MULTI-CRITERIA DECISION-MAKING FOR WATER RESOURCE MANAGEMENT IN THE BERG WATER MANAGEMENT AREA

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DECLARATION

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature : . . . .   Date : . . . .

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ABSTRACT

The concept of social welfare maximisation directs strategic decision-making within a milieu of integrated planning problems. This study applies the aforementioned statement to decision-making regarding the long-term allocation of bulk-water resources in the Berg Water Management Area of South Africa. Public goods, such as bulk water supply infrastructure, is vulnerable to failures in market and government allocation strategies because both fields are subjected to unaccounted costs and benefits. This implies a measurement problem for the quantification of the total cost/benefit of management options and result in decision-making with incomplete information. Legitimate decision-making depends on reliable and accurate information, and the measurement problem, therefore, poses an obstacle to better social welfare maximisation.

A need has been identified to broaden the decision-making context in the Berg Water Management Area to promote the accommodation of unaccounted for costs and benefits in water resource allocation decision-making. This study engaged this need by expanding the temporal and spatial dimensions of the decision-making context. Accordingly, improved indecision-making information and decision-support processes is needed. Spatial expansions manifested in physical expansions of the decision-making boundaries that led to expansions in representation in the decision-making process. Temporal expansions manifested in the consideration of different sequences of bulk supply schemes over time instead of a selection of schemes at the same time.

The study incorporated components of economic valuation theory, multi-criteria decision analysis, a public survey and a modified Delphi expert panel technique to account for the increased decision-making information load. The approach was applied in the Western Cape province of South Africa and specifically focused on a choice problem regarding different long-term bulk-water resource management options for the area. Two surveys were completed to accommodate these expansions. The first focused on public preference in water allocation management and the second survey utilized a modified Delphi technique. Questions regarding the extend of public participation in long-term water resource allocation decision-making came to the fore and the applicability of economic theory to accommodate public preference as a regulatory instrument, was questioned. A willingness to pay for "greener" water was observed and may be used to motivate a paradigm shift from management's perspective to consider, without fear of harming their own political position, "greener" water supply options more seriously even if these options imply higher direct costs.

UITTREKSEL

Die konsep van sosiale welvaart maksimering rig strategiese besluitneming binne ‘n milieu van geintegreerde beplanningsprobleme. Hierdie studie pas laasgenoemde stelling op langtermyn water allokasie besluitneming binne die Berg Waterbestuursarea van Suid Afrika toe. Publieke goedere soos grootmaat watervoorsienningsinfrastruktuur, is kwesbaar vir mislukkings in mark- en gereguleerde allokasiestategieë, aangesien beide blootgestel is aan onberekenbare kostes en voordele. Laasgenoemde weerspieël ‘n kwantifiseringsprobleem om totale kostes en voordele van verskillende bestuurstrategieë te beraam en lei tot besluitneming met onvolledige inligting. Geloofwaardige besluitneming steun egter op betroubare en akkurate inligting en die kwantifiseringsprobleem belemmer dus sosiale welvaart maksimering.

Die behoefte om die besluitnemingskonteks in die Berg Water Bestuur Area te verbreed, het onstaan om sodoende onberekenbare kostes en voordele tot ‘n groter mate in waterhulpbron allokasie besluitneming te akkommodeer. Hierdie studie fokus op laasgenoemde behoefte deur die temporale en ruimtelike dimensies van die besluitnemingskonteks verder te ontwikkel. Sulke ontwikkeling vereis verbeterde besluitnemingsingsinligting en ondersteuningsprosesse. Ruimtelike ontwikkeling is geakkommodeer deur die fisiese uitbreiding van die grootmaat water allokasie besluitnemingskonteks. Temporale ontwikkeling manifesteer deur verskillende reekse van opeenvolgende grootmaat water skemas oor tyd te vergelyk, in plaas daarvan om individuele skemas op dieselfde tydstip met mekaar te vergelyk.

Die studie het van ekonomiese waardasie teorie, multi-kriteria besluitneming analise, ‘n publieke opname en ‘n aangepaste Delphi ekspert paneel tegniek gebruik gemaak om die vergrote vraag in besluitnemingsinligting te hanteer. Die benadering is in die Wes-Kaap provinsie van Suid-Afrika toegepas en het op ‘n keuse-probleem aangaande lang-termyn grootmaat water bestuur gefokus. Twee opnames is gedoen om die vergrote konteks te hanteer. Die eerste het op publieke voorkeur in water allokasie bestuur gefokus terwyl die tweede opname ‘n aangepaste Delphi tegniek gebruik het. Vrae aangaande publieke deelname in langtermyn water allokasie besluitneming het navore gekom, waarna die bevoegdheid van die ekonomiese teorie as reguleringsintrument om publieke voorkeur te hanteer, bevraagteken word. ‘n Bereidwilligheid om vir “groener” water te betaal het na vore gekom. Dit dien as motivering vir ‘n paradigmaskuif waar waterbestuurders sonder vrees vir bedreiging van hul eie politieke posisie, “groener” watervoorsienningsopsies ernstiger kan oorweeg, ten spyte van verhoogde direkte kostes.

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"bad boundaries make bad governments . . ."

(Russell Ackoff)

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ABBREVIATIONS

BWMA	-	Berg Water Management Area
BWP	-	Berg Water Project
CCT	-	City of Cape Town
CT	-	Cape Town
CMA	-	Cape Metropolitan Area (includes Blaauwberg, Tygerberg, Cape Town, South Peninsula, Oostenberg and Helderberg)
CMABWS	-	Cape Metropolitan Area Bulk-Water Supply
CMC	-	Cape Metropolitan Council (former)
DWAF	-	Department of Water Affairs and Forestry
IWRP	-	Integrated Water Resource Planning
MAR	-	Mean Annual Runoff
MCDA	-	Multi-Criteria Decision-Analysis
MCDM	-	Multi-Criteria Decision-Making
MCEM	-	Multi-Criteria Evaluation Method
Mm^3	-	Million cubic metres (million kilolitres)
Mm^3/a	-	Million cubic metres per annum
Mkl	-	Million kilolitres (million cubic metres)
Mkl/a	-	Million kilolitres per annum
MW	-	Mega Watt
R/kl	-	Rand per kilolitre
TCTA	-	Trans-Caledon Tunnel Authority
TMGA	-	Table Mountain Ground Aquifer
UAE	-	United Arab Emirates
UN	-	United Nations
URV	-	Unit Reference Value
WCRS	-	Western Cape Reconciliation Study
WCSA	-	Western Cape System Analysis
WCSS	-	Western Cape Supply System
WMA	-	Water Management Area
WSDP	-	Water Services Development Plan

1. INTRODUCTION AND ORIENTATION

Since the 1980s, the world has seen massive reforms in economic institutions, i.e. communist regimes collapsed, trade barriers were reduced and the institutions of market capitalism have grown steadily. Most reforms sought to reduce constraints on economic activity, increase market participation and make greater use of competitive markets as allocation mechanisms. These reforms trickled down to resource allocation policies and institutions governing the use of natural resources, including water resources.

The political events during the last decade in South Africa have seen major objective-related adjustments leading to changes in the organisational structure of government. Developments in South African water policy followed the above-mentioned trend with substantial institutional reform in water resource legislation after 1994 (Act 108 of 1997: Water Services Act) and 1998 (Act 36 of 1998: National Water Act). A thrust towards the decentralisation of management, aimed at efficiency increases, ensued mainly due to water resource scarcity increases, which led to greater competition for access and usage rights. The development of an integrated approach to water resource allocation management emerged and, to some extent, anticipated a change of direction towards decentralisation and increased public participation in resource allocation. The concepts of sustainability, efficiency and equity are central to this partly resolved management challenge. Inter-relationships exist between nature and private and public interests, and the means for engaging in scarcity-related conflicts within such interrelationships, features prominently in the decision-making process.

The political, socio-economic and natural contexts have become increasingly important in resource allocation decision-making. Distributional features of different resource allocations needing to be accounted for included skewed distributions of income, wealth and power because the political reality in less developed countries is that allocation policies aimed at a stronger translation of sustainability (implying low economic growth approaches) are simply unacceptable. On the other hand, policies that only target economic growth without regard for equity considerations may also encounter resistance, especially where there is a strong organised labour movement such as in the case of South Africa.

A structured way of thinking complemented by an expanded decision-support context is needed. However, a resource base to develop such methodologies is also needed, and this study makes use of long-term water allocation management to provide this base. It uses the Berg Water

Management Area (BWMA) in the Western Cape Province of South Africa as a regional framework with water resource allocation between different users as decision-making challenge. Water resources were chosen because of its life-supporting character and different social and economic values attached to it. It therefore creates a formidable platform for resource allocation issues to develop. In addition, the BWMA and the adjacent rural areas in the Western Cape have came under increasing threat of water shortages during the past five years. Climatic change, economic growth, pollution and population demographic variables could be put forward as the three main drivers of increased demand. With new bulk supply sources becoming less accessible, more expensive and less environmentally acceptable, new and innovative water management strategies and policies are called for, making the BWMA a suitable study context.

1.1 Research problem structuring

The following section describes the basic theoretical research problem and also serves as an orientation and, therefore, reference for the rest of the dissertation. A thorough understanding of this problem is, therefore, essential to understand the context of the rest of the dissertation.

The study assumes a water resource scarcity situation within the BWMA. Preference is given to the "highest and best use" argument in resource scarcity situations (maximising marginal benefit). Given that the perceived value of water use in urban areas exceed rural use, a gradual re-allocation of water from rural to urban areas is expected. Unfortunately, the difference in perceived value are not fully quantifiable and therefore not fully accounted for in market-driven allocation systems (due to a measurement problem).

Within the BWMA the future bulk augmentation infrastructure will increasingly result in re-allocations of water between different uses and users and often from adjacent rural areas to predominantly urban areas. Such re-allocations are often primarily motivated by price elasticity of demand differentiations between users. In the process, too much emphasis is placed on the financial, political and technological impacts and too little emphasis is placed on the socio-economic and environmental impacts of allocation decisions. This leads to ignorance of some of the spatial and temporal dimensions of resource allocation decision-making leading to a serious measurement problem (see Figure 1) with regard to measuring cost and benefits in resource allocation decision-making. From a cost perspective the measurement problem holds that current cost estimation methodologies cannot fully account for the total cost of different resource allocations, thereby assuming the risk of choosing a "more expensive" option (i.e. option A) above a "less expensive" option (option B) if all (total) costs could be taken into account.

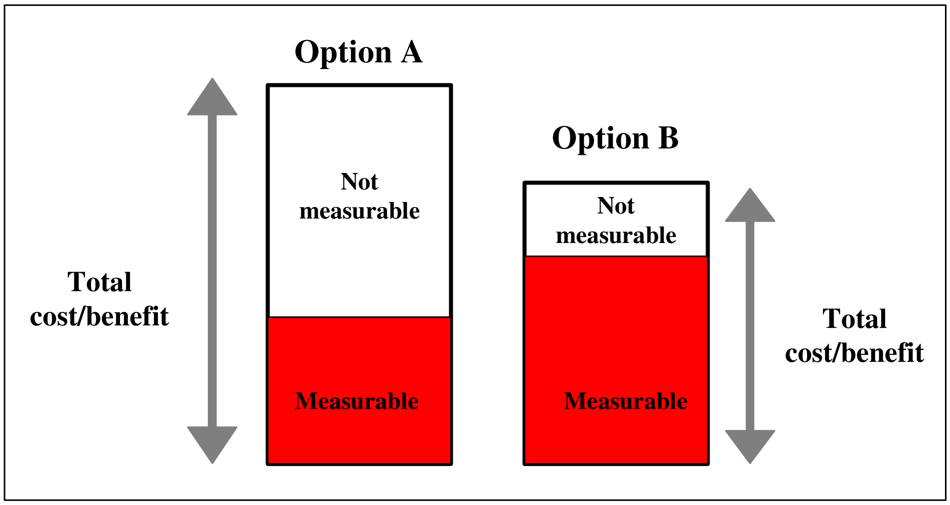

Figure 1: A measurement problem

Since different supply augmentation schemes have different proportions of measurable and non-measurable costs/benefits, the establishment of decisions predominantly on the "measurable" part of costs and benefits (see Figure 1) leads to resource allocations that are often contrary to broad government policies of efficient, but sustainable resource utilisation. As such, social welfare is unwittingly threatened. It could, therefore, be argued that the measurement problem narrows the allocation decision-making context. Allocation decisions are taken with incomplete information – a familiar scenario in the decision-making environment. However, the risk of ignoring the measurement problem results in unsustainable water resource utilisation, implying that management will realise their error (particularly adverse environmental effects) when it is too late or costly to reverse with negative social welfare impacts in the long-term. The need has, therefore, been identified to make resource allocation decision-making more sensitive to this measurement problem with the BWMA as a study area.

1.2 Orientation and context setting of research problem

The essence of this research is to embrace the measurement problem in long-term water resource allocation management in a politically sensitive way. The study assumes a water resource scarcity situation and that market and government allocation mechanisms are not completely satisfactory in terms of natural resource allocation because of the measurement problem. Government intervention is guided by resource allocation legislation with constant striving towards sustainability, efficiency, equity, and ultimately, social welfare maximisation[1]. Within such intervention, principal-agent relationships[2] emerge between the public (principal) and resource management authorities (agent).

Agents are confronted with the measurement problem, hampering their ability to account for all costs and benefits associated with different resource allocation options, i.e. a scenario of decision-making with incomplete information. User preferences account for part of such incomplete information, and the accommodation of public preference, therefore, forms a part of this study. The question could be asked that if consumers in sufficient numbers are willing to pay the premium for "greener" water, could this be presented as legitimate reason to opt for "greener" supply options. The purpose of the study is more fundamental, i.e. can economics accommodate public preferences as a regulatory instrument? For example, if "green" preferences for water management options are exogenously given, to what extent can or should agents make use of such preferences? Applications of the study are not limited to the field of natural resource management but apply to all fields where a principal-agent relationship is present (e.g. the medical aid and general insurance industries).

It should be noted that "green" preferences also impose social costs that could have a negative impact on social welfare maximisation. "Green" preferences as a regulatory policy instrument would make sense if the benchmark of "sustainable" resource allocation management were based on value judgments that differ from consumer preferences. Then, optimal environmental protection would be defined by reference to ethics, or, worse, by prescriptions from policy activists who promote their own preferences (by allocating greater weights to such criteria promoting their preferences) while giving those of the public at large (and the costs they bear) smaller weights.

Table 1 presents a conceptual layout of the above-mentioned argument presented in three columns. The first column contains the "problem statement" and point of departure for the second column, which presents relevant arguments for the problem. The third column proposes a "remedy" for the stated problem and leads to the subsequent problem statement.

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[1] In the broader sense of which the state of the environment also forms a part.

[2] The problem of resource allocation that arises because contracts that will induce agents to act in their principals' best interset are generally impossible to write or too costly to monitor (Lipsey and Courant, 1996:29).

Table 1: Conceptual layout of the study

Problem	Reasoning	Solution/Outcome
1 Market failure in water resource allocation	**2** Bulk water infrastructure has a public-good nature	**3** Government interference promotes social welfare maximisation.
4 Government failure in water resource allocation	**5** • Lobby groups • Public choice theory holds that hidden agendas and opportunity for own discretion of bureaucrats often leads to misuse of power. • Narrow decision-making context because of under-representation in management committee leading to "unsustainable" resource utilisation.	**6** • Control the controller – engage in principal-agent problem • Expand the decision-making context: o Expand physical boundaries of the decision-making context o Expand representation in terms of decision-makers and public preference o Expand decision-support mechanisms
7 Uncertainty whether public should participate in long-term strategic water management	**8** • Public compliance • Risk of "dictatorship of the uninformed"	**9** • Investigate public participation in long-term water resource management.
10 Uncertain how public should participate in water resource management	**11** • Risk of low response rates. • Objective public enquiry	**12** • Promote simple communication of a complex problem. • Transparency of the process will avoid expert and political critique regarding bias and rejection based on perceived bias in *modus operandi* of obtaining public opinion.

The market as allocation mechanism for natural resources does suffice for individual allocation decision-making, but cannot account for bulk resource allocation while simultaneously promoting social welfare maximisation (Block 1). One of the main reasons for this is that bulk-water infrastructure, as a public good, is often an example of market failure (Block 2) because market solutions to the allocation problem are the summation of the outcome of individual preference orderings (refer to the work of Kennith Arrow and the "impossibility theorem" (Arrow, 1951; Arrow, 1984a; Arrow, 1984b)). To present such an allocation as an optimal social allocation would be wrong since the individual market player did not aim his participatory behaviour towards social welfare but merely towards promoting his own. The market solution to the allocation problem is, therefore, merely an alternative allocation and cannot claim to maximise social welfare. Even if some altruistic behaviour is allowed, the market will still not promote social welfare because the individual decision-maker (market participant) is inherently limited by his personal preference ordering. This implies a faulty, telescopic view of resource allocation from the individual's perspective, which consequently, does not promote social welfare maximisation. A need, therefore, emerges for government interference (Block 3) in accounting for market failures in the case of public goods to maximise social welfare.

However, government failures in terms of resource allocation can and do occur (Block 4), amongst others due to hidden agendas and the admissibility of own discretion, often leading to the misuse of power. A narrow decision-making context owing to the measurement problem and under-representation in management committees could also be put forward (Block 5) for such failures. A need is, therefore, created to "control the controller" (Block 6) in order to ensure that government intervention promotes social welfare maximisation. This study suggests broadening the decision-making context in terms of temporal and spatial dimensions to partially satisfy this need. Consequently, decision-support techniques also need to be expanded. Temporal expansion could be implemented by considering sequences of supply augmentation schemes over time instead of different schemes at the same time. Spatial expansions could be implemented by expanding the physical decision-making boundary to include rural areas adjacent to the CCT and the BWMA. Expansion of this nature implies an expansion in representation from management and the public, leading to greater accommodation of public preferences. (i.e. these parties' preferences need to be consulted and not assumed). Expansions as contemplated above, thus, have significant impacts on the information load of decision-making and the decision-making criteria used in the process.

It is, however, uncertain whether the public should indeed be consulted with regard to long-term strategic water management issues (Block 7). Long-term water resource management has become a specialized and complex field, and the relative legitimacy of involving the general public in this type of situation becomes questionable (Block 8). However, upon investigation of the impacts of accommodating public preferences in strategic decision-making, evidence from the literature suggests tapping into public preference for water resource management (Block 9).

The exact methodology of public enquiry to obtain a legitimate answer is still uncertain (Block 10). Uncertainty refers to the objective representation of management options and the achievement of acceptable response rates from public enquiry without attracting criticism regarding bias concerning management options. The public is not an expert in long-term management, and care should, therefore, be taken not to lead public preferences (Block 11). An acceptable response rate could be achieved through simple communication of a complex problem. However, this requires advanced insight in the management problem and a limitation of relevant information. Transparency in the public enquiry process will avoid expert and political critique regarding bias. This implies that politicians and experts should buy into the public enquiry process from the inception stage.

The main objectives of the study could be summarised as follows:

- Decision-support techniques need to be expanded, refined and applied in a broader context to safeguard against the measurement problem.
- A need was identified to determine how and to what extent public opinion should be accommodated in long-term water resource management. This is because effective communication lies at the heart of successful contracting, and at present a reversed principal-agent relationship was found to exist between public and water management authorities in the BWMA. Questions regarding the rationale of simplifying complex problems, such as strategic water management, and presenting such questions to the public in order to obtain public preferences, came to the fore.
- The importance of the political process running parallel to such exercises must be acknowledged and accommodated – it should be made as transparent and tangible as possible.

To summarise, the measurement problem leads to market and government failures in managing the allocation of natural resources. Decision-support techniques, including multi-criteria decision-making (MCDM), are employed to aid in this regard, but they need to be refined to allow the confident capturing of longer-term management impacts in the broader decision-making context. This study engages in such refinement, specifically in terms of the spatial and temporal dimensions of the resource allocation decision-making context. Such expansions have direct impacts on the information load of resource allocation decision-making as well expansions of decision-support techniques. It should be clear that a systems thinking approach is called for, with MCDM being only part of an integrated management approach to long-term water allocation management. MCDM should certainly not be seen as a fail-safe method to ensure that all parties' welfare will be maximised, but rather as a method of making the water management process more tangible through making risks and uncertainties more explicit.

1.3 Chapter layout

The dissertation is presented in six chapters, a list of references and six annexures. The first chapter served as a general introduction and as a structuring and orientation of the research problem. It is followed by Chapter 2, which is a discussion of water resource management in the BWMA with regard to important demographics, water balance and future augmentation options for the area. The chapter also applies the research problem to the BWMA and discusses water management in the BWMA. Chapter 3 provides the theoretical foundation of the research problem. Short overviews of market and government resource allocation structures are given, followed by a discussion on public participation and decision-support techniques in resource allocation management. Chapter 4 develops the proposed expansions to decision-support techniques to account to a greater extent for the research problem. Expansions in the temporal and spatial dimensions of the decision-making context are discussed in detail as are details regarding two surveys, which played an important role in such expansions. Chapter 5 presents the outcomes of the two enquiry processes as well as the main contributions of the process. The last chapter consists of the conclusions, summary and recommendations for future research.

2. WATER MANAGEMENT IN THE BWMA

2.1 Introduction

Chapter 1 structured the research problem and provided the theoretical line of logic for application in the remainder of the study. However, the problem needs to be "grounded" or contextualised in physical terms to provide a framework for its application; failure to do this would cause the problem to "hang in the air" and would prevent generalised conclusions from being drawn from the outcomes.

This chapter fulfils the aforesaid requirement by describing the basics of bulk-water resource management in the BWMA. Section 2.2 presents the relevant demographics of the BWMA while Section 2.3 describes the water balance situation consisting of a detailed breakdown of current supply infrastructure (Western Cape Supply System – WCSS) and demand figures. Future demand estimations are discussed as well as possible augmentation schemes to meet growing demand. Section 2.4 applies the measurement problem to the BWMA, and Section 2.5 discusses the current management of the area in terms of allocation management, the rationale of following an integrated approach and the political process of water management in the BWMA.

2.2 Demographic orientation

South Africa has an uneven spatial distribution and significant inter- and intra-seasonal variations of rainfall over almost the entire country. With an average rainfall of only 450 mm per year, the country falls well short of the 860mm world average (Western Cape Department of Agriculture, 2005:110-113). The country could therefore be seen as a water-scarce region with 10 of the 19 water management areas (see Figure 2) facing water deficits (Department of Water Affairs and Forestry, 2004c:3). The population distribution of South Africa does not correlate with the distribution of water, mostly because of historical motivations (for example, the discovery of gold). The water requirements of urban and densely populated regions tend to exceed the supply of water, although a small surplus still exists for the country as a whole. Surface water features as the main source of water in South Africa with a combined discharge of approximately 49000 million cubic metres per year (Department of Water Affairs and Forestry, 2004c:20), which is approximately 141 times smaller (in terms of its mean annual discharge) compared to the Amazon river.

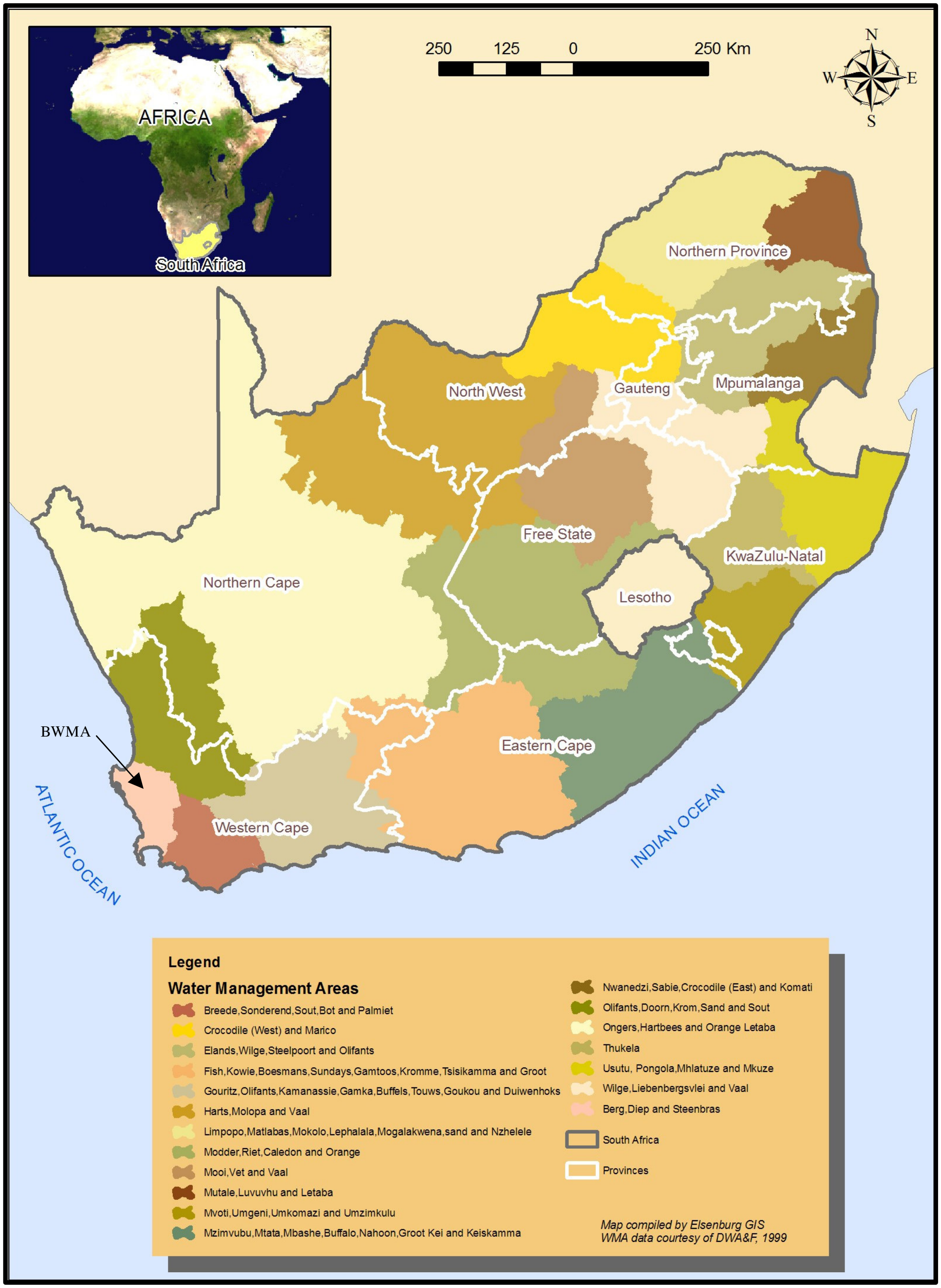

Figure 2: Water management areas and provincial boundaries of South Africa

Source: (Western Cape Department of Agriculture, 2005)

The BWMA is water management area number 19 in South Africa (see Figure 2) and is situated in the Western-Cape Province of South Africa (see Figure 3 more detail on the Western Cape).

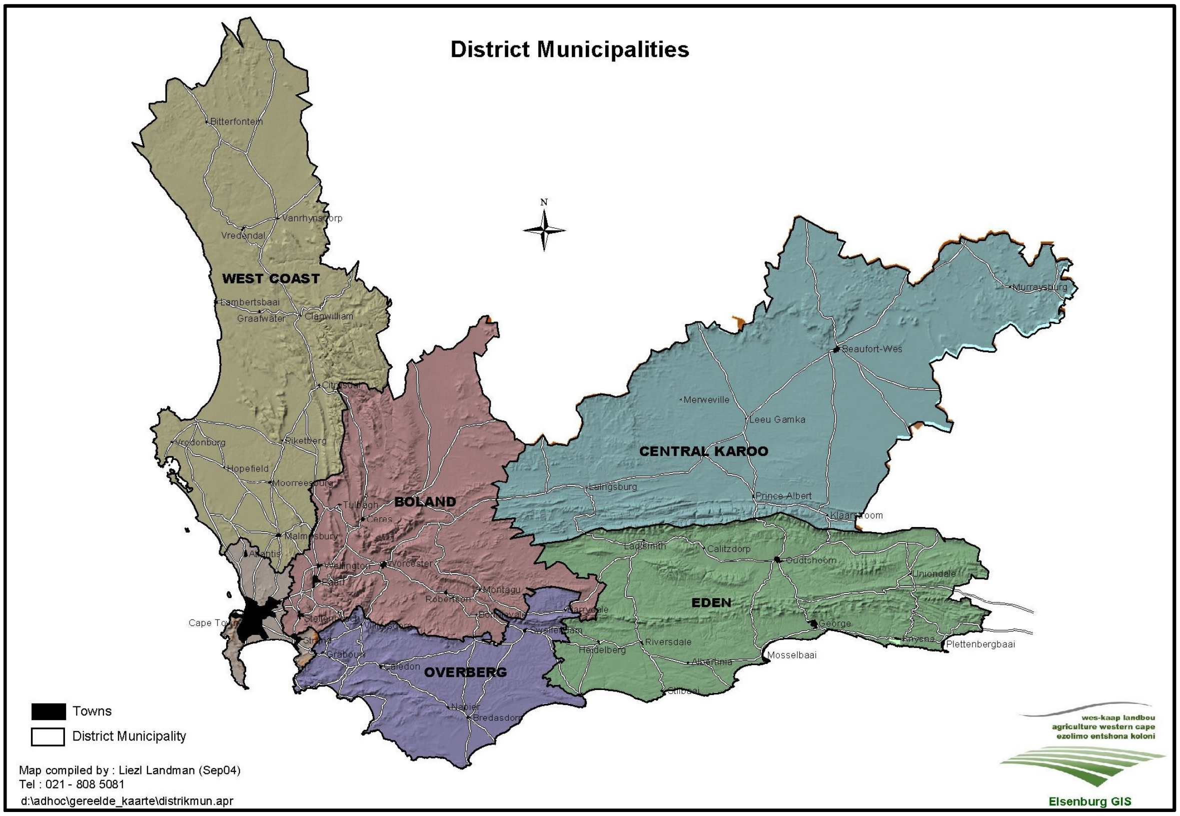

Figure 3: District municipal boundaries in the Western Cape province

Source: (Western Cape Department of Agriculture, 2005)

The BWMA is presented in Figure 4.

Figure 4: The Berg Water Management Area

Source: (Basson and Rossouw, 2003)

The BWMA is sub-divided into eight smaller management areas (see Figure 5).

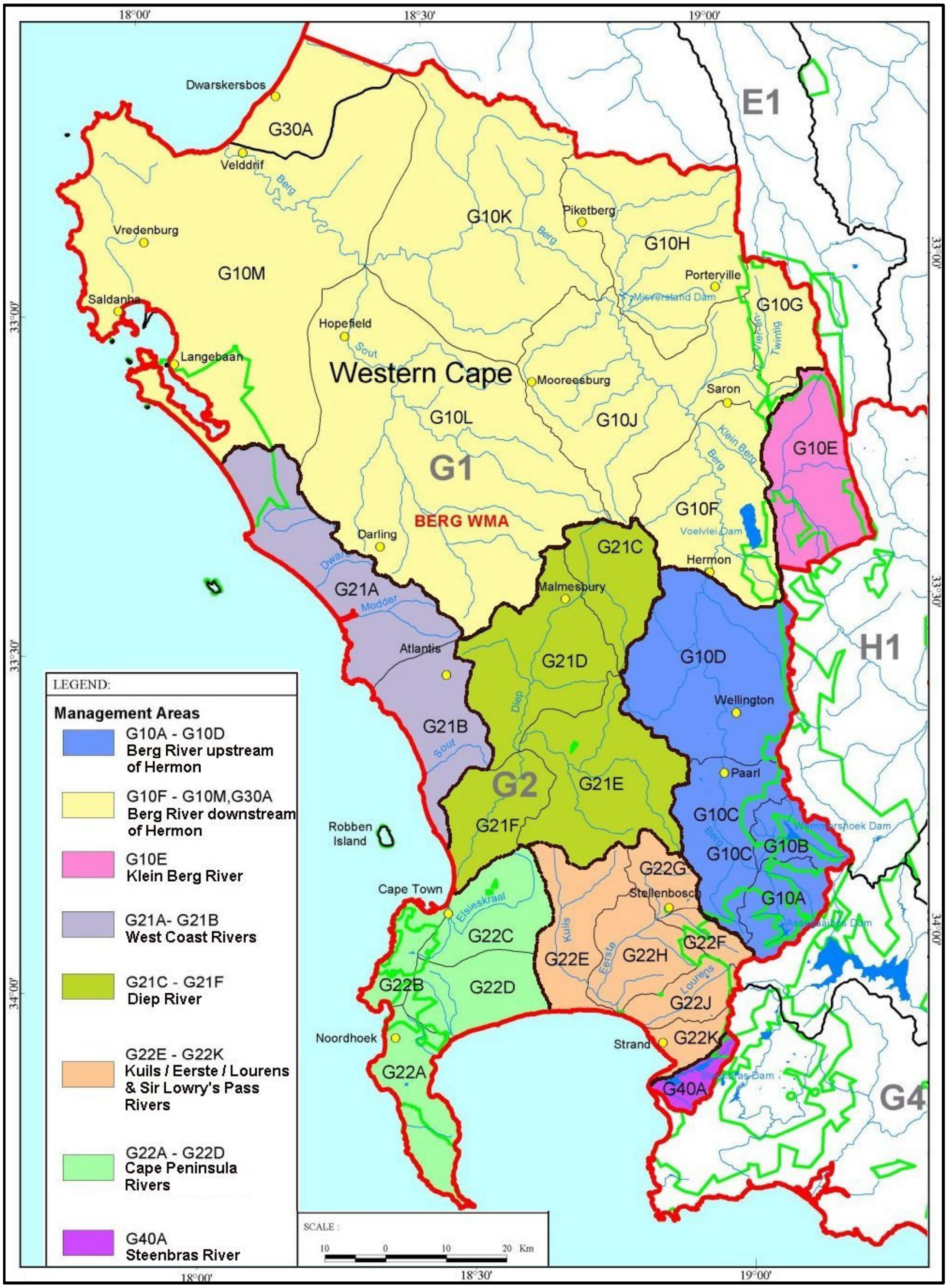

Figure 5: Eight sub-areas of the BWMA

Source: (Department of Water Affairs and Forestry, 2004b)

The BWMA is characterized by a Mediterranean climate and historically strong deterministic water supply (winter rainfall) from April to August. The average rainfall is 348mm per year, which is lower than the average of 450mm per year for the whole of South Africa. The area is, therefore, prone to seasonal droughts. Geographic variation in rainfall is significant, ranging between 3000 mm per year in the mountainous areas of Stellenbosch to less than 300 mm per year in the northwest of the area (see Figure 6). The BWMA has a MAR of 1429 million cubic metres per annum (see Table 2), the bulk of which (see Figure 6) derives from the mountainous east and southeast areas. Most of the inflows to bulk storage dams take place during winter when 90 percent of the annual runoff occurs, and water demands comprise only 30 percent of the annual demand (Department of Water Affairs and Forestry, 2004a). The summer months of November to February, are warm and dry, and are characterized by high evaporation losses, increased irrigation demands and small inflows. Approximately half of the storage capacity is required to meet the high summer demand with the difference remaining for long-term carry over storage. The area is, therefore, prone to water restrictions with storage levels dropping to the minimum during March/April. An annual water audit is done during November when decisions regarding the alleviation of water restrictions are taken.

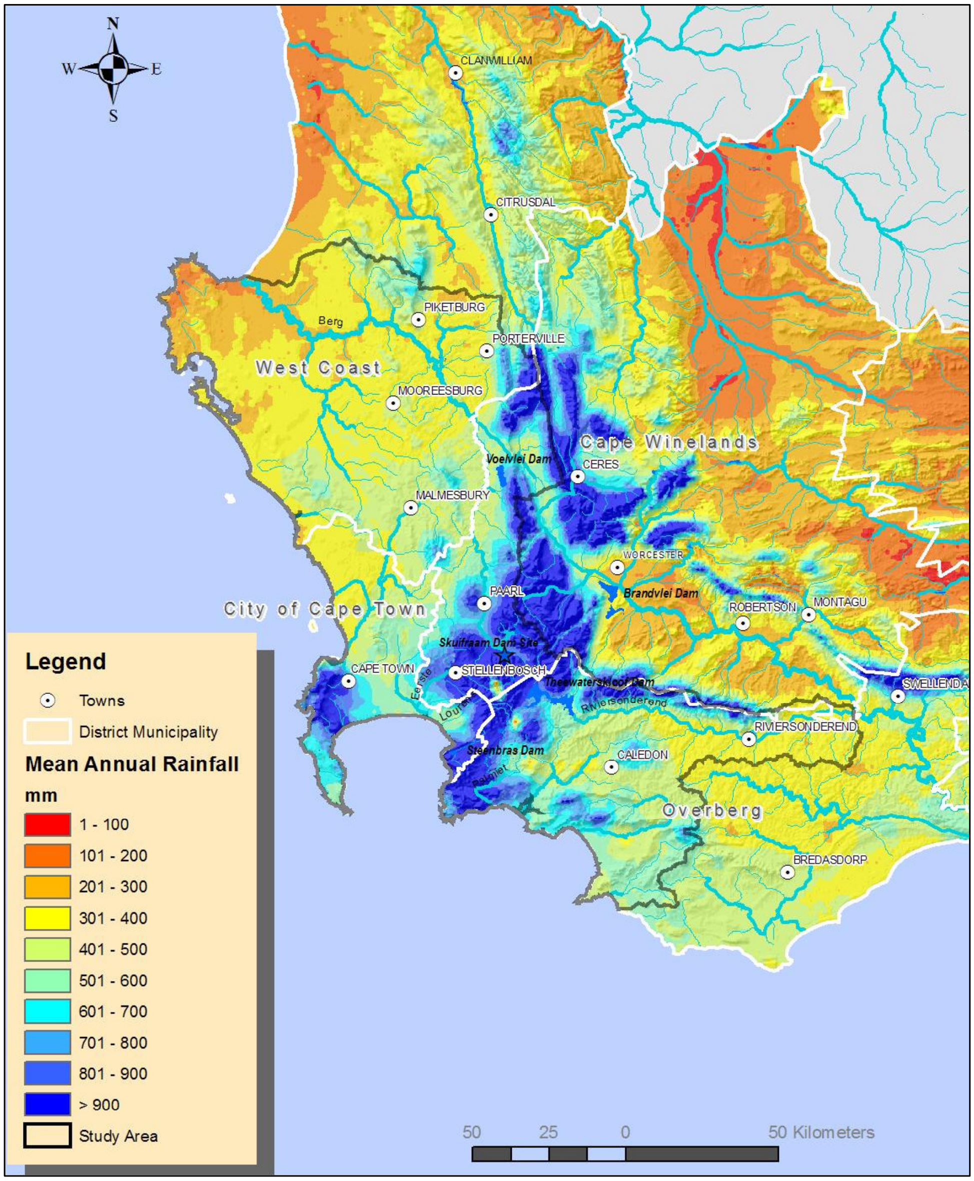

Figure 6: Mean annual precipitation in the Western Cape

Source: (Western Cape Department of Agriculture, 2005)

Table 2: Natural MAR and ecological reserve for the BWMA

	Natural MAR (Mkl/a)	Reserve (Mkl/a)
CCT	373	61
Upper Berg	849	124
Lower Berg	207	32
Total BWA	1429	217

Source: (Department of Water Affairs and Forestry, 2004a)

A strong and diversified economy exists in the BWMA. The economy is dominated by the manufacturing, transport and service sectors, which are mainly situated in the CCT, but with close linkages particularly to agriculture (see Figure 7). The region has a population of approximately 3 482 000 people and accounts for approximately 86 percent of the provincial gross regional product (Department of Water Affairs and Forestry, 2004a; Statistics South Africa, 2005).

The CCT, which is one of the major metropolitan cities and tourist destinations in South Africa, is the main water-user in the BWMA. The city comprises an area of approximately 2 500 km^2 with a population estimated at 2,6 million (Statistics South Africa, 2005). The deciduous fruit and viticulture industries are the main irrigated agricultural activities in the mountainous east and southeast areas. Moving to the central regions northwest of Paarl, Malmesbury and Moorreesburg this shifts to extensive rain-fed wheat cultivation (see Figure 7).

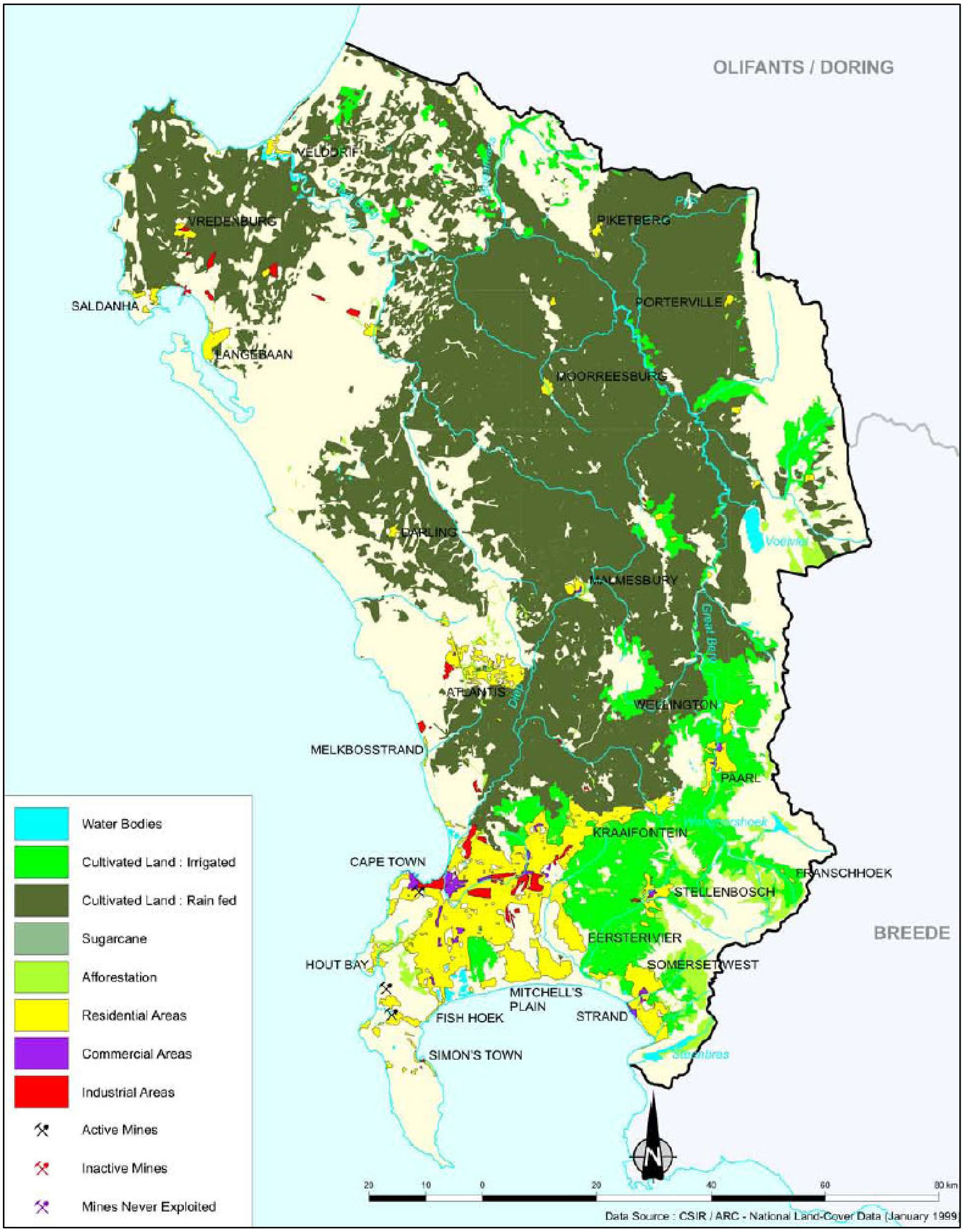

Figure 7: CCT land cover, Western Cape

Source: (Basson and Rossouw, 2003)

2.3 Water balance in the BWMA

The water balance of the region is determined by the difference between the supply and the demand for the resource. Numerous factors, which are mainly derived from the determinants of supply and demand, can influence the water balance. The following section discusses water balance as well as future augmentation options in the BWMA.

