Water, climate change and small towns

PIERRE MUKHEIBIR

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Abstract

This thesis examines the interrelationship between “water, climate change and small towns”. The research question is framed in three parts: 1) can climate change be integrated into existing planning frameworks? 2) can small towns build resilient strategies against projected climate change impacts? and, 3) is adaptation to climate change an economic issue?

It is evident that very little synergy exists between the different sectors dealing with water access. A holistic view of access and the impact of climate change does not exist in the sustainable development, urban planning and water resources management sectors. It is therefore proposed that the successful delivery of accessible water services lies with the integration of the urban planning, water resources management and climate change adaptation responses. In order to achieve this, a planning framework is introduced.

The thesis demonstrates an approach that should be adopted by small towns in developing their water adaptation responses by including an assessment of existing climate variability responses. By screening these against qualitative and quantitative criteria, robust strategies can be identified that will ensure sustainable water supplies under projected climate change impacts. Small towns are, in general, hampered by low levels of technical capacity and revenue streams, and it is therefore important that the strategic choices match the available adaptive capacity.

By drawing on a case study of a small town in South Africa, it is demonstrated that within a time frame of 30 years, even under a conservative scenario of a modest reduction in rainfall and static levels of poverty, the costs of matching water demand and maintaining access to safe water for the urban poor will exceed the resources typically available to small municipalities. The consequence of climate change impacts is indeed an economic issue. In this specific case, the future precipitation is presented as the median change of a range of seasonal projections for a 30 year period. In order to meet the same water demand under climate change conditions as compared with current normal climate conditions the investment cost quadruples over the 30 year period. This, in turn, results in an increase in the average unit selling price of the water increasing by 25%. A fundamental shift in development policy is therefore required to finance adaptation if the attainment of equitable access to affordable water is to be achieved.

Preface

The work presented in this thesis is my own. However it would not have been possible without the contributions by a number of people and organisations, whom I wish to thank.

My co-supervisors, Professors Sue Parnell and Bruce Hewitson, for their encouragement to undertake the study and their insight and guidance along the way. My colleagues at the Energy Research Centre for their assistance on various technical issues.

The Energy Research Centre has afforded me the opportunity and space to embark on climate change related research, to develop my understanding of a new field and to contribute to a rapidly growing field of knowledge.

To Teresa for undertaking the unenviable task of proofreading and together with James and Ruth, for allowing me the time to complete this thesis.

Parts of this thesis have previously been published in peer reviewed journals. Chapters 5 and 6 in particular were was informed by the work of the author published as:

1. Mukheibir, P & Ziervogel, G 2007. Developing a Municipal Adaptation Plan (MAP) for climate change: the city of Cape Town. *Environment & Urbanisation*. 19 (1), 143-158. April 2007, where I was the lead author in the published work, and I gratefully acknowledge the inputs from Gina Ziervogel.
2. Mukheibir, P 2007. Qualitative assessment of municipal water resource management strategies under climate impacts: the case of the Northern Cape, South Africa. *Water SA*. 33 (4), 575-581. July 2007.
3. Mukheibir, P 2007. Water resource management strategies for adaptation to climate induced impacts in South Africa. *Water Resources Management*. DOI: 10.1007/s11269-007-9224-6, November 2007.

Chapter 6 draws heavily on the work done for the Water Research Commission and Netherland Environmental Assessment Agency, specifically the research on the water strategies and selection methodologies which was the author’s contribution to the study.

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- Netherland Environmental Assessment Agency: Local water resource management strategies for adaptation to climate induced impacts in South Africa, Energy Research Centre, November 2005.
- Water Research Commission of South Africa: Climate variability, climate change and water resource strategies for small municipalities. Pretoria, South Africa, Water Research Commission. January 2006, WRC Report No. 1500/1/0.
- Korean Environmental Institute: The impact of climate change on small municipal water resource management: The case of Bredasdorp, South Africa (Ch 9). A Garg, W-J Han, J E Kim and K Halsnaes (Eds). *From vulnerability to resilience: The challenge of adaptation to climate change,* KEI and the UNEP Riso Centre: 125-143. ISBN 978-87-880-3650-5.
- UNITAR C^3D programme: Access to water - the impact of climate change in small municipalities, Energy Research Centre, October 2007

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Abbreviations, Acronyms and Units

AC	Annualised cost
ACRU	Agricultural Catchments Research Unit, Agricultural Engineering Department, University of Natal, South Africa
AIC	Average incremental cost
ANC	African National Congress
APF	Adaptation Policy Framework
CBA	Cost Benefit Analysis
CCT	City of Cape Town
CIF	Climate Impact Factor: this is the ratio between conditions under normal climate versus conditions under climate change.
CIF_{Pu}	Climate Impact Factor for the tariff over given period.
$CIF_{recharge}$	Climate Impact Factor for recharge for a specified period.
CIF_{runoff}	Climate Impact Factor for runoff for a specified period.
CMA	Catchment Management Agency
CO_2	Carbon dioxide
CSAG	Climate Systems Analysis Group, University of Cape Town
C_U	Unit supply cost
DEAT	Department of Environmental Affairs and Tourism (South Africa)
DLC	Discounted levelised cost
DSM	Demand side management
DWAF	Department of Water Affairs and Forestry
GCM	Global circulation model
GEF	Global Environment Facility
GHGs	Greenhouse gases
GHG	Greenhouse gas
IAP	Invasive alien plant
IDP	Integrated Development Plans
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
LC	Levelised cost
LCC	Life cycle cost
LDC	Least Developed Countries
LED	Local Economic Development
MAP	Mean annual precipitation
MCA	Multi-criteria analysis
MCDA	Multi-criteria decision analysis
MDG(s)	Millennium Development Goal(s)

MIG	Municipal Infrastructure Grant
NAPA	National Adaptation Plans of Action
NCCC	National Committee on Climate Change
NWRS	National Water Resources Strategy for South Africa
O&M	Operation and maintenance
OECD	Organisation for Economic Co-operation and Development
P_U	Unit selling price or tariff
PV	Present value
RCM	Regional Climate Model
RDP	Reconstruction and Development Programme
SA	South Africa
SADC	Southern African Development Community
SALGA	South African Local Government Association
SSA	Statistics South Africa
SSNAPP	South*South*North Adaptation Project Protocol
UARL	Unavoidable annual real loss
WCD	World Commission on Dams
WCED	World Commission on Environment and Development
WRAP	Water Resources Adaptation Plan
WSSD	World Summit on Sustainable Development

PART ONE
INTRODUCTION

You ain't gonna miss your water until your well runs dry – Bob Marley

CHAPTER 1

1. Introduction and background

1.1 Sustainable small scale urban water supplies and climate change

Access to safe water for all people is a United Nations Millennium Development Goal (MDG) and is key to a successful development strategy. The most significant resource for reducing poverty and disease and improving the life of the poor is through adequate water access and increased food security (Reid & Vogel 2006; UN 2006). However, the main thrust of these development initiatives has been in large cities and the subsistence agriculture sector and not in small towns. This is of particular concern since, for example, an estimated two thirds of the urban population in Africa live in small towns (UN 2004). In addition, many towns and cities in developing countries have unreliable piped water systems. Service delivery is deteriorating in these centres mainly because of fast population growth and urbanisation. Further, urbanisation is increasing rapidly in cities of developing countries which often struggle to cope with the existing number of people they need to support and service (UN-HABITAT 2006b). This is due mainly to the high capital costs of infrastructure and diminishing government resources for addressing and maintaining urban water issues. The result is that poor people are further marginalised and denied access to a basic human right.

Poor access to water is often confused with physical water scarcity. Scarcity is a shortage in the physical availability of the clean water resource, which can be exacerbated by drought and pollution. In some cases poor access to water is also due to political or economic policies. People who do not have access to water are mostly the marginalised, either geographically, economically, institutionally or socially. A number of discourses have evolved around resource scarcity and access to basic services, specifically water. These are presented in Part 2 of this thesis, where the responses from the sustainable development, water resource management, urban planning and climate change sectors are discussed.

The often confused issues of water scarcity and access are the key debates confronted in this study. Of specific interest is the role that small towns and water systems play in addressing these two components of water delivery, viz. the supply side management of scarcity and the demand side management of ensuring access. Both concepts are investigated by means of a case study of a South African small town, Bredasdorp (See the location map in Figure 1), which is located in a relatively arid region. This town is typical of many settlements across the developing world in that it is confronted with in-migration, a large poor population with no significant middle class to allow for cross-subsidisation, a significant capacity vacuum, weak institutional structures and low levels of data and planning information.

Figure 1: Location map of Bredasdorp

Despite the acknowledged importance of water as a basic right, there are two key deficiencies in the existing research critique around the problems confronting small towns and their role to administer small water supply systems. Firstly, currently and historically, the concerns of small urban centres fall between the cracks, since the prime focus for development has been the large urban cities and the development of a rural and agricultural economy. The issues of human and financial capacity, poor data sets, low economic bases and marginalisation by national governments and regional institutions appear to be absent from the debates concerning access to water and affordability. More than half of the urban population in Africa, Asia and Latin America live in urban market towns and administrative centres of between 5000 and 100000 people, yet little is understood of how they function economically, institutionally and socially (Satterthwaite & Tacoli 2003; Satterthwaite 2006). It is therefore appropriate that the focus of this study is on small towns, since they have an important role to play in rural development and poverty reduction and provide the nodes for local economic development, education, health and other social services.

