", "RELIABILITY", "PRICE" and "PAYMENT METHOD". The price-coefficient is the lowest of all classes reflecting that class one members are the least price sensitive with a coefficient of about -0.3. They favor a higher frequency and reliability but coefficients are the lowest of all classes. Households of class one reject both 'payment every six month' and, even more strongly, the 'prepaid payment' method (see Table 4.9).

Class two members differ from class one members with respect to certain covariates. Class two members have significantly less income than members of class one with an average total income of ZAR 6500 per household per month. The lower income may be the reason for the higher price sensitivity in this class with a coefficient of about -1. Members of class two demonstrated stronger agreement with the idea of water pricing than other classes. These households have higher actual water consumption per month, which is reflected in the estimated coefficient for the attribute "CONSUMPTION" in the CE. Both consumption-levels are found to be significant and their estimated coefficients are quite high, indicating that these households prefer higher consumption levels according to their high actual consumption. This finding is very interesting

Table 4.9: CE 1 - Estimation results of the 4-class model

Attributes	CLASS 1 Coefficients (St.err.)	CLASS 2 Coefficients (St.err.)	CLASS 3 Coefficients (St.err.)	CLASS 4 Coefficients (St.err.)
FREQUENCY	0.6978*** (0.1225)	0.814*** (0.1303)	0.9252*** (0.3163)	1.9848*** (0.4065)
CONSUMPTION				
50 liter	0	0	0	0
100 liter	-0.0218 (0.2311)	2.083*** (0.285)	-0.1998 (0.5333)	2.214*** (0.4974)
150 liter	-0.049 (0.19)	1.6219*** (0.2479)	0.4832 (0.4433)	2.007*** (0.4511)
RELIABILITY	0.1392*** (0.0178)	0.222*** (0.0274)	0.0743* (0.0448)	0.3061*** (0.0725)
PRICE	-0.2733*** (0.1054)	-1.0224*** (0.1624)	-1.5467*** (0.3428)	0.0498 (0.2479)
PAYMENT METHOD				
monthly	0	0	0	0
every 6 months	-0.4504*** (0.168)	0.6424*** (0.2338)	0.0367 (0.5054)	-0.8176* (0.4633)
Prepaid	-1.497*** (0.2431)	-0.7469*** (0.2348)	-1.1989** (0.598)	1.0514*** (0.4007)
NONE ('Opt-out'-Option)	3.3223*** (0.9199)	3.269*** (0.993)	-0.0781 (1.7662)	10.7953 (8.2295)
INTERCEPT	0	-33.0867*** (11.5782)	-5.0592 (5.3192)	-3.1787 (2.3157)
SIZE	0	1.3609 (0.8295)	-2.6126** (1.2581)	-0.178 (0.2409)
GENDER(1=female)	0	0.1594 (1.6108)	-6.1291* (3.1018)	0.5953 (0.6927)
AGE	0	-0.6886*** (0.2196)	0.3957** (0.1661)	-0.0313 (0.0307)
INCOME	0	-0.0011*** (0.0004)	-0.0007* (0.0004)	0.0002* (0.0001)
QUANTITY	0	0.207*** (0.0661)	0.0825* (0.0386)	0.0113 (0.0155)
SERVICE	0	7.9875*** (2.6478)	-1.497 (1.3946)	0.8676** (0.3938)
BILL(1=paid)	0	-3.6544 (2.3043)	-6.3229 (3.2329)	0.3934 (0.7201)
SATISFIED (1=satisfied)	0	18.1557*** (6.0576)	5.8083 (3.5172)	0.322 (0.9717)
ACCEPTANCE	0	2.915*** (1.3049)	0.5008 (1.031)	-0.6262** (0.3111)
IMPORTANCE (1=price)	0	-8.9803 (4.1435)	7.4119** (3.3248)	0.4064 (0.8299)
R^2 of classes	0.2002	0.2272	0.1585	0.4833
$R^2(0)$ of classes	0.2712	0.2607	0.1769	0.5497

*Indicates parameters significant at the 0.1 level, ** indicates parameters significant at the 0.05 level, ***indicates parameters significant at the 0.001 level. Standard error in parenthesis.

since it is usually expected that higher income goes in line with higher consumption levels[25]. Additionally, class two members are found to have stated significantly more often that they are overall satisfied with their current water services ("SATISFIED"), which is probably related to the finding that their current water services ("SERVICE") are significantly better than those received by class one and class three members. This might explain the above finding of higher consumption. Since class two members receive better water service levels, they are also able to consume more water while class one members - although having a higher income - may not have access to as much water as they would like. The result indicates that the higher consumption levels of water could probably be as a result of the positive influence of the higher quality of the water services. Usually all households in a village or region receive the same kind of water supply infrastructure. Due to the fact that providing some selected (high - income) households with a better service is very costly, this is not done. Class two members choose the status quo in 10% of the cases (see Table 4.12) since they are already quite satisfied with their current services.

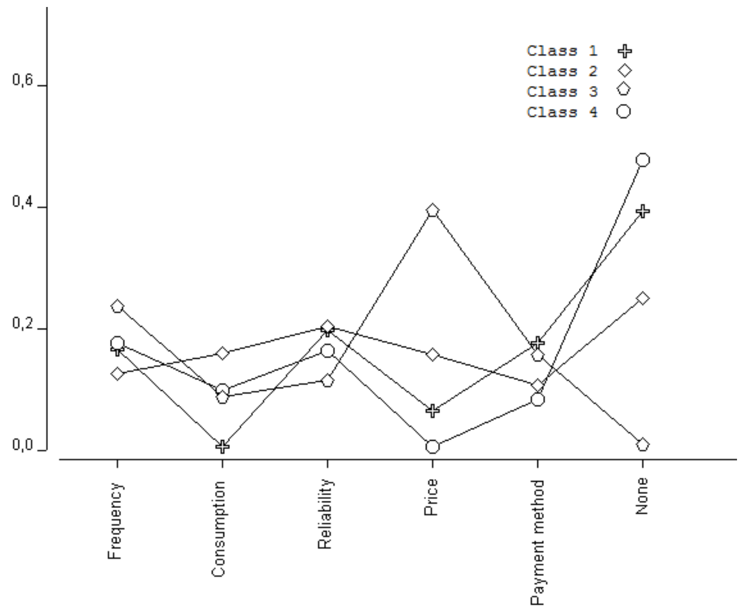

Figure 4.15: CE 1 - Relative importance of attributes within classes

Households of class three are significantly smaller (in size) than other households and respondents slightly older. Class three members are characterized by having the strongest price sensitivity with a coefficient of -1.5. These households are the poorest households; average income of this class is with 2900 ZAR per household per month very low compared to that of class one (7400 ZAR per household per month). They also chose price significantly more often as the most important attribute influencing their choice ("IMPORTANCE") than households in other classes. The difference in the importance of the price attribute is shown in Figure

[25]Income elasticities are usually positive, but their values can vary from unelastic to elastic. For example, Agthe and Billings (1980) estimated income elasticities between 1.33 and 7.829, which are relatively high estimates compared to other studies such as one conducted by Nieswiadomy and Molina (1989) with income elasticities between 0.10 - 0.14 and one by Hewitt and Haneman (1995) with an income elasticity of 0.15.

4.15, which gives an overview of the importance of each attribute within classes by presenting the rescaled maximum effect that adds up to 1. These relative importances of attributes are obtained by applying the following equation:

$$reeff = \frac{max(V_{a|sk}) - min(V_{a|sk})}{\sum_k max(V_{a|sk}) - min(V_{a|sk})} \tag{4.1}$$

where a denotes a level of an attribute k and $V_{a|sk}$ the utility associated with level a for class s. These maximum effects can be compared both across attributes and across latent classes [Vermunt and Magidson, 2005]. Figure 4.15 clearly shows the large differences in importance of "PRICE" and the 'None'-option between classes while other attributes such as frequency and reliability lie relatively closer together. Households of class three tend to opt-out in 28% of all cases (see Table 4.10), so they prefer their actual water service levels, which are provided for free. They have strong preferences to keep their status-quo than to choose a better service at higher prices. Class three comprises a higher share of male respondents. This suggests that men value improved water services as less important. Households of class three have a higher water consumption per person, but this finding is not reflected in a significant coefficients of the attribute "CONSUMPTION". The higher actual consumption in this class is not accompanied by significantly better water service levels suggesting that water consumption may not only be related to the goodness of service levels. A possible explanation for the higher consumption per person in this class might relate to the smaller household size, because economies of scale in water use are not realized. Another idea is that, since these households have significantly less income and are more often unemployed, they spend more time at home than employed households do and, hence, use more water at home. All possible explanations lack sufficient empirical evidence and therefore, differences in water consumption between households using private taps cannot be fully explained by the LC model. A deeper analysis of this issue has to be left for further analysis.

Class four is noticeable due to the finding that the price coefficient is not significant. Additionally, attribute coefficients are quite high for "FREQUENCY", "RELIABILITY" and "CONSUMPTION" so these households show strong preferences for high quality service. Concerning the covariates, households in this class have a significantly higher income, are already receiving a better water service ("SERVICE") than class one, but stated that they are less willing to pay for water ("ACCEPTANCE") than households in other classes. The missing price significance and the high quality preferences may be explained in two ways: households having a high income may prefer high standards irrespective of the price levels given in the experiment. For those households probably higher price levels would have been needed to detect a significant influence of prices. Second, households in this class indicated that they are less willing to pay for water. This might be an indication that some of the households always chose the best options but are not actually willing to pay for it; that might suggest the presence of strategic behaviour. It was tested whether the 5-class model would split up this class into the richer

Table 4.10: CE 1 - Choice of "opt-out"-option in % of total choices per class

Class 1	Class 2	Class 3	Class 4
0.3%	10%	28%	0.01%

households not influenced by prices and those who stated not to be willing to pay for water, but unfortunately, it did not split up the class as desired. Therefore, the four-class model was kept. The results of Table 4.9 indicate that class four should be considered with care due to the insignificant price coefficient and the lower acceptance of pricing. The latent class model detected this class and separated its choices from others, who made more reliable choices. A simple model such as CL model would not have detected those households and their choices would bias WTP estimates upward. As the price coefficient is insignificant, class four will not be analyzed further. Welfare estimations refer to the other three classes only.

4.4.3 Welfare estimations

The information from Table 4.9 can be used to get further insights into the welfare effects of the service attributes. The welfare theoretic foundations of choice experiments were already presented in Section 3.4.2. In the following section, first WTP for changes in single attribute levels - ceteris paribus - is calculated based on equation 3.43 in Section 3.4.2 and second, compensating surplus (COS) for changes in several attributes at once ("scenarios") based on equation 3.42. WTP-estimates of classes one, two and three according to Table 4.11 differ obviously to a great extent between the different classes. Regarding the WTP for a higher frequency, class one is willing to pay more than three times as much as of classes two and three. Households in class three have the lowest WTP for all attributes probably due to their very low income. Class two members have a strong and significant WTP for both consumption levels. With regard to prepaid payment all classes have a negative WTP, among them members of class one showing the strongest negative WTP.

When comparing the WTP-estimates of the base model (appendix, Table A.4) and the CL-model including interactions (appendix, Table A.6) to the latent class results (Table 4.11), the latter WTP-estimates reveal that there are substantial differences in WTP between classes, which cannot be identified in the CL model. The CL-model with interactions already detected certain variables influencing preferences significantly (such as Age, Income, Statement and Quantity) but the latent class model mirrors a clearer picture and facilitates interpretation of how these variable influence preference with regard to all attributes.

The theoretical discussion of Compensating Surplus (COS) under a probabilistic framework was already provided in detail in section 3.2[26]. Welfare changes are formulated as scenarios.

[26]see also Hanemann (1999), Bockstael et al. (1991).