2.3.1 Supply in the BWMA

One of the most important motivations of water distribution infrastructure development is supplying water and securing an acceptably high level of assurance of its supply. Maintaining a high level of surety of water supply is also enforced by law in South Africa (National Water Act, 1998:33). The economic development of a city depends on the adequate supply of safe water for industry and agricultural production in the surrounding areas. A lack of, or inadequate provision of, safe water and sanitation services results in poor living conditions, which significantly increases the risk of poor health among the rural and urban poor.

The bulk-water supply infrastructure in the BWMA is called the Western Cape Supply System (WCSS) (see Figure 8). Apart from numerous smaller rural and on-farm storage dams, this is the main system supplying the BWMA with serviced water. It is jointly owned by the local Department of Water Affairs and Forestry, the CCT and various district municipalities. All serviced water is bought in bulk from the local Department of Water Affairs and Forestry. It should be made clear that almost all urban demand in the BWMA is serviced by the Western Cape Supply System, while agricultural irrigation demand is supplied by irrigation boards (linked to the WCSS) and supplemented by privately owned dams or own on-farm supplies.

Surface water comprises 57 percent (404 Mkl/a) of total annual supply (approximately 709 Mkl/a) to the BWMA. Large quantities (up to 27 percent of total annual supply or 191 Mkl/a) of water are transferred to the BWMA from the adjacent Breede Water Management Area via the Riviersonderend/Berg River Scheme (Theewaterskloof dam) and the Palmiet Pumped Storage Scheme (see Steenbras dam) (see Figure 8). Ground-water supplies, abstracted mainly in the central and western parts of the water management area, account for 8 percent (57 Mkl/a) of total annual supply (Department of Water Affairs and Forestry, 2004d:96). The remainder consists of useable return flows and estimated potential gains from alien removal.

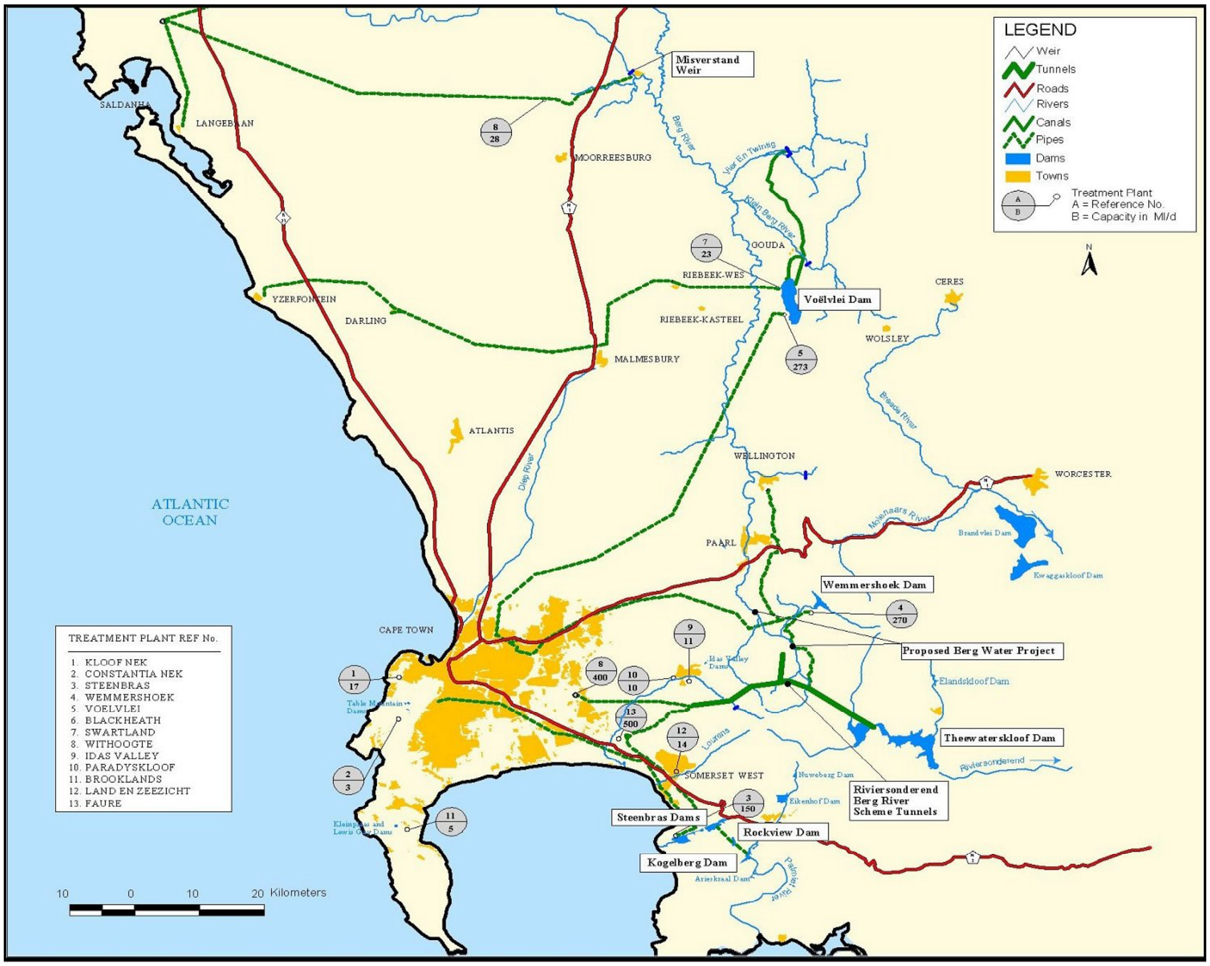

Figure 8: The Western Cape Supply System

Source: (Ninham Shand, 2002; Shand *et al.*, 2003)

The main storage schemes in the Western Cape Supply System are the Theewaterskloof scheme, Voëlvlei scheme, Wemmershoek scheme, Upper- and Lower- Steenbras schemes and the Berg Water Project (currently under construction). These schemes are operated in an integrated manner to maximise available storage for use in times of drought. This is made possible through linking the schemes to mitigate the effects of droughts by minimising spillages and wastages during the wet season and by restricting the supply for less essential uses during droughts (Department of Water Affairs and Forestry, 2004d). The storage capacity and ownership of the Western Cape Water Supply System is summarised in Table 3. It is important to differentiate between capacity and yield of the schemes; capacity refers to the gross capacity before spillage, while yield refers to the determined average total volume obtained/used from the particular scheme during one season.

Table 3: The main water supply schemes of the WCSS

Scheme	Gross Capacity (Mm^3)	Net System 1:50 Year Yield (Mm^3/a)	Owner	User
Palmiet Kogelberg Rockview	 17 17	 22	 DWAF; ESKOM	 CCT; ESKOM
Upper Steenbras	32	40	CCT	CCT
Lower Steenbras	34			
Wemmershoek	59	54	CCT	CCT; Drakenstein
Voëlvlei	172	105	DWAF	CCT; West Coast; Irrigators
Theewaterskloof	480	219	DWAF	CCT; Stellenbosch; Irrigators
TOTAL EXISTING	**811**	**440**		
Berg Water Project Supplement	127	56 25	TCTA	CCT; Irrigators; Overberg
TOTAL	**938**	**521**		

Source: (Kleynhans, 2002a; Ninham Shand, 2002; Shand *et al.*, 2003)

The latest addition to the WCSS is the Berg Water Project (BWP) which is a R1878 M (2005) project with the Trans-Caledon Tunnel Authority (TCTA) appointed as management authority (Department of Water Affairs and Forestry, 1997; Trans Caledon Tunnel Authority, 2005). It is estimated that the project will be completed in time to receive 2007 inflows (see Figure 7). Various other smaller schemes supply the CCT area (refer to Table 4). Their combined yield is estimated at 13 Mm3/a.

Table 4: Small water supply schemes in the CCT

Scheme	Catchment	Capacity	Treatment plant
Hely Hutchinson Dam	Disa River, Table Mountain	0,95 Mm^3	Kloofnek plant
Woodhead Dam	Disa River, Table Mountain	0,93 Mm^3	Kloofnek plant
Victoria Dam	Disa River, Table Mountain	0,13 Mm^3	Constantianek plant
Alexandra Dam	Disa River, Table Mountain	0,13 Mm^3	Constantianek plant
De Villiers Dam	Disa River, Table Mountain	0,24 Mm^3	Constantianek plant
Kleinplaas Dam	Woel River, Simons Town	1,36 Mm^3	Brooklands plant
Lewis Gay Dam	Woel River, Simons Town	0,18 Mm^3	Brooklands plant
Land-en-Zeezicht Dam	Lourens River	0,45 Mm^3	Somerset West
Nantes Dam	Paarl Mountain	0,82 Mm^3	Paarl
Bethel Dam	Paarl Mountain	0,54 Mm^3	Paarl
Idas Valley Dam	Eerste River	1,8 Mm^3	Stellenbosch

Source: (Kleynhans, 2002a)

Table 4 and Table 5 display raw-water supply to the WCSS. Table 5 displays the treatment work capacities of the WCSS.

Table 5: Main water treatment works of the WCSS

Treatment works	Source	Capacity (Ml/day)
Blackheath	Riviersonderend inter-basin transfer scheme	400
Faure	Lower Steenbras Dam; Theewaterskloof Dam and Palmiet pumping scheme	500
Steenbras	Lower Steenbras Dam	150
Voëlvlei	Voëlvlei Dam	273
Wemmershoek	Wemmershoek Dam	275
	Total capacity	**1598**

Source: (Kleynhans, 2002a)

Table 6 summarises the WCSS and its wastewater infrastructure.

Table 6: Summary of the WCSS and wastewater infrastructure

Supply infrastructure:	Number	Capacity/quantity	Estimated replacement value (R million)
Water treatment plants	13	1672 Ml/d	697
Storage reservoirs	131	3539 Ml	887
Pump stations	367	Unknown	234
Pipe lines		9058 km	5459
Major storage dams (excluding BWP)	5	780 Mm^3	Unknown
Sub total			**7277**
Wastewater infrastructure			
Wastewater treatment plants	20	620 Ml/d	620
Pump stations	320	190 kW	536
Pipe lines		8549 km	2498
Sub total			3655
Total			**10932**

Source: (Ninham Shand, 2001)

2.3.2 Demand in the BWMA

Demand for water in the WCSS is similar to numerous other African cities, where demand exceeds water availability (Department of Water Affairs and Forestry, 2003). With the CCT being one of the main growth centres in South Africa, its strong economic and population growth is projected to continue, and this will affect future requirements for serviced water. Historical and projected future water demands for the WCSS are shown in Table 7. The projections are based on the following:

Economic growth and water demand growth are positively correlated, and given that the Western Cape province is one of the fastest growing economies in South Africa, it is expected that future water demands will increase.

Water demand management will have significant impacts on water demand. A saving of up to 20 percent of current usage (2005) could be achieved within 10 years in accordance with the CCT's water demand management policy and strategy (Sparks, 2001). However, a diminishing marginal gain will be experienced as supply efficiency increases. Demand management strategies have therefore an inherent limited ability to accommodate future demand. Decreasing growth in irrigation demand will start to emerge as allocations from existing government water schemes become fully utilised. Urban and industrial growth along the West Coast will drive the growth in urban demand in spite of the implementation of various water demand management options. Additional supply will therefore be needed.

Table 7: Water demand estimation for the WCSS rationing-run July 2003[3]

Year ending 31st Oct	Urban						Largely Agricultural													Selected Totals							Other scenarios		
	Metro (note 1)			Other Urban			Voelvlei		Riviersonderend					Berg				Eerste		Urban			Agricultural	Urban + Agric			WDM (Note 7)		
	Total / low water demand projection	Less water from smaller sources	Nett on major dams	Swartland, PPC & Piketberg	Withoogte	Stellenbosch	24 Rivers Canal abstractions	Berg Riparian with losses	RSE IB (Note 6)	Overberg	Vyeboom	Direct pumping	RSE subtotal	Berg Siphon	Summer streamflow	Berg subtotal	Banhoek IB + Dasbos	Helderberg + Stellenbosch IB	Eerste R Releases plus compensation	Domestic	Industrial	Domestic + Industrial		Total	less Comp(Note6)	WCSA equiv (no comp)	Urban	Agric (2% Growth)	Total
WRPM DC			51	68	272	39	70	273					10			271	27	49	47										
Yield	0	0	1	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	1										
1995	300	-15	285	4	10	2	25	9	20	2	9	0	31	38	17	54	2	9	8	223	78	301	114	415	-36	379	301	78	379
1996	297	-15	282	4	10	2	19	8	20	2	7	0	30	34	17	51	2	9	3	220	77	298	102	399	-36	363	297	71	368
1997	307	-19	288	5	10	1	23	10	20	2	4	0	27	20	17	36	1	5	5	225	79	304	84	388	-36	352	305	52	357
1998	313	-15	298	5	12	1	22	23	27	2	14	0	44	36	17	52	1	9	4	235	82	317	133	450	-36	414	321	101	422
1999	328	-10	318	6	13	4	18	20	21	2	16	1	41	43	17	59	2	17	3	252	89	341	142	483	-36	447	344	111	455
2000	332	-10	323	7	15	4	21	41	15	3	10	0	28	43	17	59	2	17	3	258	91	348	151	499	-36	463	347	129	476
2001	287	-10	277	5	13	2	19	28	31	3	11	1	46	49	17	65	2	21	3	220	77	298	165	463	-36	427	354	132	486
2002	295	-10	285	5	11	1	18	28	26	3	9	2	39	27	17	43	2	14	2	224	79	303	128	431	-36	395	356	134	490
Max over 2001/03				7	15	4	21	41	31	3	11	2	46	49	17	65	2	21	3										
2002/3 Allocations				6	22	3	20	18	31	4	13	2	50	49	17	65	2	18	4										
Growth Rate	2%			6%	6%	2%	0%	0%	2%	2%	0%	0%	2%	2%	0%	2%	0%	2%	0%										
Capping Value	999			99	99	99	20	18	32	99	13	2	145	59	17	75	2	24	4										
2003 Projection	315	-14	301	6	22	3	20	18	31	4	13	2	50	49	17	65	2	18	4	245	86	331	156	488	-36	452	351	137	489
2003 Estimate	300?			5?	13?	3?	?	21?	?	?	?	?	?	49?				16?											
2003 Selection	315	-14	301	5	14	3	20	21	31	4	13	2	50	49	17	66	2	18	4	239	84	323	160	483	-36	447	356	134	490
2005	321	-14	307	6	15	3	20	21	31	4	13	2	50	50	17	66	2	18	4	245	86	331	162	493	-36	457	351	140	491
2006	328	-14	314	6	16	3	20	21	32	4	13	2	50	51	17	67	2	19	4	250	88	338	163	502	-36	466	351	140	491
2007	334	-14	320	6	17	3	20	21	32	4	13	2	50	52	17	68	2	19	4	256	90	346	165	511	-36	475	351	140	491
2008	341	-14	327	7	18	3	20	21	32	4	13	2	51	53	17	70	2	19	4	262	92	355	166	521	-36	485	351	140	491
2009	348	-14	334	7	19	3	20	21	32	4	13	2	51	54	17	71	2	20	4	269	94	363	168	531	-36	495	351	140	491
2010	355	-14	341	8	20	3	20	21	32	5	13	2	51	55	17	72	2	20	4	275	97	371	170	541	-36	505	351	140	491
2011	362	-14	348	8	21	3	20	21	32	5	13	2	51	56	17	73	2	21	4	281	99	380	171	551	-36	515	351	140	491
2012	369	-14	355	9	22	4	20	21	32	5	13	2	51	57	17	74	2	21	4	288	101	389	173	562	-36	526	351	140	491
2013	376	-14	362	9	24	4	20	21	32	5	13	2	51	59	17	75	2	22	4	295	104	399	174	573	-36	537	351	140	491
2014	384	-14	370	10	25	4	20	21	32	5	13	2	51	59	17	75	2	22	4	302	106	408	175	583	-36	547	351	140	491
2015	392	-14	378	10	26	4	20	21	32	5	13	2	51	59	17	75	2	22	4	309	109	418	176	593	-36	557	351	140	491
2016	399	-14	385	11	28	4	20	21	32	5	13	2	51	59	17	75	2	23	4	317	111	428	176	604	-36	568	351	140	491
2017	407	-14	393	11	30	4	20	21	32	5	13	2	51	59	17	75	2	23	4	324	114	438	177	615	-36	579	351	140	491
2018	416	-14	402	12	31	4	20	21	32	5	13	2	51	59	17	75	2	24	4	332	117	449	177	626	-36	590	351	140	491
2019	424	-14	410	13	33	4	20	21	32	5	13	2	52	59	17	75	2	24	4	341	120	460	178	638	-36	602	351	140	491
2020	432	-14	418	14	35	4	20	21	32	5	13	2	52	59	17	75	2	24	4	349	123	471	178	649	-36	613	351	140	491
2021	441	-14	427	14	37	4	20	21	32	6	13	2	52	59	17	75	2	24	4	358	126	483	178	661	-36	625	351	140	491
2022	450	-14	436	15	40	4	20	21	32	6	13	2	52	59	17	75	2	24	4	366	129	495	178	673	-36	637	351	140	491
2023	459	-14	445	16	42	4	20	21	32	6	13	2	52	59	17	75	2	24	4	376	132	508	178	686	-36	650	351	140	491
2024	468	-14	454	17	45	4	20	21	32	6	13	2	52	59	17	75	2	24	4	385	135	520	178	699	-36	663	351	140	491
2025	477	-14	463	18	47	5	20	21	32	6	13	2	52	59	17	75	2	24	4	395	139	533	178	712	-36	676	351	140	491
2026	487	-14	473	19	50	5	20	21	32	6	13	2	52	59	17	75	2	24	4	405	142	547	178	725	-36	689	351	140	491
2027	497	-14	483	20	53	5	20	21	32	6	13	2	53	59	17	75	2	24	4	415	146	561	179	740	-36	704	351	140	491
2028	507	-14	493	22	56	5	20	21	32	6	13	2	53	59	17	75	2	24	4	426	150	575	179	754	-36	718	351	140	491

Source: (Sparks, 2003; Sparks, 2005)

Annexure 1 displays an example of water demand estimations done for the WCSS. It should be noted that urban demand is significantly greater than agricultural demand. Similar estimations are done on a regular basis. A clear distinction should also be made between water usage in the WCSS water service area and total water usage in the BWMA, since not all irrigation usage is distributed through the WCSS, while all water supplied to urban areas in the BWMA is distributed through the WCSS. It is estimated that up to 74 percent of the WCSS goes to urban use, while the difference (26 percent) is allocated to agricultural use (see Table 7).

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[3] Note 1: Metro includes treated water supplied to Paarl and Wellington.
Note 2: Riviersonderend IB releases includes 3,18 Mkl/a compensation and losses.
Note 3: Withoogte abstraction at Misverstand assumed 21,75 = 17,4*0,75(exclude 3 months winter flow)/0,75(25 percent losses) + 17,4 *0,25(winter component from run of river).
Note 4: Historical supply to Berg River Irrigators was 27 Mkl/a which is greater than their 18,1 allocation.
Note 5: Eerste River IB releases include 1,5 Mkl/a compensation.
Note 6: Comprising compensations of 31,8 Mkl/a + 4 million m^3/a of run of river water abstracted from Misverstand Dam during winter.
Note 7: See (Department of Water Affairs and Forestry, 1991; Department of Water Affairs and Forestry, 1994; Louw and Kassier, 2002; Shand *et al.*, 2003; Sparks, 2001)

Figure 9 presents the expected long-term growth in demand for the WCSS. It assumes a less than 0.5 percent growth in demand for agricultural use, while a 2 percent growth rate for urban demand is used (Killick, 2006; Kleynhans, 2002a; Sparks, 2003; Sparks, 2005). Stabilisation in demand after 1999 was the result of strict water demand management, which came into being during the commencement of the Integrated Water Resource Planning (IWRP) study (Du Plessis *et al.*, 2001). Water restrictions, (although strictly speaking not a water demand management strategy), in particular, decreased demand. Even though the BWMA features as one of the more efficient water management areas in the Western Cape, a significant margin for efficiency gains still exists in irrigated agriculture, especially with regard to the maintenance and operational management of irrigation systems (Roux, 2005a; Roux, 2005b). Demand management strategies will dampen increases in growth only temporarily because as demand grows over time (as a result of external drivers of demand) the initial gains of the demand management strategies are taken up. Consequently, alternative supplies will be needed to increase the total yield capacity of the system to ensure an acceptable level of assurance of supply.

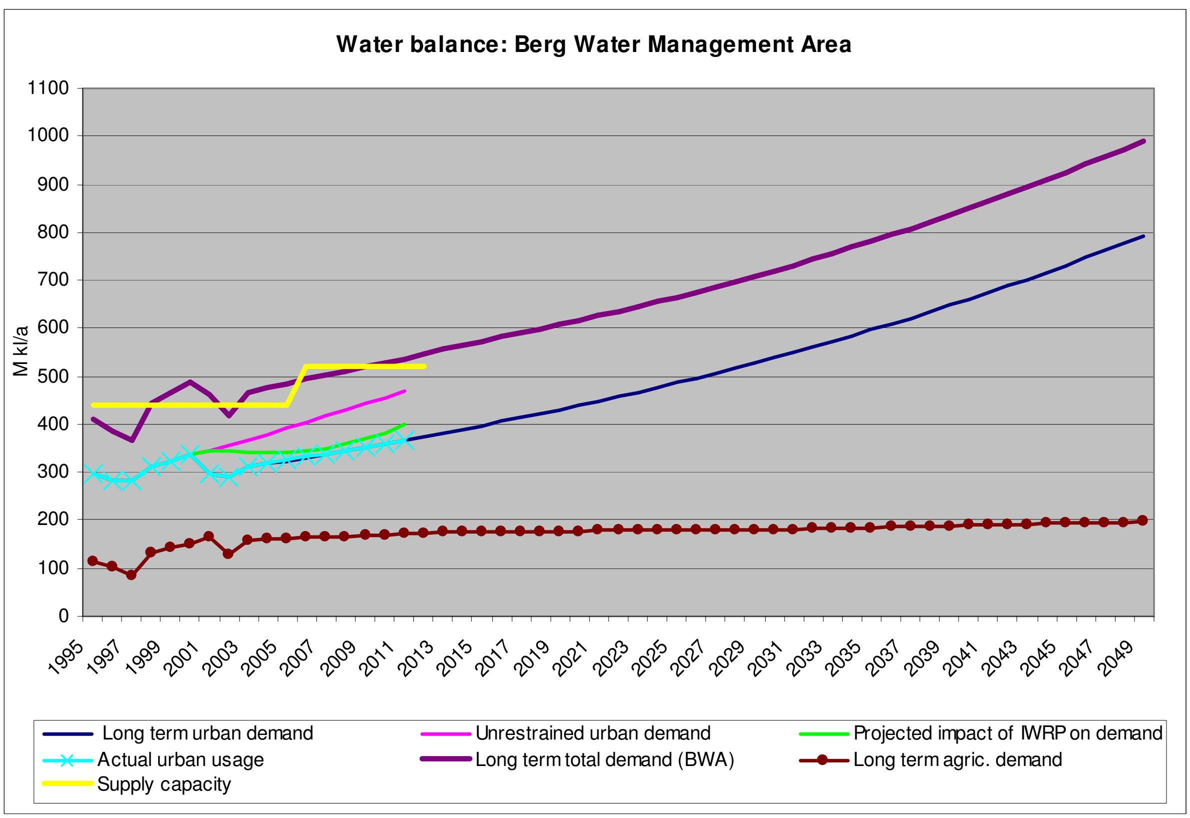

Figure 9: Water balance for the BWMA

Source: (Killick, 2006; Kleynhans, 2002a; Ninham Shand, 2001)

Figure 9 displays the supply capacity (yellow line) of the Western Cape System. According to the projections, the addition of the BWP in 2007 will only realise a maximum of four to six years of surplus capacity after which additional supply will again be needed.

Table 8 confirms that, even with effective water demand management, existing supplies to the region are likely to bring about an increasing need for restrictions until the BWP is completed and that additional sources of supply will be required as early as 2012 to 2013.

Table 8: Comparison of demand and supply in the WCSS

Year	Estimated demand (Mkl/a)	Estimated supply (Mkl/a)	Potential shortage (Mkl/a)
2003	452	440	12
2007	493	440	53
2009	515	521[4]	Nil
2020	641	521	120

Source: (Shand et al., 2003)

The maintenance of a high level of assurance of supply level for urban use is the highest priority for all service providers in the BWMA. Current resources struggle to meet the required 98 percent assurance of supply level implying that a need for the development of additional water resources will become a matter of urgency by 2012. Since the implementation of bulk-water supply projects can take up to 10 years from feasibility study level to completion, it is essential that future supply projects be confirmed as soon as possible in order for the CCT and other water service providers to plan accordingly for the conveyance and treatment of water.

2.3.3 Future augmentation schemes

It has been shown that demand management strategies will not be able to cater for future increases in demand in the WCSS and that it will be necessary to augment supply capacity by developing additional water sources in the near future. Increased demand is mainly due to the main drivers of demand (De Lange, 2005; Killick, 2006; Mostert, 2004; Sparks, 2005):

- Population demographics (including urbanisation);

[4] After the completion of the BWP.

- Economic growth demands more water;
- Climatic changes in long-term rainfall patterns impact on surface flows and drainage;
- Pollution decreases usable volumes.

Numerous studies have been undertaken on developing future augmentation schemes for the WCSS. The Western Cape Reconciliation Study (WCRS) is currently investigating the development of future strategies to reconcile projected water demands with supply from the WCSS (Thompson, 2005). This study builds on the Western Cape System Analysis (WCSA) (Department of Water Affairs and Forestry, 1991; Department of Water Affairs and Forestry, 1993), the IWRP study (Du Plessis *et al.*, 2001) and the Cape Metropolitan Area Bulk Water Supply (CMABWS) study (Eberhard and Joubert, 2002; Kleynhans, 2002a; Kleynhans, 2002b) that were undertaken between 1989 and 2002, at which time various alternative methods of augmenting the water supply were investigated.

These studies emphasized the use of a combination of demand and supply strategies for water management in the BWMA and the CCT. Their recommendations concerning demand management options have been presented to the CCT city council. Subsequently, a number of these strategies have been incorporated into the Council's water demand management strategy. Various alternative supply augmentation schemes were analysed, some at feasibility level, but most at pre-feasibility level (see Table 9).

A decision to go ahead with a detailed design for the Voëlvlei augmentation scheme Phase 1 has been put on hold even though it was ranked quite high in Eberhard and Joubert (2002) and Joubert et al. (2003) pending further information on what allocations will be made to the CCT from the BWP. A pilot project for the development of the Table Mountain Group Aquifer (TMGA) was also given the go-ahead in 2005. This will involve the drilling of several test boreholes in order to better assess the true viability of the option (City of Cape Town Administration, 2003a; City of Cape Town Administration, 2003b; City of Cape Town Administration, 2004a; City of Cape Town Administration, 2004b; City of Cape Town Administration, 2004c). A feasibility study on desalination as a supply option was also given the go-ahead, signalling the possibility of implementing this option in the near future (Kleynhans and Schutte, 2002; Thompson, 2005).

Table 9: Future supply augmentation schemes in the WCSS

Scheme	Study
Berg river project (Skuifraam dam)	(Department of Water Affairs and Forestry, 1997; Ninham Shand, 2001)
Brandvlei transfer scheme	(City of Cape Town, 2002; Joubert *et al.*, 2003; Kleynhans, 2002a; Ninham Shand, 2001)
Molenaars diversion	(City of Cape Town, 2002; Kleynhans, 2002a)
Table Mountain Group aquifer	(City of Cape Town, 2003a; City of Cape Town, 2003b; City of Cape Town, 2004a; City of Cape Town, 2004b; City of Cape Town, 2004c; Kleynhans, 2002a)
Voëlvlei augmentation scheme Phase 1	(Kleynhans, 2002a; Ninham Shand, 2001)
Voëlvlei augmentation scheme Phases 2 and 3	(City of Cape Town, 2002; Ninham Shand, 2001)
Steenbras augmentation scheme	(Kleynhans, 2002b; Ninham Shand, 2001)
Eerste river diversion	(City of Cape Town, 2002; Du Plessis *et al.*, 2001; Ninham Shand, 2001)
Lourens river diversion	(Du Plessis *et al.*, 2001; Kleynhans, 2002b)
Cape Flats aquifer	(Du Plessis *et al.*, 2001; Kleynhans, 2002b)
Desalination of seawater	(Kleynhans, 2002a; Kleynhans and Schutte, 2002; Shand *et al.*, 2003; Thompson, 2005)
Treated wastewater for local irrigation and industrial use	(Du Plessis *et al.*, 2001; Kleynhans, 2002a)
Treated wastewater for commercial irrigation	(Du Plessis *et al.*, 2001; Kleynhans, 2002a)
Treatment of wastewater to potable standard	(Du Plessis *et al.*, 2001; Kleynhans, 2002a)

Most of the above-mentioned projects are currently under review in the Western Cape Reconciliation Study (Thompson, 2005). The yields and comparative unit reference values (URV[5]) of potential future supply schemes are shown in Table 10.

[5] The URV is seen as the standard financial comparative variable for bulk supply schemes (Kleynhans, 2005; Shand, 2005).

Table 10: Comparison of selected future water supply options

Management options	Potential yield (Mm^3/a)	URV (R/kl)	Located outside CCT
Water demand management options:			
Pressure control	17	0,23	N/A
User education	10	0,5	N/A
Leakage repair	16	0,19	N/A
Tariff adjustments	10	N/A	N/A
Water efficient fittings	10	0,31	N/A
Surface water:			
Lourens river	19	0,46	No
Voëlvlei Phase 1	35	0,53	Yes
Eerste river	8	1,06	No
Raise Steenbras + Palmiet dams	45	unknown	No
Voëlvlei Phase 2	30	unknown	Yes
Voëlvlei Phase 3	125	unknown	Yes
Raise Misverstand weir	30	unknown	Yes
Upper Molenaars diversion	27	0,82	Yes
Brandvlei –Theewaterskloof tunnel	41	1,14	Yes
Groundwater:			
Cape Flats aquifer	18	1,13	No
TMG aquifer	80 (exp)	1,00	Yes
Effluent re-use:			
Local irrigation and industrial	11	0,80	Yes/No
Commercial irrigation exchange	5	1,62	Yes/No
Potable standard	46	3,10	Yes/No
Desalination of seawater	Unlimited	7,55	No

Source: Adapted from (Shand *et al.*, 2003)

Table 10 indicates that a number of the supply augmentation schemes will supply water from outside the CCT municipal boundaries to the city (see discussions on this issue in Sections 2.4 and 2.5).

Some of the most important conclusions of the IWRP and the CMABWS studies are listed below (Du Plessis *et al.*, 2001:53-60; Kleynhans, 2002a):

- Water demand management options, such as pressure management, user education, elimination of automatic flushing urinals, leakage repairs, tariff changes, metering and credit control, and water-efficient fittings are highly cost-effective and should be implemented.
- The development of private boreholes and grey-water use by private individuals are less cost effective, and grey-water has potential health hazards, especially from the Cape Flats aquifer.
- The raising of Lower Steenbras Dam will provide significant additional storage in the BWMA and some improvement in yield, but it is likely to be costly and will have some environmental impacts, particularly if additional water is abstracted from the Palmiet river.

- The raising of Misverstand weir will have an impact on the in-stream and estuarine flow requirements. Water quality might also be compromised.
- The Voëlvlei Phase 1 augmentation scheme appears to be a favourable option.
- The Voëlvlei Phase 2 scheme will entail raising Voëlvlei dam and increasing diversions into the dam. Also, potential algal problems might have an impact on the viability of this option.
- The Cape Flats aquifer is sited in an urban area with concomitant pollution risks and operating problems.
- The TMGA appears to have potential. The main concern is that major abstractions will face resistance from environmental groups.
- The diversion of Lourens river floodwater into Paardevlei and Faure water treatment works appears to be cost effective and viable.
- The Eerste river flood diversion to the Faure water treatment works will be a less viable and cost-effective option.
- The Upper Molenaars diversion, which will comprise a pump station adjacent to the Molenaars river at the Huguenot tunnel will utilise the existing pipeline laid through the tunnel. Water will be delivered into the Berg river dam or Wemmershoek dam. This scheme will be more expensive, but might still be viable.
- The Brandvlei-Theewaterskloof transfer scheme will augment the inflow into Brandvlei dam by increasing the capacity of the existing Papenkuils pump station. A canal, pipeline and pump stations will deliver the water into Theewaterskloof dam.
- Three options for re-using treated wastewater were examined:
    - Re-use for local urban irrigation and industrial use is cost-effective and should be implemented; although, health issues are of concern.
    - Reclamation for potable standard would be relatively expensive. Health risks are also a concern as well as possible social and religious objections.
    - The exchange of treated wastewater for freshwater from irrigators would be viable but would require a buy-in from irrigators and might pose health risks and cause adverse international perceptions. It might also harm the soil in the long-term.
- Desalination is still expensive relative to other options.
- Integrated management of the existing water resources together with the BWP, when this is completed, is essential.
- Urban demands are likely to continue to grow in the medium- to long-term even with intensive water demand management measures in place.

- Because it could take up to 10 years or more for studies, approvals and implementation of a new scheme, timely planning of future water schemes is essential to ensure that there is an adequate supply of water to sustain the economic hub of the Western Cape.

Given the above-mentioned, future demands can probably be met as indicated in Table 11.

Table 11: Proposed future supply schemes for the WCSS

2003 - 2008	Existing schemes, supplemented by water demand management
2008 - 2010	Existing schemes plus BWP
2010 - 2020	Introduction of a number of additional schemes, including grey-water re-use, surface water and groundwater schemes (see Table 10)
2030	Above plus desalination of seawater

Source: (Shand, 2005; Shand *et al.*, 2003)

Apart from the expense of developing bulk-water supply schemes, additional expenses will be incurred in developing and maintaining the distribution network over the next 12 to 15 years (see Table 12).

Table 12: Additional outlays for the WCSS (excluding bulk storage schemes)

Item	**Cost (R million)**
Raw water pipelines	47,4
Additional water treatment plant capacity	140,2
Bulk-system pipelines	678,2
Additional pump capacity	34,4
Additional storage capacity	213
Other	29,8
Water resource development costs (6 years)	115
Total	1269,3

Source: (Kleynhans, 2002a; Kleynhans, 2002b)

It should, thus, be clear that considerable capital outlays will be needed to safeguard a 98 percent assurance of supply level in the WCSS.

2.4 Applying the measurement problem to the BWMA

It has been indicated that the demand for water in the BWMA will grow in the long-term. Limited conventional water supply alternatives combined with the impact of climate change places the

WCSS at risk of experiencing serious water shortages in the longer term. Such concern regarding the long-term impacts of supplying the WCSS from adjacent rural areas is by no means unique. Semi-arid urban areas throughout the world often face demand outstripping supply because of the external drivers of demand (population demographics, economic growth, climate change, pollution and also equity considerations). In the Middle-East, for example, Jordan recently investigated the viability of seawater desalination as an alternative water supply solution for its Aqaba Special Economic Zone (Dweiri and Badran, 2003). The Murray-Darling basin in Australia was subjected to an investigation regarding the potential socio-economic gains of additional in-stream flows (Pinge, 2002). The American state Minnesota went through a long-term drought planning and water allocation exercise (Pirie *et al.*, 2004). Further examples of complexities regarding the impact of water management strategies in urban and rural areas may be found in New England (Massachusetts) (Ryan, 2002); Las Vegas (Stave, 2003); Pakistan (Van Steenbergen and Oliemans, 2002) and Egypt (Wichelns, 2002) to name a few.

Table 10 noted several bulk supply options lying outside of the municipal boundaries of the CCT and even outside the BWMA. These options imply re-allocations of water resources from predominantly rural to urban areas. The measurement problem outlined in Section 1.1 suggests that re-allocations are often done without acceptable consideration of the potential long-term impacts. Transfers could lead to resource allocations, which are contradictory to government policies of efficient but sustainable resource utilisation. The tendency exists to first opt for "less expensive" supply options before considering "more expensive" options, such as desalination of seawater or recycling to potable standard (see Table 11). Adopting a "less expensive" strategy could be justified by, firstly, avoiding the potential danger for decision-makers of making a politically unpopular decision (by opting for "more expensive" options), which would harm their own political positions, and secondly, by supporting the assumption that the current measuring techniques used yield a true and legitimate reflection of the total cost of proposed projects. In the short-term, this strategy certainly seems rational from the decision maker's perspective, but the question could be asked whether this is indeed an acceptable strategy in terms of social welfare maximisation and long-term sustainable resource utilisation. Inadequate measuring techniques may be the cause of inaccurate information reaching decision makers, leading to faulty telescopic views and harming social welfare and sustainability on the long-term.

Also, preference is given to the "highest and best use" argument in resource allocation decision-making, especially in resource scarcity situations (maximising marginal benefit). Given that the perceived value of water use in urban areas generally exceed rural use, a gradual re-allocation of water from rural to urban areas is expected. However, the difference in perceived value are not fully quantifiable and moslty not fully accounted. Such a strategy, therefore, falls victim to the measurement problem as mentioned in Figure 1. This is so because, although some developments in decision-support techniques focus on the valuation of long-term impacts of different schemes, such techniques are still unable to confidently quantify and draw all costs and benefits into project impact assessments. The decision-making context is still too narrowly defined to account for all costs (and benefits) associated with bulk-allocation schemes. For example, a significant number of schemes (see Table 10) lie outside the municipal boundaries of the CCT or even outside the BWMA. Current decision support has too little appreciation of the socio-economic and environmental impacts of schemes that contain inter-municipal or inter-basin transfers. It also does not satisfactorily account for considerations regarding the needed representation of such transfers – i.e. not all stakeholders are presented in the allocation decision-making process because the decision-making context is not defined broadly enough. Associated difficulties regarding communication with stakeholders (e.g. the public) in rural areas also add to this problem. Numerous potential unaccounted for effects in water allocation decision-making are, therefore, currently a reality and could lead to negative impacts on adjacent regions of the CCT and even the BWMA.

Decision support techniques, therefore, need to be refined and/or expanded to accommodate the measurement problem. The problem at hand indicates complexity within a resource scarcity context. By adding the challenge of truly sustainable but equitable and efficient resource utilisation, the problem becomes even more complex. Decision support techniques need to be adapted to capture considerations relevant in the broader decision-making environment. Expansions and refinements in terms of spatial and time dimensions could aid in this regard (see Chapter 4).

2.5 Managing the BWMA

The question could be asked how management authorities accommodate the measurement problem as discussed in Section 2.4. Water service authorities must promote an efficient but equitable and sustainable allocation of water in the BWMA (Department of Water Affairs and Forestry, 2004c). Such an allocation is, for practical reasons, impossible to achieve but does, however, serve as a management guideline. Given a budget constraint and the measurement problem, decision makers in the BWMA are challenged to opt for the water allocation option that will promote social welfare maximisation (social welfare maximisation includes environmental conservation) without harming adjacent regions.

Figure 10 presents a conceptual layout of broad bulk-water resource management strategies. It holds that water resource management could be divided into allocation and quality management. Quality management focuses on the preservation of the inherent quality (usefulness) of the resource while allocation management manages the logistics of water – i.e. which water and how much of it should be allocated to which specific use at what time.

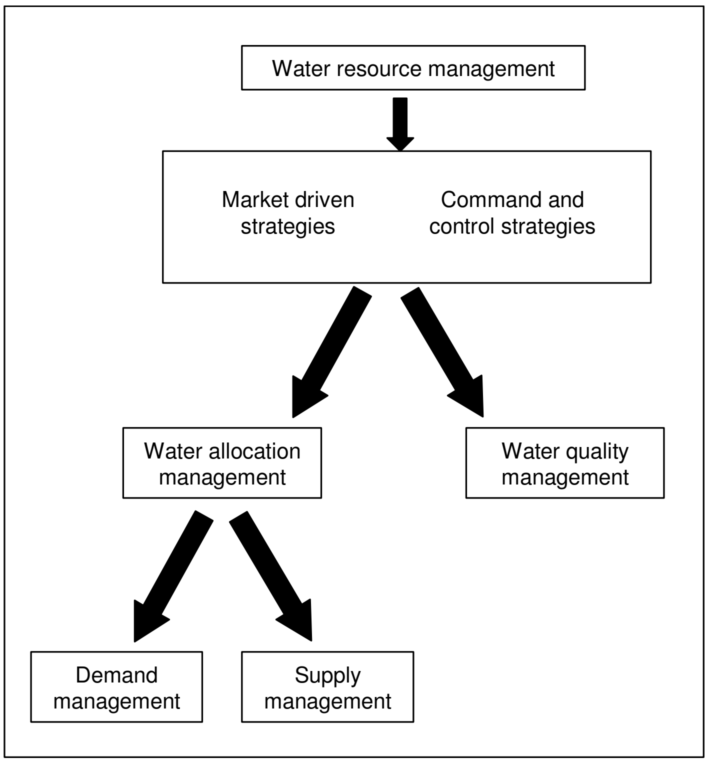

Figure 10: A framework for bulk-water resource management
Source: (De Lange, 2005)

Water resource managers apply marginal benefit and related concepts by turning to the market (see Figure 10) for water resource allocation, mistakenly seeing the competitive market as the ideal mechanism for allocating scarce water resources in the BWMA (Eberhard, 2003a:12-17; Pearce and Turner, 1991). Neo-classical economics promote the market as allocation mechanism to resolve water allocation problems by leaning heavily on rationality[6] (Pearce, 1993; Pearce and Turner, 1991; Rosenhead and Mingers, 2002). It holds that an efficient and equitable allocation of water

[6] Contrasted by revealed preference theory (Mueller, 1997). However, decision makers do not necessarily reveal their preferences through their choices (refer to the prisoner dilemma (Bergson, 1938; Bergson 1954; Little, 1949; Little, 1950), but also to the work of (Sen, 1977).

resources will be achieved if suitable market structures are in place (i.e. the assumptions of perfect competition). However, frequent market failures occur in cases involving public goods, such as bulk-water supply infrastructures because market prices do not account for all the costs and benefits associated with such goods, especially not the benefits and costs related to socio-economics and the state of the environment. High transaction costs, externalities and the faulty telescopic view of market participants also promote market failures (Blignaut and De Wit, 2004:55,66; Goodstein, 1999:454). The market also needs a large number of independent sellers and buyers, which is not always the case with tradable water use-rights in semi-arid areas like the BWMA. The market is also criticised by theoretici like Arrow who has shown the impossibility of achieving an objective socially optimum allocation via any voting procedure (such as the market), because the individual vote/decision is a function of individual choices (Arrow, 1951; Arrow, 1984b). To aggregate these choices to a social outcome, which was not evaluated by individuals in the first place may, therefore, be politically unpopular if tested. The result is that no claims can be made that the market will realise a socially optimum water allocation.