A second major gap in the literature derives from the debate around the projected impacts of climate change, where there has been relatively little focus on urban centres and even less on small towns. More recently, the concerns of the climate change community with regard to potential climate induced impacts have been taken on by policy makers and planners, however, the focus has mostly been at the national level and in the broader water and agriculture sectors.

These gaps in the global and local policy analysis of the role of small towns in delivering sustainable water access under projected climate change impacts have motivated this study. This thesis therefore focuses on the key areas of small urban centres, water resource management and projected climate change impacts.

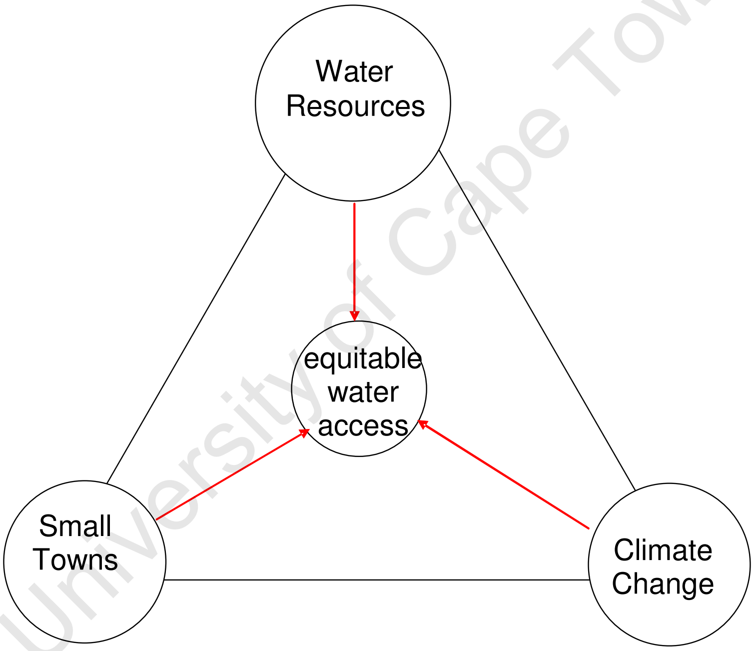

Figure 2: Equitable water access nexus showing the inter-linkages between climate change, water resources and small towns

Figure 2 provides an illustration of the inter-linkages between the three drivers to ensuring sustainable and equitable access to water. The water resources and climate change sectors are focused predominantly on resource planning, while the planning at the small town level is focused on delivery and access. All three operate at different temporal and spatial scales. Town planning focuses on a small geographic area within a relatively short time period, the climate change focus is on the global and regional scale and looks at a longer time horizon of about 30-100 years. Water resource management falls in between the two, with a major focus at the catchment level. Embracing these differences is imperative since there is a need to bring integration into planning for equitable water access, especially when faced with the prospect of projected climate change impacts.

Current water management mechanisms and policies have been developed to ensure that existing water supplies meet growing demands (Turton 1999b). Some of these mechanisms, if implemented in a sustainable manner, could help poor people cope with future drought related water shortages due to increased climate variation. However, climate change is not currently recognized as an important threat to available water resources, and robust strategies have not yet been developed to adapt to projected impacts[1]. The likely victims of this gap in forward planning are the poor , who depend on well capacitated and robust systems of water management to ensure affordability of, and access to, water.

When faced with actual or impending water shortages, water authorities throughout the world tend to estimate future requirements by extrapolating past trends in consumption, adjusted for expected increase in population, agricultural and industrial growth (Gleick 2003). The objective is then to meet the targeting demand at least cost to the authority or utility. Water planning and management relies on the assumption that the future climate will be the same as the historical trends and hence most our water-supply systems are designed with this assumption in mind. Dams are sized using available information on existing flows in rivers and historical rainfall figures. These assumptions must be challenged in the light of climate change science as published by the Intergovernmental Panel on Climate Change (IPCC 2007b) and discussed further in this thesis in Chapter 4.

The most detailed and sophisticated planning methods in use in the urban water sector treat climate as an uncertain, but stationary, process. In other words, climate is assumed to be fixed. But climate does change – it has in the past and it will in the future. Increased climate variability is expected to alter the present hydrological resources in southern Africa and add pressure on the availability of future water resources(Schulze 2005c). Scientific evidence confirms that climate change is already taking place and that most of the warming observed during the past 50 years is due to human activity. According to the IPCC (2007b), global surface temperature is estimated to have increased by 0.74°C over the past 100 years, with the rate of increase double that in the last 50 years. Superimposed on these changes are seasonal, annual and inter-annual variabilities, producing a complex climate variability and change signal.

Many uncertainties remain about the timing, direction and extent of the climatic changes, as well as the implications. The most important effect of climate change for water supply systems is the increase in uncertainty, which greatly complicates rational water resource planning (Gleick 1998a). Climate change studies inherently have to consider the significance of uncertainty. This does not mean that there is no confidence in the understanding of the science, or that the understanding is not certain enough to allow for the development of appropriate

[1] In this thesis, climate variability is defined as the variations in the mean state of the climate on all temporal and spatial scales beyond the individual events of the weather. Climate change is defined as any natural change in climate over time, whether due to natural variability or because of human activity.

adaptation strategies and policies for resource management. Rather, current research would suggest that the political and planning responses are lagging behind the understanding of climate change.

The recent United Kingdom Government report on the economics of climate change, known as the Stern Review, is an important political step in this direction (Stern 2006). It states, inter alia, that:

> "*The scientific evidence is now overwhelming: climate change presents very serious global risks, and it demands an urgent global response*".

The projections of climate change and its associated impacts for Africa and southern Africa indicate that mostly the developing nations will have to deal with climate change impacts in the context of low income levels, relatively high population densities and growth rates, high disease burdens, land degradation and increasing water stress (Vogel 2007).

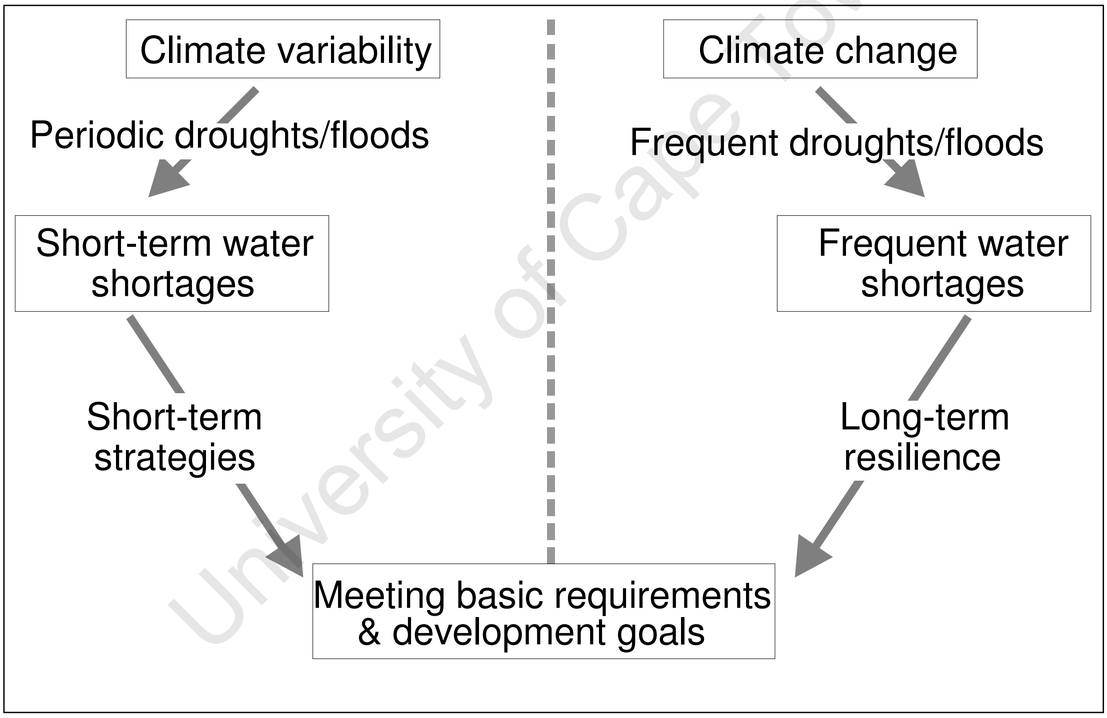

Figure 3: Climate variability, climate change and the water sector (Mukheibir 2007c)

In order to address future climate change impacts, a distinction between the responses to climate variability and climate change should be made. Climate variability affects water resources management inter alia through periodic droughts or floods, resulting in short-term water shortages at local municipal level. In order to address these shortages, short-term strategies are employed to meet basic domestic requirements (see Figure 3). On the other hand, climate change is projected to increase the frequency of droughts or floods which could in turn have the impact of more frequent water shortages. The implementation of long-term strategies is required to reduce the vulnerability to future frequent droughts in order to meet development goals.