Table 4.11: CE 1 - Willingness to pay estimates for an improvement in one attribute, ceteris paribus (in ZAR/m^3)

[a]

	CLASS 1			CLASS 2		
Attribute	Coefficient	P-value	CI	Coefficient	P-value	CI
FREQUENCY	2.5529 (0.9493)	0.0072	[0.6921;4.4137]	0.7962 (3.0958)	0.000	[-0.5419;1.6505]
100 l/dc	-0.0797 (0.8401)	0.9244	[-1.7264;1.567]	2.0374 (0.3139)	0.0000	[1.422;2.6527]
150 l/dc	-0.1791 (0.7093)	0.8006	[-1.5695;1.2112]	1.5864 (0.2486)	0.0000	[1.099;2.0738]
100-150 l/dc	-0.0994 (0.9622)	0.9177	[-1.9854;1.7866]	-0.4509 (0.242)	0.0624	[-0.9253;0.0233]
RELIABILITY	0.5094 (0.1847)	0.0058	[0.1473;0.8714]	0.2171 (0.0278)	0.0000	[0.1626;0.2716]
PAYMENT METHOD:						
6 months	-1.6479 (0.8733)	0.0592	[-3.3597;0.0638]	0.6283 (0.207)	0.0024	[0.2225;1.0341]
Prepaid	-5.4771 (1.9135)	0.0042	[-9.2277;-1.7264]	-0.7305 (0.2124)	0.0006	[-1.1469;-0.3141]
	CLASS 3					
Attribute	Coefficient	P-value	CI			
FREQUENCY	0.5981 (0.1723)	0.0005	[0.2604;0.9358]			
100 l/dc	-0.1292 (0.3466)	0.7093	[-0.8085;0.5501]			
150 l/dc	0.3123 (0.2657)	0.2397	[-0.2084;0.8331]			
100-150 l/dc	0.4415 (0.3246)	0.1737	[-0.1946;1.0778]			
RELIABILITY	0.048 (0.0245)	0.0502	[0;0.096]			
PAYMENT METHOD:						
6 months	0.0237 (0.3265)	0.9421	[-0.6162;0.6637]			
Prepaid	-0.7751 (0.3295)	0.0187	[-1.4211;-0.1291]			

[a] *Indicates parameters significant at the 0.1 level, ** indicates parameters significant at the 0.05 level, ***indicates parameters significant at the 0.001 level. (Standard error) and Confidence interval (CI) calculated using the Delta method.

The 'Status quo' in terms of the present water service levels that households experience differs between the classes. Therefore, the average current level of each attribute was calculated as a base-line for the welfare calculations (see Table 4.12).

Table 4.12: CE 1 - Before-change scenario V_0

	Class 1	Class 2	Class 3	Class 4
Quantity l/dc	78	82.9	83.4	81.1
Reliability (in hours)	19	15	18	14
Availability (in Days)	5	5	6	5
Payment	monthly	monthly	monthly	monthly

COS-estimates are calculated per class using the following scenarios (V^1)[27]:

Scenario 1 comprises medium service levels: 6 days per week, 18 hours with water supply.
Scenario 2 describes high service levels: 7 days per week, 24 hours with water supply.

Source: own definition

As expected, COS for the scenarios is positive as the scenarios describe improvements in water service.

Table 4.13: CE 1 - Compensating Surplus (COS) of improvements in several water services attributes (in ZAR/m^3)

	Scenario 1	Scenario 2
Class 1	2.0435*** (0.7949) [0.4854;3.6016]	7.653*** (2.7373) [2.2878;13.0182]
Class 2	1.5644** (0.7285) [0.1365;2.9924]	3.5466*** (0.4574) [2.6500; 4.4432]
Class 3	0.5981*** (0.1723) [0.2604;0.9359]	1.4845*** (0.3732) [0.7523;2.2160]

*Indicates parameters significant at the 0.1 level, ** indicates parameters significant at the 0.05 level, ***indicates parameters significant at the 0.001 level. Standard errors and Confidence interval (in brackets) calculated using the Delta-method.

The estimated COS-measures in Table 4.13 for an improvement in service attributes represent a household's WTP for the respective improvement. No absolute willingness to pay can be calculated (see Section 3.4.2), but WTP for scenarios one and two (after change) relative to the base-scenario (before change). WTP- estimates of class one are the highest - as before in Table 4.11. For a very good service as described by scenario two compared to the base-situation, households of class one would be even willing to pay ZAR 7.65 per m^3. WTP of class two and three is clearly lower. Households of class three are willing to pay about ZAR 0.60 per m^3 for

[27] In these scenarios, prices are not changed but kept constant. Thus the scenarios do not involve a trade-off between service improvement and increase in costs for water. Since the consumption levels were insignificant in classes 1 and 3, they could not be included in the scenario simulations, so the consumption is kept constant as well.

a medium service of scenario one and ZAR 1.49 per m^3 for scenario two. Relating the WTP to the proposed quantities results in the willingness to spend per month on water (see Table A.10 in the appendix). These calculations show that considering changes in several attribute levels makes the differences in WTP for improvements in water services between classes even more obvious.

4.5 Preferences and Willingness to pay for basic water services

This section deals with the analysis of the second choice experiment, that addresses the choice of households between the basic water service alternatives "Private Tap", "Public Tap" and "Private Borehole" (CE 2). The attributes as already presented in Table 4.3 can be either design- or dummy coded. According to the results of a Wald-test of linear restrictions, the attributes of CE 2 "FREQUENCY"[28], "DISTANCE"[29], "WAITING TIME"[30] and "PRICE" were design-coded with the actual numeric values. The variable "CONSUMPTION"[31] was dummy-coded with the first (lowest) level as base level to reveal non-linear effects.

Since CE 2 is labeled, attributes can be specified as either generic (coefficient is constraint to be equal for all alternatives) or alternative-specific (coefficient is allowed to vary between alternatives). To test for the need of alternative-specific attributes, a Wald-test of parameter equality or a Likelihood-Ratio test is applicable. Here, the specification of the attributes "FREQUENCY", "CONSUMPTION" and "PRICE" as generic versus alternative-specific was determined by means of a likelihood-ratio test. An alternative-specific specification of "FREQUENCY" did not improve model fit significantly implying that the influence of "FREQUENCY" does not differ between alternatives[32]. For the attributes "CONSUMPTION" and "PRICE" levels differed between the alternative "Private Tap" and the alternatives "Public Tap" and "Private Borehole". Therefore, "CONSUMPTION" and "PRICE" were set as alternative-specific for the alternative "Private Tap" to examine the consequences if both effects differ by alternative [Vermunt and Magidson, 2005]. The influence was found to significantly improve model fit using a log-likelihood test for the attribute "CONSUMPTION"[33]. For "PRICE", the test was not yet significant at the 5% level[34] and "PRICE" therefore treated as generic. The remaining attributes ("DISTANCE", "WAITING TIME", "PUMP") apply only to a single alternative, which was already considered in the experimental design, so they have alternative-specific

[28] FREQUENCY: $\chi^2 = 49.87$, p-value= 0.0000.
[29] DISTANCE (Public Tap): $\chi^2 = 16.81$, p-value=0.0000.
[30] WAITING TIME: $\chi^2 = 9.96$, p-value=0.0000.
[31] CONSUMPTION (Private Tap): $\chi^2 = 2.81$, p-value= 0.1000; CONSUMPTION (Public Tap): $\chi^2 = 3.15$, p-value=0.0800; CONSUMPTION (Private Borehole): $\chi^2 = 0$, p-value=0.9760.
[32] A Likelihood-ratio test (LR-test) is used to compare the fit of two models one of which is nested within the other by comparing the log-likelihood values. $LR = (-2 * (-1879.8909 + 1878.8186) = 2.1446 < 5.999_{2d.o.f.})$.
[33] LR=(-2*(-1879.8909+1870.5416)=18.6986).
[34] $LR = (-2 * (1879.8909 + 1878.8201) = 2.1416)$. A generic coefficient for "PRICE" implies, that the marginal utility of income is the same across the different price ranges and alternatives.

parameters. Alternative-specific constants were included into the model in order to capture differences between water sources that are not entailed in the attributes. Since dummy-coding was applied some confoundment between ASCs and base-level may be possible. Therefore, only the sign of the ASCs will be interpreted. The ASC of the alternative “Private Tap” was normalized to zero, so the remaining ASCs have to be interpreted relative to it.

4.5.1 Conditional logit model

Results of the conditional logit model are presented in the appendix in Table A.7. Certain interactions between attributes as accounted for in the experimental design (“DISTANCE (Private tap) x PRICE”, “DISTANCE (Public Tap) x PRICE”, “PUMP x PRICE”) were insignificant and, hence, excluded from the model.

The coefficients of almost all attributes significantly influenced choice probabilities. The ASCs capture the role of unobserved effects, that could not be captured with the choice attributes and thus represents the influence of the alternative per se [Louviere et al., 2000]. Only the parameter of the ASC of “Private Borehole” is significant. “Private Boreholes” are thus irrespective of their attributes preferred over the alternative “Private Tap”. The attribute “FREQUENCY” has a positive significant parameter, indicating that a higher frequency of water supply per week is preferred over all alternatives. For consumption of water, consumption levels were set higher for the alternative “Private tap” and therefore regarded separately. Consumption of medium and high levels refers to 50 l/dc respectively 65 l/dc for the alternative “Private Tap” and 25 l/dc respectively 35 l/dc for the alternatives “Public Tap” and “Private Borehole”. An increase from 35 liter to 50 l/dc is associated with a positive parameter while 65 l/dc are considered as negative (but not significantly). An increase in consumption is seen as significantly positive for both consumption levels of the alternatives “Public Tap” and “Private Borehole”.

Whether to have a yard connection or a private tap inside the house does not significantly influence choice of the alternative “Private Tap” (see “DISTANCE” (Private Tap)). A closer distance of public taps from the dwelling is regarded as positive and the parameter is significant. The attribute “WAITING TIME” of the alternative “Public Tap” is not significantly influencing choice behavior. The presence of a motor pump in the alternative “Private Borehole” is strongly disliked as revealed by the negative parameter. This is somewhat surprising since it was expected that a motor pump would decrease the pumping effort and would thus be preferred. Actually none of the sampled household used a motor pump so that households might not have understood well the benefits of motor pump or were afraid to use something unknown. Concerning prices of “Private Taps” and of “Public Taps/Private Borehole”, all are negative and significant as expected. Price sensitivity of the prices of “Private Tap” is a little bit higher, that may be related to the higher price levels of that alternative. Table A.9 in the appendix shows the WTP-estimates for a change in each of the attribute-levels. WTP for “FREQUENCY” differs between the alternatives “Private Tap” and “Public tap/Private Borehole” because of the different price coefficients that were estimated. WTP is smaller for the alternatives “Public Tap” and “Private Borehole”. This is due to the smaller price coefficient for these alternatives. WTP for medium and high consumption levels is calculated with 35 l/dc (“Private Tap”) respectively 15 l/dc (“Public Tap” and “Private Borehole”) as the reference level and hence interpreted as WTP for moving from a low consumption level to a medium and high level. The WTP estimated for “50-65 l/dc” and “25-35 l/dc” however refers to the medium level as base level and is thus interpreted as moving from a medium consumption to the high consumption level [Rolfe et al., 2000].

As in the model of the private in-house connections (CE 1), the Hausman-test indicates that the random error components of utility are not uncorrelated between choices and do not have equal variances so that estimates are not reliable (Table A.7, appendix). Heterogeneity is present in the data as interactions between socio-economic factors and attributes (“Income X PRICE”, “Quantity X CONSUMPTION (high)”, “Age X PRICE” and “Quantity X CONSUMPTION (medium)”) were added to the CL-model as presented in the appendix in Table A.8. As already chosen for analysis of CE 1, the latent class model was applied for data analysis to relax the assumptions of IIA and homogeneity.

4.5.2 Latent class model

Socio-economic variables, attitudes and perceptions enter the LC-model as covariates and allow for an explanation of the sources of heterogeneity. These variables serve to explain group membership of households in groups with homogeneous preferences. The variables presented in Table 4.14 are assumed to influence choices of households and were used as covariates to predict class membership.

Determining the optimal number of classes is an important issue in LC-models. Therefore, LC-models with up to six classes were estimated based on equation 3.35 and compared using Information Criteria. Table 4.15 gives an overview of the model statistics.

The BIC information criterion suggests the use of a 2-class model while the values of the AIC and AIC3 criterion continue declining. Both criteria are still declining for models with more than 2 classes but to a much lower extent than before. The 2-class model - as suggested by BIC - is readily interpretable, provides a straightforward explanation of heterogeneity among classes and was therefore chosen for further analysis. Estimation results of the 2-class model are presented in Tables 4.16 and 4.17. Class one consists of about 60% of the households and class two of the remaining 40%. Each latent class corresponds to a population group that differs with respect to the importance given to the attributes of the alternatives when expressing that class’ preferences [Vermunt and Magidson, 2005].