Market failures could, therefore, cause misallocations of water resources in terms of social welfare maximisation for the BWMA. Proof can be found in the BWMA where the continuous approval of bulk-supply options outside the boundaries of the CCT (see Table 10) will re-allocate water from rural areas to the CCT, thereby disregarding the measurement problem as mentioned in Section 2.4. In such cases, re-allocations are promoted via a stronger effective demand of urban users.

Indeed some margin is therefore created for government interference. This implies that public trust is placed in bureaucrats and politicians to compensate for market failures (Buchanan and Tullock, 1962; Mueller, 1997). The bureaucracy of South Africa is used to motivate politicians to act in the best interests of the public. This is based on the assumption that if elections are held with the risk of losing a parliamentary seat, politicians and service providers in the BWMA will indeed accommodate the needs of the public. However, in order to serve social welfare maximisation, decision-makers need legitimate and objective information upon which to base management decisions. Once again the measurement problem (see Section 2.4) comes to the fore because the quality of water-allocation decisions is a function of available decision-making information while the quality of the information is influenced by the measurement problem. It is, therefore, imperative to address the measurement problem to enable decision-making that will promote social welfare in the BWMA (refer to Chapter 4 for engagement in the measurement problem).

Apart from the measurement problem, government intervention leads to a need for detailed monitoring because problems regarding hidden incentives and different time-frames between principals and agents may influence decisions (Goodstein, 1999:215-225). Incentive-related problems occur because of the separation of power and responsibility in government intervention (i.e. those having decision-making power in government agencies often do not bear the responsibilities of their decisions, at least not to the same extent as profit seeking entrepreneurs in a market setting do). In addition, strategic decision-making in bulk-water supply management typically has a twenty-year planning horizon while the South African bureaucracy functions in four-year terms. Long-term bulk-water supply planning could, therefore, be hampered if politicians continuously opt for short-term water supply solutions to enhance their own positions.

The next two sections discuss water allocation management for the BWMA in more detail.

2.5.1 Water allocation management in the BWMA

Figure 10 holds that allocation management could further be sub-divided into water supply and demand management. In the past, the growing demand for water resources was mainly accounted for by following capacity expansion strategies. This approach was costly in terms of capital investment and involved the development of a new water supply infrastructure to satisfy the growing demand for water with little emphasis placed on effective use of water. The emphasis was on capacity expansion. Following this approach unintentionally created the public perception of water not being a scarce and valuable resource. Little incentive was created for the development of water saving technology because water was cheap and often subsidised. Since water supply networks were not optimised for the efficient distribution of water, most countries in the world could not afford to continue on this path and started gradually, as water sources became scarcer, to implement water-demand management practices (Haddad and Lindner, 2001:143). South Africa and the BWMA were no exception (Sparks, 2001).

Although demand management is not the primary focus of this study, its importance is not diminished, neither does the study ignore this type of management. It is assumed to be important part of water management running parallel to bulk-supply management in the long-term. The following is a short discussion regarding the two types of water management.

Water demand management could be defined as water management strategies specifically developed to influence the demand for water and therefore the efficiency of water usage (Department of Water Affairs and Forestry, 1994:1; Kolokytha *et al.*, 2002:392-393; Kumar and Singh, 2001:387; Louw and Kassier, 2002; Shand *et al.*, 2003:7; Sparks, 2001; Van Zyl and Leiman, 2002:4). Within the BWMA, the CCT engaged in water demand management by committing to realise a 10 percent saving on the 2010 demand estimations (Department of Water Affairs and Forestry, 1991; Kleynhans, 2002b).

Demand management options specifically employed in the BWMA include:

- Enhancements to dam flexibility operations (Department of Water Affairs and Forestry, 2004d);
- Modifying tariff structures - care must be taken because water is the most basic of all needs, and water price increases will impact negatively on the poor. It is, therefore, important that pricing policy be structured in such a way as not to deny access to clean sufficient water for basic survival and hygiene to the poorest of the poor (Eberhard, 2003b; Killick, 2004);
- Upgraded maintenance of distribution infrastructure (Kleynhans, 2002b);
- Use of advanced technology (low-pressure household appliances, irrigation, etc.) (Department of Water Affairs and Forestry, 1994; Kleynhans, 2002a);
- User education - the actions needed to achieve demand management objectives are not restricted to water authorities but often require a change in public consumption behaviour. User education is, therefore, an important aspect of successful water demand management (Kleynhans, 2002b);
- More efficient metering (Eberhard and Joubert, 2002; Kleynhans, 2002b); and
- Water markets - a great deal of demand management strategies entail taking into account the value of water in relation to its cost of provision, occasioning introducing measures that require consumers to relate their usage more closely to costs. It entails treating water like a commodity, an economic good, rather than as an automatic public service (Hellegers and Perry, 2005:11; Rogers *et al.*, 2002; Winpenny, 1994), thereby moving in the direction of water markets (Louw, 2001; Louw and Kassier, 2002:9; Mirrilees *et al.*, 1994:2-3). Tradable water-use rights have been most appropriate in the BWMA for dealing with direct abstractions (particularly for irrigated agriculture) and in the allocation of water between local authorities. Within such markets, users for whom water has low use-value will have an incentive to sell or lease their water-use rights while users with higher use-values will have an incentive to buy or lease water rights in order to expand their activities. However,

markets do not have as much scope for application among individual urban users due to the complexity of the distribution system.

Water demand management approaches in the BWMA concentrate on curtailing runaway growth in demand by implementing water saving strategies that increase the level of efficiency in water usage.

The link between supply and demand management is to be found when water-use efficiency is realised in terms of water savings, i.e. additional water resources become available creating additional "supply". However, no water management system will ever operate perfectly efficiently. As a water distribution system becomes more efficient, the marginal gain in additional investments for efficiency gains will decrease. This shows the inherent limitation of demand management strategies to accommodate a growing demand for water, such as the case of the BWMA where long-term growth for the WCSS is estimated at 2 percent per annum (refer back to Figure 9). Capacity expansion is, therefore, needed to keep up with growing demand in the BWMA.

Water supply management focuses on the expansion of the existing supply capacity of the WCSS to provide for a growing demand in the BWMA (Eberhard and Joubert, 2001; Eberhard and Joubert, 2002; Joubert *et al.*, 2003; Kleynhans, 2002a; Kleynhans, 2002b). Such strategies are normally associated with the construction of infrastructure (large storage dams or water production schemes like desalination plants or plants for recycling to potable standard) or the importation of water from neighbouring areas (inter-basin transfers), such as the Breede Water Management Area. However, such transfers are only justified if long-term net social gains are being realised (Howe *et al.*, 1990:1200-1201; Mirrilees *et al.*, 1994:2-4).

Supply management strategies are more capital intensive than most demand management strategies with numerous uncertainties regarding the long-term implications of the construction and operation of bulk-supply schemes. Normally (also in the BWMA), a combination of demand and supply management strategies are followed to ensure efficient and sustainable water resource management. Figure 11 illustrates the timing relationship between the two types of strategies (also refer back to Figure 9).

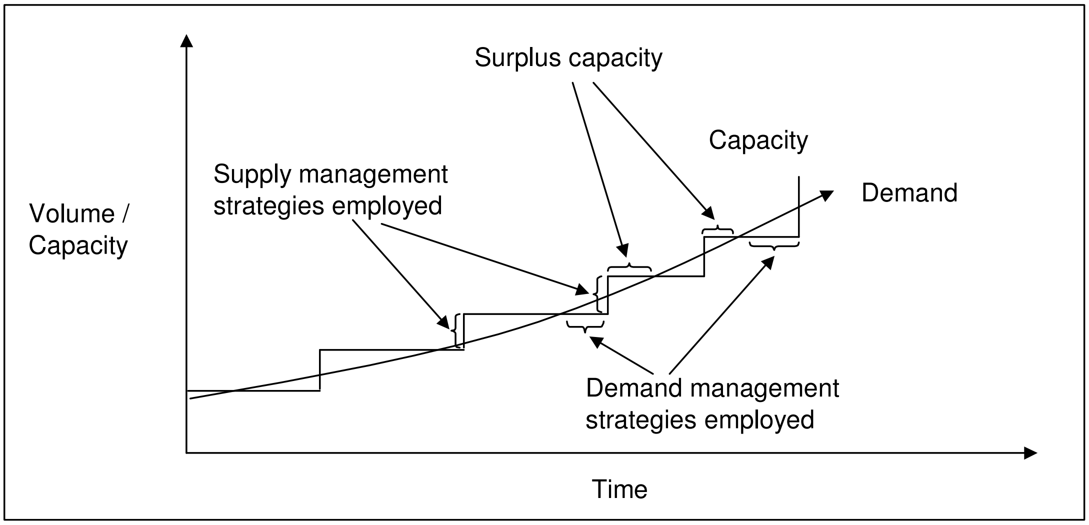

Figure 11: Theoretical capacity expansion

Source: (De Lange, 2005)

Capacity expansion paths have a typical step-wise expansion pattern because of the inability of most supply augmentation schemes to expand in a modular fashion with demand. After the implementation of a given supply scheme (e.g. the BWP), a temporary surplus capacity will exist in the WCSS. However, as demand increases, the surplus will start decreasing until demand equals supply. When demand starts to exceed supply, additional demand management strategies should be used to dampen demand (not indicated in Figure 11) until the next supply expansion scheme can be developed. This expansion pattern will continue until the growth in demand starts to stabilise as a result of stabilising impacts on the drivers of demand. It should be clear that supply and demand strategies are inter-linked and should be followed along with each other and preferably in an integrated way.

2.5.2 Integrated water management in the BWMA

The development and implementation of supply augmentation projects is complex because of the different disciplines involved in these processes: water, environment, economy, finance, social, communication, technique and technology, legislation and geography. The development of alternative water resources, therefore, needs to be made in a context of integrated water resource management.

Aristotle (384-322 B.C.) stated: *"the entirety is greater than the sum of the individual components"*. The word *system* was not mentioned, but the idea of unity and the interdependence of components was emphasized (Von Bertalanffy, 1968). This idea originated in classic scientific thought. Complex phenomena were typically explained by following a reductionistic approach with such an approach explaining the relationship between components to explain phenomena as a whole. Analytic-reductionistic thought emphasises the essentials to clarify phenomena in terms of action/reaction relationships, and positivists were convinced that analytic-reductionistic thought would also apply to social problems. However, such thought presents shortcomings in clarifying complex, value-laden and soft-structured ("messy") social problems typically associated with resource allocation and long-term water resource management in particular. The reason for such a shortcoming is that it fails to recognise the inherent potential of individuals to think freely, act creatively and to experience the consequences of their actions in a subjective way. In trying to explain social development problems in terms of action/reaction relationships, the decision-maker assumes all inter-relationships between individuals and generalises from there. This type of approach became progressively less competent in explaining the complex reality because this type of methodology ignores the potential negative effects on the socio-economic and/or eco-system factors of different allocation options. More information is, therefore, needed in order to gain insight into the different facets and interactions between facets of a decision-making problem. As a result, generalised systems theory caught on in biology, psychology, and economics (Boulding, 1956; Von Bertalanffy, 1968). A trans-disciplinary and interactive planning paradigm is called for with a systems approach replacing analytic-reductionistic thought. Such an approach would serve as a more creative and suitable foundation to obtain insights into development planning in long-term water resource allocation decision-making.

Within a systems approach the emphasis falls on understanding the individual components of the system and along with it, the interaction between such components. Systems thinking is at the core of an integrated approach to water resource management with multi-criteria decision-making forming part of the process as indicated in Figure 12.

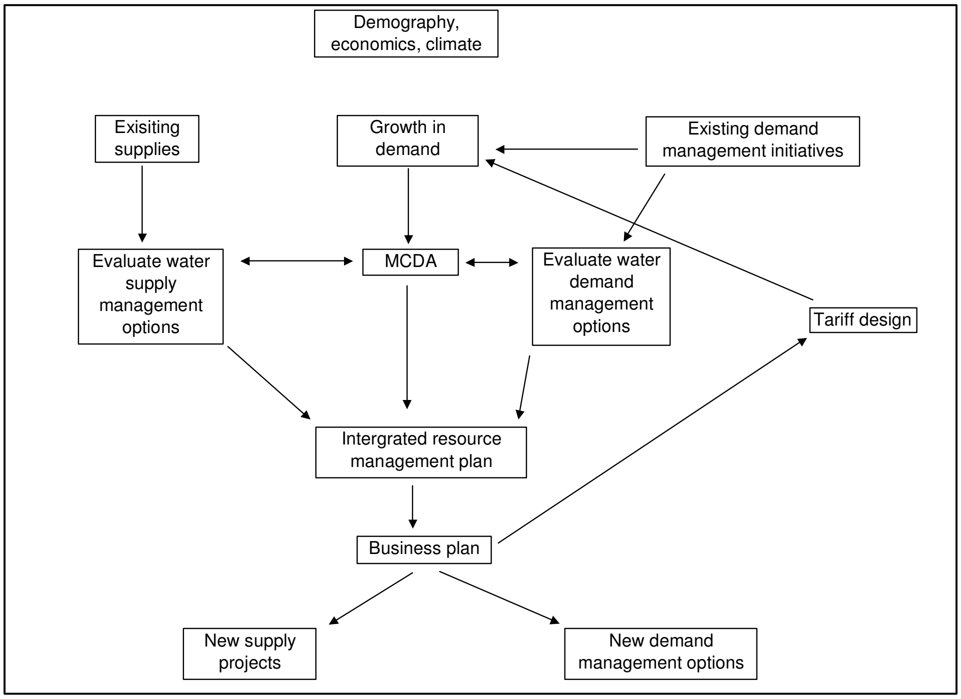

Figure 12: Integrated water resource planning in the BWMA

Source: (Du Plessis *et al.*, 2001)

Integrated water resource management for the BWMA may be considered in at least three ways (Belton and Stewart, 2002). Firstly, it can imply the systematic consideration of the various dimensions regarding the water resource as a system *per se*. Important here is the acceptance that water as a resource comprises a system formed by a number of independent components. Each component (quantity and quality, surface and groundwater) may influence other components, and therefore, needs to be managed with regard to its inter-relationships. At this level, management's attention is directed to considering aspects, such as water supply and quality. Secondly, integrated water management can imply that, while water management is a system, it is also a component that interacts with other systems. This points to interactions between water, land, and the environment, recognising that changes in any one will influence the other. At this level, management's interest becomes focused on issues like floodplain management, erosion control, non-point pollution, agricultural drainage and recreational use of water. A third and broader interpretation is to approach integrated water management via the interrelationships between water and the social and economic environments. Here the concern is to determine the extent to which water is both an opportunity for and an obstacle to social welfare maximisation. A sensitivity towards the interdependency among decision variables could be seen as the distinctive characteristic of integrated approaches. However, if the promotion of social welfare is aimed at, following an integrated approach should include running the political process parallel to resource allocation management.

2.5.3 Politics of water resource management in the BWMA

The final decision-making power regarding water allocation rests with politicians – also the case in the BWMA. The importance of the political process in long-term water allocation decision-making should, therefore, be obvious. The politics of water resource management can become extremely complex and often emotional because of the life-supporting functions it fulfils in daily life. Policy-makers in the BWMA face the challenge of accommodating a range of interests of different users against the background of a given set of policy objectives. For example, it is a challenging task to increase water-use efficiency, equity and sustainability that is simultaneously socially acceptable. Utilitarian principles aimed at the maximisation of social welfare explain this (Hicks, 1939).

Urban water users (domestic, commercial and industrial users) traditionally enjoy priority over rural users in decision-making regarding resource allocation. The reason for this is once again grounded in the measurement problem as indicated in Section 2.4. Urban users are in a position to dominate the planning process because of a better organisational structure, higher effective demand for water and locality concentration. This could result in a narrowing of the strategic planning context for long-term water resource allocation decision-making in the BWMA. Such narrowing could be in terms of temporal and spatial dimensions and could ultimately lead to negative impacts on social welfare. It also leads to growing tension between urban and rural water users because water resources are re-allocated from rural to urban areas.

Decision-makers cannot fully account for all costs and benefits (especially in the long-term) of different water management strategies in their decision-making. The reason for this is that "softer" and less tangible impacts of re-allocations (mostly of socio-economic and environmental origin) cannot be defined in terms of easily quantifiable monetary variables. Policy-makers, therefore, have little choice but to make use of the methodologies available to them. For example, the re-allocation of water based primarily on "best/highest value of use" grounds could be questioned because "efficiency" is mostly quantified in terms of volumetric or monetary variables. Decision-makers could not be certain that if it were possible to construct an aggregation model accounting for the total value of water for rural use, the re-allocation of water from rural areas to urban areas in the BWMA would still be justified.

In addition, the problem of different agendas and time horizons within the water management environment comes strongly to the fore within the politics of water allocation decision-making. Water service providers have a long-term attitude toward water-resource allocation management while politicians could have a short-term attitude toward serviced water because of the structure of the South African bureaucracy. Bureaucrats could have hidden agendas including empire building and external career building (Goodstein, 1999:215-225). Within these sometimes-conflicting interests, a long-term orientation towards water resource management is lost, leading to adverse impacts on social welfare. It is, therefore, necessary for policy makers to translate the short-term attitudes of water users into long-term preferences in order to ensure the long-term sustainable use of the resource.

The following points summarise the important problems water managers are facing from a political perspective:

- Budget constraints with regard to different management options;
- Implementation periods for bulk-water supply schemes are long (7-12years);
- Numerous stakeholders are involved, all with different needs/agendas;
- Different criteria in the decision-making process have different levels of importance;
- The difference between rational theory and actual behaviour (i.e. people will not consistently chose the "best" management alternative based on the given criteria).

It should be clear that politics contribute towards the complexity of water management, and decision-makers are in need of decision-support for long-term decision-making. See Backeberg (Backeberg, 1994; Backeberg *et al.*, 1996) for additional references regarding the politics of water resource management in South Africa.

2.6 Conclusion

This chapter presented the BWMA as a physical setting for the research problem as discussed in Chapter 1. Some demographics and the water balance were discussed. Future augmentation schemes were presented from where the measurement problem, as presented in Chapter 1, was applied in the context of the BWMA. The applied measurement problem was discussed in terms of water allocation management in the BWMA, and it became clear that the decision-making context is currently too narrowly defined and is in need of some expansion to accommodate unaccounted-for long-term effects. The aforesaid expansion should be undertaken in an integrated manner. Lastly, the politics of water resource management in the BWMA were acknowledged as having an important impact on the implementation phases of management strategies. Politicians do, therefore, need to buy into the expansion of the decision-making context if long-term sustainable resource use is to be ensured. The next chapter presents the background of the measurement problem from a theoretical point of view.

3. LITERATURE REVIEW

3.1 Introduction

This literature review presents relevant literature consulted throughout the period of the research and is roughly structured according to Table 1. The aim is to orientate the reader with the aid of relevant literature. The review starts with Section 3.2, which covers the basics of the competitive market as resource allocation mechanism and explains why the market sometimes fails in the allocation of public goods such as bulk-water resource infrastructures. Section 3.3 explains the rationale for government intervention in cases of market failures and also the problem of government failures in water resource allocation. Section 3.4 discusses decision-support for resource allocation management and links with Section 3.5 which discusses the need for information regarding public participation in water resource allocation.

3.2 The market as mechanism for natural resource allocation

The 1992 Dublin Water Principles and the 2002 World Summit on Sustainable Development support the notion of water as an economic good, which should be managed accordingly to promote equity, efficiency and sustainability (United Nations Department of Economic and Social Affairs: Division of Sustainable Development, 2004). Inherent in this view is the use of water pricing with the aim of understanding the full cost of water supply and the full value of water. The distinction between cost and value is of importance here, especially in the case of the non-market benefits of water. Such a distinction is complex and has become a controversial, but popular topic for resource policy makers.

There is a lack of insight into the strengths and limitations of economics to solve resource allocation challenges. Mostly, problems are approached from a purely technical point of view; it is not clear what role economics can play and what the interlinkages are between economic and technical considerations in the decision-making process. The question is not whether water is an economic good or not (it certainly is – see Hellegers (Hellegers and Perry, 2005:11), but rather the extent to which water allocation and use can be guided by market forces or whether it requires some extra management to serve social objectives (Robbins, 1952; Robbins, 1981). Experiences from the BWMA will be used to clarify some of the uncertainties in this study.

Market mechanisms have become important resource allocation mechanisms (Arriaza *et al.*, 2002:21; Bateman *et al.*, 2003; Brouwer and Pearce, 2005:237; Bush *et al.*, 1987:617-618; Colby *et al.*, 1993:1565; Dudley, 1992:757-759; Easter *et al.*, 1998; Eberhard, 2003a:12-14; Fishelson, 1994:321-323; Fisher *et al.*, 2002:1-3; Keenan *et al.*, 1999:279; Kloezen, 1998:437; Kumar and Singh, 2001:387; Louw, 2001; Louw, 2002; Louw and Kassier, 2002:18; Nieuwoudt, 2000:58-60). Market allocation theory states that an efficient and equitable allocation of resources will be made given that suitable market structures are in place (i.e. the assumptions of perfect competition) (Eberhard, 2003a:12-13; Pearce, 1993; Thrall, 1976). Current measurement methodologies suggest that the economic value of water for urban use is higher than the economic value of rural use. Price elasticity of demand favour urban use and the ability of urban users to pay will result in the systematic re-allocation of water from rural uses (irrigation use and in-stream flow requirements) to urban use (Alberini and Cooper, 2000; Brouwer and Pearce, 2005:51-52; Van Vuuren *et al.*, 2004; Van Zyl *et al.*, 2003; Veck and Bill, 2000:2-13). This implies that market allocation mechanisms will in the event of water shortages, allocate water away from rural use in favour of urban use (Backeberg, 1994; Carmichael *et al.*, 2001; Lutz *et al.*, 1998). To justify such re-allocation, the economic value gained should be equal to or greater than the economic value forgone in rural use to realise a net social welfare gain. Unfortunately, these costs and benefits are not fully quantifiable and, therefore, are not accounted for in market-driven allocation systems resulting in a measurement problem. Market failures, therefore, cause the market to misallocate resources in terms of social welfare maximisation - proof can be found by observing the re-allocation of water from rural to urban use, which often disregards important trade-offs. (Eberhard, 2003a:12; Livingston, 1995; Pearce, 1993; Randall, 1983:131-132). Society-wide impacts result from these re-allocations demonstrating the applicability of public choice theory in this context.

Public choice theory holds that when opinions differ, the challenge is to achieve consensus regarding decisions that concern everyone (social welfare) (Hicks, 1939). Public choice theory engages in researching the link between individual values and collective choice (Arrow, 1951; Mueller, 1997). The important question is whether and, if so, in what way social preferences could be derived from individual preference orderings (Graaff, 1957; Hicks, 1975; Scitovsky, 1951). Solutions to this challenge could aid in measuring social welfare and public decision-making (Arrow, 1984a).

The market as efficient allocation mechanism could be criticized by showing the impossibility of achieving social welfare maximisation via any voting procedure, as the market gives a weighted price aggregation of decentralised individual choices (Arrow, 1951; Arrow, 1984b; Arrow, 1984d). The social outcome of such a choice is not evaluated and may, therefore, be politically unpopular. The result is that no claims can be made to a "best" allocation; the market is just "another" allocation. If the market-allocation mechanism fails, some state intervention is needed to obtain a socially "best" allocation. Care must, therefore, be taken not to see the market as the best allocation mechanism because of the gap between economic analysis and the inability to fully address problems of institutional reform within the analytical paradigm of neoclassical economics (Dudley, 1992:757-759; Eberhard, 2003a; Randall, 1983:131; Tisdell and Roy, 1997:28-29). Additions to the market as water resource allocation mechanism are, therefore, needed.

3.3 Government intervention in natural resource allocation

As mentioned, market systems will allocate natural resources to efficient market participants; however, not all users participate in the market (e.g. the natural environment). It is, therefore, unlikely that a market system will promote social welfare maximisation, including an efficient and sustainable allocation of resources (Livingston, 1995:203-220; Sen, 1977:317-344). Water managers have to intervene to account for market failures because bulk-water supply infrastructures are of a public good nature. (Eberhard, 2003a:12-17; Livingston, 1995:203-220; Randall, 1983:131-148). Such interventions could take various forms and should be acceptable to the public to promote compliance. In order to promote acceptability, decision-making information regarding public preference needs to be expanded to enable decision-makers to make decisions in favour of social welfare maximisation without harming their own political positions (Buchanan and Tullock, 1962; Livingston, 1995:203-220).

As previously mentioned, public choice theory studies the decision-making behaviour of voters, politicians and government officials from the perspective of economic theory. It can be considered a bridge between economics and political science because it recognises that politicians as individuals are also motivated by self-interest (Arrow, 1951; Arrow, 1984b). However, the fundamental assumption of rational choice theory (also known as the first assumption of economics) and related problems were examined, and it proved wrong to build social preference orderings by examining individual preference orderings because social welfare was not accommodated in the individual preference ordering (Sen, 1977:317-344). Public choice theory is criticized when used in its simplified form, describing that bureaucrats act only in self-interest (Sen, 1977:317-344). In addition, incentive-related problems could arise in collective decision-making because of the separation of power and responsibility (i.e. those having decision-making power in government agencies do not bear the responsibilities of their decisions, at least not to the same extent as profit seeking entrepreneurs do). There are also no signals in the collective decision-making process that are comparable to profits and losses in the market environment. No reliable way exists of judging efficiency where outputs are not produced and sold under competitive conditions. However, given that competitiveness features as a measure of efficiency, it is not certain that such conditions can be seen as a suitable measure of efficiency for state intervention. Care should, therefore, be taken when using efficiency as a measurement criterion.

State intervention can (and does) fail because of incentive-related problems but also because of the short-term attitudes of politicians and the personal agendas of service providers (the agent). Hence, the link with principal-agent theory. The vulnerability of government intervention to lobby groups (in the case of the BWMA, urban users could be defined as such) could also lead to government failure. Government failures, therefore, need to be accounted for. This could partly be done by engaging in the information asymmetry problem by broadening the decision-making context. The decision-making context could by broadened by expanding the temporal and spatial dimensions of the aforesaid context. Such expansions have a significant impact on the information needed in the decision-making process and consequently on decision-support techniques. (Refer to Chapter 4 for a detailed discussion regarding the expansion of decision-support.)

The above-mentioned discussion does not eliminate the fact that a political decision will dictate resource allocation decisions, or in this context, the choice of water allocation scheme. The only watchdog available to oversee the decision-makers (agent) is a functional bureaucracy that determines who will be in the influential position of decision-making, i.e. the agent runs the risk of losing his parliamentary seat if he does not act in the interest of the principal (Mueller, 1997). Nonetheless, during democratic elections, the public entrusts their vote to agents to fulfil their expectations and needs. Voters have no guarantee that bureaucrats will operate in the public interest due to their vulnerability to lobby-groups and, therefore, their own interests (i.e. government failure). There is also no guarantee that bureaucrats can be certain of the real preferences of the public, nor can the bureaucrat be certain which user preference is sustainable in the long-term. This leads to the emergence of a principal-agent problem (Grossman and Hart, 1983:7-45; Laffont, 2003), resulting in the need for effective contracting (Bernholz, 1997:419-442; Smith, 2004; Van Bommel and Reinhard, 2005).

Insight into principal-agent theory supports an understanding of the roles of the state and society in long-term resource management. The relationship of agency is an old codified mode of social interaction. Essentially, all contractual arrangements between agents and principals contain elements of agency and problems regarding effective contracting (Ross, 1973:134-139). Much of the economic literature on moral hazard is concerned with problems raised by agency (Arrow, 1984c; Bentham, 1789; Mirrlees, 1975).

Within the context of this study, the public (principal) is confronted with a resource scarcity problem of rivalry/competition over scarce water resources, so it turns to a specialist (the agent) to act more efficient. The principal does, however, need to construct a mechanism (incentive) to ensure that the agent behaves at least partly according to the principal's interests. The principal-agent problem is that of designing such an incentive scheme – i.e. drawing up a suitable contract to co-ordinate the actions of independent decision-makers, thereby saving costs because the cost of producing such incentives adds to the principals' transaction cost (Smith, 2004).

The answer to how the principal should accommodate the agent in resource management, therefore, lies in effective contracting, i.e. aiming at minimising transaction costs. In the process, asymmetrical information, measurement problems, the risk profile, productivity levels and the size of the management structure play important roles (Grossman and Hart, 1983:7-45). In designing incentive schemes, one could question why public (principal) preference should be accommodated. Water as a public good has a typical inelastic demand for most of its uses, with few substitutes available. A demand situation like this could imply that the agent has more power than the principal (which mostly is the case in water management situations) – local authorities do not allow themselves to be manipulated by the public, while the public cannot boycott the purchase of the product because of low elasticities. Taking into account that the public view is at it best an amalgamated view of individual preferences, the public vote is simply not good enough to warrant serious consideration regarding complex decision-making in sustainable resource utilisation. Expert opinions may, therefore, not always coincide with public opinion. In cases such as these, a type of doctor-patient situation develops: the agent has superior knowledge and assumes a paternalistic or prescriptive stand in managing his principals' problem. This could result from limitations in communicating complex management problems to the public. However, some evidence exists that managers should indeed accommodate the public because a broad tendency has emerged to decentralize water resource management (Steel and Weber, 2001:119-131). It is also not certain whether a functional bureaucracy will promote sustainable water management and social welfare maximisation because of the difference between their time horizons, i.e. political elections typically have a four or five year rotation cycle while bulk-water supply infrastructure developments have 20- to 30-year cycles. It could, therefore, be argued that politicians typically have a shorter time-dimension compared to sustainable resource management requirements and this difference does not support "sustainable" resource utilisation.

The problem regarding public involvement could also be seen as a reversed principal-agent problem, i.e. at first the principal consults the agent for assistance in a given problem (in this case a resource allocation problem), however, by engaging in this problem, the agent needs to consult with the principal regarding their preferences in the management challenge. The question is whether the principal should do this, and if it does, to what extent should the agent accommodate the principal in the decision-making process (Iacofano, 1990; Wiseman *et al.*, 2003:1001-1012). In cases where urban areas tap into rural water resources, a "parted" principal could emerge. This means that urban users have a higher and often more elastic effective water demand compared to rural users – particularly in irrigated areas. In these cases water transfers from rural to urban areas contain hidden costs (loss in production, employment, environmental trade-offs) not sufficiently accounted for in agent decision-making – often to the disadvantage of the rural user. This type of situation leads to tension, loaded with emotion, between rural and urban users. The agent is in the process confronted with the problem of serving two different principals with conflicting interests regarding the same resource at the same time (Conradie, 2002).

3.4 Decision-support for resource management

As mentioned in Section 3.3, government intervention is needed to assist in accounting for market failures in resource allocation mechanisms. However, in intervening, government requires decision-support in order to confront complexities associated with allocation decisions, i.e. accounting for different climatic, socio-economic and political contexts, both over the short- and long-term (Stewart, 2004). Decision-support anticipates short-term impacts with an acceptable level of certainty; however, the long-term impacts of different allocations present major challenges. This section focuses on decision-support systems for resource management decision-making. It is by no means exhaustive, but will, nevertheless, provide grounds for the method that was used and modified in the study.

Decision-support is directly related to explaining decision-making behaviour. In order to justify and explain behaviour, rational choice theory appeals to three distinct elements in the choice situation. First, there is the feasible set (i.e. the set of all courses of action that satisfy various logical, physical and economic constraints). Second is the causal structure; in other words, interactions between actions and outcomes. The third element is a subjective ranking of the feasible alternatives usually derived from a ranking of the outcomes to which they are expected to lead. To make a rational decision, then, simply means to choose the highest ranked element in the feasible set (Belton and Stewart, 2002; Elster, 1986). Decision-support systems do not solve decision-making problems, nor are they intended to do so. Their purpose is to provide insight and creativity to aid decision makers to make "better" decisions (Belton and Stewart, 2002; Romero and Rehman, 2003:3-20).

MCDM came to the fore as a specific support system that provides a consistent approach to ranking and comparing allocation management alternatives for resource management problems (Romero and Rehman, 2003:123-133). Different MCDM methods exist, and the choice of method is critical in terms of appropriateness with regard to resource management problems. This is important not only because each method produces different rankings of the same set of management alternatives (feasible set) but also because choosing a methodology is subjective at best (Belton and Stewart, 2002; Hobbs *et al.*, 1992; Tecle, 1992:129-140) (see Table 13).

Essentially, MCDM is both a process and a methodology that compares management alternatives from different points of view (criteria). It combines these criteria (weighted scores) to obtain an overall ranking of alternatives that are used as recommendations in allocation decision-making. The process facilitates greater understanding of the management problem, involved parties, and their priorities, values and objectives. Through exploring these in the context of the problem, it guides decision-makers in identifying a preferred course of action. The method is sensitive to the different contexts of the same problem and its different stakeholders.(Belton and Stewart, 2002). It does, however, not provide a "correct" or "true" system of weights or scores because these are determined by the inputs of stakeholders in the decision-making process (Hobbs *et al.*, 1992; Stewart *et al.*, 2001; Stewart *et al.*, 1997). The weight structure reflects the trade-offs society is willing to make in a specific situation in which the importance of the decision is often related to the level of potential conflict between criteria and stakeholders regarding what criteria are relevant (Belton and Stewart, 2002; Romero and Rehman, 2003:15-20). MCDM certainly does not neutralise decision-making subjectivity - it only makes the need for subjective judgements explicit, and therefore, the decision-making process more transparent by forcing decision-makers to at least consider difficult trade-offs (Hobbs *et al.*, 1992:1767-1779; Stewart, 2004; Stewart *et al.*, 2001; Stewart *et al.*, 1997). Transparency in this process is important since it promotes stakeholder participation, especially in cases where multiple stakeholders are involved, as is the case in water resource allocation management.

The following statements describe the character of MCDM (Belton and Stewart, 2002):

- MCDM tries to take explicit account of the multiple conflicting criteria for decision-making;
- MCDM assists in structuring the problem of choice;
- MCDM provides a focus and a common language for discussion;
- MCDM facilitates decision-making by assisting the decision-maker to place the problem in context, to determine the stakeholder preferences and to present the information;
- MCDM improves the legitimacy of decisions.

Both Cost-Benefit Analysis (Brouwer and Pearce, 2005) and MCDM are rooted in utilitarian principles aimed at the maximisation of social welfare. The methods are different responses to a conceptually simple problem: when one party benefits and another loses, i.e. if a proposed course of action (allocation) is not obviously better than the status quo, how can decision-makers test to see if society as a whole is better off if such alternative allocation is implemented (Hicks, 1939; Hicks, 1940; Hicks, 1975; Kaldor, 1939)? If some members of a society experience an increase in welfare while others experience a decrease, how could the interpersonal utility comparisons needed to identify a welfare improvement be identified?

Management alternatives contain trade-offs, and trade-offs are determined by utility functions, i.e. there will be different "winners" and "losers" for different management alternatives. Finding a balance that will promote social welfare maximisation is the challenge decision-makers face. Decision-making regarding such a balance is done with the aid of differentiation criteria. Within the context of this study, we will assume that a criterion is a means or a standard of judging (Belton and Stewart, 2002), i.e. some pre-defined standard by which one particular choice could be compared to another. The consideration of a range of choices becomes a multiple-criteria decision-making problem with a number of standards in conflict. Such conflicts between standards imply the above-mentioned trade-offs. Every decision implies the balancing of the outcomes of multiple criteria in terms of social welfare as a reference framework. This implies that social welfare is defined *per se*. The subjectivity of the decisions comes into play in quantifying the trade-offs between management alternatives because not all criteria are quantifiable in monetary terms (see the measurement problem in Section 1.1). It should be clear that the decision-maker is confronted with a complex decision-making scenario.

Multi-criteria decision analysis facilitates clear and objective thinking regarding the quantification of these trade-offs. It has a facilitative role and does not intend to guarantee total objectivity and the "correct" decision since decisions are context bound. Optimality also does not feature as strongly in the multi-criteria framework and could, therefore, not be completely justified within the optimisation paradigm. MCDM does, however, integrate objective measurement with value judgements and, therefore, makes subjectivity more explicit and manageable. MCDM consists of the following (see also Figure 13) (Eberhard and Joubert, 2001):

- Problem identification and structuring. This step strives towards making sense of the decision-making problem. Key concerns, goals, stakeholders, actions and uncertainties needs to be identified. Before any analysis is possible, all stakeholders (classified in terms of level of interest and power of influence) need to develop a common understanding of the problem, the decisions that need to be made and the criteria that will be used. This is the most important step in the process since a well-structured problem is halfway solved and since a mismatch between problem and model will lead to certain failure.
- Model building – implies the design of a formal model of decision-maker preferences, trade-offs, values, and goals to compare different alternatives in a transparent manner. It is a dynamic process and the nature of the model will differ according to the nature of the problem and whether alternatives are explicitly or implicitly defined.
- Action plan development – implies translating the results of the analysis into a workable action plan.

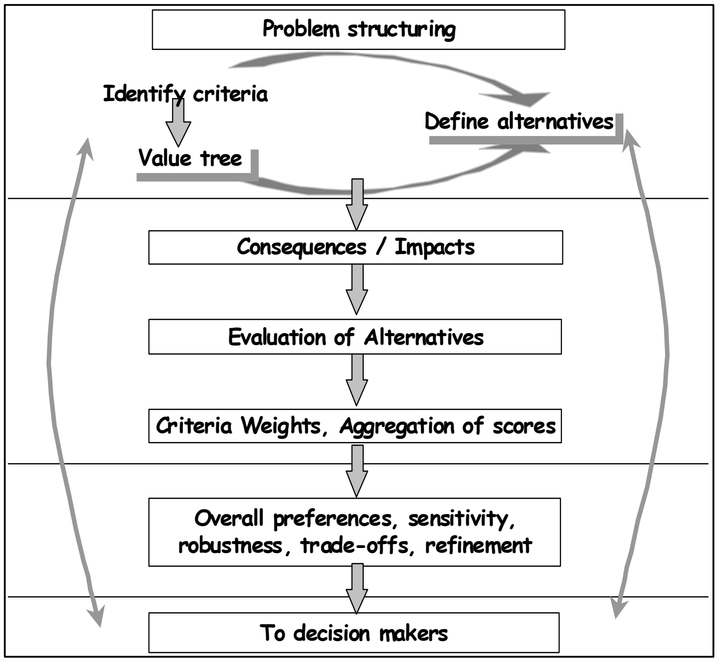

Figure 13: The process of MCDA
Source: (Eberhard and Joubert, 2002)

The multi-criteria decision-making method is useful for (Belton and Stewart, 2002):

- Problematic choice - where a choice from a set of alternatives must be made;
- Sorting actions – where management actions must be sorted or categorised;
- Ranking alternatives – where management alternatives must be sorted according to a given preference ordering;
- Description of actions – where an orderly description of actions and consequences is needed to facilitate choice;
- Design actions – where new decision alternatives are identified and designed to meet the goals identified by the multi-criteria decision-making process.

Different approaches to MCDA could be followed (Belton and Stewart, 2002; Romero and Rehman, 2003):

- Utility and value function approaches among which multi-attribute utility theory (MAUT) and analytical hierarchy process (AHP) are the best known in South Africa. These approaches first assess marginal utilities and then combine these into an overall utility function representing overall strength of preference among options. MAUT is the only technique that addresses uncertainty in its axiomatic framework by analysing the expected values. AHP assesses marginal utilities by asking for the relative strengths of preferences between each pair of possible scenarios. AHP is useful, simple and, consequently, a widely used tool.

- Goal programming and reference point techniques are the original formal forms of MCDM techniques. Goal programming searches for the scenario that minimizes a measure of underachievement of goals. The idea is that once a solution is found the decision-maker will review his or her goals, and the process will repeat itself until no significant gains are realised (Romero and Rehman, 2003:23-26). Reference point approaches start by having the decision maker specifying achievement levels for each criterion in terms of relevant performance measures. These levels are typically of three types:
    - Goal levels (performance level that will fully satisfy the goals of the decision maker);
    - Exclusion levels (performance level at which, if violated, the entire scenario becomes unacceptable);
    - Reference levels (expectation of the decision-maker of an acceptable compromise between conflicting demands of different criteria.
- Outranking approaches represent evidence for and against the statement that one alternative is as better than another. Evidence takes the form of voting between criteria.
- Game theory approaches, in which each criterion can be associated with a single player. Game theory synthesizes the utility functions of individual players into a social utility function. It assumes that each criterion is associated with a particular "player" and that marginal utilities can be associated with each policy scenario (Romero and Rehman, 2003:110-113). Game theory aims at identifying solutions to the decision problem that represent the most acceptable compromise between players. Nash equilibriums - seeking the policy scenario that maximizes the product of the marginal utilities - are the simplest forms of this type of solution.
- Interactive MCDM approaches imply a progressive evolution and definition of decision-makers' preferences through an interaction between them and the results generated from various runs of the model. This interaction becomes a dialogue in which the model responds to an initial set of the decision-maker's preferences or trade-offs, and then when this response has been examined, another set is offered, and thus, the procedure progresses in an interactive way and iterative way until the decision-maker has found a satisfactorily solution (Romero and Rehman, 2003:79-102).

It was previously mentioned that the choice of MCDM method is important because the ranking of different management alternatives depends on the chosen MCDM method itself. Care should, therefore, be taken to select the suitable method. Moving on to a choice between the different multi-criteria evaluation methods, studies were undertaken in order to try to determine the "best" MCDM method (see Table 13).

Table 13: Comparative studies on multi-criteria evaluation methods

Study	Criteria used to compare multi-criteria evaluation methods	Main conclusions
(Duckstein *et al.*, 1982:178-184)	1) Type of data required 2) Nature of the alternative systems that can be analysed (i.e. discreet or continuous systems); 3)Consistency in results among different MCDMs; 4) Robustness of results (sensitivity analysis); 5) Ease of use; and 6)Amount of interaction needed between the analyst and the decision maker.	The methodology of evaluating MCEMs could be extended to include more techniques, evaluation criteria, or other applications.
(Hobbs, 1986:384-394)	1) Theoretical validity and appropriateness; 2) Flexibility and ease of use; 3) Results compared to other methods, i.e. validity 4) Robustness.	The choice of MCEM is itself a multi-objective problem and largely depends on the problem (context). a) Decisions can depend on the choice of methods, even on such theoretically irrelevant factors such as the phrasing of questions; b) Users would be careful in applying more than one method; and c) Researchers need to broaden their theories of decision-making so that "theoretically irrelevant" factors (such as the phrasing in questionnaires) can be explained, predicted and controlled.
(Hobbs *et al.*, 1992:1767-1779)	1) Appropriateness; 2) Ease of use; 3) Validity; and 4) Differences in results (robustness).	Extended his work of 1979 and 1986 and concluded that: a) Experienced planners prefer simple and transparent MCEM methods b) The ranking of management alternatives could be more sensitive to the choice of MCEM used to rank them compared with which person applies it.
(Tecle, 1992:129-140)	1) Problem related; 2) Decision-maker related; 3) Technique related; and 4) solution related.	a) The ranking of MCEMs differs according to the problem; b) It is possible to find different rankings of MCEMs based on the experience of other analysts.
(Mahmoud and Garcia, 2000:471-478)	1) Consistency of the resultant rankings; 2) Amount of interaction required by users; 3) Ease of understanding.	MCEMs are intended to show the trade-offs among different alternative solutions when evaluated by technical and non-technical professionals to maximize agreement between all interested parties.