Much of the academic and policy focus to date has been on the impact of climate variability and drought, albeit often reactive (Holloway 2005).

Although mitigation efforts are essential to prevent continued global warming in the future and to minimise long-term climate change from occurring, they will have limited effect on greenhouse gas (GHG) concentrations in the atmosphere over the next 30 years and the earth is therefore already committed to certain amount of climate change. Therefore adaptation measures are an essential component of any climate change response strategy to minimise unavoidable adverse effects of climate change (IPCC 2007a). This is especially true for the poor and marginalised people of this world, who lack the necessary information and resources to build resilience to the projected climate impacts (Watkins 2008).

The extent to which a society is able to adapt to these climatic changes will depend on its relative adaptive capacity or resilience. Adaptive capacity is defined by the IPCC (IPCC 2001b: 18) as "the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences". In many places on earth society is already adjusting to climate change, since a gradual change in the climate will induce society to make small inexpensive changes without having to differentiate the source of the climate variability (Callaway 2004).

It is therefore proposed in this study that current adaptation strategies for climate variability in water resource management be tested against the future climate change scenarios to determine their future robustness and impact in terms of sustainable development criteria such as access, cost effectiveness and long-term applicability. Climate change models are however not predictions of the future, but are rather projections of how the future global and local climates may evolve and how these scenarios could affect local water resources. By integrating this information into a methodology, planners and decision makers should be able to adopt water development paths that deal with current water issues as well as potential future impacts.

1.2 The South African context

This study is located in the context of ensuring equitable water access to small towns in South Africa under projected climate change impacts since they present a number of characteristics which are universal to small towns located in semi-arid[2] regions around the world.

By 2001, 56% of the South Africa population was urbanised (SSA 2003). In the past decade a population growth of between 14-17% has taken place in the more urban provinces of Gauteng and the Western Cape, while the predominantly rural provinces of the Eastern Cape, Free State and North West, have only grown by less than 5% (SSA 2007). The growth in the Western Cape

[2] "Arid" regions in this thesis is defined as ecosystems with less than 250mm per annum and "semi-arid" as ecosystems fall between 250mm-500mm per annum

and Gauteng is attributed to migration. According to Atkinson et al. (2006) this has taken place across both large and small urban centres. While small towns have grown in size, due to in-migration, and the South African social grant system which essentially encourages people to stay where they are, the urban economy of the arid and semi-arid areas is still very fragile. Typically, the business sector is small, and there is virtually no industrial base, other than agriculture, to support the inhabitants (Satterthwaite & Tacoli 2003; van der Merwe et al. 2005).

The history of water supply and access in South Africa cannot be separated from the history of the country as whole, viz. apartheid and the legacy of skewed economic development. This history reflects the unequal distribution of resources and it is similar to the delivery of other social services such as electricity and housing. The South African Constitution (RSA 1996) obliges municipalities to ensure that all citizens receive access to services and to redress the historical imbalance of service delivery. The South African Constitution contains guarantees of social economic rights in addition to general municipal developmental duties; the municipality must "give priority to the basic needs of the community and to promote the social and economic development of the community". The Constitution guarantees everyone the right to access to sufficient water. It also states that all three spheres of government, viz. national, provincial and local, must take reasonable legislative and other measures, within the resources available to it, to achieve the realisation of these rights in a progressive manner.

The South African National Water Act (RSA 1998b) ranks amongst the best in the world in its intent and scope (Ashton & Haasbroek 2000). The Act replaced rights to water based on land ownership with administrative authorisation systems. All water is to be managed on a catchment basis through institutions including the Department of Water Affairs and Forestry, Catchment Management Agencies (CMAs) and Water User Associations. The Water Act is based on the philosophy of Integrated Water Resource Management, which emphasises strategies to conserve water, including water demand management (RSA 1998b). Since 1994 a comprehensive programme of water institutional reform has been implemented, which covers the policy, legal and organisational dimensions of water management and allocation. In addition to the Water Act, a new national water resource strategy, as well as policy governing licensing and service provision have been developed (DWAF 2004b; Backeberg 2005; De Coning 2006).

In 2001, 84% of all households in South Africa had access to piped potable water (SSA 2003). A large percentage of those without access to clean water live in the historically disadvantaged rural areas, specifically in the previously demarcated homelands. To address the issue of affordability, the government has committed itself to providing a 25 litres per day free of charge (life-line tariff), implemented by local authorities, amounting to 6 000 litres per household per month, based on eight people per household (Majola 2002). This provision should result in an increase in the use of water and should be considered when projecting future water use requirements.

It has been reported that water demand in the urban areas over the past decade has been growing faster than the population growth rate and faster than the economic growth rate (Gasson 2002). According to DWAF, demand for water between 1996 and 2030 is expected to triple in the urban domestic household sector, double in the mining and industrial sector, and only increase slightly in the agricultural, forestry and environmental sectors. By 2025, DWAF projects that demand will have outstripped natural supply within South Africa's borders (DWAF 2004b).

South Africa is a semi-arid country, with an annual average rainfall of 497mm (just over half of the world average of 860mm) and is therefore rated as one of the twenty most water-deficient countries in the world (Ashton & Haasbroek 2000). In 2004, 11 of the 19 Water Management Areas (WMAs) in the country were facing water deficits (Otieno & Ochieng 2004). In the Northern Cape, for example, many local municipalities resorted to providing water by road tanker water to communities whose groundwater supplies had been reduced due to drought conditions (van Dyk et al. 2005).

Factors that contribute to vulnerability in water systems in southern Africa include seasonal and inter-annual variations in rainfall, which are amplified by high runoff production and evaporation rates. The South African Climate Change Response Strategy (DEAT 2004) states that South Africa's rainfall is already variable in spatial distribution and unpredictable, both within and between years. Much of the country is arid or semi-arid and subjected to periodic droughts. A reduction in the amount, or in the reliability, of rainfall would exacerbate the already serious lack of surface and groundwater. Current climate modelling scenarios suggest that there will be significant climate change impacts in South Africa, even given a business as usual global emissions scenario. Climate change is expected to alter the present hydrological resources in southern Africa and increase the need for adaptation to climate variability of future water resources. It has been projected that by mid-century, annual average river runoff and water availability will decrease by 10-30% over some dry regions at the mid-latitudes and dry tropics (IPCC 2007a).

The South African Country Study on Climate Change found that when using GCM outputs as input to the ACRU[3] hydrological models, runoff was found to be highly sensitive to changes in precipitation. Groundwater recharge was found to be even more sensitive (Kiker 2000). Therefore, changes in the climate system will impact on hydrological systems and water resources. Groundwater in South Africa usually occurs in secondary aquifers and normally in areas where soil cover is shallow. Recharge of the aquifer depends on its type. Some aquifers are more responsive to rainfall and their recharge is closely linked to higher and persistent rains. Others, such as deep aquifers, are slow to respond and require consistent rain over a period of

[3] ACRU – a daily time step physical-conceptual hydrological model developed within the Department of Agricultural Engineering of the University of Natal in Pietermaritzburg, South Africa

time (Visser 2004). Studies by Kirchner et al. (1991) have shown that before any recharge takes place, a rainfall and soil moisture threshold must be overcome. The bulk of the recharge takes place in the years in which the average annual precipitation is exceeded and during periods of high rainfall persistence. It stands to reason, then, that the areas that are dependent on groundwater will be highly vulnerable to decreases in rainfall and/or changes in frequency. In addition, low storage aquifers are the most vulnerable to changes and variability in recharge. This is the situation in 90% of the country (Braune 1996).

To a large extent, the implications of climate change in South Africa have not yet been fully and explicitly considered within current water policy and decision-making frameworks. The financial, human and ecological impacts of climate change are potentially very high, particularly because water resources are already highly stressed in many areas, while the capacity to cope and adapt is not consistently high (Schulze 2005b). Based on the climate projections for South Africa, the most severe drought impacts are likely to occur in the western part, where small towns and subsistence farmers will be most vulnerable (Hewitson et al. 2005).

For these reasons, this study has been located in the South African context and has specifically focused the case study on a small town, Bredasdorp, located in a relatively arid part of the Western Cape where projected reductions in rainfall are likely to occur.

1.3 Research question

In response to the problems identified above, the overarching aim of this thesis is the development of a paradigm where equitable water access under projected climate change impacts is ensured in small municipal water systems which are located in arid and semi-arid regions. The research in this thesis therefore explores three key issues:

1. *To illustrate that the incorporation of climate change impacts on water resources into municipal development planning is possible through an integrated planning framework.* The adoption of such a framework will make it possible for municipalities to identify the additional cost implications and potential barriers for ensuring equitable access to water under projected climate change conditions. The implementation of such a framework will lead to the interaction between scientists and policy makers.

2. *To address the hypothesis that viable water resource management strategies for small towns, that address current climate variability, can in future also provide resilience to climate change induced impacts, if selected against a set of sustainable development criteria.* Climate variability affects water resources inter alia through periodic droughts which result in short-term water shortages at local municipal level. In order to address these shortages, short-term strategies are currently employed to meet basic domestic requirements. On the other hand, climate change is projected to increase the frequency of droughts, which will in turn have the impact of more frequent water shortages. The

implementation of long-term strategies is required to reduce the vulnerability to future frequent droughts. By evaluating and screening the short-term strategies, a suite of long-term strategies can be identified and relevant policies developed to ensure future resilience to current and future climate impacts. By developing a tool for the preparation of water resources adaptation plans this hypothesis is confirmed.