Table 4.14: CE 2 - Covariates

Variable	Definition
Socio-economic variables:	
Household size	Number of members of household
Age	age of respondents
Gender	1=female
Income	total income of household including grants and remittances
Water related:	
Water source	Main water source used by household
Quantity	Quantity of water in m^3 used per household per month
Service	Index of current water service
Get all	1= household gets sufficient water
Buy	1=household needs to buy additional water
Increase	1=quantity of water needed is expected to increase during next year
Irrigation	1=water used for irrigation of crops
Perceptions:	
Satisfaction	Satisfaction with current water service
Acceptance	Stated acceptance of pricing of water, measures a household's attitude towards pricing of water
Importance	Most important service attribute

The p-values of Wald-tests of parameter equality ("Wald(=)") in Table 4.16 indicate that there is preference heterogeneity with respect to the ASCs, and the other attributes "CONSUMPTION" ("Private Tap"), "DISTANCE" ("Private Tap") and "PRICE". Class one is characterized by a significantly negative ASC for the opt-out ("NONE") - alternative. Members of class one strongly prefer the "Private tap"-option over the status-quo situation. The ASC of the alternative "Public Tap" is significantly negative, too. This shows, that members of class 1 prefer "Private Taps" in general while they dislike "Public Taps". "Private Boreholes" are associated with a positive constant and thus provide positive utility. With respect to "FREQUENCY" members of class 1 prefer a higher frequency, but preferences among both classes are not significantly different according to the Wald(=)-test. Class 1 members place a high value on consumption of 50 l/dc in the alternative "Private Tap". An increase in consumption up to 65 l/dc is associated with a negative but insignificant coefficient. The coefficients for a higher consumption of the alternatives "Public Tap/Private Borehole" are both strongly significant. So members of this class are highly concerned about receiving enough water for their needs, and appreciated an increase up to 50 l/dc but not 65 l/dc. Regarding "DISTANCE", members of class 1 prefer having a private tap inside the house over a yard connection. A higher distance of a public tap provides - as expected - negative utility. Price sensitivity of households in class one lies around -0.4. Members of class two associate a strong positive utility with "Private

Table 4.15: CE 2 - Model statistics

model	LL	BIC(LL)	AIC(LL)	AIC3(LL)	CE[a]	$R^2(0)$	R^2
1-Class	-1879.8909	3833.8003	3785.7818	3798.7818	0.0000	0.2056	0.1164
2-Class	-1733.9731	3735.5516	3561.9462	3608.9462	0.0543	0.3216	0.2454
3-Class	-1657.8353	3776.863	3477.6707	3558.6707	0.0539	0.3641	0.2928
4-Class	-1587.0277	3828.8345	3404.0553	3519.0553	0.0356	0.3772	0.3072
5-Class	-1519.9975	3888.361	3337.9949	3486.9949	0.0288	0.4026	0.3355
6-Class	-1450.531	3943.0149	3267.062	3450.062	0.0279	0.4373	0.3741

[a]CE=Classification Error

Borehole", all other constants are not significant. Regarding "DISTANCE" of the alternative "Private Tap" those households prefer yard connections over taps inside their houses. Higher consumption for alternative "Private Tap" is significantly negative. The coefficient for 50 l/dc is highly negative, while the coefficient for 65 l/dc is not as high. This is surprising since one would expect then the coefficient of 65 l/dc to decrease utility even more than the one of 50 l/dc. Consumption levels of 25 l/dc and 35 l/dc in the alternatives "Public Tap and Private Borehole" provide positive utility. The coefficient for a quantity of 35 l/dc is lower than the one for 25 l/dc reflecting that the marginal utility of additional water decreases. Price sensitivity is found to be much higher for members of class two, with a price coefficient of -0.99. A motor pump is considered as significantly negative and a decrease in waiting time increases utility for both classes.

With regard to covariates, class two differs significantly from class one with respect to gender, household income, quantity and importance (see Table 4.17). Significantly more male respondents belong to class two. Maybe due to the fact that mostly woman are responsible for water collection in South Africa [Sangodoyin, 1993, e.g.], men value the improvements in water services as less important, have a lower WTP and hence fall into class two. The same result was already found in CE 1. In CE 1, significantly less females were captured in class 3, which was the class with the lowest WTP-estimates.

Table 4.18 gives an overview of class-specific means for numeric covariates and the probability of being in covariate level given that a household belongs to latent class s for all other covariates [Vermunt and Magidson, 2005]. With regard to income class two has less income with an average income of ZAR 1380 per month compared to ZAR 3880 per month in class one. So class two includes most of the very poor households. Furthermore, Average consumption per month differs between both classes. Households of class two use significantly less water per month, on average 2173 liter per household per month, which refers to about 16 liter per person per day. While households of class two do not differ with regard to the water sources they use, they differ with regard to the frequency of water supply (Covariate: Service (Frequency) in Table 4.17). Service quality in terms of frequency of supply is significantly lower (at the 10% level). This

Table 4.16: CE 2 - Estimation results for the 2-class model - Model for choices[a]

	CLASS 1	CLASS 2	Wald(=)	p-value
$R^2 of classes$	0.1441	0.183		
$R^2(0) of classes$	0.2467	0.3932		
Constants:				
Private Tap	0	0	37.9005	0.0000
Public Tap	-1.4904*** (0.3817)	0.7275 (0.8117)		
Private Borehole	0.8871** (0.3743)	3.8151*** (0.83)		
None (‘Opt-out’-option)	-2.1065*** (0.6483)	-0.9339 (1.0768)		
DISTANCE (Private Tap)				
onsite/yard connection)	0	0	10.3258	0.0013
inside house	0.3025** (0.1508)	-1.6676*** (0.5602)		
CONSUMPTION (Private Tap)				
35 l/dc	0	0	7.4224	0.0240
50 l/dc	0.6787*** (0.1766)	-3.5589** (1.7266)		
65 l/dc	-0.0357 (0.1774)	-0.6855* (0.4271)		
FREQUENCY (Private Tap/Public Tap)	0.4461*** (0.0368)	0.5442*** (0.0634)	1.5732	0.2100
DISTANCE (Public Tap)	-0.0031*** (0.0005)	-0.0037*** (0.0005)	0.5979	0.4400
CONSUMPTION(Public Tap/Pr. Borehole)				
15 l/dc	0	0	1.2634	0.5300
25 l/dc	0.6165*** (0.1531)	0.4239** (0.1832)		
35 l/dc	0.5983*** (0.1509)	0.3346** (0.1745)		
PRICE	-0.4257 (0.145)	-0.9926*** (0.2031)	4.4404	0.0350
WAITING TIME (Private Tap)	0.0417 (0.0348)	0.0727* (0.039)	0.3231	0.5700
PUMP (Private Borehole)				
Hand pump	0	0	0.7033	0.4000
Motor pump	-0.5111*** (0.157)	-0.7236*** (0.1823)		

[a]*Indicates parameters significant at the 0.1 level, ** indicates parameters significant at the 0.05 level, ***indicates parameters significant at the 0.001 level.

Table 4.17: CE 2 - Estimation result for the 2-class model - Model for Classes[a]

	Class 1 (st.err.)	Class 2 (st.err.)	Wald(=)	p-value
Intercept	0	7.4519 (7.4382)	1.0037	0.32
Household size	0	0.0811 (0.1021)	0.6303	0.43
Age	0	0.0121 (0.01)	1.4807	0.22
Gender (1=female)	0	-1.2146** (0.4473)	7.3745	0.0066
Income	0	-0.0007*** (0.0002)	18.807	1.40E-05
Main water source				
Private Tap	0		0.8222	0.84
Public Tap	0	-4.1356 (7.3099)		
Private borehole	0	-4.4203 (7.314)		
Other	0	-4.1567 (7.3136)		
Quantity	0	-0.0003** (0.0002)	4.7047	0.03
Service (Frequency)	0	-0.2271* (0.1411)	2.5919	0.11
Get all (1=yes)	0	-0.4532 (0.6526)	0.4823	0.49
Buy (1=yes)	0	-0.0005 (0.0009)	0.4044	0.52
Increase (1=yes)	0	-0.2427 (0.4746)	0.2614	0.61
Irrigation (1=yes)	0	-0.1182 (0.4768)	0.0615	0.8
Satisfaction	0	0.1869 (0.2098)	0.7936	0.37
Acceptance	0	-0.0017 (0.2261)	0.0001	0.99
Importance	0		11.5126	0.042
0ther	0	1.2385 (1.7943)		
Distance	0	-1.8936*** (0.5965)		
Consumption	0	-1.6147** (0.8228)		
Frequency	0	-0.5276 (0.6893)		
Price	0	-0.5638 (0.4994)		

[a]*Indicates parameters significant at the 0.1 level, ** indicates parameters significant at the 0.05 level, ***indicates parameters significant at the 0.001 level. Standard error in parenthesis.

Table 4.18: CE 2 - Percentage at each covariate level, by class (columns, by covariate, sum to 100%)

Covariates	CLASS 1	CLASS 2
Householdsize (Mean)	4.9	4.4
age(Mean)	37	43
Gender:		
male	17.72%	30.19%
female	81.60%	69.15%
Income (Mean) in ZAR/month	3883	1379
Main water source:		
Private Tap	0.58%	0.81%
Public Tap	21.63%	27.93%
Private borehole	56.26%	48.07%
Other	21.54%	23.19%
Quantity (Mean) in liter/month and household	2859	2173
Service (Frequency) (Mean)	2.9426	2.816
Getall:		
No	13.17%	15.51%
Yes	65.50%	68.31%
Buy:		
No	81.64%	79.63%
Yes	18.36%	20.37%
Increase:		
No	55.25%	57.61%
Yes	43.59%	39.97%
Irrigation:		
No	67.35%	78.68%
Yes	32.65%	21.32%
Satisfaction (Mean)	3.2	3.2
Acceptance (Mean)	1.71	1.34
Importance:		
Other	0.86%	2.04%
Distance	25.77%	9.92%
Consumption	6.89%	4.09%
Frequency	9.86%	10.45%
Price	23.11%	25.02%

finding is similar to the finding in CE 1, class two, where households with significant better service levels have a significantly higher consumption.

The finding that households of class two disliked taps inside the house compared to yard connections (“DISTANCE” in “Private Tap”) can also be explained in terms of income differences. Low-income households are more often found to live in smaller, even informal houses and traditional huts [Statistics-South-Africa, 2007]. Most of their water-using activities such as washing and cleaning dishes take place outside of the houses anyway. So they may prefer a tap outside compared to inside the house.

Class two members ranked significantly less often “DISTANCE” and “QUANTITY” as most important compared to members of class two. Accordingly, members of class two were not very concerned about choosing a water source close to the house or high consumption quantities. This finding is plausible when comparing it to the actual parameter coefficients of “DISTANCE (Private Tap)”, which is negative, and “QUANTITY”, which is insignificant, of Table 4.16.

When looking at the actual alternatives which were chosen, preferences between classes vary very much. Class 1 members tend to choose the more expensive “Private Tap” alternative in 45% of the choices, while the poor members of class 2 did so only in 7% of the choices. Reasons for this may be the presence of higher price and consumption levels which were associated with negative coefficients. Most of the members of class 2 (58%) chose “Private Boreholes”, while about 30% of them chose the option “Public Tap”. “Public Taps” were least favored among alternatives. The choice of the “None”-alternative is equally distributed among classes with about 4% of the choices.

4.5.3 Direct elasticities and marginal effects

In order to directly interpret parameter estimates of the attributes, they can be transferred into either elasticities or marginal effects [Louviere et al., 2000]. A direct elasticity is defined as the percentage change in the probability of choosing an alternative caused by a 1% change in an attribute of the same alternative. A marginal effect reflects the unit change in probability of choosing an alternative caused by a unit change in an attribute of that alternative. Marginal effects are calculated for the dummy coded attribute “CONSUMPTION” since elasticities cannot be meaningfully interpreted for categorically coded variables [Hensher et al., 2005a, Page 393]. For policy makers the calculation of elasticities and marginal effects is helpful to see how the probabilities of choosing a water source would change according to improvements in certain attributes[35]. Table 4.19 presents point- and arc-elasticities[36] and marginal effects of the attribute.

The elasticities and marginal effects unfold differences between alternatives. In general, class one is rather price inelastic: Price elasticity is highest for alternative “Private Tap” and lower for both alternatives “Public Tap” and “Private Borehole”. Choice of the alternative “Private Tap” of members of class 2 is elastic with a price (point) elasticity of -1.24. The marginal effect is quite low since the probability of choosing that alternative is already very low in this

[35] The cross-price elasticities are not presented here. Due to the IIA-assumption within classes, cross-price elasticities would be equal with respect to all alternatives.

[36] Point-elasticities can be estimated as before change or after change elasticities. Arc-elasticities represent the average of the before and after change. Hensher et al. (2005) recommend the use of arc-elasticities when the there are severe differences between before and after change elasticities [Hensher et al., 2005a, Page 392].

Table 4.19: CE 2 - Elasticities and marginal effects of selected attributes

	Class 1			Class 2		
	Point elasticity	Arc elasticity	Marginal effect	Point elasticity	Arc elasticity	Marginal effect
Increase in Price:						
Private Tap	-0.2063	-0.1951	-0.0917	-1.2382	-1.1189	-0.0023
Public Tap	-0.1594	-0.1038	-0.0452	-0.1478	-0.2071	-0.2119
Private Borehole	-0.14	-0.0824	-0.0682	-0.4491	-0.4877	-0.1680
Increase in Frequency:						
Private Tap	0.72	0.6729	0.1007	1.7207	2.099	0.0101
Public Tap	1.2244	1.0462	0.0703	1.0035	1.109	0.1415
Increase in Consumption:						
	Marginal effect: 35-50	Marginal effect: 35-65	Marginal effect: 50-65	Marginal effect: 35-50	Marginal effect: 35-65	Marginal effect: 50-65
Private Tap	0.0458	-0.1422	-0.1972	-0.4143	-0.2025	-0.278
Public Tap	0.08	0.0755	0.009	0.0758	0.0338	-0.0208
Private Borehole	0.1212	0.1213	0.0016	0.0819	0.0595	-0.1411

class. Price elasticity however for “Public Tap” and “Private Borehole” is considerably smaller and rather inelastic. Marginal effects are much more severe due to the higher probability of choosing both alternatives.