Different MCDM models include (Belton and Stewart, 2002):

- Weighted Average (WA);
- Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE);
- Compromise Programming (CP);
- ELimination Choice Translating REality (ELECTRE);
- Analytical Hierarchy Process (AHP).

Selecting the most suitable MCDM requires testing different methods to reflect the decision-maker's evaluation weights, and of course, the validity of applying the method. The criteria for selection among MCDMs should include an understanding and an acceptance of the method used by the decision-maker. This implies that the theory of multi-criteria evaluation should be understood in order to maximize the method's utility.

Refer to Belton and Stewart (Belton and Stewart, 2002); Hobbs (Hobbs *et al.*, 1992) and Romero (Romero and Rehman, 2003) for further details on the methodology of multi-criteria decision analysis *per se*. As a point of criticism, the method does assumes the problem at hand as a given (i.e. it takes the starting point as a well defined set of criteria and focuses on the evaluation). The method is, therefore, not geared towards analysing symptoms of problems or towards identifying the problem that needs to be resolved. Thus, the decision-maker should have a clear understanding of the decision-making problem.

As public acceptability of different management options is an important decision-making factor in integrated resource management, the next section focuses on public participation.

3.5 Public participation in resource allocation

The National Water act (National Water Act, 1998) promotes the decentralization of water resource management in order (among other objectives) to gain efficiency. Since the public (households) is the lowest level of decentralization, one could ask whether the public has a legitimate role to play in informing priority setting in long-term decision-making for water resource management that has potentially significant social welfare implications. Public involvement in environmental decision-making is recognized as one of the basic requirements of sustainable resource utilisation (Iacofano, 1990; Smith, 1984:253-259; Van der Veeren and Lorenz, 2002:316-376). The Rio Declaration on Environment and Development also states that: "*Environmental issues are best handled with the participation of all concerned citizens, at the relevant level"* (United Nations Department of Economic and Social Affairs: Division of Sustainable Development, 2004). Although many researchers agree on the importance of local community involvement, the level of involvement is still low in most developing countries. Sceptics warn against the "dictatorship of the uninformed" and supporters uphold the legitimacy of the participation process while it appears that the public have traditionally not been consulted (Litva *et al.*, 2002:1825-1837; Wiseman *et al.*, 2003:1001-1012). Without public participation, decision-makers assume the risk of enforcing compliance from an unwilling public. Legislators hope that involving those who will be regulated in setting the rules will lead to more effective ruling once promulgated (Maguire and Lind, 2004).

Although not all literature originates from natural resource management theory, enough evidence suggests the potential benefit of testing public preference in resource allocation decision-making (Davis, 1996; Dungumaro and Madulu, 2003:1009-1014; Maguire and Lind, 2004; Munro-Clark, 1990; Nelson and Wright, 1995; Pateman, 1970; Rahman, 1993; Smith, 1984:253-259; Wignaraja *et al.*, 1991). Such literature regarding public participation has grown substantially in the past decade due, largely, to the following:

- The public has increased access to information because of the fast growing information technology era (Stave, 2003:303-313);
- The media has become more intrusive and increasingly protected by law as freedom of speech is seen as a basic human right;
- The realization that older management approaches used in the past have failed in terms of "sustainable development" criteria (Purnama, 2003:415-439);
- The rejection of traditional structures by the public and a new sophistication and sensitivity regarding the state of the environment amongst lobby groups (Pavlikakis and Tsihrintzis, 2003:193-205).
- A shrinking resource base and visible increases in environmental degradation have increased competition for resources and challenged government agencies to find a way to manage natural resources more sustainably.
- The conflict resolution and conflict management potential of participating processes (Fisher *et al.*, 2002:1-16).

The following could be seen as important concepts regarding public participation in resource allocation:

Democracy - within this context, representative democracy refers to equal participation in the decision-making process while political equality refers to the equality of power in determining the outcomes of decisions (Pateman, 1970). This is contrasted by non-participatory democracies where the participation of the minority elite is crucial. Two paradigms can be distinguished here. Consequently, a choice exists to either believe that representative democracy offers an effective means of community involvement in public affairs through elections, accepting that the number of votes legitimises representation, or to believe that powers should be devolved to the local level to allow local communities to make decisions regarding affairs of importance to their communities. In the first framework, institutions and professionalism regulate and organise public affairs in a more centralised manner, designing policies for the "common good", while in the second framework, institutions and professional agencies recognise local heterogeneity and operate as facilitators of the development process.

The role of power – is central to participatory processes and features as one of the reasons why people may involve themselves in resource management issues while at the same time agencies are unwilling to give up their control over the resource (Nelson and Wright, 1995). The nature and the levels of participation in a policy development process are often measured in terms of power and the roles that the different stakeholders have in the decision-making process. The greater the control by those outside the local community, the less local communities tend to be involved at critical decision-making stages. If, for example, the community plays an active role in decision-making, the nature of their role changes from being "subjects" to "directors" of the process. It is often implicitly assumed that the more people participating the better the outcome for the community (Munro-Clark, 1990). However, if the necessary mechanisms for stakeholder groups to influence the integration of their opinions in policy and practice do not exist, the number of participants becomes irrelevant.

Community empowerment - "empowerment of the grassroots" is a common saying in participatory development. However, the exact meaning of such a statement is less clear and the term can easily be misused or misunderstood. It could mean that power has been devolved or decentralised and that people have a more effective say in the running of their affairs (Chambers, 1997). Or, on a more individual level, empowerment reflects a state of personal development, a state of mind through which people engage in a learning process, increasing their self-esteem and confidence and enabling them to better use their own resources (Rahman, 1993). The educative dimension of taking part in the running of a democracy is a very strong attribute of participatory democracy theories (Davis, 1996). Social welfare would be promoted if citizens, learn to become involved in civic duty, thereby becoming "better" citizens.

Changing the relationship pattern - The other positive aspect of engaging in a participatory management approach is the improved interaction between the community and the respective government agencies. As different people get involved in consultation, discussion or negotiation, different parties get to know and understand one another better and even start trusting one another. The improved knowledge certainly improves communication channels which are crucial in participatory processes (Blaikie and Soussan, 2001).

Benefits and costs of participation - the appeal of participatory planning and management lies in the assumption that when communities' views have been taken into account, the policy or the projects will fit into a social and economic reality. People, feeling a sense of ownership, will be more compliant in bearing costs, such as the costs of increased administration, opposition development, raising expectations, limiting viewpoints, representation and validation (Davis, 1996; Rahman, 1993). Unfortunately, the monitoring and evaluation of participatory processes and programs has been neglected, and little information exists on how to assess the real impacts of participation on community development.

Implementing participation - the benefits of participation will be lost when there is a mismatch between the theory and its implementation. Types of public participation techniques used include: public information, public hearings, conferences, task forces/advisory boards, workshops, collaborative problem-solving and joint decision-making. People from the wider community often come to the participatory process expecting to gain greater control over the process while at the same time government rarely wants to relinquish its control. Most consultation processes use techniques like community meetings to reveal knowledge about the decision rather than to seek opinions or to allow influence (Smith, 1984).

The promotion of public participation is only part of the challenge. Effective implementation, after having decided to accommodate the public, is equally important.

A literature search yielded a small number of studies on whether or not (see Block 7, Table 1) to include public opinion in long-term resource management (Buchy and Hoverman, 2000; Dungumaro and Madulu, 2003:1009-1014; Litva *et al.*, 2002:1825-1837; Maguire and Lind, 2004; Munro-Clark, 1990; Pateman, 1970; Steel and Weber, 2001:119-131; Wiseman *et al.*, 2003:1001-1012). However, a number of studies on how (see block 10, Table 1) to include/accommodate public opinion were found. A wide variety of methods have been used by researchers to accommodate public preferences in the decision-making process, covering system dynamics modelling (Stave, 2003:303-313); value function approaches (Ananda and Herath, 2003a:75-90); conjoint analysis (Alvarez-Farizo and Hanley, 2002:107-116; Dennis, 2000:127-137); stated preference models (Haider *et al.*, 2002); multi-criteria approval (Laukkanen *et al.*, 2001:127-137; Pavlikakis and Tsihrintzis, 2003:193-205); direct preference investigation (Kolokytha *et al.*, 2002:391-400); analytical hierarchy process (Ananda and Herath, 2003b:13-26; Duke and Aull-Hyde, 2002:131-145; Gomez-Limon, in press; Tzeng *et al.*, 2002:109-120) and even photo questionnaires (Ryan, 2002:19-35). The choice of method is as important as properly implementing the method itself because of some systematic inconsistencies between expected (rational) and actual behaviour. In other words, given a choice between management alternatives, the public will not consistently select the “best” alternative based on the evaluation criteria. Experts in public resource management, therefore, sometimes have difficulty in combining information in appropriate ways because of limitations in the intuitive decision-making process (Dinar, 1998:367-382; Goicoechea *et al.*, 1992:89-102).

The difference between whether to or how to accommodate public opinion is of importance here. Answering the question of how to accommodate public opinion implies that a decision has already been taken to accommodate it. Such studies focus on the efficiency of the given method to accommodate public opinion and the ability of the method to obtain objective and legitimate responses from the public. These studies do not engage in the fundamentally important decision of whether or not to accommodate public opinion.

3.6 Conclusion

This literature review followed roughly the structure shown in Table 1 presenting theoretical grounds relevant to the research problem. The review discussed some reasons for market failures relative to public goods, such as bulk-water supply infrastructure. The rationale for government intervention and the problem of government failures in water resource allocation were explained.

MCDM as a specific decision-support mechanism was explained. Employing this technique would certainly be a step in the right direction; however, such a process needs to be refined and expanded since the decision-making contexts for government intervention were criticized as being too narrowly defined. This has led to an ignorance of important effects and, hence, the need for expansions in decision-making contexts. Expansions with regard to the temporal and spatial dimensions of the decision-making context were proposed. But expansions have impacts on the decision-making information load, and consequently, lead to the need for expansions in decision-support techniques, such as MCDM. Expansions in decision-support techniques bring to the fore uncertainties regarding methodologies of public participation in government intervention and resource allocation decision-making. It was made clear that uncertainty regarding methodologies for public enquiry into resource allocation management decision-making, therefore, still exists. The foresaid uncertainty refers to the objective presentation of management options in order to avoid bias, thereby jeopardising the legitimacy of the findings. Political transparency becomes of extreme importance and this study is especially sensitive to this. Hence, uncertainty refers to the achievement of acceptable response rates from public enquiry. Simple communication of complex problems becomes important, implying advance insight into the management problem from the decision-maker's side. This study engages in the issue of public enquiry and the following chapter provides more detailed discussion on the proposed expansion.

4. DECISION SUPPORT DEVELOPMENT

4.1 Introduction

Chapter 1 explained the necessity for an expansion in the water allocation decision-making context and in decision-support, mainly because of the measurement-problem as mentioned in Section 1.1. Chapter 2 set the physical context for the expansions by applying the measurement-problem to the BWMA while Chapter 3 provided the theoretical grounds for the problem and for the proposed expansions.

This chapter explains the expansion of the decision-making context and the consequent expansion in decision-support in detail. Such expansion increased the need for decision-making information and led to modifications in decision-support methodology. Section 4.2 briefly introduce the two expansions. The next Section (4.3) focuses on the first expansion being a temporal expansion of the decision-making context, which is explained via the development of two sequences of bulk supply options that compel the consideration of long-term impacts over time instead of sets of options at the same moment in time. Section 4.4 discusses the second expansion, which comprises expanding the spatial dimension of the decision-making context in the BWMA. This entails expanding the physical decision-making boundary to include previously excluded rural areas in the decision-making process. Lastly, a public and expert panel survey are undertaken to preview the posited expansions. Both surveys are explained in more detail.

4.2 Expansion of decision support

The expansion of decision-support is a direct consequence of expanding the decision-making context since an expansion of the context implied an increase in decision-making information (see Figure 14). Expanding decision-support is of the utmost importance if decision-makers strive towards social welfare maximisation that includes a sustainable but efficient and equitable resource distribution. This section presents the expansion of two dimensions of the decision-making context. Each expansion will be defined and discussed regarding relative importance and methodology. In order to make it more tangible, this problem is applied to bulk-water resource management in the BWMA.

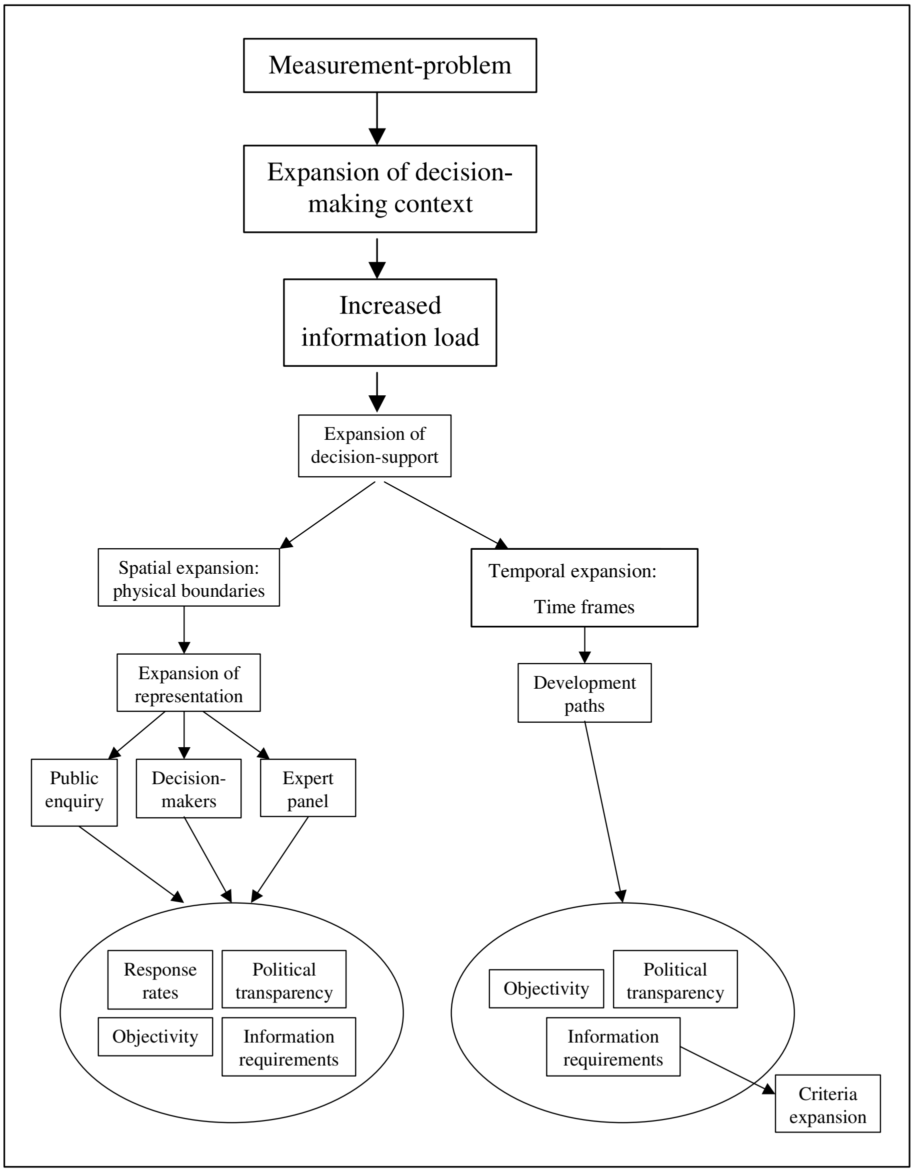

Figure 14: Expansion of decision-support
Source: (De Lange, 2005)

Figure 14 presents alternative expansion paths to decision-support in this study. The first is a spatial expansion of decision-support and the second is a temporal expansion. A spatial expansion was attempted by broadening the physical context (boundaries) of the decision-making area for water resource management. This expansion implied expansions in representation in decision-making and was accommodated via a public survey, expert panel survey and an expansion of representation of key decision-makers. The expansion needed to yield a satisfactorily response rate, be politically transparent and objective and imply changes in information loads. Expansion of the temporal dimension was attempted via the development of two “development paths” complying with objective criteria, transparency criteria and information load criteria. This also required an expansion of decision-making criteria. The temporal expansion is discussed before the spatial expansion.

4.3 Expansion of the temporal dimension

Expanding the temporal dimension will impact directly on the measurement problem since it will force decision-makers to at least consider the long-term costs/benefits that did not previously come to the fore in the decision-making process. The expansion was made tangible via the development of two sets of sequences of supply augmentation schemes (development paths or scenarios – see Table 14) for future supply in the BWMA. Each sequence represents the consideration of schemes over time instead of alternatives at the same time as has been done in previous studies (Eberhard and Joubert, 2001; Eberhard and Joubert, 2002; Joubert *et al.*, 2003; Stewart *et al.*, 1997). Each sequence was constructed in an objective and transparent way by involving local decision-makers in the development of each path (Killick, 2006; Van Rooyen, 2005; Van Zyl, 2005). The distinguishing factor of the two development paths could be regarded as water users' willingness-to-pay for "greener" water supplies. Although, still somewhat controversial, it does represent two legitimate alternatives for long-term bulk-water supply development for the WCSS. It is important to note that such a suggested outlay is not fixed and could be changed as new information (especially regarding costs) becomes available.

Table 14: Two long-term water resource management strategies

Development path A				Development path B			
Water scheme	**Implementation year**	**Scheme capacity (Mkl)**	**Total storage capacity in the WCSS (Mkl)**	**Water scheme**	**Implementation year**	**Scheme capacity (Mkl)**	**Total storage capacity in the WCSS (Mkl)**
Current water supply infrastructure	**2004**		**440**	Current water supply infrastructure	**2004**		**440**
Berg River Project	**2006**	**81**	**521**	Berg River project	**2006**	**81**	**521**
Voëlvlei scheme Phase I	**2013**	**35**	**556**	Desalination Plant 1	**2012**	**65**	**586**
Lourens River diversion	**2016**	**19**	**575**	-	**-**	**-**	**-**
Table Mountain Group Aquifer	**2018**	**70**	**645**	Desalination Plant 2	**2020**	**65**	**651**
Cape Flats Aquifer	**2026**	**19**	**664**	-	**-**	**-**	**-**
Eerste River Scheme	**2027**	**8**	**672**	Desalination Plant 3	**2027**	**65**	**716**
Desalination Plant 1	**2028**	**60**	**737**	-	**-**	**-**	**-**

Source: (De Lange, 2005)

The development paths contain different combinations of supply schemes – some investigated at feasibility level and others at pre-feasibility level (City of Cape Town: Water Services, 2002; Eberhard and Joubert, 2002; Joubert *et al.*, 2003; Kleynhans, 2002a; Kleynhans, 2002b). It is important to note that the focus is not on individual schemes, but on a development path as a whole.

Development Path A represents the more "conventional" way of supplying future bulk-water needs. It incorporates all bulk-water supply schemes up to 2004 in the BWMA (including all water demand management strategies such as leakage repair, pressure control and user education).

Development Path B poses an alternative to Development Path A, implementing "expensive" bulk-water supply options at an earlier stage. This development path challenges current decision-making and cost-estimation methodologies by questioning the relative cost of current "expensive" options compared to "cheaper" alternatives if all costs could be quantified and included in the equation. Development Path B could also be seen as a structured argument for not increasing water allocation from rural to urban areas in the study area.

In practical terms, the main difference between paths A and B relates to the timing of "more expensive" supply schemes such as the desalination of seawater. Development Path A contains more robust technology compared to B, while B is more sensitive to technological development than A; however, B has, therefore, greater potential in terms of efficiency gains with regard to technological development.

The challenge was to identify what long-term impacts each path will have and to evaluate their relative legitimacy accordingly. It was, therefore, extremely important to evaluate the two development paths as packages and not merely as the sum of individual schemes. Within the expansion of the temporal dimension, new spatial dimensions (see Section 4.4) came to the fore and, with that, additional socio-economic and ecological considerations, forcing decision-makers to think more broadly regarding the consequences of water management decisions.

4.4 Expansion of the spatial dimension

Although not the only water user entity in the BWMA, the CCT is by far the biggest (in terms of volume and number of users). It is estimated that more than 90 percent of the total annual water supply for the city originates outside the municipal boundaries of the CCT, which makes the CCT dependent on the surrounding rural areas for its water supply. However, in the past, adjacent rural areas have been accommodated to a lesser extent in long-term allocation decision-making. A situation such as this has the potential for the development of conflicting interests between different user groups. Water allocations within the administrative boundaries of the CCT (and even within the BWMA in the case of inter-basin transfers) are, therefore, often not as sensitive to allocation effects beyond the municipal boundaries of these areas compared to impacts within municipal boundaries. This is because municipal authorities are to a lesser extent responsible for effects outside their administrative boundaries and are, therefore, not as sensitive to allocation effects occurring outside their boundaries – this could lead to misallocations of water in regional contexts. Expanding the spatial dimension of the decision-making context engages in this problem of "bad boundaries make bad governments" – or in this case "governance".

The expansion of the spatial dimension of the decision-making context was made tangible via an expansion of the physical boundaries of the area included in decisions-support (see Figure 15 for a presentation of the spatial context of the study – defined in terms of secondary catchments). The red line indicates the CCT municipal boundary, while the area in green (including the CCT) represents the expansion of the decision-making context. The expansion is defined in terms of secondary catchments and includes all rural areas sharing water resources with the CCT. The area also includes some rural areas from the adjacent Breede Water Management Area, which is subjected to inter-basin transfers to the BWMA.

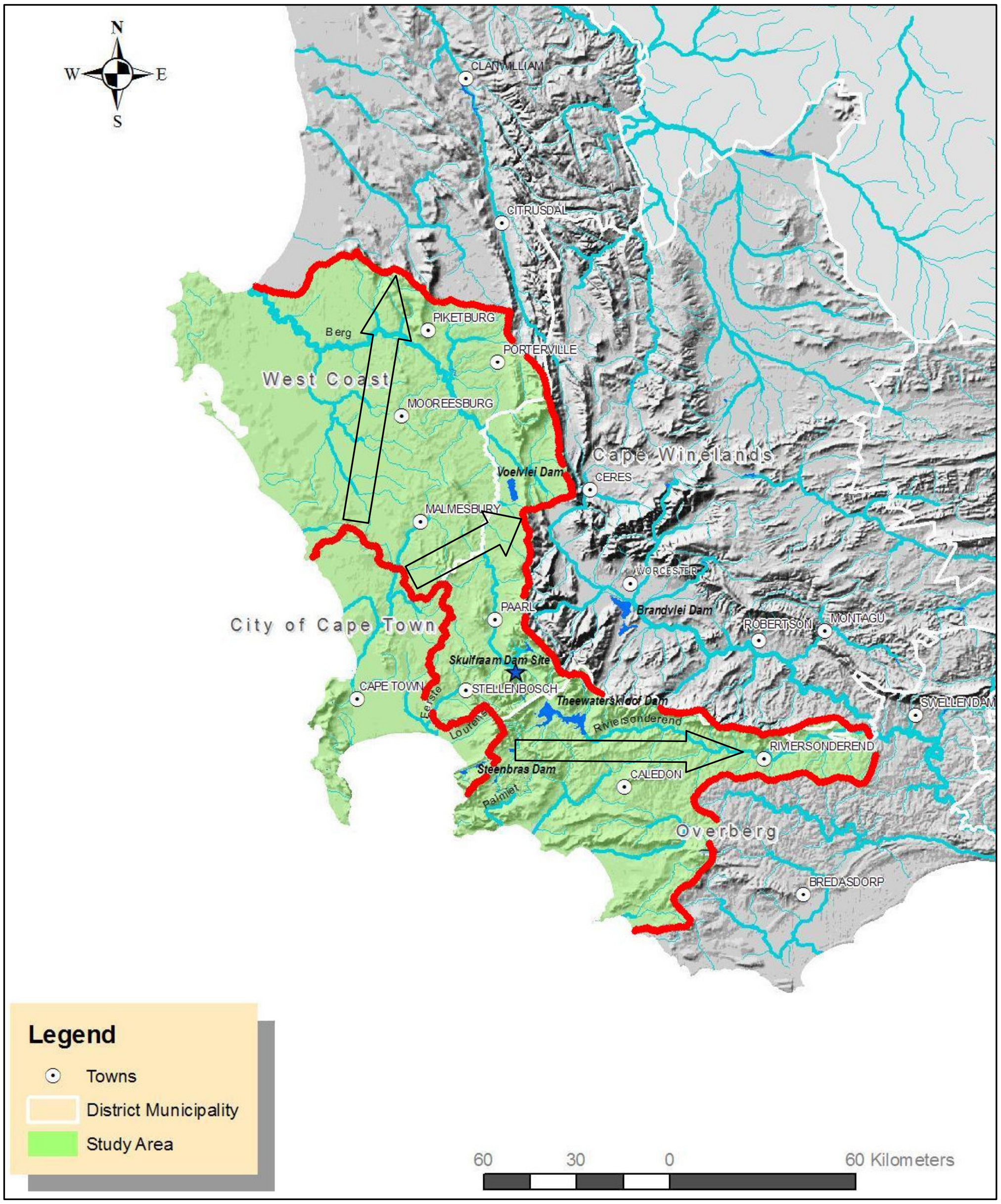

Figure 15: Physical expansion of the decision-making context

Source: (De Lange, 2005; Western Cape Department of Agriculture, 2005)

Table 15 presents the local municipalities apart form the CCT that were partly included in the expansion.

Table 15: Municipal districts included in the study

West Coast District municipality, Moorreesburg:	Boland District municipality, Worcester:	Overberg District municipality, Bredasdorp:
Berg River local municipality, Piketberg	Drakenstein local municipality, Paarl	Theewaterskloof local municipality, Caledon
Saldanha Bay local municipality, Vredenburg	Stellenbosch local municipality, Stellenbosch	
Swartland local municipality, Malmesbury		

Source: (Western Cape Department of Agriculture, 2005)

The expansion of the physical boundaries of the decision-making context resulted in an increase in the decision-making information load for decision-support. Part of this increase in information is due to an expansion of representation in the decision-making process of users in newly included areas. This expansion of representation needed to be accounted for and was, hence, accommodated in the expansion of three prominent groups in the decision-making process:

- Public enquiry
- An expert panel
- Decision-makers

The expert panel and the public were consulted via two surveys while decision-makers via the accommodation of the political process running parallel to the whole process.

4.4.1 Expert and public surveys

Since the expert panel and the public differ significantly in their roles in the decision-making process, the need for two separate surveys was identified. The first survey focused on the identification of public preferences with regard to long-term water allocation management. The outcome of this survey was used as input for the expert panel survey, which focused on determining a weighted score for the two development paths (Table 14) and was used to advise decision-makers.

Political transparency played an important role in the development of both surveys since the process could be hampered by opportunistic political behaviour. If researchers ignore the impacts of politics, the legitimacy of the results could be questioned. The study, therefore, incorporated the political process running parallel to the study right from the inception phase of the study. This did slow the development process somewhat but did ultimately enhance political acceptability of the research findings. The following is a broad chronological layout of the methodology followed in the development of the two surveys:

- Conceptual research problem formulation;
- *Consultation with decision-makers;*
- Initial literature review (updated throughout the study);
- Continuous networking management figures in BWMA;
- Research problem identification, definition and identification of theoretical shortcoming;
- Literature review and structuring of action plan;
- Initial survey planning;
- *Consultation with decision-makers;*
- Respondent identification for both surveys;
- Public and expert questionnaire development;
- *Consultation with decision-makers;*
- Public and expert survey development (logistics);
- *Consultation with decision-makers;*
- Peer review of questionnaires for political acceptability, relevance, accuracy, volume of information presented, simplicity, and criteria-groups employed. (A small selected panel of key figures from Stellenbosch University, Cape Town University, the CCT and the Departments of Agriculture and Water Affairs and Forestry conducted this review process.);
- Public sampling process;
- Expert panel identification (participation on invitation);
- Pilot run for public survey;
- Finalisation of questionnaires;
- Sampling and survey processes;
- Return of public questionnaires and expert panel questionnaires;
- Processing;
- Expert panel interviews;
- Expert panel follow-up;
- Analysis;
- Final comparison of development paths A and B and
- Reporting and communication of results

4.4.2 Assumptions

The following are the main assumptions that were made in the research that needed to be kept in mind when interpreting the results:

- Since this is not a technical study, most of the quoted technical specifications of the bulk-water supply augmentation schemes were obtained from specialised studies. These technical specifications were not verified in depth and were assumed to be acceptable for the purposes of the study.
- Although the continuation of the pilot study has been approved, this study does not assume that the CCT will automatically proceed with the Table Mountain Group Aquifer as a supply augmentation scheme.
- The individual preference orderings of rural and urban respondents were considered equally important.
- All participants in the expert panel survey are seen as specialists in their distinct fields with no distinction being made between the relative importance of disciplines. Responses and comments from the different experts are, therefore, seen as equally important.

4.4.3 Public survey

Public enquiry was accommodated by means of a survey that determined public preference with regard to the two development paths, as mentioned in Table 14, for the expanded decision-making context (see Figure 15). A conjoint-analysis based approach was followed (Alvarez-Farizo and Hanley, 2002:107-116; Belton and Stewart, 2002). This method collects and analyses individual preferences for goods and services (in this case it was a public good - bulk-water supply). The method assumes that each scheme may be described in terms of its characteristics or attributes to society and the natural environment and the extent to which respondents value the good or service (water scheme-services) depends on their valuation of the attributes of the good or service.

Survey questions may be asked in pairs or in the full-profile method. This study settled for a one-page full-profile presentation because of the obvious limitation of respondents to absorb a large volume of information. Just enough information was provided to enable respondents to display their preferences. This was done to keep the response rate as high as possible. The information presented was, for the aforesaid reason, focused to indicate differences between the two development paths and not all strong and weak points of each development path.

Presenting a legitimate and objective view of a complex situation, in simple language, on one page, proved challenging. It was anticipated that the public would use the provided information to merely guide their preferences, as responses will be a function of the information provided and own personal perceptions and contexts. Once again, the transparency of the questionnaire development process became important with the key stakeholders and local government participating in the development of the questionnaires. It became clear that building public support for resource management policies without manipulating the public in a specific direction requires raising public awareness of resource problems and developing an understanding of the consequences of different management options (i.e. an educational challenge, particularly in environmental educational sciences).

A small pilot study was done in the towns of Stellenbosch and Paarl (see Figure 15) to verify that the questionnaire was easy to understand. Minor adjustments were subsequently made.

Budget limitations allowed for a stratified random sample of approximately 7000 postal questionnaires. Raw data (a database containing 607292 rows of information in respect of all registered water users in the CCT) for the urban areas was obtained from the CCT city engineers (Mostert, 2004; Muller, 2005). Since this was a postal survey, the rows were sorted by postal address, and all records without a postal address were deleted. The database was then sorted according to land-use, from where all non-residential uses, including schools, government buildings and industries were deleted. This was done because non-residential users do not pay according to a block tariff system and the voting power does not lie with them. The data was then sorted according to land value. All records comprising municipal property values lower than R50 000 were deleted because of the risk of the non-payment problem associated with such properties. All properties with municipal valuations above R3 000 0000 were also deleted because the assumption was made that these water users will probably pay their municipal accounts via debit order and will never question their water bill each month. Approximately 195630 data entries in 60 suburbs were left in the database after checking for duplicate records. Each suburb was extracted into a separate spreadsheet and was again sorted according to land value. A random number ranging between zero and the number of the particular suburb was allocated to each property. Each suburb was then sorted according to the random numbers in ascending order.

The rural areas in the expanded decision-making context (Figure 15) were handled in much the same way. Parts of the following district municipalities were included along with the CCT (see Table 15):

- West Coast
- Boland
- Overberg

However, not the whole of the above-mentioned district municipalities were included in the sample since not the whole of each area shares water resources with the CCT. Much effort went into matching the district municipal database with the secondary catchments in rural areas sharing with the CCT. Each local municipality (as indicated in Table 15) was approached to obtain their address lists. The initial database was significantly smaller with 79382 entries remaining after the data was cleaned and ordered in the same way as was the CCT data.

The budget limitation of approximately 7000 questionnaires allowed a 2.55 percent stratified sample of the 275012 data entries. Samples equal to the representative size of each suburb/region were drawn. A total of 7029 questionnaires went out to respondents in January 2005. The timing in terms of response rate of the survey was favourable because of a newly announced 20 percent water restriction in October 2004 in almost the whole BWMA. The media also played an important role in increasing public awareness regarding water scarcity in the region.

Each participant in the public survey received the following:

- A covering letter introducing the reason and aim of the survey;
- Background information and questionnaire on a single page;
- A return envelope to increase the response rate (see Annexure 2).

The postal survey did not test the ability of the public to provide suggestions for long-term water management but merely asked the public's opinion regarding two legitimate long-term water resource management strategies for the BWMA (being the two development paths -see Table 14). The public was confronted with key expected impacts/outcomes of the two developments paths broadly structured in terms of the same criteria as used in the expert survey (see Figure 16). Respondents were merely asked to indicate their relative preference for each development path via a scoring system. The outcome of this survey was used to obtain an indication of the relative preferences of the public regarding long-term water management as well to compare the outcome of the survey with expert estimations regarding public preferences. For results on the public survey, refer to Section 5.2.

4.4.4 Expert panel survey

Expert panel enquiry followed a modified Delphi technique. The method was originally conceived as a way to obtain the opinion of experts without necessarily bringing them together face to face (Curtis, 2004), however in this study face to face interviews were necessary.

Expert panels are not responsible for the final choice of supply augmentation scheme since their sole function is to provide a legitimate information platform upon which decision-makers can base management decisions. The physical expansion of the decision-making context significantly increased the decision-making information load needed to make water allocation decisions. Consequently, the group of experts providing decision-making information also needed to be expanded. A list of key experts was identified (see Annexure 3) using the criteria structure as mentioned in Figure 16 as a guideline. The newly established expert panel was then utilized to compile an information and scoring document (see Annexure 6) to expand the temporal and spatial dimensions. Previous MCDM studies done in the BWMA (Belton and Stewart, 2002; Eberhard and Joubert, 2002; Joubert *et al.*, 2003; Kleynhans, 2002a; Stewart *et al.*, 2001; Stewart *et al.*, 1997) served as a basic point of departure for the development of the information and scoring document. In previous studies, individual water management schemes were evaluated, while for this study, the emphasis fell on the evaluation of alternative development paths (sequences of supply augmentation schemes-see Table 14) over time. The alternative development paths were compiled by amalgamating the responses of the various water management experts consulted in the Western Cape. It is important to note that the emphasis fell on the development of the two development paths as units within a regional context and not as discrete schemes.

Some standards of judgement and comparison were necessary to compare the development paths – from there, the compilation of the criteria set as presented in Figure 16. These criteria also structured the information and scoring document (Annexure 6). Political acceptability was critical for this part of the study, and the process was, therefore, made as transparent as possible via numerous discussions with the local Department of Water Affairs and Forestry, Department of Agriculture and the CCT Administration. The selection of comparison criteria for the two development paths is crucial for obtaining a legitimate answer. In order to follow a holistic approach, an extensive list of criteria was first identified to describe the two development paths. However, not all were relevant in the decision-making process, and a balance between volume of information and relevance needed to be found. It was, therefore, decided that only differentiating criteria would be used to distinguish between the two development paths, i.e. the emphasis would be placed on presenting the differences rather than the similarities between the two development paths. This was aimed at keeping the information to a minimum and as relevant as possible. Therefore, only criteria that yielded enough information to describe significant differences between development paths A and B were used in the study (see Figure 16).

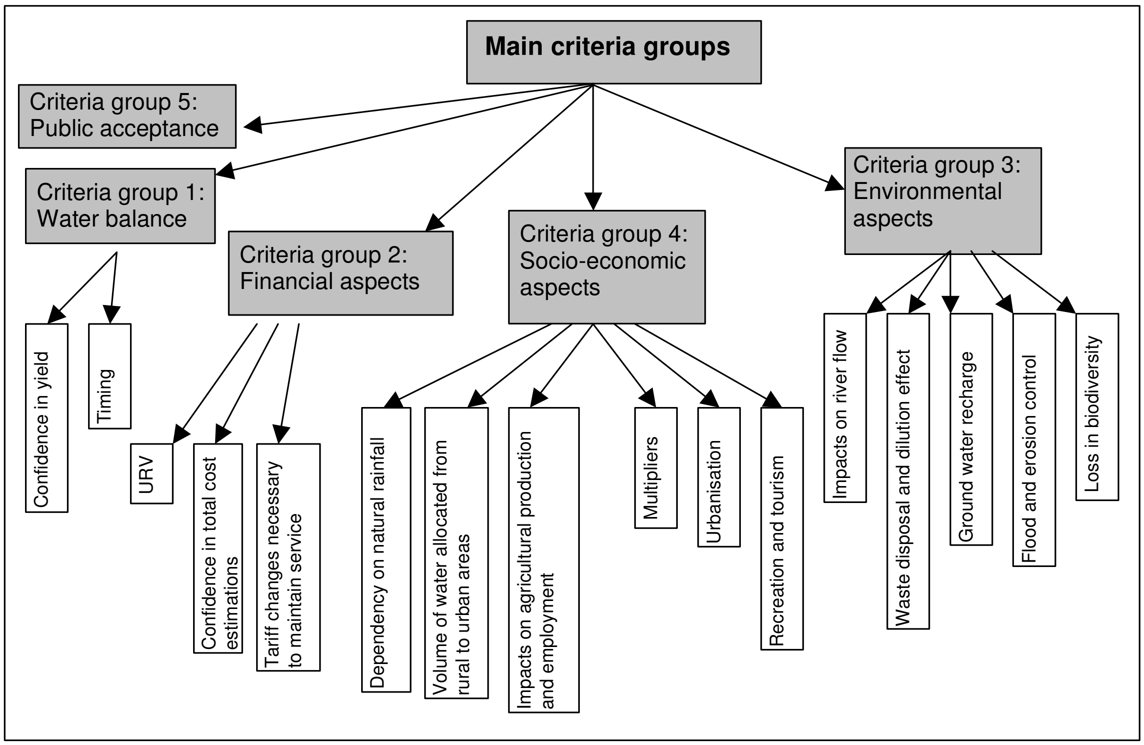

Figure 16: Criteria tree for the regional MCDA used in the study

Five main criteria groups, of which four consisted of sub-criteria, were identified:

- Water balance, with two sub-criteria. The first sub-criterion was the relative "*confidence in the yield*" expectation, because it would heavily influence the relative time before new supply schemes would be needed. The second sub-criterion was "*timing of yield*" or the timely phasing in of different schemes to supplement supply, and it was seen as an important criterion if viewed from an assurance of supply point of view – particularly if schedule one (water for human consumption and in-stream flow requirements) water users are considered as the most important users of water.

- Finances, with three sub-criteria. The unit reference value ("*URV")* was included as this measure is the standard financial indicator to compare bulk supply projects. The URV is a discounted value (over the project life-time using a predetermined discount rate) per cubic metre of water for the project. This value only accounts for the capital, operational, and maintenance costs of schemes over the project lifespan. It does not include externalities (positive or negative) and the long-term impacts of the schemes. The relative *"confidence in the accuracy of cost estimations"* impacts on water tariff settings (particularly in cases where cost-recovery strategies are followed) and, therefore, also on the relative weight of financial criteria as a whole – this criterion is, therefore, important and was included. "*Changes in tariffs"* necessary to maintain the water supply services reflect on the affordability of an option or, in this case, development path. It has an important impact on the public's acceptance of an option and eventually on the relative willingness of the public to pay for this water.
- Socio-economics included six sub-criteria. The "*dependency on natural rainfall"* and the *"volume of water allocated from rural to urban areas"* were used as the point of departure for the discussion on socio-economic impacts. One could question whether these two could be seen as criteria; however, after consideration it was decided that they should be included because they form the bases for differentiating spin-offs from themselves. The *"dependency on natural rainfall"* was included to present the basic difference between the development of additional storage capacity and water production. The relative importance of agricultural irrigation in terms of water usage was accommodated by including the impacts of water restrictions (*"impact on agricultural production and employment"*) on irrigated agriculture. These impacts were pulled through to the rest of the economy by using *"multipliers"*. *"Urbanisation"* was included for its relative importance in population demographics as an important driver of water demand and to show the opportunity cost of keeping the people in the rural areas. Finally, *"recreation and tourism"* were included because of the correlation between tourism and the natural beauty of water bodies.
- The environment criteria group proved to be a controversial topic (Day, 2005; Killick, 2006). Without being trapped in lengthy discussions on differing values and moralities, it was decided to include five sub-criteria. "*In-stream flow requirements"* proved to be the first and most important determinant in this section. Minimum in-stream flow requirements are enforced by law in South Africa, and much research effort goes into the quantification of such requirements for the different catchment areas in South Africa. *"Waste disposal and*

the dilution effect" of rivers were included because these have a direct impact on pollution as an important driver of water demand. *"Ground-water recharge and discharge"* tempos were included to focus specifically on the groundwater potential (being the next source of bulk supply because of the lack of alternative surface supply options) of the area and the differences between the two development paths in this regard. *"Flood and erosion control"* were also included; however, little scope remains for the construction of additional dams in the study area, which limits the expansion of increased flood control. The *"impacts on biodiversity"* remain rather open and were seen as the "generic criteria" of environmental impacts.

- Public acceptance was accommodated as a separate criteria group.

In compiling the list of experts used on the expert panel, 16 individuals who served on the CMABWS study (Eberhard and Joubert, 2002; Kleynhans, 2002a) were used as a point of departure. An additional 34 individuals (chosen from among authors included in the literature review and networking contacts) were identified and invited to participate (see Annexure 3). Of the 50 invitations, 17 agreed to participate in the survey.

Initially, the intention was to complete the expert panel survey at a series of workshops where all scoring and negotiations could be concluded. However, finding a date that would be suitable for all proved impossible to obtain. This proposal was abandoned and an electronic survey via e-mail was chosen instead. Participation entailed scoring the two proposed development paths in terms of a criteria tree (see Figure 16). The expert panel survey presented the two developments paths in significant detail, and the challenge was to quantify (or at least discuss) the long-term impacts of both development paths in terms of the criteria set. Experts were asked to score and make a trade-off based on the presented information and their own field of expertise. The panel were also asked to indicate the relative importance of the different criteria (see Figure 16) via a weight allocation exercise. They also received the public questionnaire (see Section 4.4.3) and were asked to provide their estimation regarding the outcome. This was important to determine whether, or to what extent, the experts (decision-makers or agents) have insight into public (principal) preference.

The e-mail session was followed by a personal consultation with each expert after completion of the scoring document. During this meeting, all scores and weights were discussed and verified, and care was taken to ensure the correct interpretation of questions. All the comments made during these meetings were noted. After completion of the round of interviews, all comments were compiled in a single questionnaire (see Annexure 6) and used in a follow-up e-mail session (see

Annexure 5) during which the expert panel were given the opportunity to respond to one another's comments. All comments were used anonymously to partially guide the statistical analysis and inference in Chapter 5.

4.5 Conclusion

It should be clear that the study area is defined in a regional context with sequences of supply augmentation schemes being compared over time. This scenario confronts decision-makers with a broader set of variables that influence scores in the MCDM process (and compilation of the weight structure) than comparing a single scheme at a time. MCDM exercises could, therefore, promote different management strategies depending on the context. The challenge, therefore, lies in defining the "best" decision-making context before comparing different management options since seemingly the "best" option for implementation when comparing single schemes could prove to be a "poor" option when viewed in a regional context over time.