3. *To demonstrate the hypothesis that climate change is also a socio-economic issue and not principally an environmental one*. By using a case study of a small town in South Africa, the economic cost of projected climate impacts on water resource management and on access to basic water supplies is investigated and the hypothesis confirmed. The methodology for achieving this hypothesis will demonstrate the use of available climate projection data in water service planning.

1.4 Scope and methodology

The scope of this study is a focus on municipal (local government) water provision in arid and semi-arid regions (dry zones) in South Africa, which are already experiencing water stress. Since much of the research and planning to date into climate change issues has focused on mitigation of greenhouse gas emissions, this thesis attempts to contribute to improving the understanding of adaptation, specifically in the water sector. The study aims to introduce a framework for integrating climate adaptation into ongoing development planning. It also sets out to develop a methodology for identifying water resource management strategies to adapt to current and future projected climate change impacts. The study will investigate the role that climate impacts play in addressing the issues of access and scarcity in this context, specifically its impact on the economic cost of supplying water.

To date many studies on vulnerability and adaptation to climate change have been conducted in rural areas focusing mainly on the agriculture sector. Very little focus has been made on urban areas and even less on municipal water supplies (Sánchez-Rodríguez et al. 2005; Parnell et al. 2007; Simon 2007a). Therefore this thesis considers a case study in South Africa to investigate what can be done locally in the face of future projected climate impacts.

Access and scarcity have been pursued by different communities who view these issues from differing scientific and political angles, and in some cases not at all. The development and water resource management discourses and approaches as they relate to water scarcity and access are reviewed. This is followed by an analysis of small towns and their approach to ensuring equitable access to water and finally a critique of the climate change community, which is a relatively new player in this field.

The case study (Chapter 7) has been undertaken in the first place to investigate the hypothesis that climate change is largely a socio-economic issue and not solely an environmental one. Climate change directly impacts on sustainable development through physical and financial stresses. In small towns these resources are generally in short supply and a negative impact on either can adversely affect the achievement, and sustained delivery, of services related to the local development goals, specifically the supply of clean safe water.

The methodology outlined in the case study has particular reference to other small towns located in arid and semi-arid regions. Bredasdorp has 13000 residents was selected for the case study since it is representative of many small towns in South Africa. It is also located in a semi-arid region with a mean annual precipitation that is very close to that of the country average, viz. 497mm. The methodology used in this study is not complex and could be implemented by municipal engineers and planners with access to the relevant climate projection information.

This study draws on climate projection information from the Climate Systems Analysis Group[4] (CSAG) and does not interrogate the accuracy of the data or methodologies used at the downscaled projections. Furthermore, rainfall intensity and frequency considerations have not been taken into account when determining the future runoff and recharge, since this involves detailed data collection and fairly technical calculations and was considered beyond the scope of this study. Rather the projections are presented as the median change of a range, since the median is considered as the likely change over the study period.

The purpose in the case study is to demonstrate the application of the information made available to engineers and planners by CSAG as it relates to the water sector. The approach used in this study could also be used in other sectors such as agriculture and health.

1.5 Outline of the study

The thesis is organized into eight chapters, grouped into five major parts. Part One includes this chapter, which provides an introduction and a motivation of the key research questions.

In Part Two, the context and key issues are set out and includes a literature review of the three responses to water access and climate change, specifically at the small town level. A distinction between poor water access and water scarcity is made in Chapter 2. The responses to these two issues including climate change by the sustainable development and water resources management communities, are introduced. In Chapter 3, the effects of scale in small towns and service delivery with regard to financial and human resources as well as how policy interventions have not been designed to accommodate the special case of small town and their role in service delivery are discussed. In Chapter 4, the response of the climate change community to water resource management and adaptation in the urban context is introduced.

The theoretical debate is then grounded in Part Three by Chapters 5 and 6, where a solution to the poor integration across the planning sectors identified in Part 2, is provided. Chapter 5

[4] CSAG – the largest climate change research centre in Africa focusing on climate projection modelling based at the University of Cape Town.

provides an outline of an integrated framework in response to the poor incorporation of projected climate change into municipal planning or water resource management. In Chapter 6, a methodology for use at a small town level is introduced. It identifies viable climate variability strategies which could also provide resilience to future climate impacts.

Part Four is made up of a case study of a small South African town which illustrates the impact of climate change on the local water resources. The reduction in water resources over time results in an increase in the future capital costs as well as the running costs. The case study illustrates the financial costs associated with adaptation to climate change impacts on the availability of water for domestic use and the consequences this has for ensuring access to potable water and the meeting of the Millennium Development Goals. The results are discussed in Chapter 7.

Part Five (Chapter 8) provides a summary of the thesis and emphasizes the key findings. It reiterates the conceptual importance of incorporating long-term value based water management that takes account of climate change while giving prominence to the issues of access and affordability.

PART TWO
WATER, SMALL TOWNS AND CLIMATE CHANGE

Droughts take us by surprise, but they're a regular part of our climate- Arizona water manager

CHAPTER 2

2. Water: scarcity and access

While water related issues have been on the international agenda for a long time, the debate on how to meet the growing global, and more specifically urban, demand, for freshwater has intensified in recent years. Freshwater is a finite resource and equitable access to it is vital for sustainable development, economic growth, political and social stability, health and poverty eradication. The issues surrounding the scarcity of freshwater have recently been further publicised by the potential impacts of climate change on water resources (IPCC 2007a). This will be discussed in Chapter 4.

Scarcity of water is widely perceived as the key feature undermining water security. However, the notion of scarcity is both a skewed and limited view of water security. It is skewed in the sense that what mostly pass as water scarcity, are policy induced consequences of mismanagement, while it is limited because physical availability is only one dimension of *water security* (Watkins 2006). *Access* to water and water services are also key aspects of water security. The issue of access to water is not always determined by scarcity, although this is often cited as the reason, because poor access to water could also be due to political or economic policies. People who do not have access to water are mostly the marginalised – geographically, economically, institutionally and socially.

Access to safe water for all people is a development goal for the South African government as well as a UN Millennium Development Goal (ANC 1994; UN 2006). Access to water is key to a successful development strategy, since, access to clean water is one of the most significant resources for reducing poverty and disease, and improving the life of the poor through rural development and for increasing food security (Reid & Vogel 2006). One of the major concerns in achieving this goal has been the slow delivery of water access to poor and remotely located people. This issue has often been confused with the notion of water scarcity. Whilst access to safe water as defined by the WHO[5] is generally accepted and measurable, the concept of water scarcity has been debated for some time and is relatively complex to determine since it could be viewed as a supply problem (physical) or a demand problem (social) or combination of both

[5] Access to water – the receipt of 25-30 litres of safe water per person per day to meet basic human requirements (WHO 1995)

(Rijsberman 2004). There is a growing consensus by some commentators, however, that the world is rapidly heading towards a physical shortage of freshwater which is likely to become a source of strategic rivalry, regionally, nationally and even locally (Postel 1996; Turton & Ohlsson 1999; Gleick 2003; Niasse 2005).

A number of discourses have evolved around resource scarcity and access to basic services, specifically water. In order to understand these debates and approaches, this chapter is structured into two main parts. The first explores the concepts of poor water access and scarcity. It explores the differences and the underlying causes of these two conditions. It unpacks the theory from the available literature on adaptive capacity of societies under these stresses in order to better understand coping mechanisms in times of climate variability and change.

The second section is an analysis of the two key responses which shape the approaches to water access and scarcity. A more resource based approach of water resources management is compared with that which is driven by a sustainable development and political agenda.

2.1 Water access, scarcity and adaptive capacity

Historically, in order to meet human water demands, society has for the most part followed a technological path in the form of the construction of large dams, long pipelines and complex centralised treatment plants. Whilst these facilities brought social and economic benefits to billions of people in the form of reduced incidences of water related illnesses, hydro-electric power and irrigated agriculture, they also had related costs such as increased debt, environmental degradation of rivers and fishing resources, millions of displaced people and inequitable sharing of costs and benefits (WCD 2000; Gleick 2003). Despite these endeavours, the most unresolved water problem globally is still the failure to provide people with *access* to a safe supply of water to meet basic human requirements, viz. an average consumption of 50 litres per person per day as suggested by the World Health Organisation (WHO 1995). Gleick (1996) explains that this volume is derived from the following allocation shown in Table 1. The WHO (1997) stresses that as a bare minimum, between 25-50 litres per person per day be accessible.

Table 1: Minimum water requirements (Gleick 1996)

Minimum Requirements	Volume (l/p/d)
Drinking	5
Sanitation	20
Bathing	15
Food preparation	10
Total	50

Currently about 1.2 billion people world wide, mostly in developing countries, still do not have access to safe drinking water. By 2025 it is estimated that due to the growing stress on water resources by population growth, unsustainable consumption patterns and uncontrolled usage, between 2.7 and 3.5 billion people globally (one third of the projected world population) will not have access to water (WHO 2000; WEHAB 2002; IISD 2006). In Africa, 36% of the population in 2000 did not have access to safe water. As can be seen from Table 2, Africa still lags substantially behind the other developing continents of Asia and Latin America in terms of basic access (UN 2006).