The attribute “FREQUENCY” is elastic for the alternative “Public Tap” but inelastic for the alternative “Private Tap”. Due to the fact, that more people of class one opt for “Private Tap”, the marginal effect is quite high: An increase in frequency by one day increases the probability of choosing the alternative “Private Tap” by 10%. For class two price elasticity is elastic for both alternatives, especially for alternative “Private Tap”. Since the attribute “CONSUMPTION” is coded as a dummy, elasticities cannot be meaningfully interpreted. Therefore, only marginal effects are calculated. For the alternative “Private Tap” an increase in “CONSUMPTION” decreases utility and accordingly, elasticities are negative.

4.5.4 Welfare estimations

Based on the coefficients already presented in Table 4.16, WTP-estimates for changes in single attributes and for changes in several attributes (”scenarios“) can be calculated. The WTP-estimates for changes in single attributes are presented in Table 4.20.

Class 1 members have a higher WTP for an increase in “FREQUENCY”. With regard to “CONSUMPTION”, members of class 1 have a significantly positive WTP for receiving 50

Table 4.20: CE 2 - Willingness to pay for changes of a single attribute (in ZAR/m^3)

	CLASS 1			CLASS 2		
Attribute	WTP	p-Value	CI	WTP	p-Value	CI
DISTANCE (Private Tap)	0.6089 (0.3551)	0.0864	[-0.0871;1.305]	-1.68 (0.6847)	0.0142	[-3.0221;-0.3378]
50 l/dc (Private Tap)	1.4444 (0.5768)	0.0123	[0.3138;2.5751]	-3.5854 (1.8512)	0.0528	[-7.2138;0.043]
65 l/dc (Private Tap)	-0.058 (0.3829)	0.8796	[-0.8085;0.6924]	-0.6905 (0.4671)	0.1393	[-1.6062;0.225]
50-65 l/dc (Private Tap)	-1.5024 (0.6036)	0.0128	[-2.6856;-0.3193]	2.8948 (1.8168)	0.1111	[-0.6662;6.4558]
FREQUENCY (Private Tap/Public Tap)	0.9745 (0.2952)	0.001	[0.3958;1.5531]	0.5482 (0.1098)	0	[0.3329;0.7635]
DISTANCE (Public Tap/Pr. Borehole)	-0.0068 (0.002)	0.001	[-0.0109;-0.0027]	-0.0037 (0.0007)	0	[-0.0052;-0.0022]
25 l/dc (Public Tap/Pr. Borehole)	1.3646 (0.5155)	0.0081	[0.3541;2.3752]	0.427 (0.1978)	0.0309	[0.0393;0.8147]
35 l/dc (Public Tap/Pr. Borehole)	1.3022 (0.483)	0.007	[0.3555;2.2489]	0.3371 (0.1865)	0.0708	[-0.0285;0.7028]
25-35 l/dc (Public Tap/Pr. Borehole)	-0.0624 (0.3232)	0.8468	[-0.696;0.5711]	-0.0898 (0.1941)	0.6433	[-0.4703;0.2905]
WAITING TIME (Public Tap)	0.0953 (0.0804)	0.2359	[-0.0623;0.2531]	0.0732 (0.0421)	0.0822	[-0.0093;0.1558]
PUMP (Private Borehole)	-1.1669 (0.4801)	0.0151	[-2.1079;-0.2258]	-0.729 (0.2262)	0.0013	[-1.1724;-0.2855]

CI=Confidence Intervals, calculated using the Delta-method l/dc while members of class 2 are not willing to pay for it, but would need compensation (but the estimate of 65 l/dc is not significant). When moving from a consumption of 50 to 65 l/dc, also class 1 members are no longer willing to pay for that increase in consumption. Having 50 l/dc and moving then to 65 l/dc accordingly reveals a negative WTP, which is found significant. Both classes have a positive WTP for an increase in consumption for the consumption levels 25 l/dc and 35 l/dc with regard to the alternatives 'Public Tap' and 'Private Borehole'.

The WTP of class one is much higher than of class two. An increase in consumption when moving from 25 l/dc to 35 l/dc is not significant for both classes. A decrease in "WAITING TIME" is regarded as positive in both classes, but WTP is quite low for it. Having a motor pump decreases utility and accordingly WTP is negative. Especially members of class one would need quite high compensation. WTP is quite different between members of both classes and households in class one have in general a higher WTP due to their higher income.

In addition to WTP for single attributes, it is possible to calculate Compensating Surplus (COS) in order to evaluate changes in several attributes and levels as scenarios. Estimated changes in COS are calculated per class using the scenarios as after-change scenarios and the before-change scenarios as presented in Table 4.21.

Table 4.21: CE 2 - Before-change scenario

	CLASS 1	CLASS 2
Distance (Private Tap)	on-site	on-site
Distance* in meters (Public Tap)	180	280
Quantity*	2880	2126
Frequency	2.8	2.9
Waiting time* in min	17	13
Pump	Hand pump	hand pump

*t-test significant at $\alpha \leq 0.05$

Scenario 1 comprises medium service levels: 5 days per week, 2-5 min walking (less than 100 meters), 5 min waiting time and consumption levels of 50 l/dc for alternative "Private Tap" and 25 l/dc for alternatives "Public Tap" and "Private Borehole".
Scenario 2 describes high service levels: 7 days per week, 1 min walking (close to dwelling), no waiting time and consumption levels of 50 l/dc for alternative "Private Tap" and 35 l/dc for alternatives "Public Tap" and "Private Borehole".

Source: own definition

Interpreting COS as WTP as in Section 4.13, households in class 1 have a higher WTP for improvements in water services (see Table 4.22). Differences in WTP between the two classes are even more obvious when considering several changes in attributes. Relating the WTP to the proposed quantities results in the willingness to spend per month on water (see Table A.10 in the appendix).

Table 4.22: CE 2 - Compensating Surplus (COS) for improvements in several water services attributes (in ZAR/m^3)

	Scenario 1		Scenario 2	
Class 1	4.0676*** (-0.8732)	[2.3561;5.7791]	7.6555*** (-2.3434)	[3.0622;12.2488]
Class 2	2.0287*** (-0.464)	[1.1192;2.9381]	4.1983***(-1.2972)	[1.6556;6.7409]

*Indicates parameters significant at the 0.1 level, ** indicates parameters significant at the 0.05 level, ***indicates parameters significant at the 0.001 level. Standard errors and Confidence interval (in brackets) calculated using the Delta-method.

4.6 Willingness to pay and demand curves

Conducting a choice experiment leads to WTP-estimates for changes in single attributes or selected scenarios. In the present study, in accordance to the NWA (1998), a price per m^3 was included in the choice experiment resulting in WTP per m^3. The total amount of money to be paid for water is therefore directly linked to how much water a household consumes per month. As water is liquid, any available quantity can be consumed, but due to the nature of a choice experiment based on attributes and respective levels, only fixed quantities can be included. In order to avoid overstraining respondents, to keep a manageable sample size and to have meaningful differences between the levels, three consumption-levels were included. Because the amount of water that is consumed is linked to the water source, a higher range of quantities was allowed for in the 'Private Tap' alternative of CE 2 and generally, higher quantities were included in CE 1.[37] By presenting quantity levels, it was possible to allow households making trade-offs between higher quantities, better service levels and higher prices of water. Though significant in the CL-model, the LC-model detects, that there is only one class in CE 1 that has a significantly positive WTP for higher quantities, for the others this is not significant. This may either reflect that households are satisfied with their current quantity and do not need more or the difficulty to capture consumption in a CE. It is already a rather complex task for a household to imagine different water sources and service levels but even more challenging to evaluate different consumption levels in the newly proposed alternatives. As the effect of an attribute on utility of an alternative can be either linear or non-linear, a Wald-test was applied to detect this influence (see Sections 4.4, 4.5). To explain the difference between linear and non-linear influences in more detail, the following example is given. For the attribute "FREQUENCY", the Wald-test suggests the presence of linear effects, indicating a linear relationship of WTP with regard to the attribute levels. The WTP for an additional day is ZAR 0.59 per m^3 in the range of 5-7 days for group 3 of CE 1 (this effect is not influenced by the kind of water source, as tested by a second Wald-test). For two additional days, households

[37] Consumption levels were taken from the literature and then discussed and finalized in focus group discussions with households.

of that group are willing to pay ZAR 1.18 per m^3. For the given range, a higher frequency always causes a linear increase in WTP.[38] With regard to the attribute "CONSUMPTION", Wald-tests showed, that there is a non-linear influence of "CONSUMPTION" on households' preferences in both CEs. Separate coefficients were estimated for the consumption levels to account for that finding. Considering the significant estimates, it can be seen that WTP for the highest consumption level is less than the WTP for the medium consumption level. In CE 1 class 2 has a WTP for additional 50 l/dc (moving from 50 l/dc to 100 l/dc) of ZAR 2.03 per m^3 while the WTP for additional 100 l/dc (moving from 50 l/dc to 150 l/dc) is ZAR 1.58 per m^3. Per month, a household of class 2 would need to pay ZAR 6.09 per m^3 per person per month for 3 m^3 (50 l/dc) and ZAR 7.11 per m^3 per person per month for 4.5 m^3 (65 l/dc). This makes sense given that households have a limited amount of income they can spend on water services. These estimates indicate the diminishing marginal utility of water. The additional utility created by a unit decreases with an increasing number of units consumed (Law of diminishing marginal utility). Actually, it has to be kept in mind, that the CE does not reflect the WTP for the first 15 l/dc. A CE can assess the values of changes in attributes - meaning relative changes compared to a reference situation. As here WTP is attributed to an improvement, the reference of 15 l/dc cannot be valued. WTP for the first 15 liters can thus be higher than the one for the additional 10 liters up to 25 l/dc - though in these calculations of monthly payments, WTP is assumed to be constant up to 25 l/dc.

The same effect was present in CE 2. Households of class 1 have a slight decrease in WTP per cubic meter for the high consumption levels given the water sources 'Public Tap' and 'Private Borehole'. The WTP for an increase by 10 l/dc is ZAR 1.36 per m^3 while the WTP for an increase of 20 l/dc is ZAR 1.03 per m^3. The budget allocated to water per month would be ZAR 1.02 per person per month for 0.75 m^3 (25 l/dc) and ZAR 1.08 per person per month for 1.05 m^3 (35 l/dc). Households of class 2 are willing to pay ZAR 0.43 per m^3 for additional 10 l/dc and ZAR 0.35 per m^3 for additional 20 l/dc. This results in a monthly WTP per person of ZAR 0.32 per person per month for 25 l/dc and of ZAR 0.37 per month for 35 l/dc.[39]

When calculating marginal WTP for an increase from the medium consumption level to a high consumption level, it becomes negative, reflecting a negative impact on utility and the probability of choosing an option. The satiation point lies somewhere between 25 and 35 l/dc in CE 2, respectively between 100 and 150 l/dc in class 2 of CE 1. The high consumption levels create disutility because they increase monthly payment for water. They may be even associated with problems due to missing storage capacity or carrying respectively pumping efforts. From the CEs two points on the 'Willingness to pay' - curve [Freeman III, 2003, page

[38] WTP is considered 'ceteris paribus', that means the other service attributes still remain constant so no improvement with regard to frequency of water source or anything else. A simultaneous improvement of several service attributes as captured in the scenarios would therefore result in a higher WTP.

[39] The estimates of 65 l/dc for alternative 'Private Tap' in class 1 is not significant and also in class 2, estimates for both consumption levels are not very reliable as only 8% of the households choose this option.

95] or ‘Shadow’ demand curve [Whynes et al., 2005] - namely the two marginal WTP estimates - can be identified.

In contrast to the demand curve, the amount available is limited to the respondent. The household cannot consume more than what is indicated in the CE. A demand curve assumes that any quantity the household would like to consume and pay for can be realized. It depicts marginal WTP for an additional unit while the CE identifies WTP estimates for 10 additional units (CE 2) or 50 additional units (CE 1). More levels and smaller steps of the attribute “CONSUMPTION” in a CE may lead to many insignificant estimates as the difference is too small in order to be evaluated meaningfully by respondents. Results of several studies showed that as the range of attribute levels narrows, the propensity for respondents to ignore attributes when making their choice increases, a phenomenon that is called ‘Attribute non-attendance’. This ‘attribute non-attendance’ can lead to biased parameter estimates and incorrect estimates of WTP [Hensher et al., 2005b, Carlsson and Martinsson, 2008].