An expansion in the decision-making context necessitated by effects not accounted for regarding previously excluded parties and increased information needs in water resource allocation management in the BWMA was explained in this chapter in detail. Two expansions were discussed, - the first was a spatial expansion of the decision-making context, which was accommodated via the development of two sequences of bulk supply options. This necessitated the consideration of long-term impacts over time instead of sets of options at the same time. This expansion forced decision-makers to at least consider previously unaccounted for effects in allocation decision-making. The second expansion comprised expanding the spatial dimension of the decision-making context in the BWMA. This was done via the physical expansion of the decision-making boundary to include previously excluded areas in the decision-making process in the BWMA.

The risk of ignorance towards the expansions was explained. Both expansions loaded the informational need in decision-making and, therefore, led to modifications in decision-support methodology. Consequently, a public and an expert panel survey were done to partially accommodate this need. The delimitation and methodology of both surveys were explained in detail. The next chapter focuses on presenting the outcomes of the expansions in terms of the results of the public and expert panel surveys.

5. OUTCOMES

5.1 Introduction

The necessity of expanding the water allocation decision-making context was explained in Chapter 1. This expansion motivated expansions in decision-support techniques and decision-making information. Chapter 2 set the context for the expansion while Chapter 3 provided the theoretical base. Chapter 4 explained the methodology behind the aforesaid expansions.

This chapter presents the outcome of the public and expert panel surveys as discussed in Chapter 4. Section 5.2 focuses on the public survey, presenting some descriptive statistics of the outcome. The public survey fed into the expert panel survey (as mentioned in Section 5.3), resulting in a final weighted score for each development path that will be used to inform long-term allocation decision-making. Important expert comments were noted in Section 5.4 and main contributions are discussed in Section 5.5.

5.2 Public survey outcome

The public survey estimated public preference relating to long-term water resource allocation management in the BWMA. Public preference for “greener” water supplies (Development Path B) compared to “traditional” augmentation schemes (Development Path A) was needed to inform expert estimations since it is important that decision-makers do not decide on preferences on behalf of the public. It was, therefore, necessary to obtain public preference in a transparent manner (as discussed in Section 4.4.3).

The two developments paths were compared in terms of the criteria set, as mentioned in Figure 16 - however, only main criteria groups were used to allow for simplicity and length of the questionnaire. Respondent were asked to state their preference on a scale out of 100. For discussion purposes the focus will be on Development Path A, since Development Path B will be the mirror image of A. The outcome of Development Path B will however be reported where necessary.

Table 16: Descriptive statistics for the public and expert panel surveys

	Public survey		Expert estimations	
Descriptive statistics	Development Path A	Development Path B	Development Path A	Development Path B
Mean	38.563	61.438	44.118	55.882
Standard Error	0.772	0.772	4.314	4.314
Median	35	65	40	60
Mode	40	60	60	40
Standard Deviation	25.473	25.473	17.787	17.787
Sample Variance	648.853	648.853	316.360	316.360
Kurtosis	-0.363	-0.363	-0.923	-0.923
Skewness	0.475	-0.475	-0.431	0.431
Range	100	100	60	60
Minimum	0	0	10	30
Maximum	100	100	70	90
Sum	41956	66844	750	950
Count	1088	1088	17	17

Source: (De Lange, 2005)

Table 16 presents descriptive statistics as well as comparative expert estimations for Development Path A from the public survey. As mentioned in Section 4.4.4 participants in the expert panel survey also received a copy of the public questionnaire to enable them to indicate their estimations regarding the outcome of the public survey. It must be noted that no generalisation could be made whatsoever with regard to the comparison of the obtained public preference and expert panel estimations since the outcome will always be a function of the issue at hand. Although possible, no statistical analysis of the comparison of the public preferences and expert panel estimations of such preferences was done. The important point is that public preferences were consulted and not assumed.

Of the original 7029 postal questionnaires that went out, 1088 were returned. This represents a 15.48 percent response rate, which is considered satisfactory, given that response rates of between 5 percent and 10 percent are often realised in surveys relating to public issues. However, expectations were higher because, at the time of the survey, the BWMA was in a one-hundred-year drought cycle accompanied by wide media coverage regarding the natural, socio-economic and financial impacts of the drought. Low response rates could hamper the legitimacy of public surveys regarding strategic recourse issues. Individual respondents may feel that public issues do not affect them directly, nor could they make a difference in the final outcome. This links up with the basic claim underlying public choice theory, which holds that sound government policies in a functional democracy are an under-provided public good, because of the rational ignorance of voters: each voter is faced with an extremely small probability that his/her vote will change the result of the outcome, while gathering the relevant information necessary for a well-informed answer/vote generally requires substantial time and effort. Therefore, the rational decision of each voter is to be generally ignorant of surveys regarding public goods, politics and is perhaps even withhold from voting. Rational choice theorists claim that this explains the gross ignorance of most citizens in modern democracies as well as low voter turnout (Buchanan and Tullock, 1962; Buchy and Hoverman, 2000; Mueller, 1997). This study attempted to compensate for significant investments in time and effort to gather decision-making information by providing for this need in an objective manner within the public questionnaire (see Annexure 2).

The outcome of the public questionnaire yielded a preference for Development Path B (and, therefore, a "greener" water allocation strategy) in the proportion of 60:40 by three indicators of relative location of the data. Although both the mode and median are preferable to the mean as indicators of relative location for non-parametric data, only small differences were realised between the three measures with all three measures indicating a preference towards Development Path B in the same magnitude (see Table 16). It was decided that the mean score of 38.56 for Development Path A (and 61.44 for Path B) would be used in the aggregation process, which follows the expert panel survey (see Table 17). Mean and median expert panel estimations approximate the outcome of the public survey except for the mode that was the exact opposite, indicating outliers (or possible disagreement) in expert opinion (see Table 16).

5.3 Expert panel survey outcome

The expert panel survey was a more detailed multi-disciplinary comparison of the two development paths. The comparison followed the structure of the criteria set as describe in Figure 16 with four of the five main criteria groups being accommodated in the expert panel survey. The fifth main criteria group (public acceptance) was measured by the public survey and was only accounted for in the aggregation process as summarised in Table 17, Table 18 and Table 19.

Two issues were of importance for the expert panel survey: first, the level of consensus among experts regarding the scores and criteria weights (relative importance of the differentiating criteria) and second, the aggregated weighted total score for each development path. The level of consensus was important since it impacted on the decision regarding which point parameter in each distribution will be used in the aggregation process. The aggregation process *per se* will allow decision-makers to make water resource allocation decisions with greater confidence without harbouring the fear that these decisions will harm their political positions.

Normal probability plots (not shown) indicated that a significant number of criteria were non-normally distributed with significant variation evident for both scores and weights (see Figure 17). This implies a relatively low level of consensus among experts regarding the level of importance of the different criteria. However, differences were expected since the panel was composed of experts from different fields of interest.

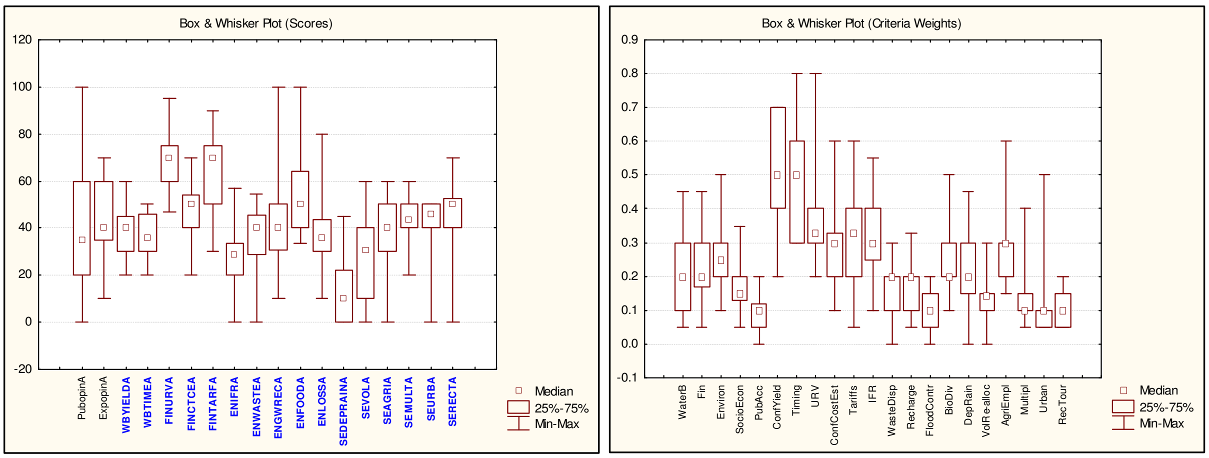

Figure 17: Box and whisker plot for scores and weights of all criteria

Source: (De Lange, 2005)

A single parameter representing each distribution of scores and weights was needed for aggregation purposes (therefore assuming normality). For the sake of comparison, the mean, mode and median were used in three separate aggregation runs for comparative calculations. Answers of the same magnitude were obtained with all three indicators displaying a majority for Development Path B. The study settled on presenting only the mean for the weight structure, which gave the most balanced view of the criteria for display purposes (see Figure 18 for the mean weight of each of the five main criteria groups and Figure 19 for the average of the different sub-criteria).

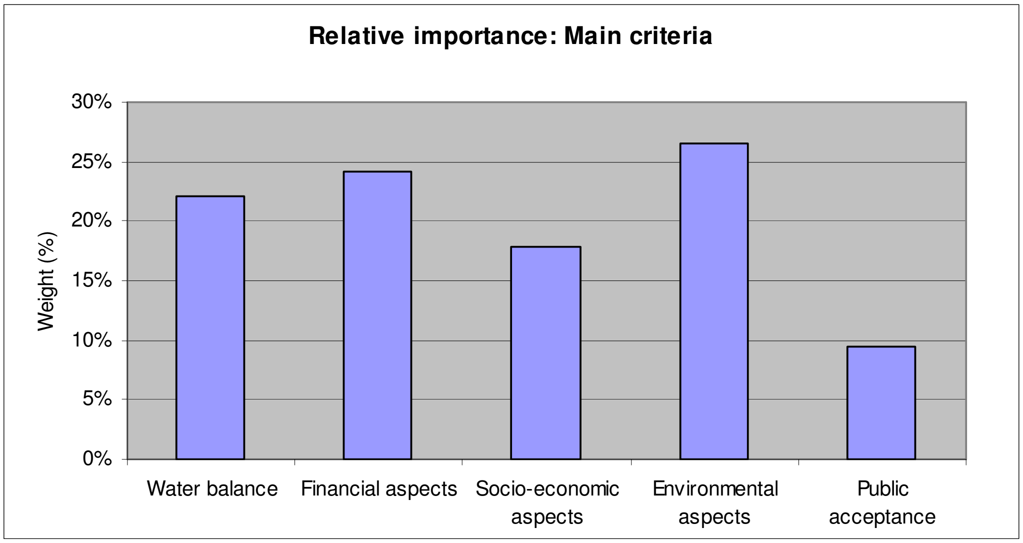

Figure 18: Mean weights: main criteria groups

Source: (De Lange, 2005)

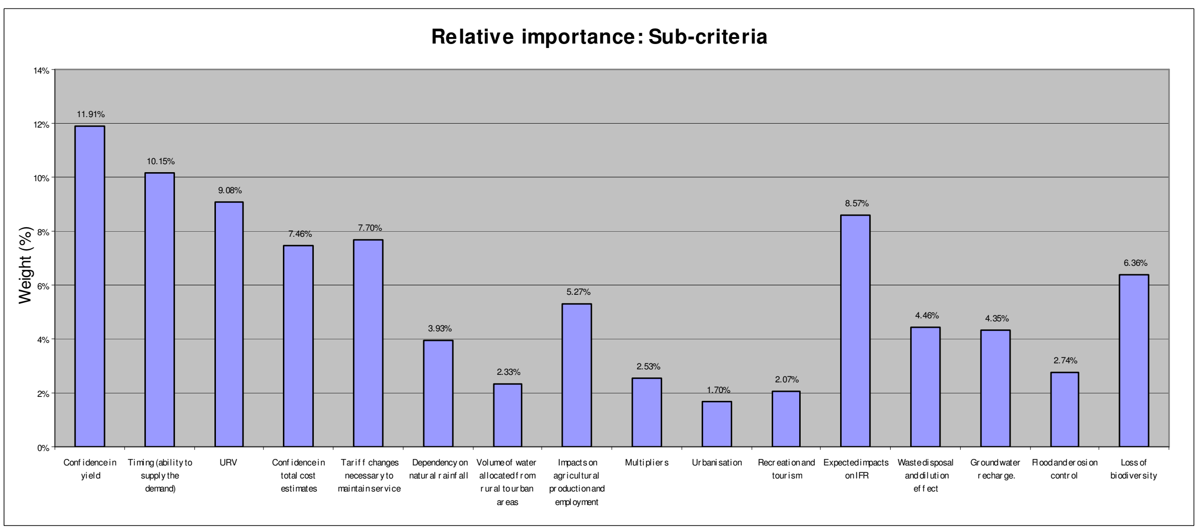

Figure 19: Mean weights: sub-criteria groups

Source: (De Lange, 2005)

Aggregated total scores for the two development paths were obtained by aggregating the weighted scores obtained from each sub-criterion. A weighted score for each sub-criterion was obtained by multiplying mean (mode or median) scores by the mean (mode or median) weight of the particular sub-criterion. Total scores for development paths A and B were, therefore, compared in terms of the mean (see Table 17), the mode (see Table 18) and the median (see Table 19). Answers of the same magnitude were obtained and using the mean was settled on, which gave the most balanced view of the criteria. (Note the placing of the outcome of the public survey under the public acceptance criteria group.)

Table 17: Aggregated score for development paths A and B (mean)

				Score (unweighted)		Score (weighted)	
Main criteria	**Sub-criteria:**	Weight	Cumulative weight	A	B	A	B
Water balance		**1.000**	**0.221**				
	Confidence in yield	0.529	0.119	0.387	0.613	0.046	0.073
	Timing (ability to supply the demand)	0.471	0.101	0.370	0.630	0.038	0.064
Financial aspects		**1.000**	**0.242**				
	URV	0.389	0.091	0.682	0.318	0.062	0.029
	Confidence in total cost estimates	0.304	0.075	0.466	0.534	0.035	0.040
	Tariff changes necessary to maintain service	0.307	0.077	0.631	0.369	0.049	0.028
Socio-economic aspects		**1.000**	**0.178**				
	Dependency on natural rainfall	0.221	0.039	0.153	0.847	0.006	0.033
	Volume of water allocated from rural to urban areas	0.130	0.023	0.267	0.733	0.006	0.017
	Impacts on agricultural production and employment	0.296	0.053	0.382	0.618	0.020	0.033
	Multipliers	0.125	0.025	0.406	0.594	0.010	0.015
	Urbanisation	0.115	0.017	0.414	0.586	0.007	0.010
	Recreation and tourism	0.112	0.021	0.445	0.555	0.009	0.011
Environmental aspects		**1.000**	**0.265**				
	Expected impacts on IFR	0.311	0.086	0.270	0.730	0.023	0.063
	Waste disposal and dilution effect	0.174	0.045	0.342	0.658	0.015	0.029
	Ground water recharge.	0.175	0.044	0.409	0.591	0.018	0.026
	Flood and erosion control	0.100	0.027	0.544	0.456	0.015	0.012
	Loss of biodiversity	0.241	0.064	0.359	0.641	0.023	0.041
Public acceptance		**1.000**	**0.094**	0.386	0.614	0.036	0.058
			1.000			**0.418**	**0.582**

Source: (De Lange, 2005)

Table 18: Aggregated score for development paths A and B (mode)

				Score (unweighted)		Score (weighted)	
Main criteria	**Sub-criteria:**	Weight	Cumulative weight	A	B	A	B
Water balance		**1.000**	**0.330**				
	Confidence in yield	0.700	0.210	0.400	0.600	0.084	0.126
	Timing (ability to supply the demand)	0.300	0.120	0.500	0.500	0.060	0.060
Financial aspects		**0.900**	**0.175**				
	URV	0.300	0.090	0.700	0.300	0.063	0.027
	Confidence in total cost estimates	0.200	0.045	0.400	0.600	0.018	0.027
	Tariff changes necessary to maintain service	0.400	0.040	0.700	0.300	0.028	0.012
Socio-economic aspects		**0.900**	**0.165**				
	Dependency on natural rainfall	0.200	0.030	0.000	1.000	0.000	0.030
	Volume of water allocated from rural to urban areas	0.150	0.030	0.000	1.000	0.000	0.030
	Impacts on agricultural production and employment	0.300	0.045	0.500	0.500	0.023	0.023
	Multipliers	0.100	0.030	0.500	0.500	0.015	0.015
	Urbanisation	0.100	0.015	0.500	0.500	0.008	0.008
	Recreation and tourism	0.050	0.015	0.500	0.500	0.008	0.008
Environmental aspects		**1.050**	**0.190**				
	Expected impacts on IFR	0.400	0.050	0.200	0.800	0.010	0.040
	Waste disposal and dilution effect	0.200	0.025	0.400	0.600	0.010	0.015
	Ground water recharge.	0.200	0.050	0.500	0.500	0.025	0.025
	Flood and erosion control	0.050	0.015	0.400	0.600	0.006	0.009
	Loss of biodiversity	0.200	0.050	0.400	0.600	0.020	0.030
Public acceptance		**1.000**	**0.100**	0.386	0.614	0.039	0.061
			0.960			**0.415**	**0.545**

Source: (De Lange, 2005)

Table 19: Aggregated score for development paths A and B (median)

Main criteria	Sub-criteria:	Weight	Cumulative weight	Score (unweighted) A	Score (unweighted) B	Score (weighted) A	Score (weighted) B
Water balance		1.000	0.170				
	Confidence in yield	0.500	0.080	0.400	0.600	0.032	0.048
	Timing (ability to supply the demand)	0.500	0.090	0.357	0.643	0.032	0.058
Financial aspects		0.960	0.200				
	URV	0.330	0.070	0.700	0.300	0.049	0.021
	Confidence in total cost estimates	0.300	0.070	0.500	0.500	0.035	0.035
	Tariff changes necessary to maintain service	0.330	0.060	0.700	0.300	0.042	0.018
Socio-economic aspects		0.943	0.157				
	Dependency on natural rainfall	0.200	0.040	0.100	0.900	0.004	0.036
	Volume of water allocated from rural to urban areas	0.143	0.020	0.308	0.692	0.006	0.014
	Impacts on agricultural production and employment	0.300	0.045	0.400	0.600	0.018	0.027
	Multipliers	0.100	0.020	0.438	0.563	0.009	0.011
	Urbanisation	0.100	0.018	0.462	0.538	0.008	0.009
	Recreation and tourism	0.100	0.015	0.500	0.500	0.008	0.008
Environmental aspects		1.000	0.230				
	Expected impacts on IFR	0.300	0.063	0.286	0.714	0.018	0.045
	Waste disposal and dilution effect	0.200	0.045	0.400	0.600	0.018	0.027
	Ground water recharge.	0.200	0.050	0.400	0.600	0.020	0.030
	Flood and erosion control	0.100	0.023	0.500	0.500	0.011	0.011
	Loss of biodiversity	0.200	0.050	0.357	0.643	0.018	0.032
Public acceptance		1.000	0.100	0.386	0.614	0.039	0.061
			0.857			0.366	0.491

Source: (De Lange, 2005)

The outcome suggests that Development Path B was the preferred option suggesting a willingness to pay for "greener" water and public acceptance of increased water tariffs to accommodate the implementation of such strategies. However, care must be taken not to use the outcome of this study as an "over-generalization" to promote "greener" allocation strategies in the CCT since, it should be borne in mind that an MCDM exercise merely aids in the decision-making process and does not replace the water manager as the final decision maker.

5.4 Expert comments

Although the public returned numerous comments, it was decided to focus only on comments from the expert panel survey (see Annexure 6). The study proved dynamic and controversial with numerous comments received from the expert panel survey. The main concerns from the expert panel could be summarised as follows:

- The risks associated with public enquiry were emphasized. One of these risks was public response always being a mixed function of the presented information and personal perception. Another was public response also being vulnerable to information overloads and bias. The study agreed with this comment.

- A bias against Development Path A with regard to criteria selection and the presentation of information was mentioned – especially with regard to the cost and affordability of desalination. However, this argument stands completely ignorant towards Figure 1.
- It was noted that the adjacent Breede Water Management Area has significant potential to augment the BWMA and that additional supply options such as the desalination of seawater are not needed at this point in time. However, the study is of the opinion that such a comment is ungrounded.
- The importance of the impact of climate change on long-term resource allocation was noted.

5.5 Main contributions

The central contribution of the study focused on engaging in the measurement problem as described in Chapter 1 by a proposed expansion in the decision-making context of water resource allocation decision-making. The decision-making context was broadened by expanding its temporal and spatial dimensions. These processes were made as transparent as possible to increase stakeholder buy-in. Expansions were discussed in detail in Chapter 4 while the current chapter expounded the two surveys that formed part of the increased information load as discussed in Section 4.4.

The outcome of the aggregation process as mentioned in Section 5.4 indicated a preference towards acceptance of "greener" allocation strategies, even if these implied an increased financial burden on the receivers of such strategies. The acceptance of a higher financial burden suggested greater understanding of the "measurement problem" as indicated in Figure 1 and implies that decision-makers could make "greener" allocations with greater confidence and without fear of harming their political positions. The outcome of the public survey also showed the value of consulting the public for its preferences as opposed to making assumptions regarding these.

The risks associated with public enquiry were emphasized. These included the public response always being a mixed function of the presented information and personal perception. Public response is also vulnerable to information overloads and bias.

5.6 Conclusion

The outcomes of the public and expert panel surveys were discussed in this chapter. These were presented in terms of an aggregated public score for the two development paths that was used along with the expert panel survey outcome to compute an overall score for both development paths. Both cases displayed a willingness to pay for greener water management options.

6. CONCLUSIONS, SUMMARY AND RECOMMENDATIONS

From this study, certain conclusions and recommendations may be drawn with regard to decision-making in water resource allocation management.

6.1 Conclusions

The study assumed a water resource scarcity situation in the BWMA, with allocations between different users as the prominent decision-making challenge. The presence of unaccounted-for effects in allocation distributions (due to the current inability to confidently estimate total costs/benefits of allocation distributions) promotes ignorance of some spatial and temporal dimensions of resource allocation decision-making, and therefore, narrows the allocation decision-making context. This leads to a measurement problem that promotes failures in market and government orientated allocation systems, thereby hampering the promotion of allocations that support social welfare maximisation. Decision-support techniques, including multi-criteria decision-making (MCDM), are employed to aid in this regard, but need to be refined to allow for the confident capturing or at least consideration of unaccounted for effects (longer-term impacts) in a broader decision-making context. This study identified the need to make resource allocation decision-making more sensitive to this measurement problem within the BWMA.

The competitive market as a resources allocation mechanism caters for individual allocation decision-making, but not to the same extent for bulk resource allocations. This is because bulk-water infrastructure, as a public good, is often an example of a market failure since market solutions to the allocation problem are the aggregate of the outcome of individual preference orderings. To argue that such an allocation will promote social welfare would be wrong since the individual market player did not aim his participatory behaviour towards social welfare but merely towards promoting his own welfare. It cannot, therefore, be claimed that market allocations are the best resource allocation mechanism. Government needs to intervene to account for market failures in the case of public goods, such as bulk-water supply infrastructures.

Government intervention is guided by resource allocation legislation which strives towards sustainability, efficiency, equity and, ultimately, social welfare maximisation. In intervening, principal-agent relationships emerge between the public (principal) and resource allocation decision-makers (agent). Agents are confronted with the above-mentioned measurement problem hampering their ability to account for all costs and benefits associated with different resource allocation options, i.e. a scenario of decision-making with incomplete information. Uncertainty regarding user (principal) preferences accounts in part for this incomplete information. It is, however, uncertain whether the public should indeed be consulted with regard to long-term strategic water management issues.

Long-term water resource management has become a specialized and complex field and the relative legitimacy of involving the general public in these matters becomes questionable. However, on investigating the impacts of accommodating public preferences in strategic decision-making, evidence from the literature suggested enquiry into public preference for water resource management; hence, the accommodation of public preference forms part of this study. The exact methodology of public enquiry to obtain a legitimate answer is still uncertain. This uncertainty refers to the objective representation of management options and the achievement of acceptable response rates from the public enquiry without attracting criticism regarding bias relating to management options. The public cannot be regarded as experts with regard to allocation decision-making, and care should, therefore, be taken not to lead public preferences. Transparency of the public enquiry process will avoid expert and political critique regarding bias. This implies that politicians and experts should, therefore, buy into the public enquiry process from the beginning. Response rates are also problematic because of the rational ignorance of the public. An acceptable response rate could be promoted through simple communication of the impacts of a complex problem. However, this implies a need for advanced insight into the management problem and a need to keep information volumes limited and relevant.

The measurement problem together with a vulnerability to lobby groups, hidden agendas and the permissibility of discretion, often leading to the misuse of power, lead to government failures. A need is, therefore, created to support government intervention, by consulting the public, to ensure the promotion of social welfare.

Structured thinking and an expanded decision-making context are needed to promote accountability with regard to the measurement problem in resource allocation decision-making. It should, therefore, be clear that an integrated approach is called for together with expansions in decision-support. Such expansion increases the decision-making information load and, therefore, the need for expanded decision-support techniques. These expansions were accommodated via spatial and temporal expansions of the decision-making context. Temporal expansions were accommodated via the development of alternative long-term strategies regarding water supply augmentation in the

BWMA. Spatial expansions entailed physically expanding the decision-making boundaries to include relevant, but previous neglected, rural areas that shared water resources with urban areas in the BWMA. This led to an expansion in representation of the newly included areas. The expansions forced the accommodation or at least the consideration of measurement problems and resulted in better decision-making information.

Decision-support (such as MCDM) for cases such as these should certainly not be seen as a fail-safe method of ensuring that all parties' welfare will be maximised, but rather as a method of making allocation processes more tangible through making risks and uncertainties more explicit. Previous MCDM runs (Eberhard and Joubert, 2002; Joubert *et al.*, 2003) yield preferences for "conventional" bulk supply schemes. However, after expanding the decision-making context, a higher willingness to pay for "greener" allocations was noted, suggesting that an expansion of the decision-making context, along with decision-support, promotes social welfare - even if all costs and benefits could not be quantified. The legitimate presentation of total costs through the promotion of political transparency safeguards against bias with regard to representation of the impacts of alternative allocations. It is important that decision-makers should not only focus on direct costs as this could lead to bias and unsustainable resource allocations.

Part of engaging in the measurement problem involves drawing the decision-making context wide enough to avoid ignorance of negative impacts on social welfare in the longer term. The delimitation of such a decision-making context should be sensitive to the spatial and temporal dimensions of long-term allocation management.

This study engaged in expanding the spatial and temporal dimensions of the decision-making context and argued the importance of noting public preference regarding proposed allocation decisions as apposed to merely assuming the nature of public preferences. Theory suggested a principal-agent relationship; instead, a reversed principal-agent relationship with a parted principal for the same agent was encountered. Agents certainly need to accommodate the principal in the decision-making process, i.e. agents must accommodate public preferences without verifying the long-term planning ability of the principals. The principal (public) needs to be confronted in advance with legitimate and objective development path and then consulted regarding its preferences. The success of presenting a legitimate development path will depend on the ability of the agent to make future trade-offs with the information available to it and to communicate a complex management problem in a simple, objective and understandable way in order to obtain a meaningful answer from the public. The ability of the agent to make future trade-offs in terms of direct and indirect costs and benefits is confronted by a measurement problem, displaying the inter-linkages and the complexity of the decision-making milieu. Agents should, therefore, involve the public in long-term water management decision-making by tapping into their preferences. The challenge is to develop communication strategies that will be consistent over time and space and that will communicate clearly and effectively with the public. Decision-makers should acknowledge the risks of tapping into public preference in terms of response rates and possible bias. The main contributions of the study could be summarised as follows:

- The study confirmed a principal-agent relationship in resource allocation management but also a reversed form of this relationship in long-term water resource allocation decision-making.
- The natural resource allocation decision-making context was expanded and refined with regard to the spatial and temporal dimensions and applied to water resource allocation decision-making. The importance of drawing the allocation decision-making context wide enough, cannot be over-emphasized.
- The importance of political processes running parallel to resource allocation management was emphasized. These processes were accounted for by making the study as transparent as possible by allowing political buy-in right from the inception phase.
- The promotion of environmental education to foster public insight into the measurement problem could be justified – this education process will also positively affect a non-payment problem that is common to basic services such as water provision.
- Applications are not bound to the field of natural resource management but apply to all fields where principal-agent relationships with regard to allocation decision-making are present (e.g. medical aid and insurance).

6.2 Summary

Water resource allocation policy decisions often have impacts exceeding the administrative boundaries of the management jurisdiction. These impacts are often experienced in rural areas, which share water resources with adjacent urban areas. If water resources become scarcer because of a shrinking resource base or increased demand, the competition for the resource will increase. This study engages in this situation via the expansion of the resource allocation decision-making context.

Allocation strategies, such as competitive markets, cater for private needs (water as a private good), but not to the same extent for public goods such as bulk supply infrastructures. Government intervention needs to account for this limitation of the market in allocation decision-making by taking a long-term but spatially expanded view of resource allocation issues. The essential point in allocation decision-making is a trade-off between immediate higher direct costs for sustainability gains. Given that more sustainable options imply immediate sacrifice (financial) in exchange for future gains, the popularity of more sustainable options decreases because uninformed users tend to prefer immediate gains to immediate sacrifice. This choice entails a value-laden judgement. The market typically makes implicit assumptions regarding such trade-offs. However, this study made the trade-offs explicit to facilitate a choice of allocation strategy. Bureaucrats and decision-makers cannot be allowed to estimate public value judgements (public preferences) since the "softer" and less quantifiable/measurable the issue, the more space is created for misinterpretations and, hence, the development of bias to manipulate the outcome. The focus on the modus operandi for the accommodation of public preference, therefore, becomes extremely important.

Finding the "correct" resource allocation strategy for a specific natural resource allocation context, which would maximise social welfare, proved challenging. Opting for the "correct" allocation strategy, is a function of applied criteria guiding the choice of strategy. Such criteria are derived from numerous physical, technological, environmental, economic, social, institutional and political variables describing the decision-making context and the allocation strategy, which are both dynamic over time and space. The choice of criteria is driven through impacts and trade-offs - both in the short- and long-term, making the choice between criteria and management strategies challenging. Ideally, such criteria should serve the inclusive vision of social welfare maximisation; however, deviations are the rule rather than the exception. Opting for the "correct" allocation strategy while implementing it in a "sub-optimal" way is preferable to opting for the "wrong" option implemented in an "optimal" way. Hence, the order of selection and implementation of decision-making criteria in long-term resource allocation management has important social welfare and sustainability impacts - first, apply social-welfare and related sustainability criteria to determine what to do or which option to implement (i.e. doing the "correct thing"), then apply efficiency criteria to determine how to implement the option (i.e. doing it the "right way").

It should be clear that resource allocation management requires informed choices from the decision-makers' side regarding the desired levels of economic activity, public acceptability and ecosystem functionality within the management area but also in adjacent management areas. It, therefore, requires legitimate and reliable information regarding the impacts of different allocation strategies to enable a choice of strategy that will promote social welfare and sustainable resource use. However, a measurement problem with adverse impacts on the quality and legitimacy of decision-making information, presents itself. Such a problem hampers the sustainable management of public goods, such as bulk-water infrastructures, by hindering the evaluation of the true cost of different long-term allocation options and strategies. This implies decision-making with incomplete information, which narrows the decision-making context, resulting in potentially negative sustainability impacts because quantifiable decision-making criteria are more easily conceptualised and accounted for than less quantifiable criteria. Ease of quantification should, therefore, not determine the relative importance of decision-making criteria. Management agents should be sensitive to this, and long-term resource allocation should be done within a regional context especially in cases where inter-basin transfers and re-allocations from rural to urban areas occur. When applied in a regional context, management agents will be forced to at least consider monetarily unquantifiable costs and benefits in order to promote use patterns that will promote social welfare maximisation.

This study engaged in broadening the resource allocation decision-making context in order to accommodate unaccounted-for costs and benefits (i.e. the "measurement problem") in the decision-making process. These expansions materialised in the form of expansions to the spatial and temporal dimensions of the decision-making context. Consequently, decision-support needed to be expanded and applied in the broader context to safeguard against the measurement problem and the impacts of ignoring long-term allocation impacts. Such expansions were made tangible by focusing on long-term water allocation in the BWMA of South Africa. Bulk-water resource allocation in semi-arid areas (such as the BWMA) is influenced by a variety of considerations, including increased competition for water resources and the need for acknowledging the geographically wider impacts of re-allocations. Allocation strategies, such as market and state intervention strategies, are employed but can and often do fail because the measurement problem has different impacts on market- and government-oriented allocation strategies. Market-driven allocation strategies have been accused of excluding important non-participants while government intervention often fails because of mixed and, often, corrupt incentives.

To acknowledge the wider impacts of allocation strategies requires integrated decision-making with expansions in the decision-making context. Despite a general acceptance of an integrated approach to water resource management, progress in the actual implementation of it has been slow because decision-makers are learning as they proceed, with no obviously correct methodology to follow. As a result, researchers are usually cautious and follow an incremental strategy in which they proceed slowly.

The expansion of the decision-making context materialised through an expansion of the temporal and spatial dimensions of the decision-making context. Expanding the temporal dimension was made tangible through the comparison of alternative approaches to long-term water resource allocation management in terms of key management criteria. Sequences of bulk-water supply schemes were considered over time instead of using previous methodologies that compared selections of management options and schemes simultaneously. Two management regimes or "development paths" were developed and compared in terms of a carefully chosen criteria set. The first path promoted a "conventional" (cost-recovery strategy – i.e. in terms of measurable costs) long-term water management strategy, while the second path displayed the measurement problem in the form of a scenario of higher up-front, direct costs in return for "greener" water. It was by no means an exhaustive exercise, but it did provide some of the basics for the study and some ground rules for the development of a more detailed run.

The expansion of the spatial dimension was accomplished by expanding the physical boundary of the decision-making context in the BWMA. This expansion necessitated the consideration of re-allocation trade-offs in a geographically expanded area (for the case of the study: rural to urban areas). A need was consequently indicated to expand representation in the decision-making process via the inclusion of new and relevant stakeholders leading to the question of how and to what extent to accommodate public opinion in long-term water resource management.

Both expansions increased the need for legitimate and reliable decision-making information. Two separate surveys were done to partially account for such increased demand. The first was a public survey aimed at accommodating the public through enquiring about their preferences regarding trade-offs in different resource allocations. The public were, therefore, consulted regarding their preferences as indicated in terms of distinguishing criteria. The challenge of communicating complex issues in a simple way in order to obtain a legitimate answer came to the fore. The rationale and risks of simplifying complex problems, such as strategic water management, and presenting these questions to the public in order to identify their preferences were explained and discussed. The second survey was an extended expert panel survey in which the two development paths were compared against a criteria set. The outcome of this survey was used to make recommendations regarding long-term water resource allocation management methodologies.

The public survey consisted of a stratified random public survey comprising 7029 questionnaires of which 1088 were returned. The 15.48 percent response rate was considered satisfactory; however, a higher response rate (20 percent) was expected given that at the time of the survey, the BWMA was in an in one-hundred-year drought cycle. The expert panel survey invited 50 selected experts of which 17 agreed to participate (34 percent response rate). A personal interview for verification and discussion purposes followed.

Both surveys yielded a broad conceptual willingness to pay for "greener" water even if such this led to increases in direct costs (water tariffs). The outcome may be used to motivate a paradigm shift from management's side to consider "greener" water supply options more seriously even if such options implied higher direct costs. These could then be implemented without fear of harming managers' own political positions. Such willingness to pay would also relieve pressure on an already narrow tariff resource base to absorb tariff increases that could lead to increases in the current non-payment problem.

6.3 Recommendations

Most of the limitations of this study are associated with the assumptions it makes. Therefore, further research is required to substantiate the following assumptions:

- The preference orderings of rural and urban respondents were considered equally important. Such an assumption is debatable especially if differences in willingness and ability to pay are taken into account.
- No objective method exists of verifying and comparing the level of importance of the participants in the expert panel survey. All participants in the expert panel survey are seen as specialists in their distinct fields, and no distinction was made regarding the level of importance of these disciplines. Responses and comments from the different experts are, therefore, seen as equally important.

This study showed the value of improved resource allocation decision-making information. This implies internalising externalities as explained in the discussion on the measurement problem leading to the constant development of quantification techniques. Specific needs include the following:

- Decision-support needs to be developed further with regard to the quantification of the impacts of different management options. As such, some refinements are also needed with regard to the establishment of decision-making criteria hierarchies for long-term bulk-water resource management. Improved estimations of the socio-economic impacts of different management options could be done by unifying water allocation models with multi-sector economic models. To date, no such project has been undertaken in the BWMA.
- The "drivers" (or criteria) of the relative level of importance of different decision-making criteria need to be formalised. Such drivers could include the ease of quantification, but additional drivers should be identified.
- Although numerous studies are underway, not enough legitimate information regarding the effect of climate change on land-use patterns is available to back resource allocation decision-making. This is due to the context-specific attributes of the impacts of climate change. The long-term impact of climate change on homogenic land-use patterns should, therefore, be modelled.
- Additional research is also required into the crop-water-yield requirements of different long-term crops (viticulture and deciduous fruit) specifically in the BWMA since it promotes the accurate estimation of direct and indirect impacts of water restrictions/droughts as well as opportunity estimations of water allocations.
- A series of "green" water supply scenarios need to be developed and compared in terms of revised criteria sets.
- The economic impact of significant water tariff increases on the Western Cape economy needs to be modelled. Dynamic spatial equilibrium models could be employed, but these models are extremely data intensive. The output of this type of study should prove to be useful to aid in arguments regarding management issues on the affordability of "greener" water.

Agents must have a clear understanding of public preferences to inform resource allocation decisions. The public must be confronted with a legitimate and objective decision-making scenario and to be consulted accordingly. The relative success of presenting a legitimate vision depend on the ability of agents to make future trade-offs with the information available to them and to communicate a complex management problem in a simple, objective and understandable way in order to obtain a meaningful answer from public. Agents should therefore not verify the principals' ability to foresee the future but consult their preferences regarding the future and use these revealed preferences to inform allocation decision-making.

7. REFERENCES

Alberini A & Cooper J (2000). *Applications of the contingent valuation method in developing countries: A survey*. FAO Economic and Social Development Paper, Report No: 146, Rome.

Alvarez-Farizo B & Hanley N (2002). Using conjoint analysis to quantify public preferences over the environmental impacts of wind farms: An example from Spain. *Energy Policy* 30:107-116.

Ananda J & Herath G (2003a). Incorporating stakeholder values into regional forest planning: A value function approach. *Ecological Economics* 45:75-90.

Ananda J & Herath G (2003b). The use of Analytic Hierarchy Process to incorporate stakeholder preferences into regional forest planning. *Forest Policy and Economics* 5:13-26.

Arriaza M, Gomez-Limon JA & Upton M (2002). Local water markets for irrigation in southern Spain: A multi-criteria approach. *Australian Journal of Agricultural and Resource Economics* 46(1):21-43.

Arrow K (1951). *Social choice and individual values.* Yale University Press, New Haven.

Arrow K (1984a). *A difficulty in the concept of social welfare.* Collected papers of Kenneth Arrow: Social choice and justice, Oxford, UK.

Arrow K (1984b). *Formal theories of social welfare.* Collected papers of Kenneth Arrow: Social choice and justice, Oxford, UK.

Arrow K (1984c). *The economics of moral hazard: Further comment.* Collected papers of Kenneth Arrow: The economics of information, Oxford, UK.

Arrow K (1984d). *Values and collective decision making.* Collected papers of Kenneth Arrow: Social choice and Justice, Oxford, UK.

Backeberg GR (1994). *Die politieke ekonomie van besproeiingsbeleid in Suid Afrika.* PhD dissertation, Department of Agricultural Economics and Rural Development, University of Pretoria, Pretoria.

Backeberg GR, Bembridge TJ, Bennie ATP, Groenewald JA, Hammes PS, Pullen RAY & Thompson H (1996). *Policy proposal for irrigated agriculture in South Africa: Discussion paper.* Water Research Commission, Report No: KV 96/96, Pretoria.

Basson MS & Rossouw JD (2003). *Berg Water Management Area: Overview of Water Resources Availability and Utilisation*. BKS (Pty) Ltd, Report No: P WMA 19/000/00/0203, Cape Town.

Bateman IA, Lovett AA & Brainard JS (2003). *Applied environmental economics.* Cambridge University Press, UK.

Belton V & Stewart TJ (2002). *Multiple criteria decision analysis: An integrated approach.* Kluwer Academic Press, London.

Bentham J (1789). *Introduction to the principles of morals and legislation - 1950 reprint.* Athlone, London.

Bergson A (1938). A reformulation of certain aspects of welfare economics. *Quarterly Journal of Economics* 52:310-334.

Bergson A (1954). On the Concept of Social Welfare. *Quarterly Journal of Economics*.

Bernholz P (1997). Property rights, contracts, cyclical social preferences and the Coase theorem: A synthesis. *European Journal of Political Economy* 13:419-442.

Blaikie P & Soussan J (2001). *Understanding Policy Processes: Livelihood-Policy Relationships in South Asia.* Department for International Development (DFID), Report No: unknown, UK.

Blignaut JN & De Wit M (2004). *Sustainable options: Development lessons from applied environmental economics.* UCT Press, Cape Town.

Boulding KE (1956). General systems theory: The skeleton of science. *Management Science* 2(3).

Brouwer R & Pearce DW (2005). *Cost-Benefit Analysis and Water Resources Management.* Edward Elgar, Cheltenham, UK.
Buchanan JM & Tullock G (1962). *The Calculus of Consent.* University of Michigan Press, Michigan.
Buchy M & Hoverman S (2000). Understanding public participation in forest planning: a review. *Forest Policy and Economics* 1:15-25.
Bush DB, Martin WE & Brown TC (1987). Do water market prices appropriately measure water values? *Natural Resource Journal* 27(3):617-651.
Carmichael SS, Forsyth D & Hughes DA (2001). *Decision support system for the development of rural water supply schemes.* Water Research Commission, Report No: 837/1/01, Pretoria.
Chambers R (1997). *Whose reality counts? Putting the last first.* Intermediate Technology, London, UK.
City of Cape Town (2002). *Integrated water resource planning study*. Ninham Shand and CSIR, Report No: unknown, CMC Administration, Cape Town.
City of Cape Town (2003a). *Drilling and Pumping Report.* Prepared by the TMG Aquifer Alliance as part of the Preliminary Phase of the Table Mountain Group Aquifer Feasibility Study and Pilot Project, Report No: 3, CMC administration, Cape Town.
City of Cape Town (2003b). *Societal and Legal Report*. Prepared by the TMG Aquifer Alliance as part of the Preliminary Phase of the Table Mountain Group Aquifer Feasibility Study and Pilot Project, Report No: 3491/9944, CMC Administration, Cape Town.
City of Cape Town (2004a). *Ecological and Environmental Investigation.* Prepared by the TMG Aquifer Alliance as part of the Preliminary Phase of the Table Mountain Group Aquifer Feasibility Study and Pilot Project, Report No: 3681/9944, CMC Administration, Cape Town.
City of Cape Town (2004b). *Hydrological Report*. Prepared by the TMG Aquifer Alliance as part of the Preliminary Phase of the Table Mountain Group Aquifer Feasibility Study and Pilot Project, Report No: 2, CMC Administration, Cape Town.
City of Cape Town (2004c). *Wellfield Operation Report*. Prepared by the TMG Aquifer Alliance as part of the Preliminary Phase of the Table Mountain Group Aquifer Feasibility Study and Pilot Project, Report No: 8, CMC Administration.
City of Cape Town Administration (2003a). *Drilling and Pumping Report.* Prepared by the TMG Aquifer Alliance as part of the preliminary phase of the Table Mountain Group Aquifer feasibility study and pilot project, Report No: 3, CMC Administration, Cape Town.
City of Cape Town Administration (2003b). *Societal and Legal Report*. Prepared by the TMG Aquifer Alliance as part of the preliminary phase of the Table Mountain Group Aquifer feasibility study and pilot project, Report No: 3491/9944, CMC Administration, Cape Town.
City of Cape Town Administration (2004a). *Ecological and Environmental Investigation.* Prepared by the TMG Aquifer Alliance as part of the preliminary phase of the Table Mountain Group Aquifer feasibility study and pilot project, Report No: 3681/9944, CMC Administration, Cape Town.
City of Cape Town Administration (2004b). *Hydrological Report*. Prepared by the TMG Aquifer Alliance as part of the preliminary phase of the Table Mountain Group Aquifer feasibility study and pilot project, Report No: 2, CMC Administration, Cape Town.
City of Cape Town Administration (2004c). *Wellfield Operation Report*. Prepared by the TMG Aquifer Alliance as part of the preliminary phase of the Table Mountain Group Aquifer feasibility study and pilot project, Report No: 8, CMC Administration, Cape Town.
City of Cape Town: Water Services (2002). *Integrated water resource planning and CMA bulk water supply studies*. Ninham Shand and CSIR, Report No: unknown, Cape Town.
Colby BG, Crandall K & Bush DB (1993). Water right transactions: Market values and price dispersion. *Water Resource Research* 29(6):1565-1572.
Conradie B (2002). *The value of water in the Fish-Sundays scheme of the Eastern Cape.* Water Research Commission, Report No: 987/1/02, Pretoria.