Table 2: Access to drinking water in developing countries in 1990 and 2000 (UN 2006)

	Year	Drinking Water		
		With Access %	Without Access %	Household Connection %
Africa	1990	59	41	17
	2000	64	36	24
Asia	1990	73	27	43
	2000	81	19	49
Latin America	1990	82	18	60
	2000	87	13	66
Total	1990	72	28	41
	2000	79	21	47

The adoption of the Millennium Development Goals (MDGs) in 2000 was a step towards addressing the imbalance in access to basic services. They include, amongst others, a specific water related goal aimed at reducing the proportion of people without adequate access to affordable water by half by 2015 (UN 2000). According to the 2006 Millennium Development Goals Report (UN 2006), some inroads have been made in the developing world with the share of people with access to safe water increasing to 79% in 2004, from 72% in 1990. In South Africa over the ten years from 1994 to 2004 this increased from 60% to 79% with a 2015 target of 80% (SARPN 2005).[6] [7]

As can be seen from Table 3, urban access to improved water access is higher than for rural areas, even though the improvement in rural areas has been greater. In 2004 the rural access to water in South Africa was still only 64%, with urban access at 88%, slightly better than the rest of Africa, where about 50% of those living in rural areas had access versus 86% in urban areas (Chenje & Johnson 1996; Otieno & Ochieng 2004; SARPN 2005). In addition, the removal of

[6] In South Africa, basic service levels for water are defined as a minimum quantity of 25 litres of potable water per person per day within 200 metres of a household not interrupted for more than 7 days in any year and a minimum flow of 10 litres per minute for communal water points. This is a substantially higher standard than the basic services defined by the Millennium Development Goals as 20 litres of potable water per person per day within 1 000 metres of a household (SARPN 2005)

[7] The figures are lower than the official South African census data which states that access to piped clean water in 2001 was 84% (SSA 2003). DWAF has also projected that the remainder will all have access to water infrastructure by 2008.

apartheid in South Africa led to large socio-economic differences between suburbs and townships being exposed. The process of unifying these areas in cities and towns required that planning take these differences into account. The legacy of apartheid has specific issues which play out in an urban setting – inequity of water access and service provision, racial mistrust and political tensions (UN-HABITAT 2006c). Further, access to improved water sources often changes with time. In East Africa, for example, systems for piped clean water in cities have degraded over the past 30 years due mostly to inadequate maintenance and urban population growth. This has left more households without reliable access to safe water than in the past and thereby decreasing their consumption of water.

Table 3: Summary of indicators of access to safe drinking water in South Africa (SARPN 2005)

Indicators	1994	2004	2015 target	Progress towards target
Proportion of ***total*** population with access to an improved water source (%)	60.1	78.7	80.1	Good
Proportion of ***rural*** population with access to an improved water source (%)	44.4	63.6	72.2	Good
Proportion of ***urban*** population with access to an improved water source (%)	70.3	87.7	85.2	Achieved

Wide disparities between countries, rural and urban areas and within cities still persist. In South Africa urban demand accounts for less than 25% (including water demanded by commercial and light industry) as compared with agriculture which consumes almost two thirds (see Figure 4) (DWAF 2004b). The later compares favourably with the average agricultural water consumption for developing countries being more than 80% of total consumption (Watkins 2006).

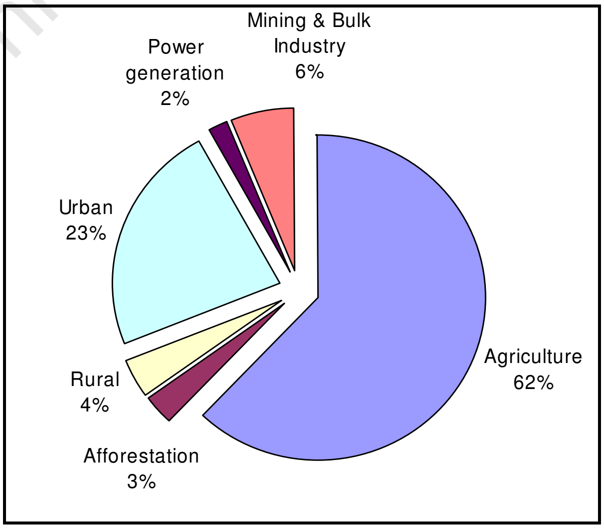

Figure 4: Water demand in South Africa, per sector, in 2000 (DWAF 2004b)

Jaglin (2004) suggests that equitable levels of water provision will be prohibitive due to affordability and natural resource constraints, unless there is a theoretic shift in thinking. Natural resource constraints on urban consumption mean that we can not all consume water at the levels currently associated with the urban rich. If we are to achieve equity at an urban scale, it is not only necessary, argues Parnell (2007), to raise the living standards of the poor, but also to reduce the consumption patterns of the wealthy. High income areas in developing countries enjoy high levels of water delivery, whist those living in slums would be regarded as fortunate to receive a basic minimum. This also applies to water for livelihoods, where, for example, wealthy farmers in India pump groundwater in large volumes for irrigation, while neighbouring small holders depend largely on rainfall. These water systems are generally not geared to keep pace with growing populations, nor are the current systems well designed, financed or maintained (WEHAB 2002; UN-HABITAT 2006b; UN 2006; Watkins 2006).

It was not until 2002 that the United Nations Committee on Economic and Social and Cultural Rights declared that the foundation for water security was sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use (CESCR 2002). It is implicit that institutional structures and capacity are in place as well as financial mechanisms to ensure that this security is guaranteed and affordable and, where necessary, basic levels of service are subsidised. South Africa was the first country to give explicit recognition to both human and environmental rights to water under the 1996 Constitution and 1998 National Water Act which places a duty on the government to ensure the fulfilment of this right (RSA 1998b). To address the issue of affordability, the South African Government committed itself to providing a life-line tariff, implemented by local authorities, amounting to about 6 000 litres of water per household per month free. Whilst the Constitution provides that the State must take reasonable legislative and other measures within its available resources, to achieve the progressive realisation of the right to sufficient water, many citizens still have not been provided with this basic daily supply due to various difficulties in implementing this policy (Stein & Niklaas 2002). These include institutional and financial capacity issues and are discussed further in Chapter 3.

Parnell (2007) suggests that since the demand for affordable basic urban services will dominate international and local urban policy debates, it is important that increased prominence be given to identifying mechanisms that allow developing countries to deliver on the demand for the right to water. This leads to the question of whether *access to water* is a human right or a human need. It involves a discussion on the meaning of “rights” at an urban scale and within the context of limited resources and capacity at the local government level. It also requires a shift in focus from institutions of delivery to the recipients of services and to issues of access and equity.

The issue of the “right to water” bears directly on the water privatisation debate, since the view that human rights are violated by privatisation is often based on the assumption that privatisation of water services is accompanied with profit making, and that this may interfere with the task of providing access to water to the poor as well as the wealthy. In some cases privatization programmes have delivered water on an equitable basis, while the vast majority have not. In most cases the promise of reduced water tariffs does not materialise and in fact the opposite occurs (Loftus & McDonald 2001). Water sector privatisation has the characteristics of a monopoly and in many cases where there is a large poor population, government subsidies are still required, whether the provider is public or private. The debate on privatisation often diverts attention from public utility reform. Public utility providers account for more than 90% of water delivered in developing countries, often failing to meet the needs of the poor through a combination of inefficiency and unaccountability (Watkins 2006).

There is general consensus that public utilities have been too slow in extending access to services and that they can be inefficient and corrupt. It is no surprise, therefore, that during the 1990s, private participation was vigorously promoted on the water policy agenda for developing countries as a means of achieving greater efficiency and expansion in the water sector. These efforts were mainly focused in countries with large economies and populations with relatively high levels of urbanisation. It is also interesting to note that the promotion of privatisation is not grounded in the experience of the water sector itself, but derives from other infrastructure sectors, such as energy, where the levels of investment were far greater (Watkins 2006).

It is not surprising, therefore, that according to Budds and McGranahan (2003) (who have put the supply of global water by privately owned utilities at only 5%), the rate of privatisation has been slowing due to a combination of underestimation of risks and an overestimation of profits. The debate surrounding privatisation has attracted much attention, but has clouded the fact that the majority of the population in developing countries continues to be served by the public sector or small-scale and informal providers. Budds and McGranahan argue that many of the barriers to service provision in poor settlements can persist whether water utilities are privately or publicly owned, since neither public or privately owned utilities are well suited to serving the majority of low-income households, including rural households, with adequate safe water. Furthermore, many public service providers have already learnt to act like private sectors providers, by using stringent cost recovery measures, and therefore there is little incentive for a multinational company to take over the running of the water services (Loftus 2004). Barriers to provision such as land tenure still impede service provision in informal settlements. In addressing pro-poor policies, measures such as low-cost technology, flexible payments and local participation have been proposed by both public and private utilities, but have failed to address the lack of access to basic water services due to the economics and politics of the service provision (Bakker 2003b; Budds & McGranahan 2003).