4.7 Comparison of results between Choice Experiment 1 and Choice Experiment 2

Both CEs - as dealing with water service levels - were built in a similar manner, but CE 1 considered a greater scope of water sources and attributes. In both CEs, all attributes and most of their levels were found to significantly influence choice behavior of households. Attribute coefficients of the same attributes are not directly comparable since levels and reference categories vary, but the direction of influence coincides. The conclusion that a higher “FREQUENCY” increases utility and thus choice probability while higher prices decrease choice probability can be drawn from both CEs validating the findings. Comparing the WTP-estimates of the two CEs shows that even the poor and low-income households of CE 2 have a positive WTP for service improvements: Considering the common attribute “FREQUENCY” households of CE 2 would be willing to pay ZAR 0.97 per m^3 and ZAR 0.55 per m^3 for an additional day of supply, which is quite comparable to the amount households of CE 1 are willing to pay (Classes 2 and 3).[40]

With regard to the attribute “CONSUMPTION”, similar findings exist: some households preferred higher consumption quantities (class 1 of CE 2 for alternative “Private tap”, class 2 and 4 of CE 1) while others did not (class 2 of CE 2 for alternative “Private Tap”). The attribute “CONSUMPTION” was supposed to capture consumption of water given varying service lev-

[40] What has to be kept in mind when comparing both CEs is that the quantities considered are much lower in CE 2 than in CE 1, because the presented quantities in CE 2 lie between 2.1 m^3 and 4.9 m^3 per month for public tap and borehole and between 4.9 m^3 and 9.2 m^3 per month for private taps. Monthly water bills would therefore be much lower for CE 2. Of course, adjustments in quantities given better water services are likely. This issue was tried to incorporate by presenting the higher service levels, but given the quantitative nature of water and the limited cognitive ability of respondents to imagine how they would change their water consumption under new service levels, it is difficult to capture.

els. As new and improved water services are presented in the alternatives, the limited cognitive ability of respondents to imagine how they would change their water consumption under new service levels has to be considered. As coefficients of the different water service levels vary from positive to negative and zero depending on class, may reflect heterogeneity of preferences but also difficulties with regard to this attribute when making choices. Price as an attribute in the CEs was defined as price per cubic meter in CE 1 and price per 25 liter canister in CE 2. Using the given quantities and prices as an indicator of water bills and some classes turned out to dislike higher consumption levels as they lead to higher water bills.

In general, preference heterogeneity among households of both CEs was detected. The CEs discovered that income acts as a major factor influencing class membership and thus preference heterogeneity among households. But also other factors such as gender, current service levels and attitudes and perceptions towards water services and pricing play a role for preferences and WTP.

To sum up, both CEs have differences with regard to their attributes and thus coefficients are not directly comparable, but the general findings such as significance of influence of attributes on choice, WTP for better services even of the low-income classes, heterogeneity with regard to preferences and the strong influence of income on preferences and WTP were the same in both CEs validating them.

In both CEs, a single price per cubic meter of water was presented in each option. The survey site 'Lebowakgomo' which represents the only urban area is located in the municipality of Lepelle Nkumpi, one of the few municipalities which have not yet implemented increasing block tariffs. Such a tariff scheme however would lead to a much more complex calculation of water bills. Water quantities were given as fixed in the CEs, though in reality it is very difficult to control water use in a household - usually consisting of several household members. Households in both CEs had a limited knowledge on their water use (in liters or in cubic meters). Therefore, with regard to price and quantity, the CEs reflect a situation of perfect information on both of them, which may not be found to that extent in reality and even less in municipalities with increasing block tariffs. In a typical household setting, the quantity of water consumed is difficult to control due to the independent uses of water by all household members and the missing metering of water at taps (especially when several taps inside the house exist - as it is often the case for households in CE 1). A better control of water quantities however is possible for households of CE 2 with basic water services and limited availability of water per week - as water is usually fetched in 25-liter canisters. The Choice experiment better reflects the situation with regard to quantity of households in CE 2 than of households in CE 1.

4.8 Comparison of results with other studies

As the results of choice experiments are context-specific, comparability to other studies that vary with regard to design, attributes and attribute levels is limited. But some general comparisons between the present study and other studies using CEs to value domestic water services can be drawn. Regarding the design of the choice experiment, most studies used unlabeled designs, presenting water source as an attribute - only the study by Yang et al. (2006) applied a labeled approach but without alternative-specific attributes. Including alternative-specific attributes and levels that are associated with single water sources such as "Distance" and "Waiting time" especially with regard to price allows a more flexible and realistic design of choice options. That makes options more credible. This feature of the present study is thus an improvement of the prevailing studies. With regard to the attributes, most studies in similar settings included "Water Source", "Water quantity" and "Water quality" [Hope and Garrod, 2004, Hope, 2006, Yang et al., 2006, Kanyoka et al., 2008], some "Productive uses" such as kitchen gardens [Hope and Garrod, 2004, Hope, 2006, Kanyoka et al., 2008], Kanyoka et al. (2008) included "Frequency of supply" and Yang et al. (2006) "Hours of supply". These attributes influenced choice behavior of respondents significantly. The present study included the attributes "Frequency of supply", "Water quantity", "Hours of supply" as well as additional alternative-specific attributes and attributes referring to payment methods, which were not yet used so far. With regard to "Water quantity" the use of 25 liter as measurement unit is common in the South African studies. However, the attributes "Water quality" and "Productive uses" - though very appealing in the South African context - were not included in the choice experiment for the following reasons. Describing water quality assessments in terms of "purified" or "improved" water quality is rather inconcrete and implies that the quality of the water provided is not adequate. Households indicated neither in the household survey nor in the focus group discussions to have problems with regard to water quality when it is provided from a tap. What may cause quality problems is that households have to store water in open tanks and canisters as fresh water from the tap cannot be accessed every day. In the study area, problems of water quality are closely related to the attribute "Frequency" of water supply rather than to the quality of the water itself and are therefore indirectly captured. The attribute "Productive uses" consists of the levels "Current" and "More" in the study of Kanyoka et al. (2008) and as "Kitchen gardens" "Yes" or "No" in the studies of Hope (2006) and Hope and Garrod (2004). But actually, whether households involve themselves in kitchen gardens is a rather complex issue as it depends on many factors - not only water. The household survey confirmed that the lack of water is indeed the major reason (33%) that hinders households from irrigation (see Table 4.13), but it also identified factors related to land, labor or knowledge on agricultural cultivation that influence the decision to cultivate/irrigate crops. Actually, the water constraint is already captured in the attribute "Water quantity" as a higher water quantity allows to allocate some water to crops.

In this study, what actually matters for the valuation of water services is whether households engaged in kitchen gardens or irrigated vegetable production have different preferences and WTP for water services. Instead of including irrigation activities as an attribute of CE 2, it was added as a covariate ("Irrigation") to the LC-model. But this covariate was not found to be significantly influencing class membership and thus did not affect preferences and WTP.

As attribute levels as well as the definitions of payment vehicles (price defined as a percentage change of current bill, monthly payment and price per m^3) differ, comparing the results of the CEs conducted so far in terms of WTP for an improvement in certain attributes to this study is not possible.

The only study estimating classes of households with similar preferences was done by Hope (2006). The author identifies two classes; one class (88% of the households) that is significantly influenced by all service attributes but productive uses of water and a second class (12% of the sampled households) that values only the attribute referring to productive uses. Socio-economic variables or other factors - as in the study at hand - were not included in the construction of the classes. Therefore, identifying and weighting the influence of the different covariates as included in the latent class model of this study is an improvement. Findings with regard to the influence of household income on price sensitivity can be confirmed by the studies of Kanyoka et al. (2008) (using sub-samples of poor and non-poor households) for South Africa and Yang et al. (2006) for Sri Lanka.

4.9 Reflections on equity issues

The analysis of household-level data in this chapter strongly rejected the assumed homogeneity of households with regard to preferences for domestic water services. So households have different preferences for water service attributes. For some households it is more important to have better water services in terms of water source or in terms of days per week. In addition, price sensitivity differed between households. Some were very price sensitive (class three of CE 1 and class two of CE 2), while others did not seem to be influenced by price at all (class four of CE 1). Accordingly, some households were willing to pay higher amounts for certain attributes than others. The latent class model allowed for an explanation of the different preferences by taking into account socio-economic characteristics, water-related variables as well as attitudes and perceptions. The model classified households into groups with similar preferences and similar characteristics.

These classes were found to differ significantly with regard to the above mentioned characteristics. Both CEs identified one class including poor and low-income households (class 3 of CE 1 and class 2 of CE 2). The LC-model of CE 1 identified significant income differences in all four classes. Accordingly, willingness to pay was found to be lower in low-income groups and to be increasing with increasing income. This finding reflects the close connection between willingness to pay and ability to pay in the Middle Olifants. Low-income households cannot afford to pay much for water due to their scarce income. In the class with predominantly low-income households, the highest share of respondents that chose the "opt-out" option to keep the current -free- water services was found. In these classes the highest share of households with less than ZAR 1000 per month exists, in class 2 of CE 2 even 50% fall within that category. So preferences and willingness to pay differ strongly with regard to income and, accordingly, price sensitivity varies.

4.10 Summary and conclusions

In this chapter, household-level data from households in the Middle Olifants was analyzed to describe the current situation of households with regard to domestic water services, their preferences and willingness to pay for an improvement in service characteristics. A household survey in four villages and one town was conducted. The questionnaire consisted of questions on socio-economic characteristics, current water services and water use habits, satisfaction with current water service, a ranking of water service characteristics and a choice experiment. Due to the nature of the choice experiment and the differences in water service levels, two separate choice experiments were developed to ensure that they mirror realistically situations based on a common 'Status-quo'-situation of households with regard to water services. The total sample size of 475 households was therefore split up into those households having private in-house connections and yard connections in urban areas (CE 1) and all other households (CE 2). For both CEs, relevant attributes and attribute level were determined by literature review, expert interviews, focus group discussions and pilot studies. Experimental designs including selected two-way interactions were developed to maximize statistical efficiency and minimize correlations among attributes. For CE 1 an unlabeled design was used because for those household only the option of private taps inside the house at varying service levels was a credible option. As attributes of water services, frequency (in days of supply per week), reliability (in hours of supply per week), Consumption (in liter per day per capita), price and payment method were included. For the second experiment, since households are confronted with a variety of different water sources in the Middle Olifants, the choice experiment allowed choices among private taps (in-house and on-site), public taps and private boreholes. Here, relevant attributes such as frequency, distance (in minutes), consumption (in 25 liters per day per capita), waiting time (in minutes) and type of pump were considered. To avoid hypothetical bias in the CEs, a script was added that reminded households on the option to "opt-out" and not to choose any of the presented alternatives and mentioned a fine for non-payment to reflect true choices and avoid strategical behavior.

Socio-economic characteristics of respondents differed between households in the two CEs especially with regard to income. Average income was much lower for households of CE2. With regard to the current water services situation, service levels differ significantly among water sources. Concerning quantity, average consumption differed significantly with regard to water source and average consumption was less than 20 l/dc when using basic water services as those households in CE 2. Just 62% of the households in CE 2 indicated that the amount of water they receive is mostly sufficient to cover their basic domestic needs. Household equipped with a private tap connection use on average 78 l/dc which was mostly sufficient (98%) to cover their domestic needs. Households of CE 1 were supposed to pay for the water they receive, but 40% of them indicated to have problems to afford water bills and indeed, these households were found to have a significantly lower average household income. Households using basic water services in CE 2 were not found to be charged for water services provided by the municipality. But water selling/vending activities as well as investments in water-related infrastructure and storage capacities such as water tanks or pipes take place. Various reasons exist that hinder households of CE 2 from using water for irrigation purposes to improve food security, among them, a major reason is the lack of enough water for that.

These socio-economic, water-related and perceptual variables were then used as covariates in the analysis of the two CEs. A latent class model was chosen for analysis because it simultaneously classifies households according to their observed choice behavior and their covariates into homogeneous classes. With this approach heterogeneity is incorporated in a very straightforward and concrete way.

Preferences and WTP for private in-house connections of households in CE 1 lead to classification of households into four classes:

- Class 1: Relatively strong preferences for better service (in terms of more days and hours of supply), prefer payment every month, least price-sensitive class [higher-income households]
- Class 2: Strong preferences for better service in terms of days and hours of supply, prefer payment every 6 months, strong preference for higher quantities of water, medium price sensitive [medium-income households, receiving better water service than others, younger, higher acceptance of pricing, high water use]
- Class 3: Strong preferences for better service with regard to days per week [low-income households, small household size, older respondents, less females, very concerned about prices]
- Class 4: Prefer very good service with respect to all service attributes but no price influence [high-income households, but also lower acceptance of pricing]

The latent class model found that households are very heterogeneous with regard to preferences and WTP for water services. The LC-model linked heterogeneity to socio-economic characteristics, especially income, water use and acceptance of pricing. The latent class model of CE 2 detected two classes of households with different preferences for basic water services.