Curtis IA (2004). Valuing ecosystem goods and services: a new approach using a surrogate market and the combination of a multiple criteria analysis and a Delphi panel to assign weights to the attributes. *Ecological Economics* 50:163-194.

Davis G (1996). *Consultation, public participation and the integration of multiple interests into policy making.* OECD, Report No: unknown, Paris.

Day J (2005). *Personal communication*. Department of Zoology, University of Cape Town, Cape Town.

De Lange WJ (2005). *Own calculations*. Western Cape Department of Agriculture, Elsenburg.

Dennis DF (2000). An ordered probit analysis of public values for use in multiple objective decision-making. *Computers and Electronics in Agriculture* 27:127–137.

Department of Water Affairs and Forestry (1991). *Long-term urban water demand in the Western Cape Metropolitan region 1990-2020*. Water Research Commission, Report No: PG000/00/1590, Pretoria.

Department of Water Affairs and Forestry (1993). *A review of the groundwater resources of the Western Cape.* Department of Water Affairs and Forestry, Report No: PG000/00/2591, Cape Town.

Department of Water Affairs and Forestry (1994). *Western Cape System Analysis: Water demand management.* Department of Water Affairs and Forestry, Report No: PG000/00/4693, Cape Town.

Department of Water Affairs and Forestry (1997). *Skuifraam feasibility study: Main Report.* Department of Water Affairs and Forestry, Report No: G100/00/0596, Cape Town.

Department of Water Affairs and Forestry (2003). Wes-Kaap Waterberaad: Main Report. *Wes-Kaap Waterberaad*, Stellenbosch Lodge.

Department of Water Affairs and Forestry (2004a). *Berg Water Management Area: Internal Strategic Perspective.* Prepared by Ninham Shand Consulting Services in association with Jakoet and Associates, Umvoto Africa and Tlou and Matji, Report No: P WMA19/000/00/0304, Cape Town.

Department of Water Affairs and Forestry (2004b). *National Water Management Strategy: Water management areas in South Africa (Appendix D: Additional information and strategic perspectives with respect to water management areas).* Department of Water Affairs and Forestry, Report No: unknown, Cape Town.

Department of Water Affairs and Forestry (2004c). *National Water Resource Strategy of South Africa.* Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (2004d). *Western Cape Supply system: Operating rules.* Department of Water Affairs and Forestry, Cape Town.

Dinar A (1998). Water policy reforms: Information needs and implementation obstacles. *Water Policy* 1:367-382.

Du Plessis J, Kleynhans S & Shelly A (2001). *Integrated water resource planning study: Main report*. Ninham Shand Consulting Services, Report No: 3216/9026, Cape Town.

Duckstein L, Gershon M & McAniff R (1982). Model selection in multi-objective decision making for river basin planning. *Advances in Water Resources* 5:178-184.

Dudley NJ (1992). Water allocation by markets, Common property and capacity-sharing: Companions or Competitors? *Natural Resources Journal* 32(4):757-778.

Duke JM & Aull-Hyde R (2002). Identifying public preferences for land preservation using the analytic hierarchy process. *Ecological Economics* 42:131-145.

Dungumaro EW & Madulu NF (2003). Public participation in integrated water resources management: The case of Tanzania. *Physics and Chemistry of the Earth* 28:1009-1014.

Dweiri SF & Badran MI (2003). Desalination: an imminent solution for the future water needs in the Aqaba Special Economic Zone (ASEZ). *Desalination* 152(1-3):27-39.

Easter KW, Dinar A & Rosegrant M (1998). *Markets for water: Potential and performance.* Kluwer Academic Press, Massachusetts.

Eberhard R (2003a). Economic regulation of water. *Trade and Industry Monitor* 26:12-17.

Eberhard R (2003b). *Water pricing in South Africa: A Report for National Treasury.* Palmer Development Group, Report No: unknown, Cape Town.

Eberhard R & Joubert AR (2001). *An evaluation of alternative water supply augmentation and demand management options for the City of Cape Town using Multi-Criteria Decision Analysis.* Palmer Development Group and University of Cape Town, Report No: 3216/9026, Cape Town.

Eberhard R & Joubert AR (2002). *CMA bulk water supply study: An evaluation of additional water supply options using MCDA*. Palmer Development Group and Ninham Shand Consulting Services, Report No: 3245 / 9531, Cape Town.

Elster J (1986). *Rational Choice.* New York University Press, New York.

Fishelson G (1994). The water market in Israel: An example for increasing the supply. *Resource and Energy Economics* 16(4):321-334.

Fisher FM, Arlosoroff S, Eckstein Z, Haddadin M, Hamati SG, Huber-Lee A & Jarrar A (2002). Optimal water management and conflict resolution: The middle east water project. *Water Resources Research* 38(1):1-16.

Goicoechea A, Stakhiv E & Fu L (1992). Experimental evaluation of multiple criteria decision models for application to water resources planning. *Water Resources Bulletin* 28(1):89-102.

Gomez-Limon JA (in press). Identification of public objectives related to agricultural sector support. *Journal of Policy Modeling*.

Goodstein ES (1999). *Economics and the environment.* Prentice Hall Publishers, New Jersey.

Graaff JdV (1957). *Theoretical Welfare Economics.* Cambridge University Press, UK.

Grossman SJ & Hart OD (1983). An analysis of the principal-agent problem. *Econometrica* 51(1):7-45.

Haddad M & Lindner K (2001). Sustainable water demand management versus developing new and additional water in the Middle East: A critical review. *Water Policy* 3(2):143-163.

Haider W, Rasid R & Khalid B (2002). Eliciting public preferences for municipal water supply options. *Environmental Impact Assessment Review* 22:337-360.

Hellegers PJGJ & Perry CJ (2005). *Water as an economic good in irrigated agricuture: Theory and practice.* Agricultural Economics Research Institute, Report No: 3.04.12, The Netherlands.

Hicks J (1939). The Foundations of Welfare Economics. *Economic Journal* 69:696-712.

Hicks J (1940). The Valuation of Social Income. *Economica* 7:105-124.

Hicks J (1975). The Scope and Status of Welfare Economics. *Oxford Economics Papers* 27:307-326.

Hobbs B (1986). What can we learn from experiments in multi-objective decision analysis? *Man and Cybernetics* 16(3):384-394.

Hobbs B, Chankong V & Hamadeh W (1992). Does choice of multi-criteria method matter: An experiment in water resource planning. *Water Resources Research* 28(7):1767-1779.

Howe CW, Lazo JK & Weber KR (1990). The economic impacts of agricultural-to-urban water transfers on the area of origin: A case study of the Arkansas River valley in Colorado. *American Journal of Agricultural Economics* 72(5):1200-1204.

Iacofano DS (1990). *Public involvement as an organizational development process.* Garland Press, New York.

Joubert A, Stewart TJ & Eberhard R (2003). Evaluation of water supply augmentation and water demand management options for the City of Cape Town. *Journal of Multi-Criteria Decision Analysis* 12(1):17-25.

Kaldor N (1939). Welfare Propositions in Economics and Interpersonal Comparisons of Utility. *Economic Journal* 69:549-552.

Keenan SP, Krannich RS & Walker MS (1999). Public perceptions of water transfers and markets: Describing differences in water use communities. *Society and Natural Resources* 12:279-292.

Killick M (2004). *Water tariff approach to the Berg Water Poject and the impact on the average water tariff.* City Engineers: Bulk water supply services, CMC Administration, Cape Town.
Killick M (2006). *Personal communication*. City of Cape Town Administration: Water Management Services, Cape Town.
Kleynhans S (2002a). *CMA bulk water supply study: Main report*. Ninham Shand Consulting Services, Report No: 3245/9531, Cape Town.
Kleynhans S (2002b). *Integration of raw water sources supplying the CMA*. Ninham Shand Consulting Services, Report No: 3243/9690, Cape Town.
Kleynhans S (2005). *Personal communication*. Ninham Shand Consulting Services, Cape Town.
Kleynhans S & Schutte C (2002). *The potential for utilising seawater as a potable source*. Ninham Shand Consulting Services, Report No: 3245/9531, Cape Town.
Kloezen W (1998). Water markets between Mexican water user associations. *Water Policy* 1:437-455.
Kolokytha EG, Mylopoulos YA & Mentes AK (2002). Evaluating demand management aspects of urban water policy: A field survey in the city of Thessaloniki,Greece. *Urban Water* 4:391-400.
Kumar M & Singh O (2001). Market instruments for demand management in the face of scarcity and overuse of water in Gujarat, Western India. *Water Policy* 3:387-403.
Laffont JJ (2003). *The principal agent model: The economic theory of incentives.* Edward Elgar publishers, Cheltenham, UK.
Laukkanen S, Kangas A & Kangas J (2001). Applying voting theory in natural resource management: A case of multiple-criteria group decision support. *Journal of Environmental Management* 64:127-137.
Lipsey RG & Courant PN (1996). *Economics.* Harper Collins publishers, New York.
Little IMD (1949). The Foundations of Welfare Economics. *Oxford Economic Papers* 1:237-238.
Little IMD (1950). *A Critique of Welfare Economics.* Oxford University Press, UK.
Litva A, Coast J, Donovan J, Eyles J, Shepherd M, Tacchi J, Abelson J & Morgan K (2002). "The public is too subjective" : Public involvement at different levels of health-care decision making. *Social Science and Medicine* 54:1825-1837.
Livingston ML (1995). Designing water institutions: Market failures and institutional response. *Water Resources Management* 9(203-220).
Louw DB (2001). *Modelling the potential impact of a water market in the Berg river basin.* PhD dissertation, Department of Agricultural Economics, University of the Orange Free State, Bloemfontein.
Louw DB (2002). *The development of a methodology to determine the true value of water and the impact of a potential water market on the efficient utilisation of water in the Berg River basin.* Water Research Commission, Report No: 943/1/02, Pretoria.
Louw DB & Kassier WE (2002). *The costs and benefits of water demand management.* Centre for International Agricultural Marketing and Development, Paarl.
Lutz E, Binswanger HP & Hazell P (1998). *Agriculture and the Environment: Perspectives on sustainable rural develoment.* The World Bank, Washington, Report No: Unknown, Internet Web Page, URL: http://lnweb18.worldbank.org/ESSD/envext.nsf/44ByDocName/Publications,
Maguire LA & Lind EA (2004). *Public participation in environmental decisions: Stakeholders, Authorities and Procedural Justice*. Nicholas School of the Environment and Fuqua School of Business, Report No: unknown, Duke University.
Mahmoud M & Garcia LA (2000). Comparison of different multi-criteria evaluation methods for the Red Bluff diversion dam. *Environmental Modelling & Software* 15:471-478.
Mirrilees RI, Forster SF & Williams CJ (1994). *The application of economics to water management in South Africa.* Water Research Commission, Report No: 415/1/94, Pretoria.
Mirrlees JA (1975). *The theory of moral hazard and unobservable behavior: Part I.* Mimeo publishers, Nuffield College, Oxford University.

Mostert H (2004). *Personal communication.* City of Cape Town Administration: City Engineers (Water Services), Cape Town.
Mueller DC (1997). *Perspectives on public choice.* Cambridge University Press, UK.
Muller J (2005). *Personal communication.* City of Cape Town Administration: City Engineers (Water services), Cape Town.
Munro-Clark M (1990). *Citizen participation in government.* Hale & Ironmonger, Sydney.
National Water Act (1998). *National Water Act No. 36 of 1998.* Statutes of the Republic of South Africa: Water, Pretoria.
Nelson N & Wright S (1995). *Power and participatory development: Theory and Practice.* Intermediate Technology,, London, UK.
Nieuwoudt WL (2000). Water market institutions: Lessons from Colorado. *Agrekon* 39(1):58-67.
Ninham Shand (2001). *Water Services Development Plan of City of Cape Town*. Ninham Shand Consulting Services, Report No: HO 27/1/3, Cape Town.
Ninham Shand (2002). *Berg Water Management Area: Water Resources Situation Assessment - Main Report*. Ninham Shand Consulting Services, Report No: P19000/00/0101, Cape Town.
Pateman C (1970). *Participation and democratic theory.* Cambridge University Press, UK.
Pavlikakis GE & Tsihrintzis VA (2003). A quantitative method for accounting human opinion, preferences and perceptions in ecosystem management. *Journal of Environmental Management* 68:193-205.
Pearce DW (1993). *Economic values and the environment.* The MIT Press, UK.
Pearce DW & Turner RK (1991). *Economics of natural resources and the environment.* John Hopkins University Press, Maryland.
Pinge I (2002). *The socio-economic impact of reduced water allocations in the Murray Darling basin.* Centre for Sustainable Regional Communities, La Trobe University, Bendigo.
Pirie RL, De Loe RC & Kreutzwiser R (2004). Drought planning and water allocation: An assessment of local capacity in Minnesota. *Journal of Environmental Management* 73:25-38.
Purnama D (2003). Reform of the EIA process in Indonesia: Improving the role of public involvement. *Environmental Impact Assessment Review* 23:415-439.
Rahman A (1993). *People's self development: Perspectives on participatory action research.* Zed Publications, London, UK.
Randall A (1983). The problem of market failure. *Natural Resource Journal* 23:131-148.
Robbins LC (1952). *The theory and economic policy of in English classical political economy.* MacMillan, London.
Robbins LC (1981). Economics and Political Economy. *American Economic Review* 71(2).
Rogers P, De Silva R & Bhatiac R (2002). Water is an economic good: How to use prices to promote equity, efficiency and sustainability. *Water Policy* 4:1-17.
Romero C & Rehman T (2003). *Multiple-Criteria Analysis for Agricultural Decisions.* Elsevier, Amsterdam.
Rosenhead J & Mingers J (2002). *Rational analysis for a problematic world revisited.* John Wiley & Sons, New York.
Ross SA (1973). The economic theory of agency: The principal's problem. *American Economic Review* 63(2):134-139.
Roux A (2005a). *Die evaluering van besproeiingstelsels.* Western Cape Department of Agriculture, Elsenburg.
Roux A (2005b). *Personal communication*. Deputy Director: Agricultural Engineering Services, Western Cape Department of Agriculture, Elsenburg.
Ryan LR (2002). Preserving rural character in New England: Local residents' perceptions of alternative residential development. *Landscape and Urban Planning* 61:19-35.
Scitovsky T (1951). The State of Welfare Economics. *American Economic Review* 41:303.
Sen AK (1977). Rational fools: A critique of the behavioural foundations of economic theory. *Philosophy and Public Affairs* 6(4):317-344.

Shand M (2005). *Personal communication*. Ninham Shand Consulting Services, Cape Town.
Shand M, Sparks A, Kleynhans S & Beuster H (2003). *Challenges in managing and developing the region's water resources to meet the demands of Cape Town and other users*. Ninham Shand Consulting Services, Report No: unknown, Cape Town.
Smith LG (1984). Public participation in policy making. *Geoforum* 15:253-259.
Smith SA (2004). *Contract Theory.* Oxford University Press, New York.
Sparks A (2001). *Water demand management policy for the City of Cape Town*. City Council and Ninham Shand Consulting Services, Report No: unknown, Cape Town.
Sparks A (2003). Water demand figures for the Cape Metro. Medium: *Excel spreadsheet*: Ninham Shand Consulting Services.
Sparks A (2005). *Personal communication*. Cape Town.
Statistics South Africa (2005). STATSSA. Medium: *Internet Web page*: www.statssa.gov.za.
Stave KA (2003). A system dynamics model to facilitate public understanding of water management options in Las Vegas, Nevada. *Journal of Environmental Management* 67:303-313.
Steel B & Weber E (2001). Ecosystem management, decentralization and public opinion. *Global Environmental Change* 11:119-131.
Stewart TJ (2004). *Personal communication*. Department of Statistics, University of Cape Town, Cape Town.
Stewart TJ, Joubert AR & Liu D (2001). *Group decision support methods to facilitate participative water resource management.* Water Research Commission, Report No: 863/1/01, Pretoria.
Stewart TJ, Joubert AR, Scott L & Low T (1997). *Multiple criteria decision analysis: Procedures for consensus seeking in natural resources management*. Water Research Commission, Report No: 512/1/97, Pretoria.
Tecle A (1992). Selecting a multi-criterion decision making technique for watershed resources management. *Water Resources Bulletin* 28(1):129-140.
Thompson I (2005). *Personal communication*. Department of Water Affairs and Forestry, Cape Town.
Thrall RM (1976). *Economic modelling for water policy evaluation.* North Holland Publishing Company, Amsterdam.
Tisdell C & Roy K (1997). Good governance, property rights and sustainable resource use. *South African Journal of Economics* 65(1):28-41.
Trans Caledon Tunnel Authority (2005). *Annual report*. TCTA, Report No: unknown, Franshhoek.
Tzeng GH, Tsaur SH & Laiw YD (2002). Multi-criteria analysis of environmental quality in Taipei: public preferences and improvement strategies. *Journal of Environmental Management* 65:109-120.
United Nations Department of Economic and Social Affairs: Division of Sustainable Development (2004). Earth summit: Agenda 21. Medium: *Internet web page*: http://www.un.org/esa/sustdev/documents/agenda21/index.htm.
Van Bommel KHM & Reinhard AJ (2005). *Water related services and contract economics.* Agricultural Economics Research Institute, The Netherlands.
Van der Veeren R & Lorenz CM (2002). Integrated economic-ecological anlysis and evaluation of management strategies on nutrient abatement in the Rhine basin. *Journal of Environmental Management* 66:361-376.
Van Rooyen PC (2005). *Personal communication*. Head of the Department, Western Cape Department of Agriculture, Elsenburg.
Van Steenbergen F & Oliemans W (2002). A review of policies in groundwater management in Pakistan 1950–2000. *Water Policy* 4:323-344.

Van Vuuren DS, Van Zyl HJD, Veck GA & Bill MR (2004). *Payment strategies and price elasticity of demand for water for different income groups in three selected urban areas.* Water Research Commission, Report No: 1296/1/04, Pretoria.

Van Zyl G (2005). *Personal communication*. Department of Water Affairs and Forestry, Cape Town.

Van Zyl H & Leiman A (2002). *Development of a framework for the economic evaluation of water conservation/water demand management measures with specific application to decision-making in Cape Town.* Water Research Commission, Report No: 1275/1/02, Pretoria.

Van Zyl JE, Haarhoff J & Husselman ML (2003). Potential application of end-use demand modelling in South Africa. *Journal of the South African Institute of Civil Engineering* 45(2):9-19.

Veck GA & Bill MR (2000). *Estimation of the residential price elasticity of demand for water by means of a Contingent Valuation Approach.* Water Research Commission, Report No: 790/1/00, Pretoria.

Von Bertalanffy L (1968). *General systems theory: Foundations, development and applications.* Georege Braziller publishers, New York.

Western Cape Department of Agriculture (2005). *Geographical Information Systems (GIS) division*. Western Cape Department of Agriculture, Elsenburg.

Wichelns D (2002). Economic analysis of water allocation policies regarding Nile River water in Egypt. *Agricultural Water Management* 52:155-175.

Wignaraja P, Hussain A, Sethi H & Wignaraja G (1991). *Participatory development: Lessons from South Asia.* Oxford University Press, Karachi.

Winpenny S (1994). *Managing water as an economic resource.* Routledge publishers, London.

Wiseman V, Mooney G, Berry G, Tang KC & Khalid B (2003). Involving the general public in priority setting: Experiences from Australia. *Social Science and Medicine* 56:1001-1012.

Annexure 1: WCSS demand estimations

Concern regarding the long-term impacts of supplying the CCT from adjacent rural areas as mentioned in the previous chapter, is by no means unique. Semi-arid urban areas throughout the world are often in the position where demand outstrips supply because of external drivers of demand (population demographics, economic growth, climate change, pollution and also equity considerations).

It has been indicated that the demand for water in the BWMA areas will grow for a considerable time in future. Urban demand is growing faster than rural demand because of demographic and economic-growth related factors. Rural and urban water users are and will increasingly compete for the same water resources. Limited conventional water storage alternatives (such as the construction of additional storage dams), combined with global-warming-driven changing rainfall patterns that may affect the supply of water adversely, place the CCT and the study area at risk of experiencing serious water shortages in the near future.

The Western Cape System Analysis (Department of Water Affairs and Forestry, 1991; Department of Water Affairs and Forestry, 1993; Department of Water Affairs and Forestry, 1998) modelled the adequacy of the major dams in the Western Cape system and excluded small local sources of the City of Cape Town, Saldanha, Paarl and Stellenbosch. The Western Cape System Analysis only reported the demands on the dams, which were regarded as 'demand centres' that could be curtailed in times of droughts. Compensation releases were not included with the 'demand centres' (Kleynhans, 2002a). This appendix provides a detailed breakdown of the demands that were included in the Western Cape System Analysis (Kleynhans, 2002a):

Water demands (Mkl)

	Description	**1998**	**1999**
	Total demands		
A	Metropolitan consumption[1]	317	332
B	Own supplies of Paarl/Wellington	1	1
C	DWAF to other urban areas[2]	19	22
D	Estimate of own supplies of Stellenbosch and Swartland/Salhanha[6]	5	5
E	Agricultural demands on Theewaterskloof and Voëlvlei[3]	136	141

F	Estimate of additional pumping directly from Theewaterskloof	13	13
G	TOTAL	491	514
	Demands not included with the yields of the WCSA prior to 1 Nov 1998[4]		
H	Localised metropolitan sources	15	10
I	Own supplies from Stellenbosch, Swartland/Saldanha and Paarl/Wellington[6]	6	6
J	Compensation releases from Theewaterkloof/Voëlvlei[5]	15	15
K	Abstractions from the 24 Rivers Canal upstream of Voëlvlei	22	18
L	Estimate of pumping from Theewaterskloof at 1990 level	8	8
M	TOTAL	66	57
	Actual demands corresponding to yields reported in the WCSA, Berg River project and annual re-runs of the WCSA		
N	Metropolitan consumption and sales to Paarl/Wellington (N=A-H)	302	322
O	DWAF supply direct to Stellenbosch and Swartland/Saldanha (O=C)	19	22
P	Agricultural demands on Theewaterskloof and Voëlvlei (P=E-J-K)	99	108
Q	Estimate of growth in pumping from Theewaterskloof since 1990 (Q=F-L)	5	5
R	TOTAL	425	457

Notes:

1. Includes the supply by the City of Cape Town of purified water from Wemmershoek Dam to Paarl and Wellington, which are outside the Cape Metropolitan boundaries.
2. DWAF supplies raw water directly from Theewaterskloof to Stellenbosch and from Voëlvlei to Swartland/Saldanha.
3. Includes abstractions from 24 River canal system upstream of Voëlvlei.
4. Not all the demands were included in the yields reported in the WCSA and the Berg River feasibility studies for two reasons:
    - Some of the demands act on relatively small local sources that were not included like the own supplies of the City of Cape Town, Stellenbosch and Saldanha.
    - Compensation releases from the major dams and the agricultural demands on the 24 Rivers Canal were not grouped with the curtailable ‘demand centres’ and therefore, were not counted as part of the system yield.

5. Initial compensations were Theewaterskloof ($3,8*10^6 m^3/a$), Kleinplaas ($1,5*10^6 m^3/a$) and the Berg siphon ($10*10^6 m^3/a$), totalling $15*10^6 m^3/a$. In runs after 2000, the compensations were increased to include transmission losses becoming $17*10^6 m^3/a$ in total.
6. Assuming $4,7*10^6 m^3/a$ from the Stellenbosch own resources. In 2000, Saldanha may take $1,5*10^6 m^3/a$ from an aquifer.

Sub-system historical firm yield and long-term stochastic yields (million cubic metres)

Sub-system	**Historical firm yield**	**Long-term characteristic yield**			
		1 in 20	**1 in 50**	**1 in 100**	**1 in 200**
Theewaterskloof	193	236	216	210	203
Voëlvlei	96	112	105	101	98
Wemmershoek	50	58	54	52	51
Steenbras	38	42	40	39	38
Palmiet transfer	22,5	22,5	22,5	22,5	22,5
TOTAL	399,5	470,5	440,5	424,5	412,5

Source: (Kleynhans, 2002a)

Annexure 2: Public survey questionnaire

SAY YOUR SAY IN WATER ISSUES!

You are invited to participate in this survey on:

Water user preferences in the Western Cape

Water supplies from storage dams in the Western Cape are becoming increasingly inadequate to satisfy the growing demand for water. Authorities must decide when to implement the desalination of seawater as supplement to the existing water supply infrastructure. Seawater desalination will be inevitable on the long-term.

We want to determine your preference for one of the following two water supply schemes. Both water supply schemes A and B with their costs and benefits are explained in the accompanying questionnaire. Indicate your preference by allocating a higher score to the strategy of your choice and a lower score to the other strategy. The scores for strategy A and B must add to 100 points.

Although your participation will be highly appreciated, you are under no obligation to complete the survey. Please note that each completed questionnaire will be considered for a lucky draw for several prizes, including weekends at De Kleine Hoop Guesthouse (Jonkershoek Valley, Stellenbosch) and estate wines from winemaker Etienne le Riche.

Please return questionnaires to the postal address below before **31 March 2005** to be considered for the draw.

WJ de Lange
Western Cape Department of Agriculture
Private Bag X1
Elsenburg
7607

QUESTIONNAIRE REGARDING THE TWO WATER SUPPLY STRATEGIES

Each of water supply strategies **A and B consists of suggested water schemes** that will be implemented at different times in the future. The following table shows each scheme, the implementation date and the contribution to water supply**:**

Development Path A				Development Path B			
Water scheme	**Implementation year**	**Scheme capacity (million kiloliter)**	**Total storage capacity in the Western Cape (million kiloliter)**	**Water scheme**	**Implementation year**	**Scheme capacity (million kiloliter)**	**Total storage capacity in the Western Cape (million kiloliter)**
Current water supply infrastructure	**2004**		**440**	Current water supply infrastructure	**2004**		**440**
Berg River Project	**2006**	**81**	**521**	Berg River Project	**2006**	**81**	**521**
Voëlvlei scheme Phase II	**2013**	**35**	**556**	Desalination Plant 1	**2012**	**65**	**586**
Lourens River Diversion	**2016**	**19**	**575**	-	**-**	**-**	**-**
Table Mountain Group Aquifer	**2018**	**70**	**645**	Desalination Plant 2	**2020**	**65**	**651**
Cape Flats Aquifer	**2026**	**19**	**664**	-	**-**	**-**	**-**
Eerste River Scheme	**2027**	**8**	**672**	Desalination Plant 3	**2027**	**65**	**716**
Desalination Plant 1	**2028**	**60**	**737**	-	**-**	**-**	**-**

Water supply strategy A expands the current water storage capacity up to the maximum before it changes to the desalination of seawater. Water supply strategy B changes to seawater desalination at a much earlier date. After 2028 both strategies opt for seawater desalination.

Water supply strategy A and B compare as follows:

Financial implications for the public	➢ Long-term **water tariffs** with Strategy **A** will stay after 2012 approximately 12%-20% **lower than B. Water will therefore stay more affordable with Strategy A.**
Availability of water	➢ Water supply Strategy **A** is **more dependent on rainfall** in the long-term than B. **Strategy A** will therefore **expose the public more to** seasonal municipal **water restrictions** than B. ➢ Strategy **A has higher risks for** negative impacts on agricultural production, employment and the rest of the Western Cape economy than B.
Environmental impacts relevant for the public	➢ Strategy **A has higher risks for** increased levels of **pollution** in rivers **and losses in bio-diversity** than B. ➢ The harvesting of aquifers in Strategy **A has potential negative impacts for underground water.**

Give the highest score to the water supply strategy of your choice. The two **scores must add to 100**.

Your score for development path A : **Your score for development path B :**

[ ] **+** [ ] **= 100**

To be considered for the lucky draw, please indicate a telephone number (preferably a cell number):

Please make use of the return envelope and return the questionnaire **before 31 March 2005** to:

WJ de Lange
Western Cape Department of Agriculture
Private Bag X1, Elsenburg, 7607

THANK YOU FOR YOUR TIME AND HAVE A NICE DAY !

Annexure 3: Expert panel invitation

February 2005

Invitation to participate in an expert panel survey on:

Multi-Criteria Decision Analysis in bulk water supply management in the Western Cape

Dear Prof, Dr, Mr, Me

You are one of approximately 50 experts from various disciplines invited to participate in an expert panel survey regarding bulk water supply management in the Western Cape. The outcome of the survey is part of a larger multi-disciplinary study regarding current methodologies used to compare water management alternatives in the province. The research initiative is jointly managed by the Western Cape Department of Agriculture and Stellenbosch University, and is partly funded by the National Research Foundation.

The current drought in the Western Cape emphasize the need for additional research on alternative water supply options such as the desalination of seawater or recycling to potable standard. The numerous complexities associated with long-term water resource management, necessitate contributions of different perspectives from different experts. This is where your participation will provide valuable information for sustainable water resource management in the Western Cape.

We would like you to indicate your willingness to rate (score) two different long-term water management strategies against various criteria and to dedicate approximately one hour of your time for an appointment and discussion regarding the scores. Please indicate your willingness to participate in the survey by indicating three possible times for an appointment.

☐ No, I am not willing / able to participate in the survey.

☐ Yes, I am willing to participate in the survey by reading through an information document (approximately 30 pages) and rating the two alternatives.

- three suitable dates and times for appointments are (before end of June 2005):

______________________ ; _____________________ or ____________________

- my preferred e-mail address : ____

Please return via e-mail to: willemdl@elsenburg.com

Your participation will be highly appreciated
Kind regards,

WJ de Lange
(Agricultural Economist)

Departement Landbou | Department of Agriculture | Isebe Lwezolimo

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Tel: (021) 808 5203 ? Faks/Fax: (021) 808 5210 ? Webwerf/Website: www.elsenburg.com
LANDBOU-ONTWIKKELINGSENTRA / AGRICULTURAL DEVELOPMENT CENTRES:
ELSENBURG-GEORGE-MOORREESBURG-OUDTSHOORN-VREDENDAL

Invitations to:

Name	Institution	e-mail
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Helen Davies	City of Cape Town Administration	Helen.Davies@capetown.gov.za
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Stephan Kleynhans	Ninham Shand Consulting	Stephan.Kleynhans@shands.co.za
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Richard Hill	University of Cape Town	hill@enviro.uct.ac.za
Chales Boucher	Stellenbosch University	cb@sun.ac.za
Sue Milton	Stellenbosch University	sjm@sun.ac.za
Dave Pepler	Stellenbosch University	dp@sun.ac.za
Kobus Jooste	Stellenbosch University	jfj@sun.ac.za
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Tony Letsoalo	CSIR-Environmentek	aletsoalo@csir.co.za
FH Kolbe	TELKOM	fhkolbe@telkomsa.net

Annexure 4: Expert survey cover letter

Expert panel survey: Multi-Criteria Decision Analysis on strategic bulk water resource management in the Western Cape

What is the survey about?

Multi-Criteria Decision Analysis (MCDA) is a decision support technique to assist in strategic and/or challenging decisions. The technique plays a supporting role by structuring the decision-making process and to make uncertainties more tangible. MCDA were used in water resource management in the Western Cape in numerous feasibility and pre-feasibility studies and the current research initiative build on this by refining the methodology with regard to time and spatial variables.

The survey compares two long-term bulk water supply strategies (development paths) in terms of a selection of criteria. Each development path must be **scored as a package** according to these criteria. As an expert, base your scores on the important background information as well as personal expertise and experience. The outcome of the survey will form part of a larger study on strategic choice in bulk water resource management in the Western Cape and will provide valuable information for decision makers in long-term water resource management.

What must I do?

Each invited expert will have to score two different long-term bulk water supply strategies according to selected criteria. You should have received electronic copies of the following four documents:

- The cover letter, which you are busy reading know is for orientation and instruction purposes.
- The expert evaluation document - must be used to do the scoring of the two development paths.
- The public survey cover letter – was part of a public survey
- The public survey background information and questionnaire – should be complete not as member of the public but as your guesstimate of overall public preference regarding the two development paths.

All the documents are self-explanatory. However should you require additional information please contact the researcher at the following:

E-mail: willemdl@elsenburg.com
Tel: 021 - 8085203

What happens after completing the questionnaire?

Please return both the "expert evaluation document" and the "public survey background information and questionnaire" to the researcher **via e-mail**. The researcher will pay each expert a visit to discuss the document and to rectify possible problems.

After confirmation of the score sheet of each expert, the researcher will analyse the data and report (via e-mail) to the expert group within one month after completing of the last appointment. The aggregated scores and weights of the two development paths will then be open for discussion. After possible alternations, the scores will be finalised and used the broader study.

Thank you for your time effort to participate in this study.

Kind regards,

WJ de Lange

(Agricultural Economist)

Departement Landbou | Department of Agriculture | Isebe Lwezolimo

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Annexure 5: Expert survey follow-up letter

May 2005

Expert panel survey: Multi-Criteria Decision Analysis on strategic bulk water resource management in the Western Cape

Dear Prof, Dr, Mr, Me

You were one of 18 experts who participated in an expert panel survey regarding bulk water supply management in the Western Cape. Each of you have completed the two questionnaires and met with the researcher to discuss your most important comments.

The need was identified to communicate the outcome of the expert panel survey in the form of a “report back” of the main comments on the survey. We have compiled such a document where all comments mentioned in the meetings are included. The idea is to show to the rest of the panel what the other respondents have commented on. Please feel free to make additional comments or changes regarding the comments and your scores where you feel suitable. (Please indicate such changes clearly.)
Attached to this e-mail you will find two documents.

The first entitled “Expert Comments(24May).doc” is the background information document with all the comments from the different respondents. The second document entitled “Copy of Survey results(19May).xls” is a spreadsheet of preliminary data.

Two weeks are allowed (until 9 June) for comments from where we will close this opportunity and do the final analysis.

Once again thank you for your time and effort to participate in this study.
Kind regards,

WJ de Lange
(Agricultural Economist)

Departement Landbou | Department of Agriculture | Isebe Lwezolimo

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Annexure 6: Expert survey questionnaire

It was decided that all comments will be handled anonymously.

Expert Panel Survey:
Multi-Criteria Decision Analysis on Water User Preference in the Western Cape

Orientation and instructions

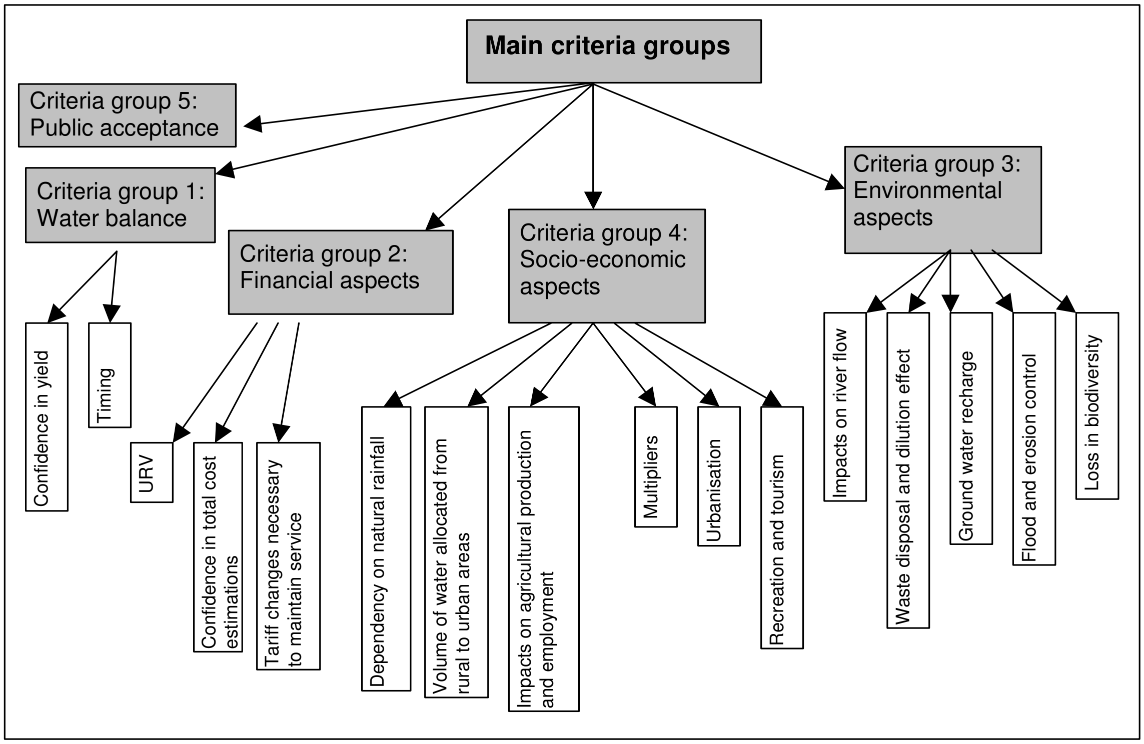
The aim of this document is to enable a selected panel of experts from different disciplines to evaluate two alternative long-term water management development paths (DPs) for the Western Cape. The document presents some general background information from where the scoring process starts. The document is organised in five main criteria groups that will be used to evaluate the two different long-term water management strategies (development paths). Each main criteria group is divided into smaller sub-criteria (see the tree diagram). To keep the process as simple as possible, each of the five sections starts with a small table for the evaluation (scoring) of each of the development paths. Please read the information provided in each section before attempting to complete the score sheet.

All experts are asked to score each development path in terms of the given criteria. The scoring commences as follows:

Each section starts with a table containing the criteria that need to be scored for that section. Read the background information provided in the section, and then make use of the table at the beginning of the section to give your personal score for each development path. Scores should be based on your judgement of the given information, personal experience regarding the criteria, area of expertise and subjective value judgements. Note that Criteria Group 5 is covered by a public survey, and no scoring of public acceptance will, therefore, be done in this document. We did include the original public survey as a separate document. Please complete that survey, not as member of the public, but as your guesstimate of public preference regarding the two development paths.

PLEASE FEEL FREE TO COMMENT ON ANY ASPECT OF THE DOCUMENT – INDICATE YOUR COMMENTS BY USING THE REVIEW FUNCTION IN MS WORD.

TREE DIAGRAM OF CRITERIA:



INTRODUCTION

For the public survey, the public responded on their perception - i.e. their response is not totally a function of the information provided.

The Western Cape experienced a dry 2004 season, implying a problem of water resource scarcity. The biggest domestic user in the area is the City of Cape Town (CCT), which receives its water from mainly rural areas outside the municipal boundaries of the area. Resource scarcity implies increased competition and in this case increased competition/tension between rural and urban users. Various management strategies could be employed to engage the situation with demand management campaigns currently in the news. However, demand management strategies alone will not suffice and some forms of supply (capacity expansion) strategies will have to be implemented. Authorities faced with such a complex issue currently face a fundamental choice between two long-term development paths to secure the long-term water supply in the Western Cape. They must either choose A) the “cheapest” option possible over the short-term and reverse the negative long-term effects of it at a later stage, or B) accept significantly higher water tariffs at an earlier stage, but ensure an important reduction in the long-term negative impact on society and the environment.

Both development paths contain different combinations of known supply schemes. It is important to note that the focus is NOT on individual schemes (because such an exercise has already been done), but on the development path as a whole. Each development path has its own strong and weak points, and water service providers face a major challenge in deciding which one to implement. The process of multi-criteria decision analysis is employed to aid in this regard. It is a logical and systematic way to compare the two paths by using a selection of key criteria. The challenge is to identify what the impact of each path will be in terms of the key criteria and to evaluate the legitimacy of each impact. It is, therefore, extremely important to evaluate the two development paths as packages and not merely as the sum of individual schemes.

GENERAL BACKGROUND INFORMATION

The study area is in the Western Cape province of South Africa, with the focus on the CCT and all rural areas sharing its water resources with the CCT (see to Figure 1). These areas include the irrigation districts of Malmesbury, Drakenstein and Helderberg. The deciduous producing areas of Groenland, Villiersdorp, Grabouw and Vygeboom are also included.

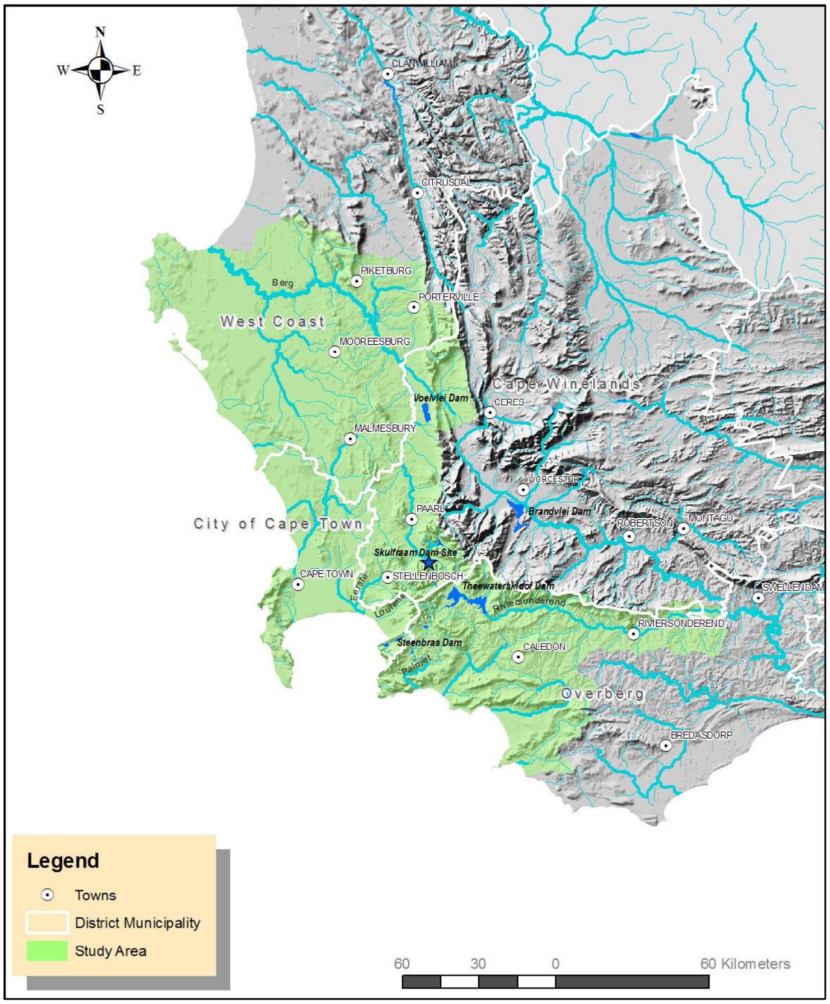


Figure 1: An indication of rural areas sharing with the CCT
Source: (Western Cape Department of Agriculture, 2004)

The main bulk-water supply system in the area is indicated in Figure 2. Some details on various individual schemes are found in Table 1.