Pricing and water markets can also result in reducing access to water by marginalised communities. This too creates a water scarcity and associated social stresses, usually for the poor. A real tension exists in large urban towns that have engaged with some form of privatisation of the water supply, in that they have to grapple with seeking to achieve greater efficiencies in the system, whilst also trying to meet their social obligations, particularly in marginalised areas (Smith 2004). Bakker argues that there are few examples of private sector participation contracts which have countered the spatial differentiation of water supply access in urban areas in the South. In contrast to the North, where urban areas are more spatially homogenous and well networked for service delivery, the South still has huge disparities in service delivery (Bakker 2003a). This lack of access translates to an induced social water scarcity.

These issues are illustrated in the analysis of South Africa privatisation cases presented by Smith and Ruiters (2006), where public-private partnerships have not always lived up to expectation. Privatisation is more than just a transfer of functions or assets, it is a configuration and change in the service itself. Whilst touted as one of the key drivers, cost recovery has not improved under the regime change, and in fact more people have had their water supplies cut off due to bad debts. Many of the poor beneficiaries therefore opt out of the system and return to unsafe sources. Despite the contested argument that privatisation is financially more efficient, it has proven socially inefficient in South Africa based on the assertion that the development goal is universal access to clean safe water (Smith & Ruiters 2006).

Swyngedouw (2004) further warns that the notion of "water scarcity" has in some circumstances, due to environmental awareness and the risk of diminishing resources, allowed water utilities to invoke price increases as a demand management measure, rather than invest in further capital infrastructure. A market economy requires "scarcity" to work, and therefore as price is seen as the prime mechanism to manage scarcity, the creation of water as a scarce resource becomes an important strategy towards commoditisation and privatisation (Swyngedouw 2004).

However, the notion of *scarcity* is introduced too conveniently to explain why global and local access to water is not universally equitable. While the availability of water is indeed a concern in some countries, the scarcity referred to globally is rooted in power, poverty and inequality and not always in the physical availability. Scarcity is driven by a combination of three principal forces, viz. depletion and degradation of the resource, population growth and unequal distribution or access. However, the underlying cause of scarcity is largely institutional and political. In some countries the scarcity experienced is due to public policies that have resulted in overuse of water through subsidies and under-pricing of water. Mexico City, for example, relies on the Mexico Valley aquifer for most of its water supply, but the aquifer has been so depleted that the city is sinking due to shifting land (Postel 1996; UN-HABITAT 2006b; Watkins 2006).

In understanding the concept of water *scarcity* in a global and regional context, it is useful to be able to measure it, just as access can be measured by the number of people with direct access to the levels of water supply as defined by the WHO. Hydrologists typically assess scarcity by looking at the population-water equation. According to the *Falkenmark Water Stress Index*[8], when a country falls below 1000 m^3 per person per year it experiences water stress and below 500 m^3, absolute scarcity (Falkenmark et al. 1989). International experience has shown that countries with renewable freshwater resources below 1000 m^3 per capita per year are prone to experience severe water scarcity that will impede development and be harmful to human health (WRI 1996). About 700 million people in 43 countries live below this level (Watkins 2006). South Africa, for example, is expected to dip below the 1000 m^3 benchmark by 2010 based on national population growth and water resource projections (DEAT 1999). Based on this indicator, it is obvious that as populations increase, so the index will decrease given that the available water is relatively finite. This index unfortunately does not indicate the localised water scarcity nor account for seasonality or social and political choices in allocation (Rijsberman 2004). Currently, for example, 538 million people in northern China already live in a water stressed region. Globally some 1.4 billion people live in areas where water abstraction exceeds supply. This is likely to increase as water stress intensifies in China, India and Sub-Saharan Africa (Watkins 2006).

The Falkenmark approach also suggests that with the increase in population and the demands on the world's water expanding, the future points to an arithmetic shortage. Africa has a relatively low urban population in comparison to the rest of the world. However this is set to change, since the annual urbanisation in Africa has been estimated to be 3.5% between 2000-2015 (UNCHS 2001). Based on this growth rate, the African region is likely to be confronted by various urban challenges, a key one being urban water management. The concentration of people in urban areas makes them vulnerable to two effects of climate change, viz. the increase in extreme weather events such as flooding, droughts and heat waves, as well as the gradual stress on environmental resources, e.g. water, through changes in weather patterns. The urban poor suffer the most from extreme weather events since they tend to occupy marginal land and do not have the financial and social resilience to reduce their vulnerability (Ashton & Haasbroek 2000).

However, urbanisation is not the main driver for water scarcity. The volume of water withdrawal has increased seven fold from 1900 to 2000 and population growth only four fold

[8] The *Falkenmark Water Stress Index* is based on the relationship between water availability and human population and is expressed as m^3 per person per year. 1700 m^3 of freshwater per person per year has been proposed as the threshold to sustain household, agricultural, industrial, energy sector and environmental freshwater demands. (Folke et al. 2002).

for the same period (Watkins 2006). Global water use has increased fourfold in the past 60 years due to urbanisation and industrialisation (Gleick 1998b). This translates to the doubling of per capita use of water globally, which is not equally distributed to all people around the world. The wealthy use much more water individually and collectively than they did 100 years ago (Watkins 2006). Alcamo et al. (2007) considered future global stress by assessing the impact of climate change, population growth, income distribution, electricity production and water use-efficiency. The modelled scenarios projected that water stress would increase in 62%-75% of river basins.

In the past, governments responded to water scarcity by developing supply strategies. Large scale river diversions, as in the case of China and India, highlight the appeal of this option. For wealthier countries desalination and "virtual water[9]" imports are options. However, when *supply side* strategies fail to meet the demand needs, a second phase of water management, namely *demand side management*, comes into play. Hence a series of changes is needed within a social entity to meet the challenge of increased water scarcity (Turton 1999b). Figure 5 illustrates this point. Demand, driven by population growth and social upliftment, is initially met by supply side management, even as the supply of water moves into one of water scarcity. This then progresses to a period of *water deficit,* which is characterised by social stress due to second order scarcity, as discussed above.

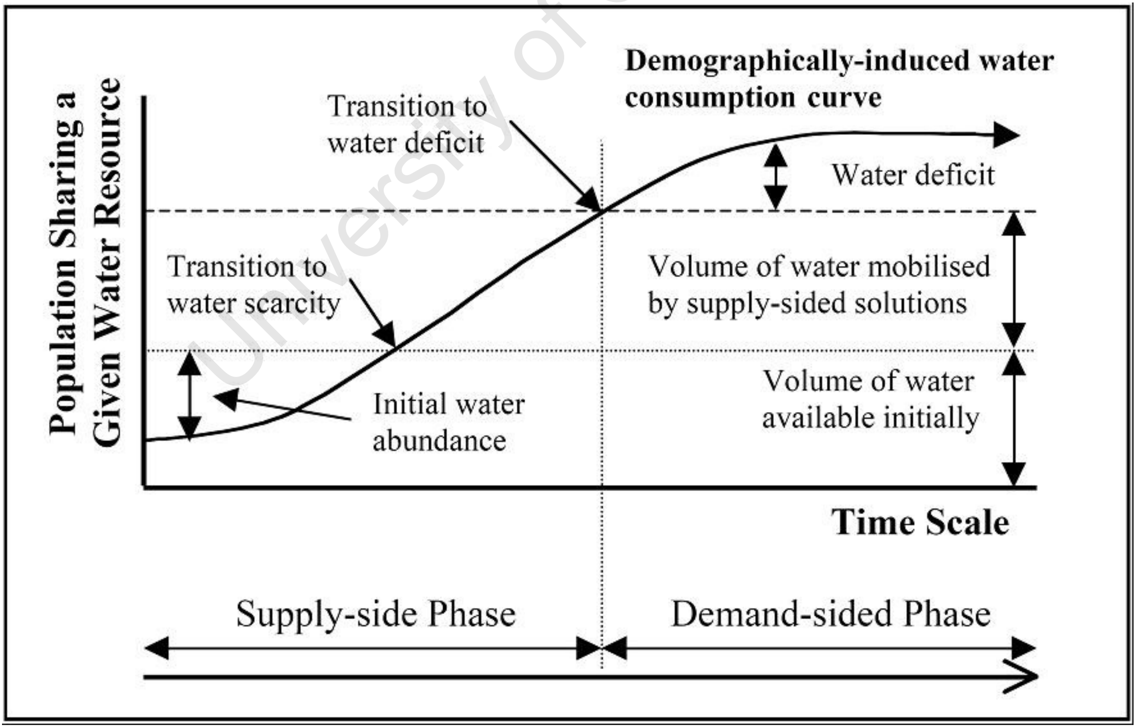

Figure 5: Transition from a supply side to a demand side phase of water management (Turton 1999b).

[9] Virtual water – importation of food from well watered regions to offset the water shortage in the local country.

Water scarcity can therefore be defined as a quantitative concept, requiring quantitative supply-side solutions, whereas w*ater deficit* on the other hand, is a qualitative concept and requires social responses. This requires society to develop coping strategies to overcome the water deficit. Initially supply side solutions are favoured since they are perceived to be politically easier to apply. The deficit crisis therefore opens an opportunity for decision makers to change the current discourse and introduce water demand management. The timing of this is important, since demand side management options are often viewed as publicly unpopular and linked to political vulnerability (Turton 1999b).