- Class 1: Strong preferences for better service (in terms of more days, distance and waiting time), strong preference for private boreholes and private taps, medium price sensitivity
- Class 2: Stronger preference for public taps and private boreholes, dislike private taps [less often females, poor, low-income households, rank 'Quantity' and 'Distance' as less important]

The LC-model differentiated between two classes, one with preferences for better water services and a private water source and one with a preference for basic water services at lower costs. On the basis of the latent class model, welfare measures for changes in attribute levels and for changes in alternatives (as so called "scenarios") can be calculated. According to the varying preferences between classes, welfare changes differ as well. WTP can be calculated for a change in a certain attribute level compared to its base-level, ceteris paribus. In CE 1, WTP is highest for households in class one in general, while class two members show a quite high WTP for additional water. Class three has the lowest WTP of all classes. Results of class four are not used for analysis of welfare measures because of the insignificant price coefficient and the potentially presence of strategic behaviour. Calculating WTP for changes in several attributes, differences between groups become even more obvious. In CE 2, class one has a higher WTP than class two with strong differences in some attributes (e.g. "DISTANCE" in the "Private Tap"-alternative). Results of CE 1 and CE 2 validate each other as findings such as significance of influence of attributes on choice, WTP for better services even of the poor classes, heterogeneity with regard to preferences and the strong influence of income on preferences and WTP were discovered in both of them. Based on the attribute "CONSUMPTION" WTP estimates can serve to provide points on a demand curve. Wald-tests revealed information about the non-linear relationship between WTP estimates of the "CONSUMPTION"-levels. These estimates suggest the presence of diminishing marginal utility of water as found in both CEs. Due to the phenomenon of 'attribute-non-attendance' only a limited number of levels in a broad range can be evaluated in a CE.

Criticism of CEs is based on the hypothetical market setting constructed in a CE, in which households are perfectly informed about prices and respective quantities - a situation that is not given to that extent in real settings. Analyzing equity with regard to the different classes, households in the classes differ significantly from each other with regard to income and price sensitivity. Low-income households cannot afford to pay high prices, so WTP was reduced. With decreasing income, price sensitivity of households increases. When comparing CE 1 and the demand function, which are both predominantly based on households respectively municipalities with a high share of private tap connections, findings concerning average water consumption are in-line and plausible. Results with regard to price sensitivity differ in both approaches implying contradictions between them - though it has to be considered that the dependent variables differ and results are not directly comparable. The CE is based on a hypothetical market setting in which households are perfectly informed about prices and respective quantities - a situation that is not given to that extent in real market settings and in the demand estimation. This may explain to some extent differences in findings.

Chapter 5

Discussion and policy recommendations

5.1 Summary

This research was divided into five chapters. The introductory chapter 1 explained the need for economic valuation to achieve efficient water allocation in regions where water is scarce. So far, the approach to better water management in South Africa at the level of Water Management Areas (WMAs) is rather administrative, since it uses tools such as registration and licensing of all water uses. But this approach does not necessarily result in an efficient water allocation from an economic perspective. Information on economic values of different water uses are missing and the project 'IWRM-Middle Olifants' aims to address this gap by providing a water allocation model that is based on the values of water in the major uses - domestic water use, mining and commercial irrigation. Within this framework, the study at hand deals with the value of water in domestic water uses.

Chapter 2 characterizes the study area - the Middle Olifants sub-basin - in terms of location, natural, physical and socio-economic conditions as a water scarce region with a poor and predominantly rural population. Households in former homeland areas lack access to sufficient and reliable water services, sometimes even access to an improved water source. The current water use leads to overuse at the expense of domestic and environmental water needs. Recognizing water scarcity and the need for a better water management, the legislative framework of water management in South Africa was basically reformed under guidelines of an Integrated Water Resources Management (IWRM). To account for negative social impacts when treating water as an economic good that should be paid for, the free basic water policy was introduced in 2000, which aims to ensure access to 25 l/dc or 6000 l/month and household for free to satisfy basic domestic needs. But the practical implementation of IWRM in South Africa is still in its beginning and confronted with problems, as newly established organizations such as Catchment Management Agencies (CMAs) and Water User Associations (WUAs) need time to adapt to their roles, information on water values and consumption is missing at the catchment level and roles of traditional leaders and new institutions have to be clarified.

Chapter 3 focuses on concepts and techniques used for economic valuation of water with special emphasis on non-market valuation techniques. Important concepts were defined such as preferences, willingness to pay, demand curves, Consumer Surplus, Compensating and Equivalent Variation as well as the here applied concept of Compensating Surplus and Equivalent Surplus. For a better understanding, these concepts were embedded in the framework of consumer and welfare theory, whereby special attention is given to the differences between continuous and discrete data. The choice of the appropriate valuation techniques under the conditions in the Middle Olifants and the objectives of this study is discussed in detail. For individual households in the Middle Olifants water tariffs and water metering are often absent and, therefore, a non-market valuation technique need to be applied. Choosing between Choice Experiments (CEs) and Contingent Valuation Method (CVM), the CE has several advantages that allow a better fit to the situation of households in the Middle Olifants: water services are multi-dimensional with a variety of service levels, which can adequately be captured by the choice experiment. Willingness to pay and preferences for single attribute can be calculated separately, allowing attributes to be either 'utility-increasing' or 'utility decreasing' independently of a researcher's expectation.

Subsequently, chapter 4 presented the procedures, analyses and results of a household survey conducted in the Middle Olifants. First sampling procedures, structure of the questionnaire and design of the choice experiments were presented. Differences in service levels and water sources made a division between households using basic water services (public taps, yard connections) and unimproved water sources (boreholes, river water etc.) on the one hand and households with private in-house connections and private yard connections (in urban areas) on the other hand necessary to be able to design appropriate and meaningful choice experiments. Descriptive analysis of the questionnaire provided a clear picture of socio-economic characteristics of households, water use, water service and pricing structures in the Middle Olifants. Especially in rural areas (CE 2), households were found to be very poor and often completely dependent on governmental grants, a situation which was most severe in female-headed households. Water service levels differed significantly between households of the two choice experiments as mostly rural households received much lower service levels in terms of frequency of supply (in days and hours), quantities and break-downs. Accordingly, satisfaction levels of household of CE 2 were relatively low. Regarding quantity, sampled households connected with private taps in CE 1 consume on average 78 l/dc while average consumption of households of CE 2 with using water sources such as yard connections, public taps, boreholes and rivers is with 18.68 l/dc lower than the amount necessary for health requirements as recommended by WHO [Howard and Bartram, 2003]. The econometric analysis of the choice experiment as a discrete choice model proved the conditional logit model not to be valid for both CEs since assumptions of homogeneity and IID-error terms were not maintained. A latent class model relaxed both assumptions and allowed for a special consideration of household characteristics such as income, current water services, and attitudes of households in the analysis. The latent class model of CE 1 found four distinct classes:

- Class 1: Relatively strong preferences for better service (in terms of more days and hours of supply), prefer payment every month, least price-sensitive class [higher-income households]
- Class 2: Strong preferences for better service in terms of days and hours of supply, prefer payment every 6 months, strong preference for higher quantities of water, medium price sensitive [medium-income households, receiving better water service than others, younger, higher acceptance of pricing, high water use]
- Class 3: Strong preferences for better service with regard to days per week [low-income households, small household size, older respondents, less females, very concerned about prices]
- Class 4: Prefer very good service with respect to all service attributes but no price influence [high-income households, but also lower acceptance of pricing]

The latent class model of CE 2 detected two classes of households with different preferences for basic water services:

- Class 1: Strong preferences for better service (in terms of more days, distance and waiting time), strong preference for private boreholes and private taps, medium price sensitivity
- Class 2: Stronger preference for public taps and private boreholes, dislike private taps [less often females, low-income/poor households, 'Quantity' and 'Distance' ranked as less important]

The study has given special consideration on the relationship between the estimated WTP and the corresponding 'shadow' demand curve as well as on equity issues. The WTP estimates of the levels of the attribute "CONSUMPTION" reflect some points on a non-linear demand curve and suggest the presence of diminishing marginal utility of water. Equity is analyzed in a way to consider price sensitivity of different income classes. Price sensitivity was found to differ according to income. With decreasing income, price sensitivity of households increases. Using price as a tool to induce conservation would result in a higher conservation share of low income households and can - from an equity perspective - not be recommended. The CE is based on a hypothetical market setting in which households are perfectly informed about prices and respective quantities - a situation that is not given to that extent in real market settings and in the demand estimation.

5.2 Discussion and conclusions

Important points, relevant findings and policy implications will be raised and discussed according to the chapters presented so far:

- **Varying quality of water services**

  Households using yard connections or fetch water at public taps do not have access to water every day. Nearly half of the public tap users indicated that they receive water only once a week or do not even know when water is flowing. Water service levels in terms of frequency of water supply, reliability, distance and waiting time were found to differ between households and between water sources. Still, 20% of the rural households collect water at unimproved water sources such as borehole, rivers, canals etc. From these findings, it is strongly recommended to policy-makers to focus on the provision of improved water sources but also to consider service levels of the existing water infrastructure. Willingness to pay-estimates of the two choice experiments reveal a preference ranking of the relevant service attributes and basic water sources (CE 2) and can guide policy-makers in prioritizing service developments. Accordingly, particular emphasis should be given on improvements with respect to days of supply per week, a general quantity increase with regard to basic water sources and a quantity increase for private taps given certain class characteristics.

- **Water consumption**

  Average water consumption differs significantly between water sources. While households equipped with private connections inside their houses were found to use on average 78 l/dc, average consumption of households using basic water services is 18.68 l/dc. This is less than the free basic water of 25 l/dc and less than the minimum for basic health protection of 20 l/dc as quantified by Howard and Bartram (2003). While the majority of the sampled households managed to satisfy domestic needs, about one third cannot. The basic level of supply should be regarded as a minimum quantity of water and WHO recommends to increase levels of service to yard connections and a quantity of 50 l/dc [Howard and Bartram, 2003,Gleick, 1996]. The low water availability is also a major reason that hinders households from irrigation to improve their food security situation. These findings lead to the conclusion that available water has to be increased to ensure basic domestic needs. A better provision in terms of quantity may also encourage households to start irrigation activities as already supported by the government.

- **Heterogeneity among households and Willingness to pay**

  Households in the Middle Olifants are heterogeneous with regard to their socio-economic characteristics (especially income), water service levels, attitudes and perceptions. Accordingly, their preferences and WTP with regard to domestic water services vary. Results of both choice experiments show how different groups of households value certain characteristics of domestic water services.

  According to results of the choice experiments households are willing to pay for better water services - although their current water services are provided for free. All classes value a higher frequency of water supply per week and a higher consumption given basic water services highly. In CE 1 households of all classes show a positive 'Willingness to pay' for a higher frequency of supply between ZAR 0.60 and ZAR 2.55 per m^3 while only households of class 2 have a significant positive 'Willingness to pay' for a higher quantity to tap water. In CE 2, households of class 1 and class 2 are willing to pay ZAR 0.98 per m^3 and ZAR 0.55 per m^3 respectively for an additional day of supply and about ZAR 0.30 per m^3 and ZAR 0.4 per m^3 for an increase of 25 l/day and person for basic water services. 'Willingness to pay'-estimates with regard to other service attributes are more diversified between households. This can help policy makers to design water services according to preferences of each group. For class 2 of CE 2 having improved water services in terms of frequency and quantity in particular, but still basic water sources such as public taps or yard connections would be acceptable. As there are substantial disparities in the socio-economic characteristics between geographical areas, water services can be designed according to the preferences of the predominant classes of households in an area.

Positive 'Willingness to pay'-estimates stress the need for further water service developments and continuous improvements since even very poor households as in class 2 of CE 1 with an average income of less than ZAR 1380/month would be willing to pay for better water services. Households value particularly a higher frequency of supply and higher quantities for basic water services. The close connection between WTP and affordability to pay can be seen since the latent class model identifies different income classes and their respective WTP. WTP is strongly linked to income since it increases with increasing income of households. For policy-makers this finding could be set into practice by building a closer link between prices for water and income by using subsidies.

- **Price sensitivity of households**

  The results of both choice experiments show that low income households such as class 2 of CE 2 and class 3 of CE 1 are much more price sensitive than higher income classes. Increasing water tariffs would therefore result in water savings predominantly by low-income households. So low-income households would take the major conservation burden, which is something contradicting the equity objectives of the South African government. To induce water savings from households, quantity restrictions would be preferable to price increases since they would be targeted at high-quantity users which are likely to use water for non-essential uses (gardening, car washing etc.). Households with large household-sizes may need special consideration when applying quantity restrictions to ensure they are able to fulfill their domestic needs.