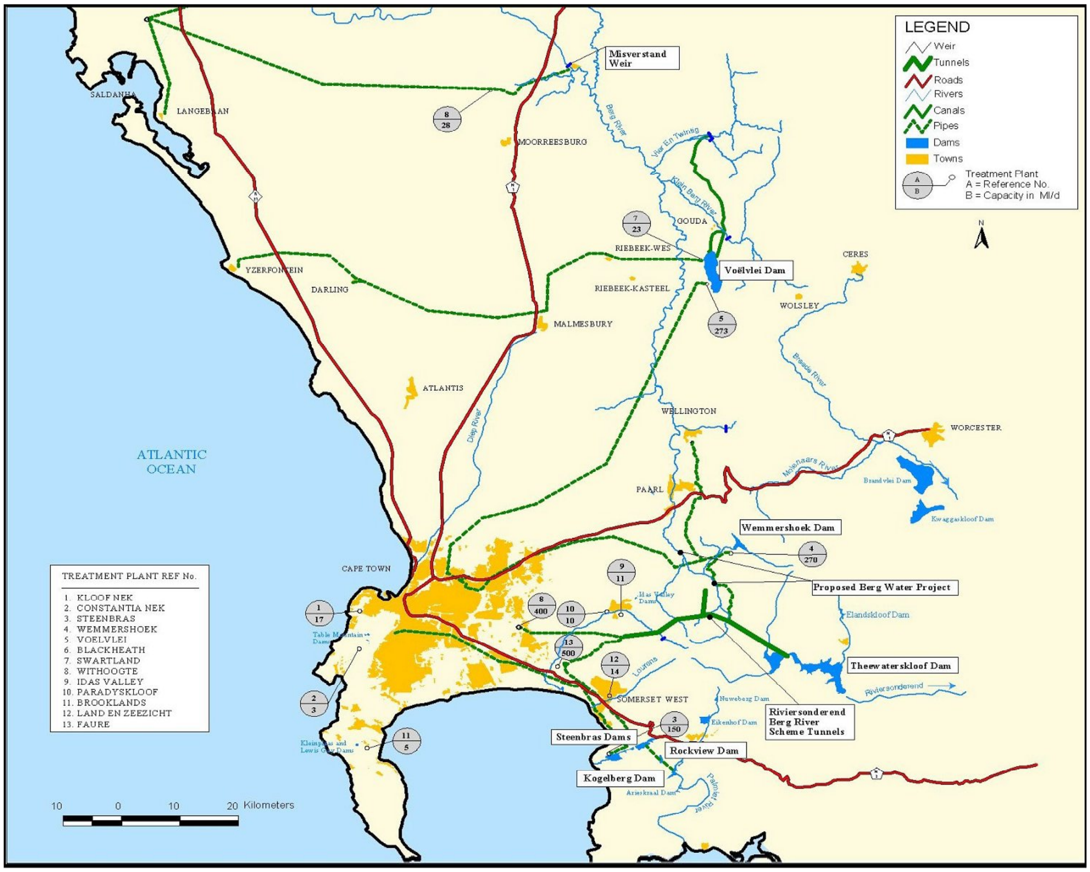


Figure 2: The Western Cape water supply infrastructure
Source: (Shand et al., 2003)

Table 1: The main existing and new water supply schemes supplying the Western Cape

Scheme	Gross Capacity (Mm^3)	Net System 1:50 Year Yield (Mm^3/a)	Owner	User
Palmiet Kogelberg Rockview	 (17) (17)	22	DWAF; ESKOM	CCT; ESKOM
Upper Steenbras	32	40	CCT	CCT
Lower Steenbras	34			
Wemmershoek	59	54	CCT	CCT; Drakenstein
Voëlvlei	172	105	DWAF	CCT; West Coast; Irrigators
Theewaterskloof	480	219	DWAF	CCT; Stellenbosch; Irrigators
TOTAL EXISTING	811	440		
Berg River Project: Dam Supplement	 127	 56 25	TCTA[7]	CCT; Irrigators; Overberg
TOTAL	938	521		

[7] Trans-Caledon Tunnel Authority.

Source: (Shand et al., 2003)

The following table (Table 2) presents the two suggested development paths (DPs). However, it is important to note that such a suggested layout is not "cast in concrete" and could be changed as new information becomes available. It does, however, represent two legitimate alternatives for long-term bulk-water supply development in the Western Cape.

Table 2: Development Paths A and B

Development Path A				Development Path B			
Water scheme	Implementation year	Scheme capacity (million kilolitres)	Total storage capacity in the Western Cape (million kilolitres)	Water scheme	Implementation year	Scheme capacity (million kilolitres)	Total storage capacity in the Western Cape (million kilolitres)
Current water supply infrastructure	2004		440	Current water supply infrastructure	2004		440
Berg River Project	2006	81	521	Berg River project	2006	81	521
Voëlvlei scheme Phase I	2013	35	556	Desalination Plant 1	2012	65 50?	586
Lourens River diversion	2016	19	575	-	-	-	-
Table Mountain Group aquifer	2018	70 rather 50	645	Desalination Plant 2	2020	65 50?	651
Cape Flats Aquifer	2026	19	664	-	-	-	-
Eerste River scheme	2027	80?	672	Desalination Plant 3	2027	65 50?	716
Desalination Plant 1	2028	60	737	-	-	-	-

Source: (De Lange, 2004a; Enright, 2005; Khan, 2004; Killick, 2004; Kleynhans, 2004; Louw, 2004; Shand, 2003; Sparks, 2003a; Van Zyl, 2004b)

The difference between "yield" and "capacity" was explained

The notation : million cubic metre (m^3) or m^3 * 10^6 instead of Mkl is proposed.

Numerous other alternatives are available before desalination. However, one should not see DP B as merely "desalination" – the two DP's represent two different ways of long-term water management – the two DP's is making this difference more tangible (desalination could be replaced with recycling or any other "greener and more expensive" – ito direct costs) option!

DP A does not contain major surface schemes – the environmental impacts associated with surface schemes could therefore be ignored and more focused be placed environmental effects of underground schemes. Mitchells pass could be an option and Eerste river is unlikely to become a reality. However, few big surface schemes are left for development and much uncertainty regarding impacts of groundwater schemes exists.

Development Path A represents the "conventional" development path to supply future bulk-water needs. The scheme assumes all bulk-water supply schemes up to 2004 (including water demand management schemes such as water restrictions, leakage repair, pressure control and user education). All technical specifications of the Berg River Project (BWP), Voëlvlei Dam, Lourens River, Table Mountain Group Aquifer, Cape Flats aquifer, Eerste River scheme and desalination are also assumed. "Expensive" alternatives such as desalination of seawater or recycling to potable standard will become a reality only in 2028.

Development Path B is a proposed alternative to Development Path A. This development path implements "expensive" bulk-water supply options at an earlier stage compared to Development Path A. This development path challenges current decision-making methodologies, as well as cost-estimation methodologies by questioning the relative cost of desalination compared to alternatives if all costs could be quantified and included in the equation.

The main difference between A and B is the timing of desalination as an alternative supply option. Development Path B makes use of desalination much earlier (2012 opposed to 2028).

Each development path will now be discussed in terms of the four main criteria groups.

CRITERIA GROUP 1: WATER BALANCE

Read through the section before completing the score sheet, below. Note that the scores of each sub-criteria group should add up to 100.

The scores do not need to add up to 100 – it could be the case that both A and B score poorly/good in a specific criteria. If the scores add to 100 , only the relative difference between the DPs' should be scored. If the scores do not add up to 100, it could be weighted at a later stage.

	Description	DP A	DP B	
1.1) Confidence in yield (Level of confidence in the accuracy of yield estimations.) Climate change impact rainfall/run-off and, therefore confidence in yield	100 = totally confident in yield estimations 0 = no confidence at all in yield estimations			= 100
1.2) Timing (Timing of the schemes and the ability to supply the demand of water in such a way that no significant surplus or shortages occur.)	100 = demand and supply are matched perfectly 0 = a total miss-match between demand and supply resulting in times of severe shortages and surpluses.			= 100

DP A has more robust technology compared to DP B, which has greater sensitivity with regard to technological developments. DP B has greater potential in rerms of efficiency gains with regard to technological development.

Numerous technical challenges with regard to implementation of desalination were mentioned. However, one should not allow technical challenges and logistics to dominate the decision-making process – "doing the right thing in a wrong/sub-optimal way" is preferable to "doing the wrong thing in the right way". I.e. the implementation order of decision-making criteria in long-term water management has important sustainability impacts. -- First, apply sustainability criteria to determine WHAT to do (the "right thing") then apply efficiency criteria to determine HOW to do it ("doing it the right way")

Desalinisation tariffs should be smoothed out over time.

1.1 Confidence in yield

Numerous uncertainties exist regarding confidence in yield estimations for Development Path A. Environmental impacts associated with bulk-water supply mining such as the Table Mountain Group aquifer contributes to such uncertainties. The existence of some controversy regarding in-stream flow requirements adds to uncertainty regarding confidence in the yield. Little uncertainty exists with regard to the yield of the desalination process because it could be seen as a water production process. A probably less known fact is that more than twenty desalination plants of a patented South African design are already operational in South Africa and in the rest of the world (see Table 3). The contractor has also completed numerous international projects, and it should be clear that capacity exists locally to successfully construct and manage desalination technology on a commercial scale.

The Breede WMA has huge potential water surplus that could be utilised in Berg WMA. However, such gains are estimated at a maximum 19Mkl.

Table 3: Projects installed by a leading South African desalination contractor

Year	Project	Client	Country	Feed water	Permeate quality	Average capacity Mkl/a
1995	Bitterfontein	West Coast Water board	South Africa	Brackish water	Potable water	197
1997	Kenton-on-Sea	Albany Water Board	South Africa	Sea water	Potable water	480-528
1998	Sobhengu Lodge	Gooderson Leisure	South Africa	Sea water	Potable water	24
1998	Robben Island	Department of Public Works	South Africa	Sea water	Potable water	264-312
1998	Cairo	Intech	Egypt	Sea water	Potable water	9.6-12
1998	Spoornet	South African Railways	South Africa	Brackish water	Potable water	19.2-24
1998	Moorreesburg	Private	South Africa	Brackish water	Potable water	19.2-24
1998	Witsand	Private	South Africa	Sea water	Potable water	12
1998	Kanon	Kanon Hotel Resort	South Africa	Brackish water	Potable water	19.2-24
1998	Cape Town Harbour-Boat	Santa Monica	South Africa	Sea water	Potable water	2.4
1998	Palm Beach Florida	Palm Beach Country Club	USA	Brackish water	Irrigation	1920
1998	Kangaroo Island	South Australian Water	Australia	Sea water	Potable water	250
1999	United Utilities Australia	United Utilities Australia	Australia	Industrial effluent	Heavy process feed water	12000
1999	Aqua Services	Private	Namibia	Brackish water	Potable water	48
1999	Silverhill Nursery	Nursery	South Africa	Borehole	Potable water / irrigation	24
1999	Kazakhstan Aktau	Caspian Seawater Development	Kazakhstan	Sea water / Brackish water	Potable water	4704
2000	RAMA	Rao/TEAM	India	Brackish water	Potable water	30-70
2001	Bedok (HCAP)	Hitachi Chemical Asia Pacific	Singapore	Industrial effluent	Process water	920
2002	Loyang (HCAP)	Hitachi Chemical Asia Pacific	Singapore	Industrial effluent	Process water	850
2003	Port of Singapore Authority		Singapore	Sea water	Potable water	1200
2004	Abu-Dhabi, UAE		UAE	Sea water	Potable water	400
2004	PUB, Newater		Singapore	Sea water	Potable water	300
2004	Kanonberg	Private	South Africa	Brackish water	Potable water	90
2004	D Jack	Private	South Africa	Brackish water	Potable water	20
2004	HH Dairies	Private			Potable water	30
2004	Derrick Muller	Private	South Africa	Brackish water	Potable water	25
2004	BradCam	Private	South Africa	Brackish water	Potable water	25
2004	John Braithwaite	Private	South Africa	Brackish water	Potable water	25
2004	Fraser Thompson	Private	South Africa	Brackish water	Potable water	25
2004	Worcester Farms	Private	South Africa	Brackish water	Potable water	500
2004	AM Rossouw Trust	Private	South Africa	Brackish water	Potable water	500
2004	JS Jordaan Boerdery	Private	South Africa	Brackish water	Potable water	600
2005	T Coombs	Private	South Africa	Brackish water	Potable water	20
2005	Tsunami	GrahamTek	Maldives	Sea water	Potable water	1500

Source: confidential

1.2 Timing

Timing refers to the ability of the development path not only to supply the growing demand for water, but also to minimise surplus capacity. With regard to timing, the following could be seen as some of the more important determinants of the growth in demand:

- Seasonal variation
- Population growth
- Economic growth
- Higher living standards

The influence of political interference on demand was noted.

The challenge is to match water supply to demand as closely as possible at all times. Figure 3 indicates the expected long-term water demand for the study area. The agricultural demand is limited to the registered water use rights for this sector, while urban demand was conservatively estimated at 2 percent per year.
The potential of ground-water for agricultural supply was mentioned. On the demand side, potentially 20Mkl was suggested for future growth in demand.

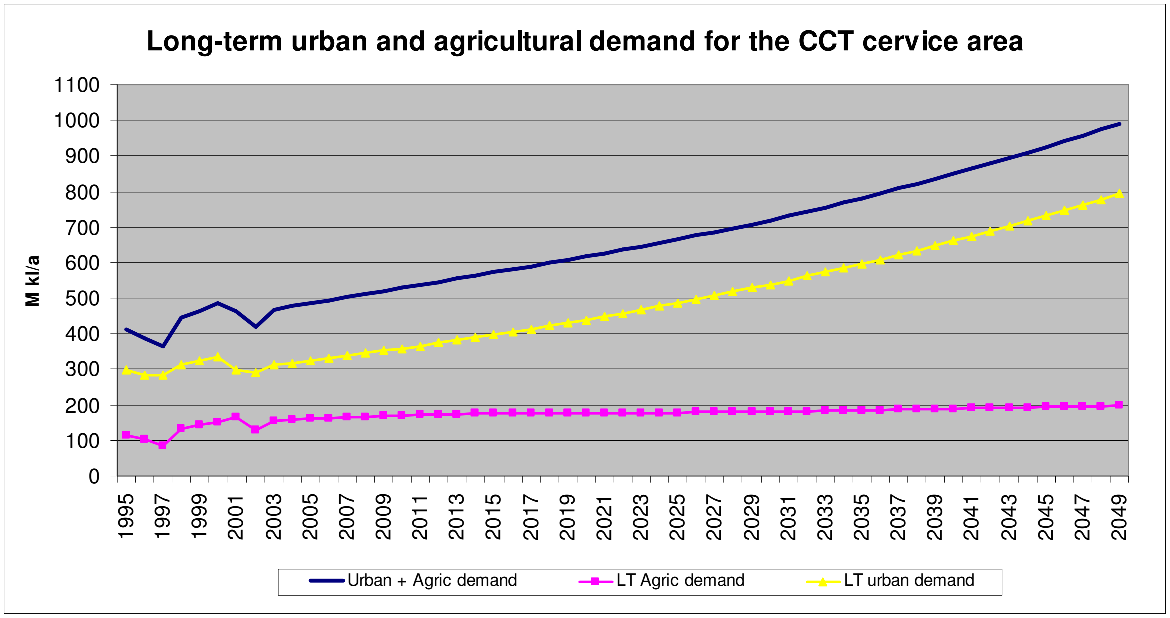


Figure 3: Long-term urban and agricultural demand expectations in the CCT
Source: (Killick, 2004; Sparks, 2003a; Sparks, 2003b)

If the yield expansion schedules of both development paths are plotted against the urban and agricultural demand in Figure 3, Figure 4 will be obtained. It should be clear that Development Path A yields a significantly larger surplus/shortage capacity (476Mkl/year) compared with B (54Mkl/year). In other words, Development Path B could match supply and demand better in the long and short-term compared with Development Path A (also refer to Figure 5). This was expected because the incremental increases in total capacity for Development Path B are smaller compared with A and one should remember that with desalination capacity expansion is modular with the added benefit of turning off the plant when it is not needed.

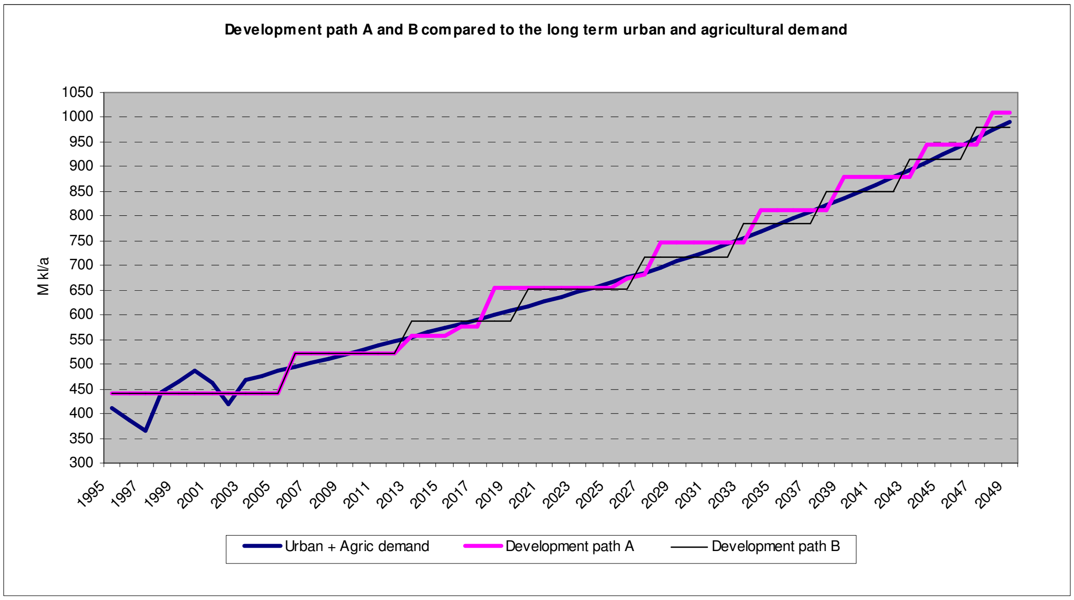


Figure 4: Relative surplus/deficit of development paths A and B in terms of LT demand
Source: (De Lange, 2004a)

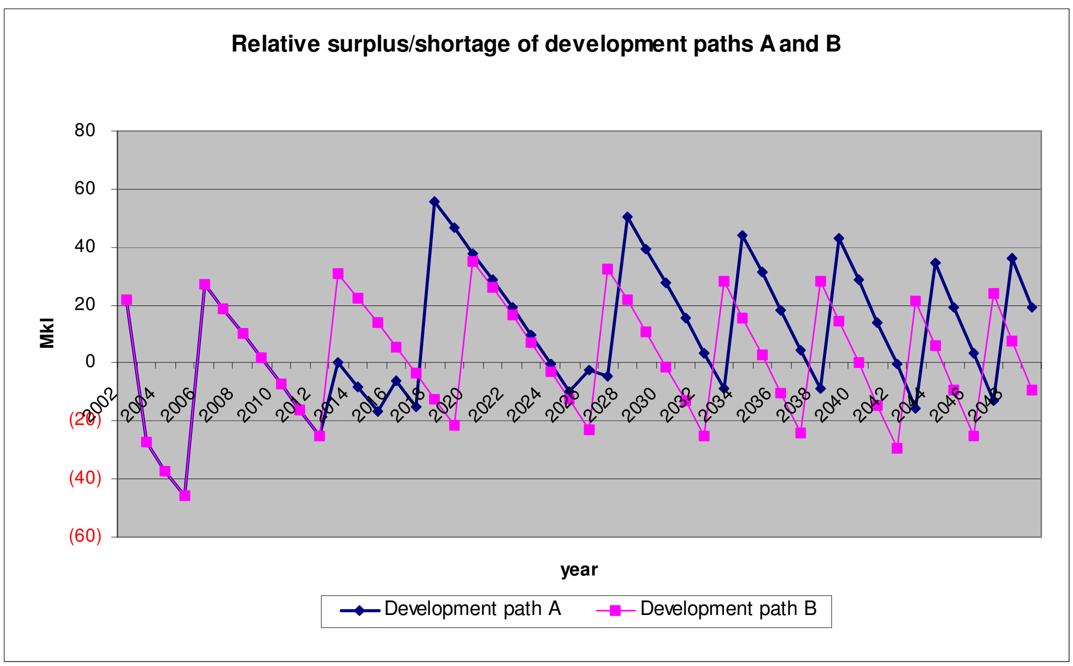


Figure 5: Surplus/shortage comparison between development paths A and B
Source: (De Lange, 2004a)

Please return to the beginning of this section and complete the score sheet before proceeding to the following section.

CRITERIA GROUP 2: FINANCIAL ASPECTS

Read through the section before completing the score sheet, below.

	Description	DP A	DP B	
2.1) Direct cost (URV) (The Unit Reference Value (URV) is the discounted capital and maintenance cost of a scheme over the life-time of the project. It does not include the long-term socio-economic and environmental impacts.) The difference between direct, in-direct and total costs was emphasized.	100 = the direct cost of the development path is affordable. 0 = the direct cost of the development path is totally unacceptable and too expensive			= 100
2.2) Confidence in total cost estimates (Level of confidence in the accuracy of the cost estimations.)	100 = totally confident that cost estimations will match the total cost of the development path 0 = absolutely no confidence in cost estimations			= 100
2.3) Tariff changes necessary to maintain services (The relative changes in water tariffs necessary to enable water service providers to maintain a safe level of assurance of supply to water users.)	100 = no impacts on tariffs 0 = unacceptably high increases on tariff structure			= 100

It was mentioned that desalination has hidden costs : energy, brine disposal, blending. This is the so-called indirect cost – refer to the measurement problem.

The rich often manage their finances in a "better" way compared to the poor – biggest savings in rich areas. However one could argue that water savings in rich areas is due to a higher elasticity of demand in such areas and due to "better" financial management.

The importance of politics in tariff determination was mentioned.

2.1. Unit Reference Value (URV)

Table 4: Average URV for development paths A and B (constant 2004 values)

Development Path A			Development Path B		
Year	Scheme	URV	Year	Scheme	URV
2006	Berg River Project	R 1.35	2006	Berg River Project	R 1.35
2013	Voëlvlei scheme, Phase 1	R 0.53	2013	Desalination Plant 1	R 7.73
2016	Lourens river diversion	R 0.46	-	-	
2018	Table Mountain Group Aquifer	R 1.00	2020	Desalination Plant 2	R 7.73
2026	Cape Flats Aquifer	R 1.13	-	-	
2027	Eerste River Scheme	R 1.06	-	-	
2028	Desalination Plant 1	R 7.73	2027	Desalination Plant 3	R 7.73
2034	Desalination Plant 2	R 7.73	2033	Desalination Plant 4	R 7.73
2039	Desalination Plant 3	R 7.73	2038	Desalination Plant 5	R 7.73
2044	Desalination Plant 4	R 7.73	2043	Desalination Plant 6	R 7.73
2048	Desalination Plant 5	R 7.73	2047	Desalination Plant 7	R 7.73
Average URV up to 2028		R 1.89	Average URV up to 2028		R 6.14
Average URV up to 2049		R 4.02	Average URV up to 2049		R 6.93

Source: (De Lange, 2004; Kleynhans, 2002)

Since 2002, a strong appreciation in the Rand against the US dollar (see Figure 6) as well as new advances in reverse osmosis technology have led to an approximate 30% decrease in direct cost estimations for desalination by means of reverse osmosis. (However, we did not include this reduction in our cost estimations.) Claims have been made by numerous suppliers of URVs from as little as R5.28 to R6.89 per cubic metre of produced water. Such reductions have been made possible by significant reductions in the pre-treatment costs of raw feed water. The new technology makes use of flow distributors and electromagnetic fields to prevent the need for chemical conditioning of raw feed water, resulting in "cleaner" brine effluents. The use of flow distributors expels gasses from the feed water while under pressure creating micro bubbles that actively scour the reverse osmosis membranes preventing foulants from settling. Electric and magnetic fields are used to disorientate the steric formation of active crystal growth, subsequently separating the chemical bonds and preventing foulants from building up on the surface of the membranes. Such technologies greatly enhance the life expectancy of the membranes, thereby reducing the maintenance cost of the plant.

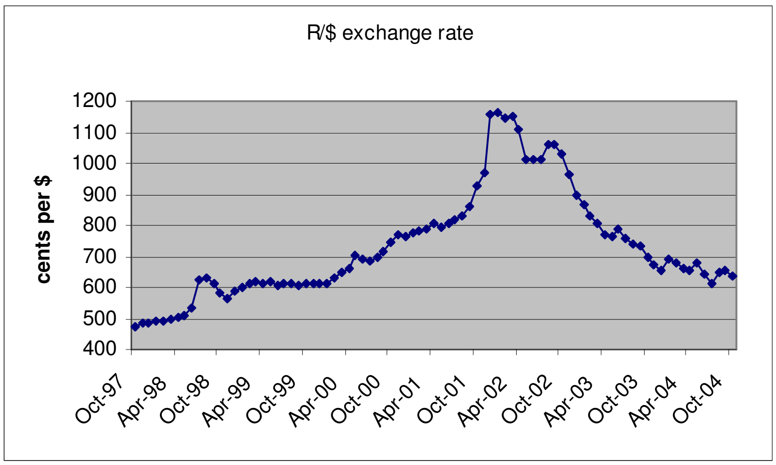


Figure 6: ZAR Rand / US Dollar exchange rate
Source: (De Lange, 2004a)

The question was asked – for how long will the Rand maintain its level.

2.2. Confidence in cost estimation

The total cost of a scheme consists of direct and indirect costs. Current cost estimation methodologies are unable to confidently estimate the indirect cost (long-term socio-economic and environmental impacts) of a particular scheme resulting in some uncertainty regarding the legitimacy of total cost estimations. Schemes including the Lourens, Voelvlei, Eerste, TMGA and Cape Flats aquifers typically contain relatively more long-term impacts and it may therefore be possible that such schemes tend to be underestimated in terms of total cost, while schemes with smaller indirect costs (such as in the case of desalination) tend to be reported more accurately. Although the direct cost estimate for Development Path A is lower than B, the confidence in such estimation is lower compared to B because desalination could be seen as a water production process that contains less uncertainty regarding long-term cost estimations – it could therefore, be possible that B is less expensive in terms of total cost estimations.

The argument of energy requirement for desalination was raised.

2.3. Tariff changes

The development paths will affect the water tariff structure differently. Although the determination of water tariffs is often more politically motivated and budget related, the fact remains that A will be cheaper in terms of water tariffs than B. Figure 7 presents the relative difference in tariffs per kilolitre between the two developments paths. The sudden increases are evident because supply schemes in the two development paths are not perfectly synchronised due to differences in the yield of various schemes. It should be clear that the difference decreases over time and stabilise between 10 and 13 percent suggesting that Development Path A will stay less expensive compared to B in terms of water tariffs.
Technological development in desalination technology could have efficiency gains and cost decreasing effects.

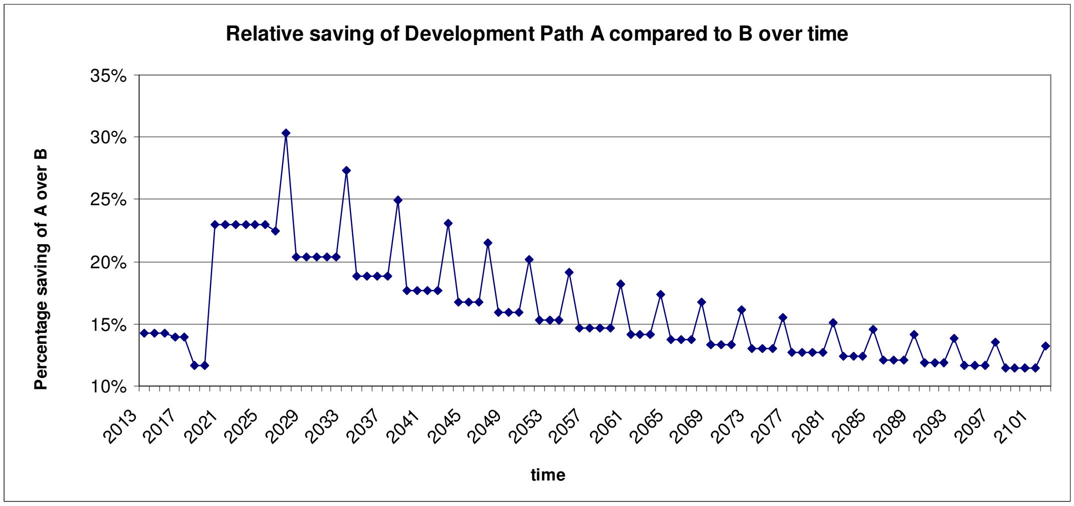


Figure 7: Theoretical average price of domestic water in the CCT
Source: (De Lange, 2004a)

Figure 8 translates the 10 to 13 percent difference to Rand per kiloliter and suggests that the difference would stabilise at R1.55/kl, implying that water from Development Path A will stay cheaper compared to B. The question that could be asked is – what is the real cost of having cheaper water from A compared to B?

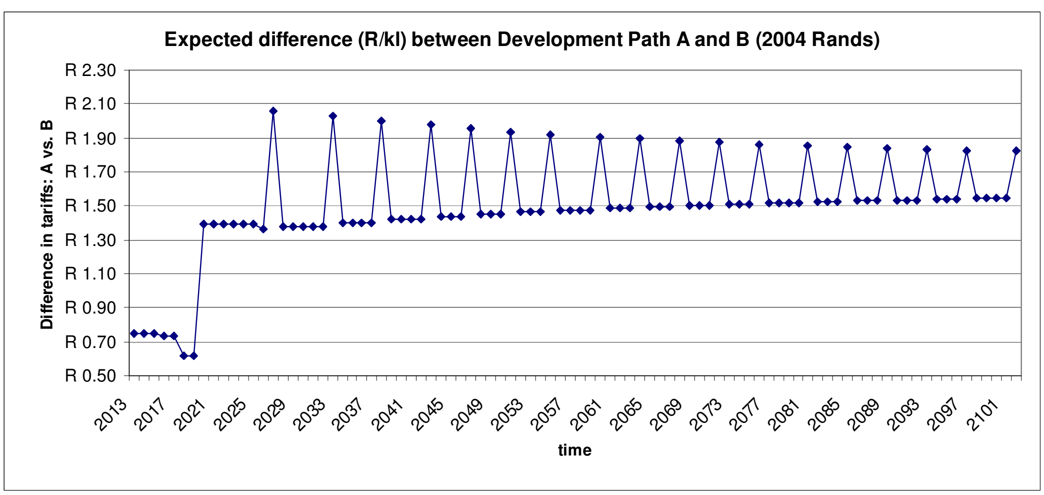


Figure 8: Relative cost saving of Development Path A over B (R/kl)

Source: (De Lange, 2004a)

Figure 9 presents the relative difference between the two development paths in terms of the percentage change of each on CCT domestic water tariffs over time. Development Path B opts for desalination in 2012 with an estimated 19.6 percent increase in domestic water tariffs; while Development Path A opts for Voëlvlei phase 1 with an estimated 0.8 percent increase in tariffs. Figure 9 also shows that when A opts for desalination in 2028, Development Path B will opt for its third plant, resulting in A having a bigger impact on tariffs compared to B. However, this does not mean that B will be less expensive than A (refer back to Figure 8).

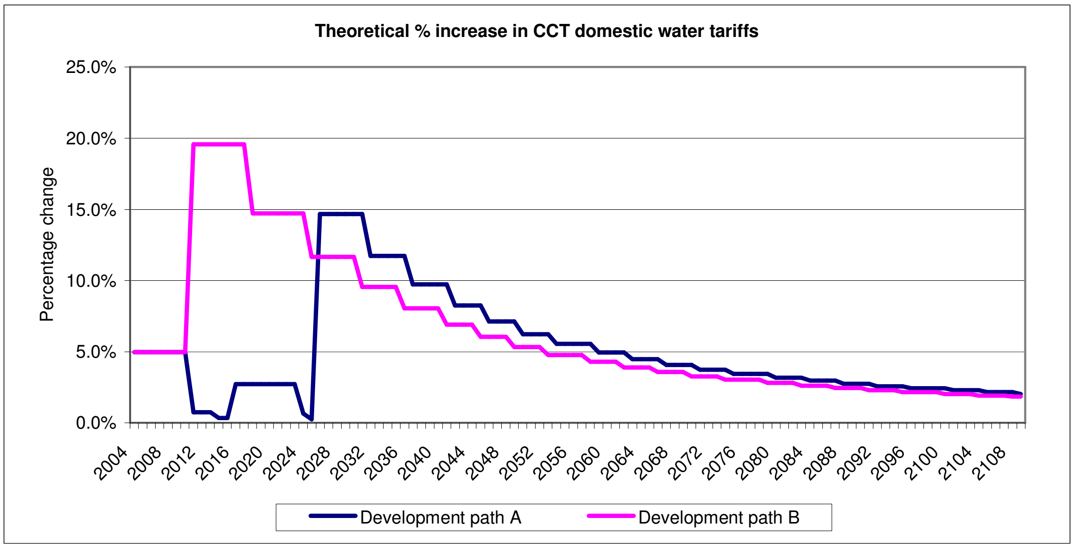


Figure 9: Theoretical percentage increase in CCT domestic water tariffs
Source: (De Lange, 2004a)

It should be clear that Development Path A postpones desalination for as long as possible and that A is cheaper compared with B in terms of increases in water tariffs. However, Development Path A does contains numerous unaccounted-for environmental and socio-economic costs (criteria 4 will discuss this issue in more detail). It should also be noted that water tariffs are not the only costs associated with the development paths and it is not certain that B will be more expensive if all costs could be accounted for.

Table 5 summarises the financial criteria of the two development paths.

Table 5: Financial criteria for development paths A and B

	Development Path A	Development Path B
Unit Reference Value (URV)	Significantly lower compared to B, but the difference decreases over time. The average URV up to 2028 = R1.89/kl Average URV up to 2049 = R4.02/kl	Significantly higher compared to A Average URV up to 2028 = R6.14/kl Average URV up to 2049 = R6.93/kl
Confidence in total cost estimates	Lower confidence in accuracy of cost estimations because of a bigger portion of poorly-measurable long-term negative	High confidence because desalination could almost be seen as a production process with fewer uncertain costs

	impacts	
Tariff changes necessary to maintain service	Initially only small increases are expected with the first few supply schemes, but a significant increase is expected when desalination becomes a reality	Initially a high increase in tariffs is expected.

Please return to the beginning of this section and complete the score sheet before proceeding to the following section.

CRITERIA GROUP 3: ENVIRONMENTAL ASPECTS

Read through the section before completing the score sheet, below.

The importance of the creation of additional storage capacity was mentioned. However, it was also mentioned that already too many dams have been constructed in the BWMA.

Development Path A is more flexible compared to Development Path B because A has more storage capacity. This contradict a previous comment on p. 4

	Description	DP A	DP B	
In-stream flow requirements Rivers need a minimum flow to maintain the ecological functioning of the system Off-steam dam needs long winter to fill.	100 = enhance the average yearly flow 0 = severely negative impact on average flow The word "severely" could have been left out. What is the impacts on average flow ? However, WHAT is average flow?			= 100
Waste disposal Rivers play an important role in transporting and diluting pollutants Water quality will become issue before water availability.	100 = enhance the average water quality – increase effective waste disposal 0 = severely negative impact on water quality			= 100
Groundwater re-charge Underground-water resources need to be re-charged to ensure supply (boreholes) Borehole pumping could enhance groundwater recharge and have negative impact on groundwater discharge.	100 = enhance ground-water recharge tempo 0 = severely negative impact on ground-water recharge tempo			= 100
Flood and erosion control Flood and erosion control are important to maintain soil fertility; erosion increases silting of storage dams and, therefore, decreases the storage capacity. Constant flows have negative impacts: establish aliens.	100 = enhance flood and erosion control 0 = severely negative impacts on flood and erosion control			= 100

Loss in biodiversity Biodiversity is a key aspect of sustaining a functional ecosystem and also a functioning society The risk of double counting was mentioned here.	100 = enhance biodiversity 0 = severe loss in biodiversity			= 100

Bias against DP A ito questions asked. However by noting that bulk of additional supply developments will be allocated to city – implies re-allocation – justify criteria and argument.

Energy for desalination = 10MW for 21.9Mkl/a – the question was asked whether this is a significant amount of energy.

Perceived values of decision makers influence their choices or decisions, with optimal decision-making requiring the full valuation of the different costs and benefits of the options under consideration. The different values associated with environmental impacts range from tangible consumptive and non-consumptive use values, to less tangible values, such as option and existence values. The estimation of environmental values in monetary terms will certainly promote and justify conservation actions at public policy and decision-making level; it does, however, remain a controversial topic. The quantification of such effects proved to be extremely complex and messy and should be seen as a study on its own; however, Table 6 does give an indication of the expected impact of the two development paths in terms of selected criteria.

Table 6: Expected environmental impact of Development Paths A and B

One respondent strongly disagreed with this table. Reasons for such response is still awaited.

Criteria	Development Path A	Development Path B
In-stream flow requirements	Higher risk of non-compliance	Lower risk of non-compliance
Waste disposal	Smaller dilution effect compared to DP B	No negative impacts on current dilution effects
Groundwater re-charge	Potential negative effect on recharge tempo It was mentioned that DP A would have negative impact on dis-charge tempo and positive effect on recharge – creating an underground dam when you pump	No effect
Flood and erosion control	Increased control because of more dams	Current level of control is maintained
Impact on biodiversity	Negative	Little/No-effect (positive)

It was noted that more than natural flow of water is not necessarily better. Differential between summer and winter flows needed for species for breeding ; migrating ext – if regulated – no more cue - impact

It is important to note that negative environmental impacts of the current water supply system in the Western Cape should be ignored in the comparison between development paths A and B. It should also be noted that neither of the development paths would have negative environmental impacts upstream from any new bulk-water scheme. All potentially negative impacts are, therefore, associated with down-stream effects such as in-stream flow requirements, waste disposal and dilution effects, flood and erosion control and estuary bio-diversity.

As mentioned, Development Path A will allocate more water to urban areas compared with Development Path B. Development Path A could, therefore, have more potential negative impacts on the environment because a further decrease in the already regulated in-stream flows will not enhance river bio-diversity. An exact estimation of negative environmental impacts is not as important here as the relative difference between the two development paths. The discussion will follow this notion.

As mentioned, Development Path A will allocate more water to urban areas compared with Development Path B. Development Path A could therefore have more potential negative impacts on the environment because a further decrease in the already regulated in-stream flows will not enhance river bio-diversity. An exact estimation of negative environmental impacts is not as important here as the relative difference between the two development paths. The discussion will follow this notion.

In-stream flow requirements safeguard the ecological functioning of catchments[8] and, therefore, the long-term supply of water to all users. Development Path A allocates more water away from catchments compared to Development Path B and it could, therefore, result in less water for in-stream flow requirements. Dilution effects and waste disposal also need a minimum level of flow to avoid causing a biohazard. Again, Development Path A could have a weaker dilution effect because of possible lower levels of in-stream flow. The same argument could be followed for groundwater recharge. In-stream storage dams are prone to silting but could be used for flood and erosion control purposes. In this regard, Development Path A is better off compared with B. However, the study area is not prone to dangerous floods Biodiversity and in-stream flows are directly related, and it is, therefore, expected that Development Path A could have a negative impact on biodiversity, whereas Development Path B will have little or no-effect.
The Cape Flats is prone to yearly flooding because of relatively shallow water table. – pumping of "greywater-polluted water" from aquifer could lower the water table and supplement supply.

Lastly, some facts are offered to clarify possible uncertainties regarding the potential negative effects of brine disposal associated with desalination plants. Although some countries do not recognise brine TDS (total dissolved solids) as a pollutant (Del Bene et al., 1994), high salinities can impact ocean biota if the necessary precautions are not in place. Hecht (Hecht and Deacon, 1996) investigated the potential effects of brine discharge in the Atlantic and advised with regard to the following (Hecht and Deacon, 1996):

TDS concentration is an indication of the relative efficiency of the desalination technology employed - higher concentrations of TDS in the brine indicate a more efficient technology (more fresh water from the same volume of seawater). However, a high TDS increases brine densities to levels significantly higher than ambient seawater, resulting in a tendency for the effluent to sink to the sea floor. Benthic (floor) marine organisms are, therefore, at greater risk to saline exposure for prolonged periods if the brine is not diluted quickly. The rate of dilution is therefore important to

[8] Including (Boucher (Boucher, 2004): 1) habitat diversity in the river; 2) appropriate water quality; 3) an appropriate riparian zone; 4) free passage between different habitats; 5) connectivity with the floodplain; 6) near-natural temperature regimes; and 7) appropriate natural variation in flow regimes.

minimise the area impacted by the discharge. Hecht (Hecht and Deacon, 1996) advised the disposal of brine via submerged vertical effluent pipes or surface discharge in the surf zone to promote rapid dilution of the discharge. It should be noted that reverse osmosis has a lower recovery rate (40 to 45 percent of the intake) compared to various distillation processes (recovery rates of 80-85 percent) resulting in a less concentrated brine that will, therefore, pose a smaller risk of salinity exposure.

Temperature deviations as well as chemical additives could pose some risk for the marine environment if the necessary precautions are not taken. Although reverse osmosis has no temperature elevations (as in the case of distillation technologies), the brine usually contains small quantities of anti-scalant (sulphuric acid) and biocide process chemicals. Although these components either break down or are bio-degradable, they may alter the chemical composition of the brine concentrate. The de-scaling action of sulphuric acid decreases the pH of the brine from 8.4 (seawater) to 5.8. Such decreases severely alter the properties of the brine when compared to natural seawater. Once again, it should be noted that new technological advances such as the use of flow distributors and electromagnetic fields in reverse osmosis technology lessen the need for chemical additions to raw feed water resulting in "cleaner" brine effluents. If the latest reverse osmosis technologies could be employed in the CCT area, the risk of negative environmental impacts of brine disposal would be negligible. As new reverse osmosis technologies exclude the use of pre-treatment chemicals, the potential effect posed by chemical additives is also removed. Disturbance of sediment and destruction of benthic organisms should be avoided if an upward angled discharged port is adopted. Any effects would be further alleviated if the effluent were discharged into zones of high natural mixing, such as the surf zone.

Please return to the beginning of this section and complete the score sheet before proceeding to the following section.

CRITERIA GROUP 4: SOCIO-ECONOMIC ASPECTS

Read through the section before completing the score sheet, below.