Postel (1996) puts forward a more holistic view by addressing water scarcity through the establishment of priorities and policies for allocating water among competing uses. While supply side options cannot be ignored, more efficient and productive use of water should be encouraged and institutions should be better shaped to manage the projected era of water constraints. Investments in conservation, recycling and increased efficiency are more economical than establishing new sources of water such as the construction of new dams or desalination plants (WCD 2000). However, large subsidies to agriculture and other water users discourage efficiency measures. There are many sound social reasons why farmers should receive subsidised irrigation, especially poor farmers. However, they should at least be charged for the operation and maintenance costs of supplying the water in order to send a positive signal about water efficiency. In South Africa, and globally, agriculture accounts for two thirds of the water consumption (see Figure 4 for South African figures), so even a small percentage saving could free up substantial quantities of water for urban areas and the ecosystem (Postel 1996; DWAF 2004b).

Dealing with water scarcity and access requires a shift in thinking that recognises that the subject has moved from simple supply reliability and demand reduction to more complex issues of variable water quantity and quality. This shift requires social, cultural and economic adaptation. The level to which a society can adjust to uncertain or undefined change has been termed its "*adaptive capacity*" (Adger & Vincent 2005; Jeffrey & Gearey 2006; Smit & Wandel 2006). Societies with a high adaptive capacity will be able to respond with fewer social, financial and environmental costs and vice versa. Generally the poorer communities and nations will be harder hit by climate change impacts, not necessarily because of the direct impacts per se, but rather because they are less likely to be able to respond and adapt to those impacts.

Smit and Pilifosova (2001) have developed a generic tool which assists in understanding this concept of adaptive capacity. By evaluating these key assets, the level of capacity of the community, local government, sector etc can be assessed (after Smit & Pilifosova 2001):

- Economic resources - Low economic resources decrease adaptive capacity
- Technology - Lack of technological capacity limits potential adaptation options

- Information and skills - Low information access decreases the likelihood of timely and appropriate adaptation
- Infrastructure - Limited infrastructure inhibits adaptation since it limits the available options
- Institutions and networks - Poorly developed institutions inhibit adaptive capacity
- Equity - Inequitable distribution of resources reduces adaptive capacity

However, Adger and Vincent (2005) warn that in conjunction with different temporal and geographical scales, there are relevant uncertainties attached to determining *adaptive capacity,* such as the reliability of the qualitative data, the clarity of the processes of adaptation and vulnerability and the contestability of the theories of social and economic change. They also warn that adaptive capacity only highlights the available resources available for adaptation and not the processes for decision making.

Therefore the idea of *adaptive capacity* is limited to helping to understand that resource demand management only becomes an option once societies have developed their political economies to a point where these alternatives can be considered. The rising level of resource scarcity is met through the higher level of adaptive capacity in the form of high levels of financial, human and institutional capital. The opposite would then also be true, that some societies are not able to cope with the stress since they have exhausted their internal adaptive capacity to implement the demand management policies. The trend can be altered by means of external interventions such as foreign aid. However, this is rarely sustainable in the long run (Turton 1999b).

The interrelationship of *water scarcity* and the *adaptive capacity* of a society, which could also be viewed as a resource, was first developed by Ohlsson in the 1990s (in Turton 1999b). Whilst low development could be attributed to scarce resources ("first order scarcity"), this would be compounded by the low level of adaptive capacity within a society, i.e. "*second order scarcity*". By shifting the focus onto *second order scarcity* instead of the resource scarcity, an understanding can be achieved of why and how certain societies cope with resource scarcity better than others do (Turton 1999b).

By linking the concepts of water scarcity and adaptive capacity, two possible end conditions can be generated viz. "*water poverty*" and " *structurally-induced water abundance*" (See Figure 6). *Water poverty* is the end condition that is the likely result of significant environmental degradation together with low social adaptive capacity, which results in reduced access to water by marginalised groups. The prevailing conditions of water scarcity result in the cost of water supply rising, and this in turn increases the unit selling, price as will be illustrated in the case study in Chapter 7. The ability of the society to absorb these additional costs, whilst still ensuring access to basic services for the poor, will depend on the level of its adaptive capacity.

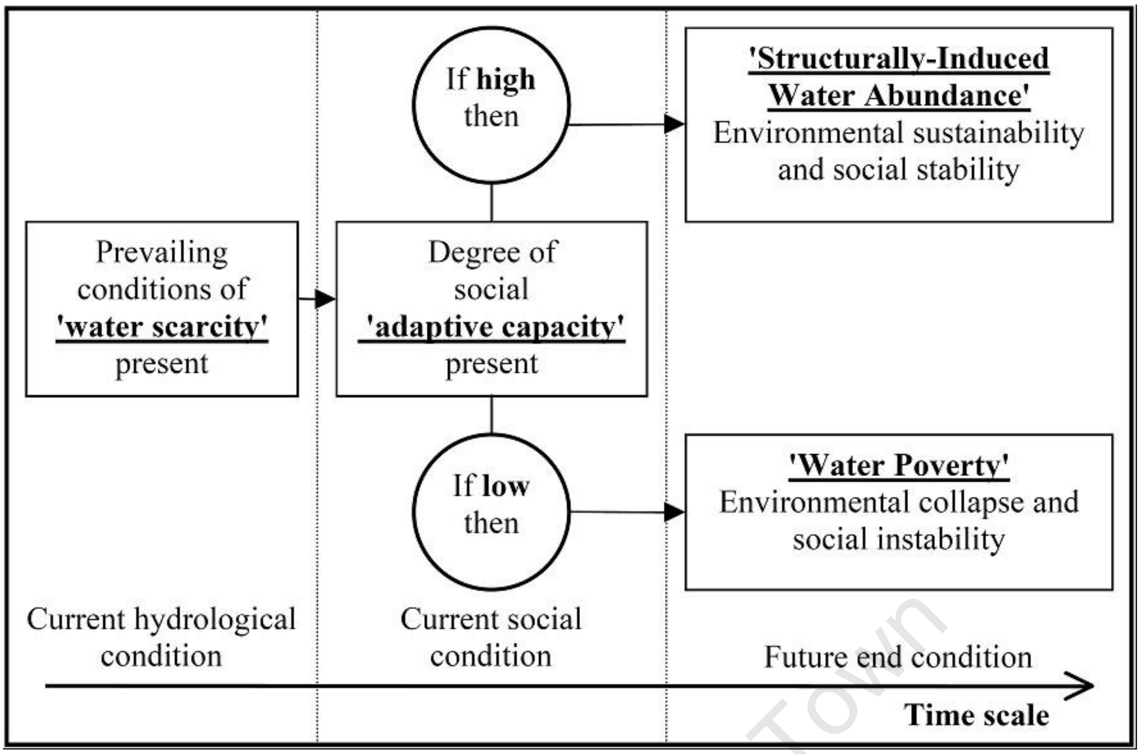

Figure 6: Schematic representation of linkages between water scarcity, adaptive capacity and possible consequences (Turton 1999a)

On the other hand, *structurally-induced water abundance* would be due to economic and environmental stability together with a high social adaptive capacity. Thus the key variable in this theoretical conceptualisation is social *adaptive capacity* or *resilience.* Resilience is defined as the capacity to buffer change and thereby, through learning, develop to be more resilient to even larger impacts (GWP 2000). Institutional dimensions and governance, together with social capital are key elements for the enhancement of resilience and overall adaptive capacity to climate risks. For example, Israel has experienced water scarcity, but owing to its high social adaptive capacity, it is able to avert the debilitating conditions of water poverty. Whilst in Namibia, the country has high levels of water scarcity as well as a low level of adaptive capacity, which in turn causes the country to experience social stresses due to constant water shortages (Turton 1999a; Reid & Vogel 2006).

The dilemma of providing all citizens with access to water whilst facing a projected supply shortage is one which most developing countries in arid and semi-arid regions face and is clearly highlighted in the South African example. Prior to 1994 the government had a very low level of political legitimacy and provided water resources to only a small portion of the country, but also installed large supply schemes. After 1994, the first democratically elected government introduced the Reconstruction and Development Programme (RDP) which sought to right the previous wrongs through distributing the water resources more equitably (ANC 1994). However, they are confronted with the predicament of trying to provide all people with access to water, whilst facing a projected water shortage. In order to address this, a series of water related development policies need to be developed that are specifically aimed at averting “water poverty" and encouraging "structural-induced water abundance". It is reported that although South Africa may be considered to have relatively high levels of technological resources, it still lacks the necessary capacity and social resources to provide equitable access to water. Access to water in South Africa is interlinked with the complex ongoing process of providing capacity at local government level and it will therefore struggle to avoid the debilitating effects of "*water poverty*" at a local level (Hemson 1999; Turton 1999a; Bakker & Hemson 2000; Swilling 2006; Parnell et al. 2007).

Having explored the obstacles to universal access to water and the relationship between adaptive capacity and scarcity, the relevant conceptual responses to ensuring access the basic water services and overcoming water scarcity are discussed in the following section. The well-established approaches of sustainable development and water resources management are discussed and compared. The more recent introduction of the climate change response is presented in Chapter 4.