- **Forms of subsidies**

  In general, to ensure affordability of water for low-income households and to closely link water tariffs and income, different tools can be applied which are either tariff-related or income-supporting (or mixtures of both). Tariff-related measures refer to the water tariff structure, e.g. increasing block tariffs and design of tariff levels while income-supporting measures consist of vouchers, tariff rebates, discounts or direct income-subsidies according to the definition of the OECD [OECD, 2003]. Income-supporting measures have the advantage that they do not interfere with the economic and environmental scarcity signals of water tariffs, while lower domestic water tariffs - as a means of tariff-related subsidies - may not decrease consumption. With increasing block rates a tariff scheme is implemented which already aims to provide incentives for water conservation. Free basic water is implemented as a form of cross-subsidy, high quantity-users pay higher prices so that they indirectly pay for the free basic water as well.

More and more, municipalities tend to incorporate the free basic water into their indigent policy to target the subsidy to poor households only. Since the government already targets especially poor households by giving child grants and old-age pensions to them, extending the existing administration and infrastructure to water services is feasible. Households above the threshold of being considered as poor, do not benefit anymore and pay full water price - though they may still belong to low-income households. Among the sampled households of CE 1, 60% indicated to have problems to afford the water bills and they were also found to have a significantly lower average income- but not low enough to be eligible for the indigent policy. Non-payment of water bills seems to be connected to a lack of income. In a study of Center for Development Support (CDS) and the University of the Free State it was shown that in many instances poverty is the main cause of non-payment of services [CDS, 2002], which confirms this finding. Accordingly, higher household income was found to be linked to a higher WTP for water in both CEs. Providing additional subsidies including low-income households could help to ensure access to sufficient water and lead to higher payment rates of water bills.

The decision on what kind of subsidy to use has to be taken by policy-makers. Income subsidies are less distorting, but it is difficult to ensure the use of the subsidy for payment of the water bill. Low-income households may have other pressing financial needs that may be regarded as more important as the water bill.[1] Setting lower prices for low-income households may contradict the need to set appropriate scarcity signals. The different classes of the choice experiments could serve as an indicator for setting the appropriate income threshold and WTP-estimates may serve as a basis for setting lower water tariffs or calculating the required income subsidies.

- **Prepaid meters**: Essential for providing incentives of water scarcity in the region is metering of water and the true enforcement of water bills. Households without meters have neither control on their water use nor any incentive to save water. Missing enforcement of water bills also does not make household appreciate the value of water. An idea to address both issues at once was the introduction of prepaid-payment water meters. These meters can be installed as public taps but also as private taps. After loading money on a card and inserting it, the water is flowing. With this system, water is metered and

[1] Restricting the use by distributing vouchers that are directly linked to water services can mitigate that problem.

payment of households is ensured. Free basic water can also be ensured through that system. Some implementations of prepaid meters - as in Phiri, Soweto - have shown a lack of acceptance in the population. This can also be confirmed by results of the first choice experiment. Here, all classes (but class 4) associate significantly negative utility with prepaid meters and would need to be compensated. Findings of CE 1 indicate compensations between ZAR 0.75 to ZAR 5.50 per m^3 depending on class membership. When the government decides for further introduction of prepaid meters, lowering prices seems to make households indifferent according to the findings of the choice experiment.

5.3 Issues for further research

This chapter finally makes some suggestions for future research in the area of domestic water services in South Africa.

Chapter 4 presented the analysis and results of two choice experiments. Since the value of water is strongly linked to the quantity of water that is available, this issue was incorporated as an attribute with three levels depending on water source. Setting these levels could only capture certain exemplified discrete quantities of water, and not the whole range of possible water quantities. The issue of combining the values generated from choice experiments directly with respective quantities demanded is a topic that did not receive much attention yet. Methods to be able to capture values of continuous goods in choice experiments are still missing.

In politically active areas as Phiri in Soweto, households were hardly accepting prepaid meters and have brought the issue of lawfulness of prepaid meters to trial. Presenting the use of prepaid payment systems as one attribute level of choice experiment 1 in Chapter 6 showed that households associated negative utility with prepaid meters compared to traditional billing methods. While prepaid meters are considered as a useful tool to encourage water conservation, because they establish a direct relation between payment and use by the government, they lack obviously acceptance in the population. It would be advisable to have a closer look why prepaid meters are valued that negatively and what additional factors - besides lower prices - may increase their acceptance in the population.

A general suggestion refers to sanitation services. Basic sanitation was not part of this study, but is closely connected to domestic water services. Access to a basic sanitation service as a human right is enshrined in the Constitution of South Africa (1996). Municipalities have an obligation to provide basic sanitation services to the poor (Free Basic Sanitation (FBSan) policy). Concerning the facilities, there is a strong emphasis on providing Ventilated Improved Pit (VIP) and dry toilets instead of water-borne sanitation due to the water scarcity situation. Research on preferred sanitation services and willingness to pay for improved sanitation is still missing and would be an important area for further research.

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Appendix

Definition and Concepts of IWRM

Integrated Water Resources Management (IWRM) is defined as a process, which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems [GWP, 2000]. The different users of a water course are interdependent and therefore integrated management is needed to ensure participation of all users. Water users are households (water for domestic purposes), agriculture (water for food), industries and other uses (water for production) and the environment [GWP, 2000].

Global Water Partnership (GWP) defined Integrated Water Resource Management as *a process that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.* [GWP, 2000].

The Dublin Principles (1992) are the guiding principles underpinning IWRM. In detail, these principles are:

- Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment
- Water development should be based on a participatory approach, involving users, planners and policy-makers at all levels
- Woman play a central role in the provision, management and safeguarding of water
- Water has an economic value in all its competing uses and should be recognized as an economic good

In pursuing IWRM social, economic and natural conditions have to be considered:

- Economic efficiency. Since water is increasingly getting scarce, the finite and vulnerable nature of water as a resource, and the increasing demands imposed on it by various users, it must be used with maximum possible efficiency.
- Equity. People have a right to water. It must be ensured that people can access water that is safe to drink and that is sufficiently enough to cover at least basic human needs.

- Environmental and ecological sustainability. Water resources need to be managed in a sustainable way that does not undermine the life-supporting qualities of water and does not comprise use by future generations.

In an IWRM framework the following elements of an effective water resources management system must be developed and coordinated:

- The environment and local/national conditions refers to the framework of national policies, legislation and regulations and information for water resources management stakeholders
- the institutional roles and functions of the various administrative levels and stakeholders
- the management instruments, including operational instruments for effective regulation, monitoring and enforcement that enable the decision-makers to make informed choices between alternative actions. These choices need to be based on agreed policies, available resources, environmental impacts and the social and economic consequences

In IWRM, economic valuation of alternative water uses gives decision makers important guides to set priorities, under consideration of social, economic and environmental goals [The-World-bank, 2004].

Sampling design

The DWAF-database used for stratification did not include socio-economic data of households. To see whether the sample is representative with regard to household income, education and household size, data from the Statistical Service (StatsSA) in South Africa was used [Statistics-South-Africa, 2005]. Unfortunately, the Statistical Service deals with administrative boundaries and thus does not provide information for hydrological boundaries such as the Middle Olifants sub-basin. Instead, data for the Province Limpopo had to be used and compared to the Middle Olifants sub-basin, which is only partly located in Limpopo.

A comparison of the distribution of socio-demographic characteristics in the sample and in Limpopo (see Table A.2) shows that the sample entails more respondents with high income per household per month than the Province Limpopo. Regarding education, the sample is also polarized towards households with a better education than on average in the Province Limpopo. These findings are probably related with each other. Concerning household size, the sample perfectly fits the average household size of Limpopo.

Some additional findings of the households survey not included in the final data analysis can be found in Figures A.1 and A.2. The Figures present households' expenditures related to food and non-food items.

Table A.1: Studies on households' 'Willingness To Pay' for better water services in South Africa

Authors	Method	Water Service attributes	Results
Goldblatt (1999)	CVM	Connection to metered piped water scheme and consumption of 25 l	15% have a WTP $\leq$ 20 cents/25l, 20% 20 $\leq$ WTP $\leq$ 30 cents/25l, 26% 30 $\leq$ WTP $\leq$ 40 cents/25l, 15% 40 $\leq$ WTP $\leq$ 50 cents/25l, 13% 50 $\leq$ WTP $\leq$ 60 cents/25l
Banda et al. (2006)	CVM	Improved availability and quality	WTP ZAR 4.03/m^3 (Collective tap users), ZAR 6.15/m^3 (River water users)
Banda et al. (2007)	TCM	Improved availability and quality	ZAR 2.91/m^3 (Collective tap users), ZAR 4.34/m^3
Snowball et al. (2008)	CE	decrease in bacteria count (a), decrease in number of households affected by water discoloration (b), decrease in number of households affected by service interruptions (c)	WTP(a)= 15.72% increase in water price; WTP(b)= 0.12% increase in water price; WTP(c)= 0.13% increase in water price
Kanyoka et al. (2008)	CE	Quantity (a), Frequency (b), Quality (purified) (c), Water source (access to private tap (d))	WTP(a)= ZAR 0.10/month per liter (without private tap), ZAR 0.06/month per liter (with private tap); WTP(b)= ZAR 14.64 per month (without private tap), ZAR 6.60 per month (with private tap); WTP(c)= ZAR 19.44/month, ZAR 11.74 per month; WTP(d)= ZAR 27.67/month (without private tap)

TCM=Travel Cost Method, CVM=Contingent Valuation Method, CE=Choice Experiment; Own compilation

Table A.2: Comparison between Sample and Province Limpopo

Characteristic	Description	% of sample	% of Limpopo Province
Income[2]	≤R799	40.7	36.5
	R800-R1799	29.8	19.8
	R1800-4999	17.8	16.9
	R5000-10000	7.3	16.2
	≥ 10000	3	10.6
Education[3]	no schooling	13.8	33
	some primary/complete primary	11.7	19.1
	some secondary/complete secondary	56.8	40.1
	higher degree	17.7	6.8
Household size[4]	Average household size	4.5	4.5

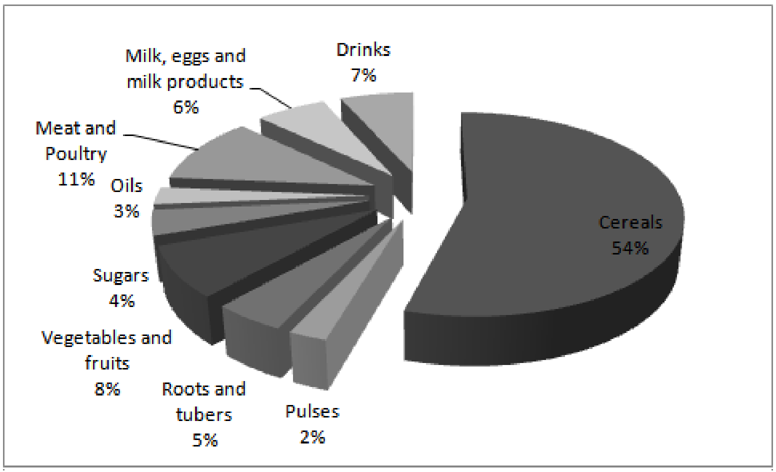

Figure A.1: Expenditure for food and drinks

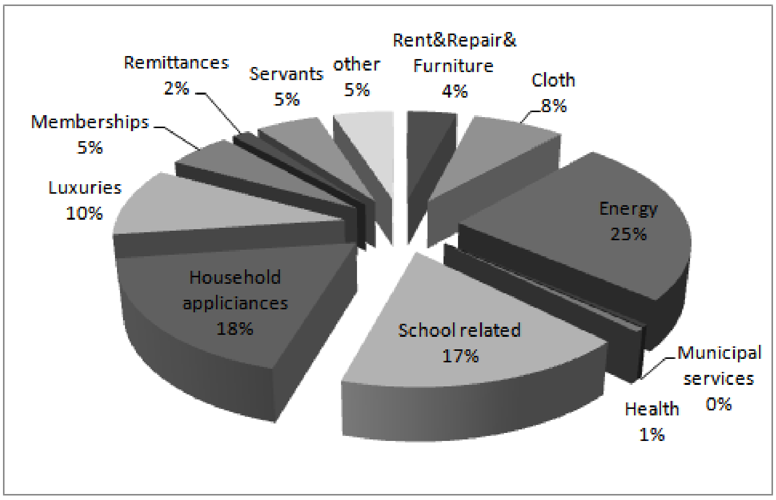

Figure A.2: Expenditure for non-food items

Choice Experiment I

Table A.3 presents estimation results of the CL-model. All parameters except "Payment every 6 months" are significant.

The estimated parameters are then used to calculate respondents' WTP. WTP values for each level of the attributes were calculated with reference to the base level for each attribute and additional to the medium level for the attribute "CONSUMPTION". Standard errors and 95% confidence intervals were calculated using the Delta method[5] in NLOGIT 3.0 (statistical software). For increasing frequency by one day per week respondents are willing to pay ZAR $1.64/m^3$ of water everything else equal. These WTP-estimates indicate that consumers are willing to pay higher prices for water when they receive a better service especially in terms of frequency and reliability. Interestingly, for moving from a consumption of 50 liter per day

[5]The delta method is a general approach for obtaining confidence intervals for functions of maximum likelihood estimator. Here, the function is the division of a coefficient of an attribute with the price-coefficient [Greene and Hensher, 2003, Xu and Long, 2005].