	Description	DP A	DP B	
4.1) Dependency on natural rainfall. The relative dependency of schemes on natural rainfall to maintain the supply; it does not help if the storage capacity exists, but it does not rain. This criterion could be under "Water balance"	100 = decrease the dependency on natural rainfall 0 = increase the dependency on natural rainfall			= 100
4.2) Volume of water allocated from rural to urban areas The volume of water that will be allocated from rural to urban areas if the development paths are followed. This criterion is the cause for impacts on agriculture and the economy ect. – not a criterion?	100 = no additional water allocated to urban areas 0 = extreme re-allocations from rural to urban areas			= 100
4.3) Impact on agricultural production and employment The impact on the volume of agricultural production (foodstuffs and fibres and the impact on permanent and seasonal labour). It was mentioned that water is not the most important production factor in agric. However, little sense in arguing on the relative importance of water as production factor – a whole bunch of factors is important – fact is that water has inelastic agric. demand!	100 = enhance agricultural production and employment 0 = severely negative impact on production and employment			= 100
4.4) Impact on the rest of the economy. All sectors (agriculture, industry and services) of an economy have an impact on one another, the agricultural sector being one of the sectors that has a significant impact on the rest of the economy.	100 = positive impact on the rest of the economy 0 = negative impact on the rest of the economy			= 100
4.5) Urbanisation Migration from rural to urban areas places more pressure on urban infrastructure.	100=decrease urbanisation 0=increase urbanisation			= 100
4.6 Recreation and tourism. The extent to which the natural environment supports the tourism industry.	100=support recreation and tourism 0=severe negative impact on recreation and tourism			= 100

It was mentioned that the current agric allocation would not be affected with future schemes – it is also unlikely that new schemes will be affordable to irrigation farmers. So what is meant with "re-allocation"? If the fact that by building schemes in rural areas imply the allocation of water to urban areas, it is a different story.

Socio-economic influences include all direct and indirect, as well as short and long-term, influences applicable to social welfare and society as a whole. Such influences are typically difficult to quantify because of their diverse nature. It is expected that most of the criticism against this study will be concentrated in this section.

4.1 Dependency on natural rainfall

Carry-over capacities in dams are dependent on natural rainfall. There is no point in creating additional storage capacity if the average rainfall does not qualify such expanded capacity - the potential impacts of global warming add to this uncertainty. Development Path B is less dependent on natural rainfall because seawater desalination could be seen as a water production process with the sea as an unlimited supply of water. It could therefore be argued that B will ensure a higher level of assurance of supply compared with A. It should be noted that the above-mentioned difference is extremely small given the fact that the biggest contribution to capacity expansion in A comes from underground sources (still dependent on natural rainfall).

The energy argument regarding desalination was mentioned again.

4.2 Volume of water allocated from rural areas to urban areas

As mentioned in the introduction, the CCT receives more than half of its water supply from outside its municipal boundaries. This brings rural uses into competition with urban use and presents a new complex dimension to the already complicated water management decision-making environment. Water availability is important for the development of any region and it is expected that Development Path A will re-allocate a greater volume of water from rural areas to urban areas because more supply schemes will be built in rural areas with the aim of providing for urban demand. Development Path B does not include the construction of additional water supply schemes (apart from the BWP) in rural areas because desalination will make use of seawater and not rural water supplies. The difference in the volumes allocated from rural areas has numerous socio-economic (and also environmental) effects, which will be discussed below.

To facilitate an illustration of the impact a re-allocation of water to urban areas will have, a theoretical 20 percent volumetric water restriction is assumed on rural water users in competition with the CCT. Such a restriction is not equal to the volume Development Path A will re-allocate, but could give a broad indication of the kind of impacts to be expected of such a reallocation. The rural areas affected by the restriction are (see also Figure 1):

- Berg River irrigation area (including Malmesbury, Piketberg, Wolseley, Tulbagh, Paarl, Franschhoek and Cape Town)
- Eerste River irrigation area (including the Stellenbosch and Helderberg areas)
- Theewaterskloof irrigation area (including Villiersdorp, Vygeboom and Groenland areas)

The following discussion attempts to display the complexities associated with such a restriction. It is by no means exhaustive but should serve as a point of departure (and motivation) for further and more specialised studies.

4.3 Impact on agricultural production

The agricultural sector has strong impacts (multiplier effect) on the rest of the Western Cape economy, and therefore, it would seem logical to use the impact of water re-allocations on the agricultural sector as a point of departure.

The relative importance of water for the agricultural sector is directly related to the importance of agriculture in the Western Cape because of the relative low demand-elasticity of water in agricultural use. If the relative importance of agriculture in the Western Cape is understood, some insight will be gained into the relative impact of allocating water from rural to urban areas.

The Western Cape agricultural sector could be counted as the largest in terms of gross farm income in South Africa, with horticulture by far the biggest contributor towards gross farming income in the province (see Table 7 and Figure 10). As such, the focus in this study on irrigated agriculture (viticulture and the deciduous industries) within the Western Cape could be justified.

Table 7: Breakdown of gross farming income per industry

	R 1,000					
Province	Field crops	Horticulture	Animals	Animal products	Other products	Total
Western Cape	1,236,449	5,960,849	1,595,016	1,585,005	275,994	10,653,313
South Africa	16,476,933	14,197,267	14,546,912	6,675,706	1,074,396	52,971,210

Source: (STATSSA, 2004)

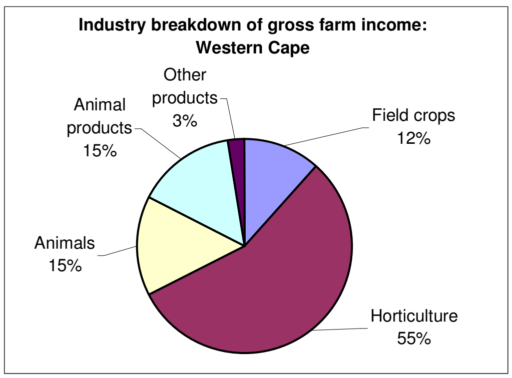


Figure 10: Industry breakdown of gross farm income in the Western Cape
Source: (STATSSA, 2004b)

The registered water use rights in the study area (refer back to Figure 1) are indicated in Table 8, with the registered hectares under irrigation indicated in Table 9.

Table 8: Registered water use rights in selected areas (million kilo litres)

	Capped (Max legal use not fully developed) (Mkl)	Present max unrestricted use (Mkl)	Agric registered (Mkl)	
Bankhoek IB	2	2		
Upper Berg IB (Includes Wemmershoek Exchange)	59	49		
Lower Berg River IB	18	18	**79**	**BergR**
Vyeboom	13	13		
Zonderend IB	32	32		
Directly pumped from THW Dam	2	2	**46**	**THW**
Stellenbosch IB	12	10		
Helderberg IB	12	8		
Lower Eerste River	3	3	**27**	**EersteR**
	150	134		

Source: (De Lange, 2004a; STATSSA, 2004b; Van Zyl, 2004b)

Table 9: Listed hectares under irrigation in study-selected areas

	Wine grapes (ha)	Table grapes (ha)	Deciduous fruit[9] (ha)
Eerste River irrigation area[10]	16582	72	1461
Berg River irrigation area[11]	31763	4313	7336
Theewaterskloof irrigation area[12]	0	5	14860
Total	48345	4390	23657

Source: (De Lange, 2004a; STATSSA, 2004b; Van Zyl, 2004b)

Crop-water-yield relationships, as well as expected impact on labour, need to be established to estimate the impact of restrictions in the study area. This proved to be a challenge given the diverse crop and cultivar portfolios of irrigation farmers in the study area. The Western Cape produces 42 percent of the total horticultural production in South Africa and horticulture (deciduous and viticulture) makes up 56 percent of the total Western Cape gross farm income. The study area represents roughly 44 percent of the Western Cape deciduous and viticulture industries in terms of irrigated hectares (De Lange, 2004a; DFPT, 2003; Western Cape Department of Agriculture, 2004).

Although some research had been done (Beukes, 1999; Piaget and Lategan, 1986; Scheepers et al., 1991) on crop-yield-water relationships in South Africa, a lack of norms is still evident. Most of this research was done on wine grapes in the Western Cape, with no South African research done on crop-yield-water relationships on deciduous fruit, vegetables and citrus. A need for such research is evident. The fact that wine grapes could, in contrast to most deciduous fruit, be produced under sub-optimal irrigation practices, such as supplemental and deficit irrigation or even dry-land conditions, makes the relative abundance of research into yield-water relationships done on wine grapes somewhat ironic (Louw and van Schalkwyk, 2001). Water stress during the production season of deciduous fruit can reduce both quantity and quality sufficiently to include severe negative economic consequences, and research on this topic would, therefore, seem viable (Bourbon-Levtley, 2004; Malan, 2004). The crop-water relationship of wine grapes (Scheepers et al., 1991) was adapted for deciduous fruit and table grapes. Table 10 indicates some of the assumptions regarding hectares planted, yield per hectare, and price per ton as well as the estimated gross value per crop/cultivar for selected areas. The assumptions were used to calculate the impact of a 20 percent water restriction in the study area.

[9] Peaches, plums, prunes, apricots, apples, pears and nectarines.

[10] Stellenbosch and Helderberg

[11] Piketberg, Wolseley, Tulbagh, Berg, Franschhoek and Cape Town.

[12] Groenland (Elgin, Grabouw), Villiersdorp and Vygeboom.

Table 10: Assumed impact of water restrictions for wine and deciduous fruit industries in the study area

	Malmesbury				Paarl				Stellenbosch			
	ha	t/ha	R/t	Total value	ha	t/ha	R/t	Total value	ha	t/ha	R/t	Total value
Cabernet Sauvignon	2303	4.0	R 5,416.00	R 49,855,016.58	3303.16	4.7	R 5,416.00	R 84,645,927.42	4119.08	5.0	R 5,416.00	R 111,546,116.22
Cinsaut	635.51	8.7	R 2,548.33	R 14,061,282.86	1196.98	7.9	R 2,548.33	R 24,221,169.32	302.33	10.7	R 2,548.33	R 8,209,188.26
Merlot	908.654	5.9	R 5,169.33	R 27,857,330.56	1362.981	7.0	R 5,169.33	R 49,580,936.96	2142.796	7.1	R 5,169.33	R 78,460,554.88
Pinotage	1809.685	8.3	R 4,383.00	R 65,550,131.82	1358.971	9.7	R 4,383.00	R 57,510,964.71	1522.867	8.7	R 4,383.00	R 57,820,163.45
Shiraz	1579.044	4.4	R 5,170.67	R 35,864,860.86	1805.868	5.6	R 5,170.67	R 52,485,162.24	2119.932	5.1	R 5,170.67	R 55,401,004.59
Cabernet Franc	44.115	1.1	R 5,098.67	R 242,793.41	187.705	5.5	R 5,098.67	R 5,266,749.31	432.5	3.3	R 5,098.67	R 7,265,125.82
Ruby Cabernet	126.65	6.9	R 3,610.67	R 3,163,810.56	238.102	8.2	R 3,610.67	R 7,065,843.58	68.391	9.0	R 3,610.67	R 2,214,667.39
Colombar	452.066	14.0	R 1,099.00	R 6,936,283.55	628.482	15.7	R 1,099.00	R 10,820,602.34	110.26	11.4	R 1,099.00	R 1,387,256.71
Semillion	121.634	6.0	R 2,080.00	R 1,523,446.08	208.373	11.7	R 2,080.00	R 5,060,939.52	139.58	8.5	R 2,080.00	R 2,478,827.52
Cape Riesling	97.992	6.3	R 1,341.67	R 831,862.85	442.325	8.4	R 1,341.67	R 5,012,506.92	129.295	8.2	R 1,341.67	R 1,429,097.72
Sauvignon Blanc	951.177	4.5	R 3,363.67	R 14,523,532.30	999.078	7.3	R 3,363.67	R 24,418,686.17	2196.603	6.0	R 3,363.67	R 44,687,791.68
Chenin Blanc	3942.3	8.1	R 1,652.67	R 52,841,663.27	3845.675	8.8	R 1,652.67	R 55,647,415.30	1913.175	9.0	R 1,652.67	R 28,525,145.66
Chardonnay	722.412	7.7	R 3,104.67	R 17,169,381.03	1063.551	8.1	R 3,104.67	R 26,663,038.78	1076.929	8.2	R 3,104.67	R 27,269,016.93
Weisser Riesling	30.4	7.2	R 2,486.00	R 541,351.36	93.44	4.9	R 2,486.00	R 1,143,604.75	84.16	8.2	R 2,486.00	R 1,718,790.57
	13724.639			R 290,962,747.08	16734.691			R 409,543,547.31	16357.898			R 428,412,747.39

	Apples				Pears				Apricots			
	ha	t/ha	R/t	Total value	ha	t/ha	R/t	Total value	ha	t/ha	R/t	Total value
Groenland (THW)	7595	45	R 3,100	R 1,059,502,500	1755	40	R 3,070	R 215,514,000	12	23	R 5,188	R 1,431,750
Villiersdorp/Vygeboom (THW)	3495	45	R 3,100	R 487,552,500	929	40	R 3,070	R 114,081,200	61	23	R 5,188	R 7,278,063
Piketberg (Berg)	384	45	R 3,100	R 53,568,000	244	40	R 3,070	R 29,963,200	208	23	R 5,188	R 24,817,000
Somerset-Wes (Eerste)	143	45	R 3,100	R 19,948,500	255	40	R 3,070	R 31,314,000	19	23	R 5,188	R 2,266,938
Wolseley/Tulbagh (Berg)	69	45	R 3,100	R 9,625,500	1182	40	R 3,070	R 145,149,600	159	23	R 5,188	R 18,970,688
Bergriver (Berg)	55	45	R 3,100	R 7,672,500	306	40	R 3,070	R 37,576,800	67	23	R 5,188	R 7,993,938
Stellenbosch (Eerste)	34	45	R 3,100	R 4,743,000	223	40	R 3,070	R 27,384,400	1	23	R 5,188	R 119,313
Franschhoek (Berg)	16	45	R 3,100	R 2,232,000	52	40	R 3,070	R 6,385,600	2	23	R 5,188	R 238,625
Cape town (Berg)	8	45	R 3,100	R 1,116,000	8	40	R 3,070	R 982,400	18	23	R 5,188	R 2,147,625
Total	11799			R 1,645,960,500	4954			R 608,351,200	547			R 65,263,938
THW	11090			R 1,547,055,000	2684			R 329,595,200	73			R 8,709,813
Eerste	177			R 24,691,500	478			R 58,698,400	20			R 2,386,250
Berg	532			R 74,214,000	1792			R 220,057,600	454			R 54,167,875
Total	11799			R 1,645,960,500	4954			R 608,351,200	547			R 65,263,938

	Nectarines				Peaches				Plums&Prunes				Total
	ha	t/ha	R/t	Total value	ha	t/ha	R/t	Total value	ha	t/ha	R/t	Total value	
Groenland (THW)	22	20	R 4,700	R 2,068,000	36	30	R 5,425	R 5,859,000	476	21	R 4,860	R 48,580,560	R 1,332,955,810
Villiersdorp/Vygeboom (THW)	38	20	R 4,700	R 3,572,000	297	30	R 5,425	R 48,336,750	144	21	R 4,860	R 14,696,640	R 675,517,153
Piketberg (Berg)	105	20	R 4,700	R 9,870,000	406	30	R 5,425	R 66,076,500	72	21	R 4,860	R 7,348,320	R 191,643,020
Somerset-Wes (Eerste)	2	20	R 4,700	R 188,000	9	30	R 5,425	R 1,464,750	157	21	R 4,860	R 16,023,420	R 71,205,608
Wolseley/Tulbagh (Berg)	146	20	R 4,700	R 13,724,000	1610	30	R 5,425	R 262,027,500	623	21	R 4,860	R 63,583,380	R 513,080,668
Bergriver (Berg)	157	20	R 4,700	R 14,758,000	130	30	R 5,425	R 21,157,500	908	21	R 4,860	R 92,670,480	R 181,829,218
Stellenbosch (Eerste)	30	20	R 4,700	R 2,820,000	42	30	R 5,425	R 6,835,500	546	21	R 4,860	R 55,724,760	R 97,626,973
Franschhoek (Berg)	14	20	R 4,700	R 1,316,000	72	30	R 5,425	R 11,718,000	289	21	R 4,860	R 29,495,340	R 51,385,565
Cape town (Berg)	1	20	R 4,700	R 94,000	12	30	R 5,425	R 1,953,000	13	21	R 4,860	R 1,326,780	R 7,619,805
Total	515			R 48,410,000	2614			R 425,428,500	3228			R 329,449,680	R 3,122,863,818
THW	60			R 5,640,000	333			R 54,195,750	620			R 63,277,200	R 2,008,472,963
Eerste	32			R 3,008,000	51			R 8,300,250	703			R 71,748,180	R 168,832,580
Berg	423			R 39,762,000	2230			R 362,932,500	1905			R 194,424,300	R 945,558,275
Total	515			R 48,410,000	2614			R 425,428,500	3228			R 329,449,680	R 3,122,863,818

	Table grapes				Total(Deciduous + Table grapes)
	ha	t/ha	R/t	Total value	
Groenland (THW)	5	19	R 4,451	R 422,859	R 1,333,378,669
Villiersdorp/Vygeboom (THW)	0	19	R 4,451	R 0	R 675,517,153
Piketberg (Berg)	1158	19	R 4,451	R 97,934,202	R 289,577,222
Somerset-Wes (Eerste)	1	19	R 4,451	R 84,572	R 71,290,179
Wolseley/Tulbagh (Berg)	62	19	R 4,451	R 5,243,455	R 518,324,122
Bergriver (Berg)	3090	19	R 4,451	R 261,327,017	R 443,156,234
Stellenbosch (Eerste)	71	19	R 4,451	R 6,004,601	R 103,631,574
Franschhoek (Berg)	0	19	R 4,451	R 0	R 51,385,565
Cape town (Berg)	3	19	R 4,451	R 253,716	R 7,873,521
Total	4390			R 371,270,422	R 3,494,134,239
THW	5			R 422,859	R 2,008,895,822
Eerste	72			R 6,089,173	R 174,921,753
Berg	4313			R 364,758,389	R 1,310,316,664
Total	4390			R 371,270,422	R 3,494,134,239

Source: (Agricultural Research Council - Infruitec/Nietvoorbij, 1999; Beukes and Weber, 1982; Beukes, 1999; De Lange, 2004a; DFPT, 2003; Green, 1985; Louw, 2001; Louw, 2004; Louw and van Schalkwyk, 2001; SAWIS, 2004a; SAWIS, 2004d; Van Zyl, 2004a; Van Zyl, 2004b; WESGRO, 2004)

Crop-water-yield relationships are complex and bound to a localised context, with inter-crop variation complicating the situation further. It is therefore extremely difficult to present a complete and accurate estimation of yield relationships for the study area. Some assumptions were called for and Figure 11 indicates the assumed crop-water-yield relationships that were adopted from Louw and van Schalkwyk (Louw and van Schalkwyk, 2001). Calculations are based on secondary data obtained from a literature survey and it should be clear that further research is needed in this regard.

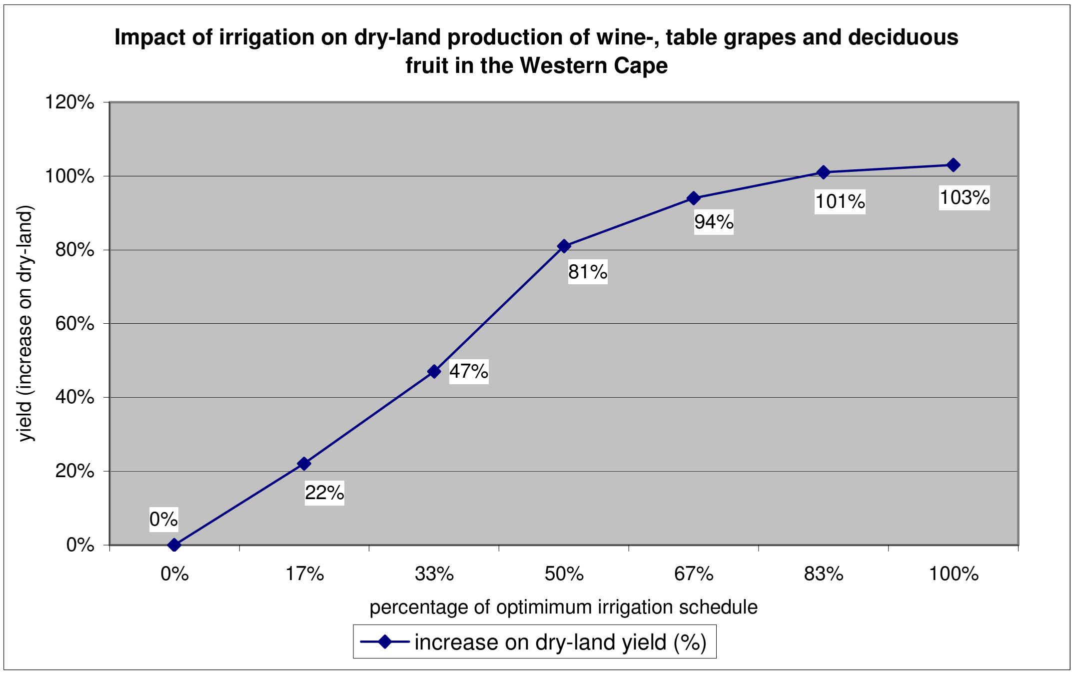


Figure 11: Assumed crop-water-yield relationship

Source: (Beukes, 1999; De Lange, 2004a; DFPT, 2003; Louw and van Schalkwyk, 2001; Malan, 2004; SAWIS, 2002; SAWIS, 2004d; Scheepers et al., 1991; Van Zyl, 2004)

Quality impacts was not accounted for.

The following assumptions were made to construct the relationship:

- Assume equal volumes with each irrigation. (I.e. the irrigator irrigates a fixed volume of water with each application.)
- Assume that six applications are 100 percent of the total number of applications and therefore 100 percent of the total volume irrigated in one irrigation season.
- Assume the above-mentioned yield relationship to be under normal production conditions.

Within Figure 11, dry-land production was assumed as the base yield (0 percent), with the percentage increase as shown for each incremental (17 percent) irrigation (Louw and van Schalkwyk, 2001). A typical S-curve could be identified, with the most dramatic yield increase (81 percent above dry land) taking place within 50 percent of the optimum irrigation schedule from where a typical diminishing return in yield sets in.

An approximate 2% drop in yield could be associated with a 20% water restriction (given 100% of the optimum irrigation level) (Louw and van Schalkwyk, 2001). Apart from this, Beukes and

Weber (Beukes and Weber, 1982) associate a 5% decrease in yield (apples) with a 20% stress on the optimum irrigation schedule while Goode (Goode, 1971) mentioned a 9% (apples) decrease in yield with a 20% increase in water stress. Malan (Malan, 2004) and Bourbon-Levtley (Bourbon-Levtley, 2004) mention a 7% (deciduous in general in the Berg Irrigation area) drop associated with a 20% restriction from the optimum irrigation schedule. It was, therefore, assumed that a 20% water restriction will have a 5% decrease in the average yield. Such an assumption certainly is debatable given the vast number of management strategies irrigation farmers could follow to minimise the impact of a 20% restriction.

Table 11 translates Table 10 with respect to the above-mentioned assumptions into the expected theoretical impact on total gross margin for the study area. The impact of a restriction should be clear.

Table 11: Expected decrease in production associated with a 20 percent water restriction in the study area

	Wine industry	Table grape industry	Deciduous fruit industry	Total
Gross margin (without restriction)	R 1,128,919,042	R 371,270,422	R 3,122,863,818	
Gross margin (with restriction)	R 1,072,473,090	R 352,706,900	R 2,966,720,627	
Difference	R 56,445,952	R 18,563,521	R 156,143,191	R 231,152,664

Sources: (Abbott, 2001; Beukes and Weber, 1982; Beukes, 1999; De Lange, 2004a; DFPT, 2003; Green, 1985; Louw and van Schalkwyk, 2001; SAWIS, 2002; SAWIS, 2004a; SAWIS, 2004b; SAWIS, 2004c; SAWIS, 2004d; Scheepers et al., 1991; STATSSA, 2004a; STATSSA, 2004b; Van Zyl, 2004)

This table was verified.

The above-mentioned argument regarding the impact of a 20% restriction creates an expectation regarding the impacts of a restriction. It could, however, be over simplistic because if restrictions become the norm rather than the exemption, this situation could lead to structural changes with a movement from deciduous fruit to more drought resistant crops like wine grapes or even cash crops, which are most flexible in terms of water restrictions (De Lange, 2004b).

4.4 Impact on employment in agriculture

The above-mentioned influences on production will have spin-off effects for employment, as well as for other sectors in the economy. The following sections focus on structural changes resulting from ongoing (permanent) water restrictions and the expected impact on employment, urbanisation, tourism and the rest of the economy.

In general, agriculture is more sensitive regarding employment in reaction to water restrictions than to other sectors. This is due to in-elastic demand characteristics of irrigation water in the production process. Louw and van Schalkwyk conducted detailed research on the economic impact of ongoing water restrictions (structural changes) in the Berg River irrigation area (Louw and van Schalkwyk, 2001). They made use of two scenarios in their study. The first allowed trading of water use rights and the second did not. Although their study showed that a trade scenario could be advantageous in some circumstances, the assumption of no-trade will be used in this document, as the market for tradable water use rights is not very active in the study area. Their study could be seen as a legitimate estimation of the relative impact of water restrictions on the current study area.

Figure 12 presents the theoretical impact of water restrictions on permanent labour in the long-term. As restrictions intensify to a 40 percent restriction, the permanent labour force decreases from 5200 in the base analysis (being an unrestricted situation) to approximately 4600 (representing a decrease of 11.5 percent). Figure 12 shows that a 20 percent water restriction will result in a 4,8 percent decrease in permanent employment (given the no-trade scenario for water use rights).

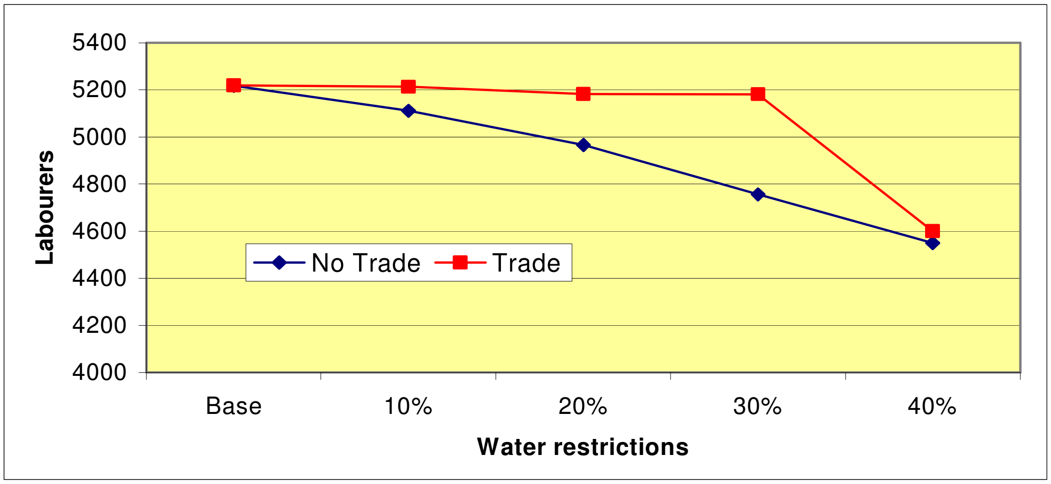


Figure 12: Decline in the permanent labour force during water restrictions
Source: (Louw and van Schalkwyk, 2001)

The situation with regard to casual farm workers could be even worse (see Figure 13). The casual labour force declines from approximately 111 000 workers (with approximately 345 000 dependents) in the base analysis to just under 90 000 workers (representing a decrease of 18,9 percent) in the event of a 40 percent restriction (under the no-trade scenario). The associated decrease for a 20 percent restriction is estimated at 5,4 percent. Each of these workers earn an average cash wage of approximately R 2835 to R 5000 *per season* (STATSSA, 2004a), resulting in a loss in income of approximately R 82M per annum.

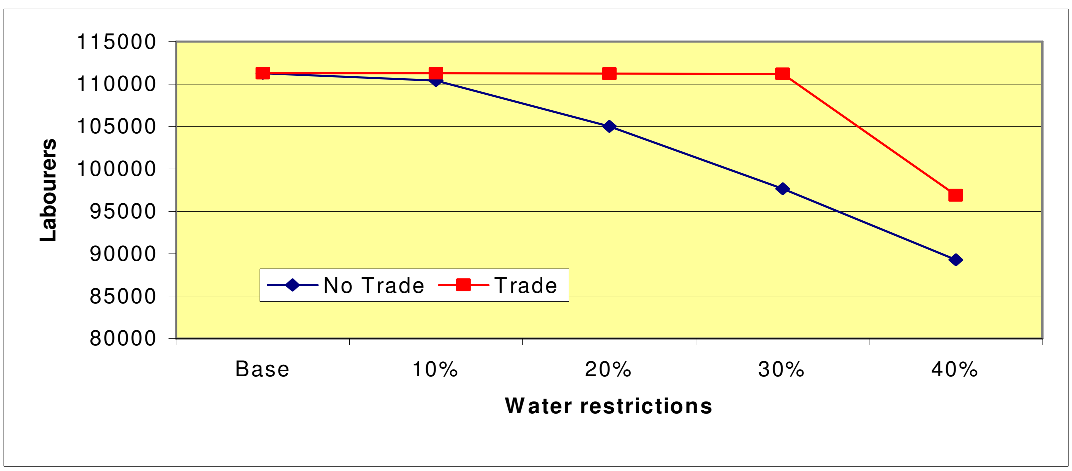


Figure 13: Decline in the casual labour force during water restrictions
Source: (Louw and van Schalkwyk, 2001)

The combined impact of job losses could decrease the general welfare of the communities in the Western Cape because most of this income is spent in the local economy. According to Table 12, the average cash remuneration of full-time farm labourers in the Western Cape is approximately R 14269 per annum (R 1189 per month), being the second highest (after Gauteng) in South Africa.

Therefore, for every 100 permanent farm workers losing their jobs, approximately R 1.4 million less will be spent in the local economy.

Table 12: Agricultural employment and employee remuneration per province

Province	Owners/proprietors	Full-time workers		Casual and seasonal workers	
	Number	Number	Remuneration R1 000	Number	Remuneration R1 000
Western Cape	7 283	94 659	1 350 718	117 149	332 139
Northern Cape	6 948	34 195	350 200	73 072	136 081
North West	5 516	39 597	394 693	45 060	58 666
Mpumalanga	3 947	68 297	669 201	51 767	96 141
Limpopo	3 065	45 750	395 735	30 141	72 489
KwaZulu-Natal	3 775	79 662	817 415	37 545	106 691
Gauteng	1 320	21 492	363 827	9 054	22 690
Free State	8 576	61 277	565 024	62 152	73 647
Eastern Cape	5 597	36 442	345 438	33 504	64 787
South Africa	**46 027**	**481 371**	**5 252 251**	**459 444**	**963 331**

Source: (STATSSA, 2004)

If the figures in Table 12 are broken down, it will be found that the Western Cape deciduous industry alone employs approximately 104439 labourers (permanent and seasonal), with 417756 dependants (DFPT, 2003), while the Western Cape wine industry employs approximately 3500 cellar personnel and 345000 farm labourers (including dependants) (SAWIS, 2004d). To compensate for double counting, the following will be assumed for the sum of labourers in the study area:

Permanent labour	43166
Seasonal labour	50798
Dependants	181146
Total	275110

According to Table 13, a 20% water restriction could result in a decrease in income of approximately R 36.5 million (permanent and seasonal labour) in the study area. This would have multiplier effects on other sectors in the Western Cape economy. The unemployed would have to be accommodated elsewhere, which would fuel urbanisation and could overstrain RDP initiatives of the Government even faster. A market for water use rights could delay these employment impacts, as more water could be made available through trade of water use rights (Louw and van Schalkwyk, 2001). However, such a measure should be seen as a demand management approach.

Table 13: Theoretical impact of 20 percent restriction on the number of labourers in the study area

	No restriction	20% restriction	Difference	Income loss
Permanent labour	43166	41091	2075	R 29,612,984
Seasonal labour	50798	48052	2746	R 7,785,515
Dependants	181146	172437	8709	
Total	275110	261580	13530	R 37,398,499

Source: (De Lange, 2004; DFPT, 2003; SAWIS, 2004; STATSSA, 2004)

Table 14 indicates the combined impact on production and the loss in household expenditure as a result of a 20 percent water restriction in the study area. In monetary terms, an estimated income loss of approximately R38 million could be expected for a 20 percent water restriction in the study area.

Both the production and income losses are presented in Table 14 with the estimated total loss in production and income equal to R268 million.

Table 14: Expected losses in production (producer prices) and labour income associated with a 20 percent water restriction

	Wine industry	Table grape industry	Deciduous fruit industry	Total
Loss in production	R 56,445,952	R 18,563,521	R 156,143,191	R 231,152,664
Loss in labour income	R 9,132,466	R 3,003,417	R 25,262,616	R 37,398,499
				R 268,551,163

Source: (De Lange, 2004; DFPT, 2003; SAWIS, 2004)

The above-mentioned argument should demonstrate some of the impacts associated with a re-allocation (restriction) of water from rural to urban areas. In terms of the two development paths, it should be clear that allocating more water to agriculture, Development Path A could have decreasing effects on the rural population in terms of loss of production and income. Such negative impacts will be avoided with Development Path B.

4.5 Impact on the rest of the economy (multipliers)

The agricultural sectors affect the rest of the economy. Economists have developed forward multipliers for different sectors and industries to quantify such effects. The higher a multiplier the bigger the potential effects of the specific industry for the economy.

Table 15: Forward multipliers for selected industries/sectors in the Western Cape

Industry/sector	Forward multiplier
Viticulture	10.73
Deciduous fruit	10.90
Forestry	7.00
Mining	9.61
Meat production	9.70
Dairy production	9.77
Animal feed production	10.36
Other manufacturing	8.80
Electricity and water	10.34
Construction	2.92
Trade	9.95
Transport and communication	10.30
Services	9.88

Source: (Berning and Nowers, 2000; McDonald and Punt, 2001)

Table 14 and Table 15 translate into Table 16 by indicating a rough estimation of the decrease in gross income for the Western Cape economy if a 20 percent re-allocation of water should apply in the study area. It should be clear that substantial deviations will be found in practice, but such figures will only become certain AFTER the shock (water restrictions) has been implemented. The aim of multipliers is to be pro-active and to provide decision makers with a rough estimation of the future consequences of certain bulk-water management strategies.

Table 16: Estimated impacts on the rest of the Western Cape economy (2004)

Industry	Decrease in gross farm income	Multiplier	Gross income decreases for the Western Cape economy
Viticulture (Wine and Table)	R 75,009,473.16	10.73	R 804,851,647.05
Deciduous fruit	R 156,143,190.88	10.9	R 1,701,960,780.54
	R 231,152,664.04		R 2,506,812,427.59

Source: (Berning and Nowers, 2000; De Lange, 2004; Punt, 2005)

Table 17 places the above-mentioned figures in context. According to the figures, a 4.41 percent (R231,152,664 / R5,241,000,000) decrease in gross farm income could be expected if a 20 percent water restriction is implemented in the study area. Such a decrease represents a 2.94 percent (R2,596,812,412 / R88,303,000,000) decrease in the gross geographic product for the province as a whole.

Table 17: Key provincial statistics: Western Cape

Economic sector	South Africa Rand (million)	South Africa %	Western Cape Rand (million)	Western Cape %
Agriculture, forestry and fishing	23 658	4	5 241	6
Mining and quarrying	34 472	6	166	0
Manufacturing	108 085	20	16 687	21
Electricity, gas and water	20 728	4	2 769	3
Construction (contractors)	16 670	3	3 387	4
Wholesale retail trade, catering and accommodation	74 161	13	11 734	15
Transport, storage and communication	58 141	11	8 826	11
Financial intermediation, insurance, real estate and business services	104 191	19	21 758	27
Community, social and other personal services	29 358	5	3 692	5
General government services	82 160	15	6 523	8
All indices at basic prices	**551 624**	**100**	**80 783**	**100**
Taxes less subsidies on products	51 765		7 521	
GDP at market prices	**603 389**		**88 303**	

Source: (Statistics South Africa, 2005)

It could, therefore, be argued that Development Path A will have a negative effect on agriculture and on the Western Cape economy as a whole. Development Path B is more expensive in terms of water tariffs, but it will save on production losses.

4.6 Urbanisation

A certain minimum population is necessary to maintain economic functionality in rural areas. Development Path A does not support maintaining the rural population to the same extent as B because A enhances urbanisation through increased unemployment in the irrigated agricultural sector (as result of possible decreases in production because of water restrictions). Increased urbanisation results in numerous other problems for urban areas, including increased water demand, electricity and housing.

4.7 Recreation and tourism

Tourism is the single biggest industry in the world and the Western Cape is no exception. Recreation and tourism depend on the maintenance of sustainable water eco-systems with many of the natural attractions in rural areas related to water resources. If such water resources are re-allocated to urban areas, it could be expected that rural amenities associated with water resources will decrease. The Western Cape has a 28 percent share of the South African tourist market, with a total of R 9304 million (10.54 percent of Western Cape GDP) being spent by tourists in the province. Overseas tourist spending could be seen as a derivative from investment in agriculture. According to WESGRO (WESGRO, 2004), 43 percent of all foreign tourists visiting South Africa visit the winelands and the wine industry, contributing more than R 3500 million (3.96 percent of Western Cape GDP) annually to the tourism industry.

Please return to the beginning of this section and complete the score sheet before proceeding to the following section.

CRITERIA WEIGHTS

The last section allocates weights to each main criteria group and the associated sub-criteria. Each weight indicates the relative importance of the criteria. If necessary, refer to the tree diagram of the criteria at the beginning of the document. The following table is an example of randomly chosen weights of the completed weight allocation procedure.

EXAMPLE:

Main criteria	**Main criteria weight**	**Sub-criteria:**	**Sub-criteria weight**
Water balance	9	Confidence in yield	30
		Timing (ability to supply the demand)	70
			100
Financial aspects	25	URV	30
		Confidence in total cost estimates	20
		Tariff changes necessary to maintain service	50
			100
Environmental aspects	20	Expected impacts on average flow	25
		Waste disposal and dilution effect	25
		Ground water recharge.	20
		Flood and erosion control	5
		Loss of Biodiversity	25
			100
Socio-economic aspects	28	Dependency on natural rainfall	10
		Volume of water allocated from rural to urban areas	20
		Impacts on agricultural production	20
		Impacts on employment in agriculture	20
		Multipliers	10
		Urbanisation	10
		Recreation and tourism	10
			100
Public acceptance	18		
	100		

PLEASE ALLOCATE APPROPRIATE WEIGHTS TO THE CRITERIA BY COMPLETING THE FOLLOWING TABLE:

Note that we are indeed aware of the subjective nature of the weight allocation procedure and that the stated weights will be used merely as a point of departure for a negotiation process determining the final weights. Please note that all weights will be made available to all experts for discussion in order to obtain a final set. Your weight should be based on your interpretation of the relative importance of the particular main or sub-criteria in the decision-making process.

Main criteria	Main criteria weight	Sub-criteria:	Sub-criteria weight
Water balance		Confidence in yield	70
		Timing (ability to supply the demand)	30
			100
Financial aspects		URV	30
		Confidence in total cost estimates	40
		Tariff changes necessary to maintain service	30
			100
Environmental aspects		Expected impacts on average flow	25
		Waste disposal and dilution effect	20
		Ground-water recharge.	15
		Flood and erosion control	15
		Loss of Biodiversity	25
			100

Socio-economic aspects		Dependency on natural rainfall	40
		Volume of water allocated from rural to urban areas	10
		Impacts on agricultural production	10
		Impacts on employment in agriculture	10
		Multipliers	10
		Urbanisation	10
		Recreation and tourism	10
			100
Public acceptance	A more paternalistic view could be assumed. Water tariffs is mainly a issues of balancing the budget.		
	100		

FINAL COMMENTS

Please feel free to make ANY comments:

Page 5 refers to "mining" - continuous depletion of a groundwater resource. This is rarely practiced, and would not be the intention if TMGA were developed. The aim would be to abstract on a sustainable basis – not mine the resource. However, one could ask the question WHAT is a sustainable basis?

Page 6 – The agric demand limited to registered water use rights. Is this valid? I think you are only accounting for surface water in this case. Groundwater could continue to be developed by agriculture over time – add approx 20Mkl.

Confidence in R/$ exchange is very uncertain – does this not impact severely on the cost estimation for desalination? However, exchange rate impact prices of imported parts – RSA does have capacity to produce all RO technology locally. Economists expect that R will stabilize at R5-R7 against the $ . . .

Criteria Group 3 and 4 is unfair way of handling? In many cases, the only option is to assign a score of zero for option A because the criterion is not applicable to option B. The bias inclusion of criteria that will force a poor score for A and have no impact on B. This forces a "severe" zero score for A when in reality the impacts could be limited if managed correctly. However, the reality is uncertain – propose alternatives? It was noted that careful consideration and motivation is needed for each criteria.

Development Path B neglects the negative impacts of utilising "dirty energy". Desalination would only be environmentally friendly if such technology makes use of clean energy. However one should not see DP B as "desalination" – the two DP's represent two different ways of long-term water management – the two DP's is making this difference more tangible (he mentioned that we could replace desalination with recycling or any other "greener and more expensive – ito direct costs) option!

Bias in favour of DP B – in terms of the questions and criteria. However, previous studies were biased towards A ? – balancing the view?

The importance of climate change on the water balance has been noted.

The impact of "sediment hungry" water from dams – have bigger erosion potential on the recovery distance was noted.

It was noted that desalinisation must be considered for implementation sooner rather than later and the option of linking it to other development options such as energy production must be considered as this will have an impact on the costs.

A bias in the analysis is represented in my opinion by the assumption made on the need for re-allocation of water from rural to urban areas in Strategy A and the consequent socio-economic impacts. If we look at table 2, the total storage capacity at year 2028 in the Western Cape is 737 million kilo-litres per year for the Development Path A and 716 million kilo-litres per year for the Development Path B. It means that an equivalent available yield corresponds to the two alternatives at the same year. It is clear that strategy A would ask for a transfer of water from rural to urban areas, whereas strategy B would "produce" water directly in the urban area. But this does not mean, if I understand your figures, that a reduction of water availability occurs in the rural areas in strategy A because the improved capacity of storage exists in this strategy too (440 -> 737 million Kl/year). The eventual shortage in rural areas if this strategy is chosen depends, in my opinion, on the higher sensitivity of Development Path A to rainfall (climate) than Development Path B.

Generally speaking, one has the impression that if the technology is available and reliable, Development Path B is the better option, as results also from my score (43.9 option A; 56.1 option B making the hypothesis that both alternatives have the same public acceptance). I have the impression that certain costs associated with Development Path B have not been considered or are underestimated (potential breakdowns of the plants and relative environmental/financial consequences, uncertainties in the long-term functioning of these structures, etc.).

Some assumptions in the document seem to be quite "heavy" and not enough explained. For instance, why was urban demand growth was estimated at 2 percent/year? The same for the productivity of water in the agricultural sector and the use of multipliers.

Please return the completed questionnaire via e-mail to:

willemdl@elsenburg.com

THANK YOU FOR YOUR PARTICIPATION