Table A.3: CE 1 - Results of CL-model

Attributes	Parameter	Standard Error	P-Value
FREQUENCY	0.7124	0.0667	0.0000
CONSUMPTION			
50 liter/day and capita			
100 l/dc	0.7384	0.1225	0.0000
150 l/dc	0.5450	0.1111	0.0001
RELIABILITY	0.1342	0.0115	0.0000
PRICE	-0.4342	0.0665	0.0000
PAYMENT METHOD			
monthly	0.0000		
every 6 months	-0.0973	0.1025	0.3425
Prepaid payment	-0.6233	0.1221	0.0000
Opt out	3.3801	0.5100	0.0000
Log-likelihood	-1015.8545		
R^2	0.1389		
$R^2(0)$	0.1886		
Prediction error	0.4803		
Hausman-test: with 7 df			
Alternative	Wald	p-value	
Exclude a	14.05	0.0421	
Exclude b	3.46	0.8390	
Exclude c	8.31	0.3067	

and person to 100 l/dc, households willing to pay ZAR 1.70/m^3 and from 50 to 150 l/dc ZAR 1.26/m^3. When moving from a medium water quantity of 100 l/dc to a high water quantity of 150 l/dc results in a negative WTP estimate of ZAR -0.45/m^3. Since the price is linked to the quantity consumed, a higher consumption of water leads to a high monthly bill. Households dislike prepaid-systems ("Prepaid") and would accept them when being compensated with ZAR 1.43/m^3.

Testing for IIA-assumption

The CL-model assumes Independence of Irrelevant Alternatives (IIA), which is the behavioral result of the IID error terms. In the labeled choice experiment at hand, it is assumed that the ratio of probabilities between the tap water and public tap alternative is not influenced by the attributes of the borehole alternative. Furthermore, this leads to the property of equal cross elasticities of choosing any alternatives [Hausman and McFadden, 1984]. An increase in the probability of choosing one alternative by improving one attribute decreases the probability of choosing the remaining alternatives proportionally. Different tests were developed to analyze whether IIA holds true or not of which the most frequently used ones are described in the following. They are based on testing whether eliminating one of the alternatives from the

Table A.4: CE 1 - Willingness to pay estimates for CL-model (in ZAR/m^3)

6

Attributes	WTP (Std. Err.)	CI
FREQUENCY	1.6407*** (0.2386)	[1.1729;2.1084]
100 l/dc	1.7004*** (0.3743)	[0.9667;2.4341]
150 l/dc	1.255*** (0.2881)	[0.6903;1.8197]
RELIABILITY	0.3091*** (0.0433)	[0.2241;0.3941]
PAYMENT:		
every 6 months	-0.2239 (0.2431)	[-0.7006;0.2526]
Prepaid payment	-1.4354*** (0.2652)	[-1.9554;-0.9155]
100-150l/dc	-0.4454 (0.3192)	[-1.0712;0.1803]
None	7.7842*** (1.7927)	[4.2705;11.2979]

choice set changes choice behavior and or still obeys IIA property. The tests compare an unrestricted model (including all alternatives) with parameter estimates b^f and a restricted model (one alternative e.g. j is eliminated from the choice set) with b^r. Multiple tests are necessary depending on the number of alternatives.

- McFadden, Train, and Tye Test: The approximate likelihood ratio test of IIA proposed by McFadden et al. (1981) is calculated as

$$MTT = -2 * (L^r(b^f) - L^r(b^r)) \tag{5.1}$$

  where L^r is the log-likelihood function for the restricted estimation. The test compares the value of the log-likelihood equation from the restricted model to the value obtained by inserting estimates from the full model into the log-likelihood from the restricted model. MTT is as distributed chi-square with degrees of freedom equal to rows of β^r.

- Hausman and McFadden test [Hausman and McFadden, 1984]: applied a Hausman specification test procedure [Hausman, 1978] that tests whether the Null hypothesis of IIA is maintained and the parameters are approximately the same (and thus the CL model is appropriate). The test statistic is described as follows:

$$t = (b^f - b^r)' * (V^r - V^f)^{-1} * (b^f - b^r) \tag{5.2}$$

  where b^f (b^r) is the column vector of the parameter estimates from the unrestricted (restricted) model and V is the variance-covariance matrix.

- Small and Hsiao Test: Small and Hsiao (1985) show that MTT is asymptotically biased towards accepting the null hypothesis[7]. So they proposed a modified version of MTT to avoid this bias. The sample is to be divided randomly into two parts of similar size A and B. The full model from equation 5.2 is estimated for both subsamples to get b^f_A and b^f_B.

[7]for empirical application see Frye and Harris (1996, 1998).

Table A.5: CE 1 - Results of conditional logit model including interactions

Attributes	Parameter	Standard Error	P-Value
FREQUENCY	0.7145	0.0668	0.0000
CONSUMPTION			
100l/dc	0.7420	0.1226	0.0000
150 l/dc	0.5466	0.1114	0.0000
RELIABILITY	0.1347	0.0115	0.0000
PRICE	-0.5633	0.1041	0.0000
PAYMENT			
every 6 months	-0.0990	0.1027	0.3400
Prepaid	-0.6258	0.1222	0.0000
NONE	3.2845	0.5132	0.0000
Interactions:			
INCP	0.0001	0.0000	0.0027
AGEP	-0.0022	0.0016	0.1600
SUMP	0.0285	0.0218	0.1900
Model statistics	0		
Log-likelihood (LL)	-1006.5569		
R^2	0.1493		
$R^2(0)$	0.1984		
Prediction Error	0.4803		
Hausman-test: (11 degrees of freedom)			
Alternative	Wald-statistic	P-value	
Exclude a	101	0.000	
Exclude b	32	0.000	
Exclude c	19.25	0.0567	

Table A.6: CE 1 - WTP of conditional logit model including interactions

Attribute	WTP (ZAR/m^3)	St.error	CI
FREQUENCY	1.2804***	(0.238)	[0.8139;1.7469]
100 l/dc	1.3459***	(0.3268)	[0.7053;1.9865]
150 l/dc	1.0962***	(0.2696)	[0.5677;1.6246]
RELIABILITY	0.2335***	(0.0418)	[0.1515;0.3154]
every 6 month	-0.2570	(0.1893)	[-0.6281;0.1139]
Prepaid	-1.0890***	(0.2472)	[-1.5737;-0.6043]
150-100	-0.2497	(0.2401)	[-0.7205;0.221]

The weighted average of the coefficients from the two subsamples can be received with the following equation

$$\beta^f_{AB} = \frac{1}{\sqrt{2}} * b^f_A + 1 - \frac{1}{\sqrt{2}} * b^f_B \tag{5.3}$$

A restricted subsample is created from subsample B by excluding all cases with choice alternative j. The Small- Hsiao statistic using log likelihood as in MTT is:

$$SH = -2[L_r(b^f_{AB}) - L_r(b^r_B)] \tag{5.4}$$

SH is asymptotically distributed as chi-square with the degrees of freedom equal to the number of parameters in the restricted model.

The second set of specification tests are based on a generalization of the logit model such as the nested logit model. Since the CL model is a special case of the nested logit model when a given parameter equals one, classical test procedures such as the Wald, likelihood ratio, and Lagrange multiplier tests can be used. Each test leads to a test for the Null hypothesis that the scale parameter equals 1. Hausman and McFadden (1984) compared all tests (except SM-test) with each other and conclude in their paper that Hausman test and Wald test are the best choice for testing the IIA assumption. A recent comparison of MTT, Hausman and SH test was done by [Fry and Harris, 1998, Cheng and Long, 2007]. Fry and Harris concluded that multiple test should be used. Cheng and Long (2007) found drawbacks of all tests. For this application, due to the simplicity of the Hausman-test and its widespread application in the literature, Hausman-test and additionally Wald-tests were used to test for the IIA assumption.

Choice Experiment II

Table A.7: CE 2 - Results of conditional logit model

Attributes	Coefficient	St.err.	p-value
CONSTANTS			
Private Tap	0.0000	.	0.0000
Public Tap	-0.9333	0.2693	0.0005
Private Borehole	1.3252	0.2679	0.0001
None	-2.1052	0.4584	0.0000
DISTANCE (Private Tap)			
onsite	0.0000	.	0.4300
inside	0.0885	0.1111	
CONSUMPTION (Private Tap)			
35 l/dc	0.0000	.	0.1400
50 l/dc	0.1264	0.1365	0.3544
65 l/dc	-0.1500	0.1339	0.2626
FREQUENCY	0.4004	0.0262	0.0000
DISTANCE (Public Tap)	-0.0032	-0.0032	0.0000
CONSUMPTION (Public Tap/Pr. Borehole)			
15 l/dc	0.0000	.	0.0000
25 l/dc	0.4349	0.1017	0.0000
35 l/dc	0.4262	0.1001	0.0000
PRICE	-0.4952	0.0982	0.0000
WAITING TIME	0.0595	0.0238	0.0120
PUMP			
Hand pump	0.0000		0.0000
Motor pump	-0.5899	0.1033	
Log-likelihood	-1879.8909		
R^2	0.1164		
$R^2(0)$	0.2056		
Prediction error	0.4966		
Hausman-test			
Alternative	Wald	p-value	dof
Exclude a	16	0.0576	9
Exclude b	24	0.0128	11
Exclude c	32	9.94E-01	12

Table A.8: CE 2 - Conditional logit model including interactions

Attribute	Coefficient	St.err.	p-value
Private Tap	0.0000	.	.
Public Tap	-0.9144	0.2712	0.0008
Private Borehole	1.3765	0.2702	0.0000
None	-2.1082	0.4622	0.0000
onsite	0.0000	.	.
inside	0.1102	0.1133	0.3300
35 l/dc	0.0000	.	.
50 l/dc	-0.1162	0.2458	0.6400
65 l/dc	-0.4580	0.2287	0.0450
FREQUENCY	0.4049	0.0265	0.0000
DISTANCE (public Tap)	-0.0032	0.0003	0.0000
15 l/dc	0.0000	.	.
25 l/dc	0.2633	0.1689	0.1200
35 l/dc	0.5133	0.1673	0.0022
PRICE	-0.5626	0.1118	0.0000
WAITING TIME	0.0614	0.0239	0.0100
Hand pump	0.0000	.	.
Motor pump	-0.6130	0.1043	0.0000
Income x PRICE	0.0000	0.0000	0.0000
Age x PRICE	-0.0015	0.0011	0.1800
Quantity x 35 l/dc	0.0000	.	.
Quantity x 50 l/dc	0.0001	0.0001	0.2400
Quantity x 65 l/dc	0.0001	0.0001	0.0950
Quantity x 15 l/dc	0.0000	.	.
Quantity x 25 l/dc	0.0001	0.0001	0.1900
Quantity x 35 l/dc	0.0000	0.0001	0.5300
Log-likelihood	-1852.0832		
R^2	0.1354		
$R^2(0)$	0.2227		
Prediction error	0.4658		

Table A.9: CE 2 - WTP-Estimates according to CL-model (in ZAR/m^3)

Attribute	WTP (St.err.)	p-value	CI
DISTANCE (Private Tap)	0.1787 (0.2257)	0.4287	[-0.2638;0.6212]
50 l/dc	0.2552 (0.28)	0.3621	[-0.2936;0.8041]
65 l/dc	-0.3029 (0.2799)	0.2792	[-0.8515;0.2457]
50-65 l/dc	0.8085 (0.1635)	0	[0.488;1.129]
FREQUENCY	-0.0064 (0.0012)	0	[-0.0089;-0.0039]
DISTANCE (Public Tap/Pr. Borehole)	0.8782 (0.2625)	0.0008	[0.3636;1.3928]
25 l/dc	0.8606 (0.2566)	0.0008	[0.3576;1.3636]
35 l/dc	0.1201 (0.0549)	0.0287	[0.0124;0.2278]
25-35 l/dc	-1.1912 (0.3127)	0.0001	[-1.8042;-0.5782]
WAITING TIME	-0.5581 (0.3069)	0.069	[-1.1597;0.0434]
PUMP	-0.0175 (0.2128)	0.9342	[-0.4346;0.3995]

Table A.10: Estimated willingness to pay (in ZAR) per household per month

	CE 1		CE 2	
	Scenario 1 (50 l/dc)	Scenario 2 (50 l/dc)	Scenario 1 (25 l/dc)	Scenario 2 (35 l/dc)
Class 1	14.10	52.78	14.95	39.41
Class 2	10.53	23.96	6.66	19.40
Class 3	2.70	6.88		