2.2 Conceptual responses to access and scarcity in the water sector

The approach to water provision has developed over time and has been determined largely by economic development. Allan suggests that five paradigms of water resource development have evolved (Allan 2001) viz.:

- *Pre-modern* communities with limited technical or organisational capacity; and
- *Industrial modernity* which was manifested as the hydraulic mission of the mid-twentieth century;

then being followed in the North by three reflexive responses, viz.

- *Environmental awareness* through the allocation of water to the environment;
- The concept of the *Economic value of water* and the notion that water was a scarce resource; and
- *Integrated water resource management* (IWRM) which is slowly gaining acceptance with the realisation that water management is also an intensely political process. This approach is discussed in the following section.

Currently most developing countries are engaged in an industrialising mode which involves the control of water resources for agricultural output and to generate power. Politically feasible circumstances do not yet exist in many regions for the inclusion of environmental and economic priorities into water policy (Allan 2001).

South Africa is an interesting case in this regard, while in many ways it is still a developing country with relatively low levels of water access when compared with the developed world, it has many, and in some cases better, water regulations and water laws (Ashton & Haasbroek 2000). The South African Water Act (RSA 1998b) makes explicit provision for a water allocation for the environment and has attached an economic value to water resources. IWRM has also been acknowledged as the framework in which water resources are to be managed (DWAF 2004b). However, the linkage between resource management and ensuring universal access to water is not always made, since these two concepts are mostly pursued by different political and scientific communities.

Three distinct sectoral communities have evolved, with they own characteristic responses to the issues of water as a key development goal, viz.:

- *Sustainable development;*
- *Water resources management; and*
- *Climate change adaptation*

Whilst they all actively champion water as key to national and local development, their policy agendas differ and they often operate in parallel, with little or no intersection or interaction. The development sector has preoccupied itself with the concept of universal access to water and embarked on local level projects and programmes to achieve this aim. Little or no attention has been paid to the issue of water scarcity. This field has been left to the water resource management sector, who have for the most part addressed this problem historically by concentrating on large infrastructure supply schemes and more recently with the introduction of demand side management strategies. Since the late 1990s the issue of water scarcity has been publicised by the projections of climate change impacts such as enhanced drought and flooding, which cause water shortages and contaminated water respectively. The climate change response concerns itself with the consequences of long-term climate induced impacts on water scarcity and, together with water resource management, has not generally focused on access to or affordability of clean water. The related institutional issues are also absent from these approaches. It is also worth noting that these discourses play themselves out in the South African policy agendas, with little acknowledgement of how they complement or conflict with each other. The first two responses are discussed further in this section, and the climate change response is addressed in Chapter 4.

Sustainable Development

The concept of "*sustainable development*" has been accepted world wide, following the 1992 Earth Summit in Rio de Janeiro and the adoption of the United Nation's Agenda 21. However, how to achieve this has been the focus of much debate ever since. The three key factors of sustainable development are defined as social, environment and economic. The economic sector is driven by the consumption of goods and services in order to improve human welfare and is driven by factors such as growth, efficiency and stability. The development and transfer of technology is further influenced by the economic level of a society. The environmental sector focuses on the protection of the integrity and resilience of the ecosystem and is affected by pollution and natural resource depletion, and finally the social sector is geared mainly towards the enrichment of human relationships through empowerment and good governance (WCED 1987; Munasinghe 2001).

If we use this concept to understand the water sector more fully, we can see that for a water system to be sustainable and to meet the objectives of sustainable development, it should address all three components, all of which have both drivers as well as impacts/barriers. In the social context the key driver would be the equitable distribution of water, whilst the barrier would be local institutional management, technical capacity and the level of social capital available to withstand impacts such as water shortages. Preservation of the ecological reserve would be an environmental driver and impacts due to climate variability, flooding or droughts and pollution would be threats. Economically viable water provision with appropriate pricing structures would drive the system towards a sustainable path, but the poverty levels and low levels of capital would undermine these efforts.

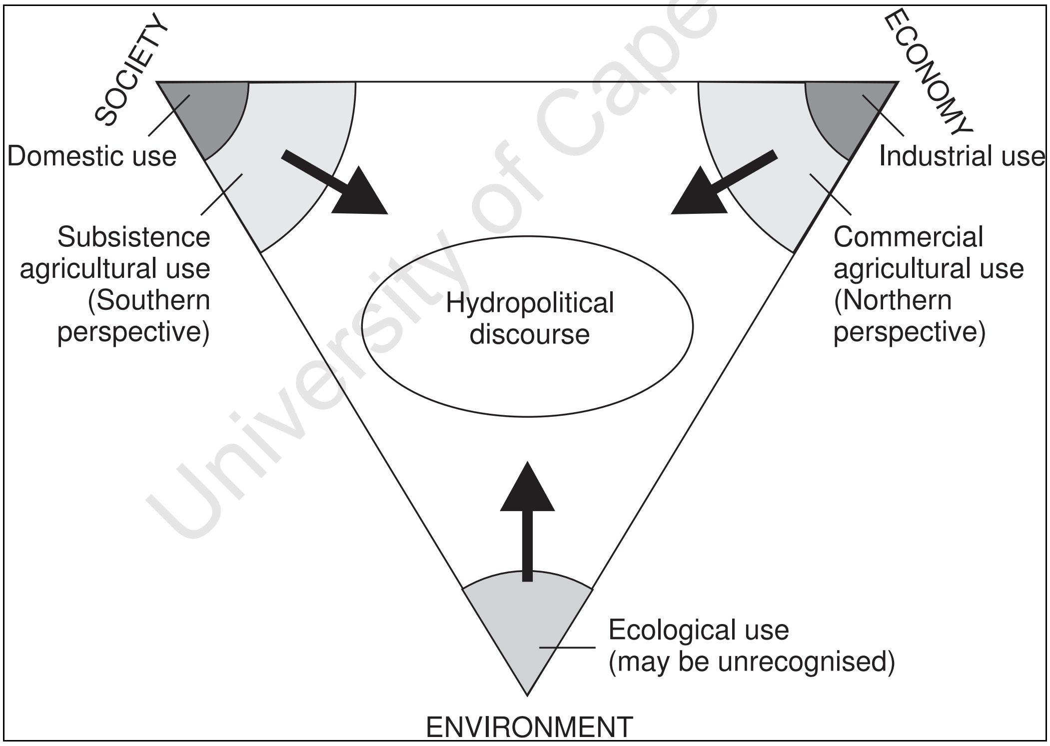

Figure 7: The concept of sustainability and the water sector (Allan 2001)

The hydropolitical discourse at various levels of government is one where priorities associated with these three dimensions play a role in determining the uses and policy outcomes in a particular society. Figure 7 provides an illustration of the developmental priorities of the three sectors. The water needs of society are focused around domestic use and subsistence agriculture in the developing world. Economic demands require water for industrial and commercial agriculture, whilst water for the ecological reserve is often recognised or sacrificed to meet the other two needs. For water resources to be managed in a sustainable manner, water management policies have to prioritise interventions and resource allocation so that society, the economy, as well as the environment are sustainable. Political processes at national and local levels determine whether this balance is achieved or not (Allan 2001). If the balance is not achieved, water shortages and stresses will be experienced.

The sustainable development agenda is driven mainly by political forces with the focus on delivery and not necessarily on ongoing operation and maintenance of supply schemes. This is exacerbated by the lack of financial and institutional capacity at local level to manage the water resources and supply (Rural Support Services et al. 1997; Smith 2000; Mosdell & Leatt 2005). For example, in order to meets its social obligations, the South African basic minimum human water need is 25 l/p/d at a walking distance of less than 200m, as specified in the RDP (DWAF 1994). This limitation is not set so much by the availability of water, but rather by the capital and operational costs to set up and run water schemes in rural areas. In urban areas, this limitation is overcome by the ability to cross-subsidise the "losses" by the higher tariffs that can be levied against higher income earners and by the introduction of "life-line" tariffs, which permit payments which the poor can afford for basic levels of service (Postel 1996). However, in smaller rural towns with low economic bases, systems tend to break down when maintenance funding cannot be found within local government budgets (Braden & Mankin 2004).

The impending crises of poor *access* to safe water and the related spread of waterborne diseases, led in part to the United Nations General Assembly at the turn of the century to adopt the Millennium Development Goals (MDGs). As stated previously, these include amongst others, a specific water related goal aimed at reducing the proportion of people without adequate access to affordable water by half by 2015 (UN 2000). The MDGs were proposed and driven by the development community and developing countries, primarily seeking financial assistance to address the lack of water provision in their countries through programmes aimed at building technical and institutional capacity as well as physical infrastructure. However, the focus of the MDGs is on actual numbers of people with access to water and fails to address the mechanisms to achieve these goals or how to sustain them in future. We have seen in South Africa how, through the Community Water Supply Services Programme, the focus was on the improvement of water access to all people, but little or no emphasis was placed on ensuring the sustainable operation and maintenance of these schemes. This resulted in many schemes breaking down after a short while due to a combination of technical, financial and institution problems (Rural Support Services et al. 1997).

The sustainable development approach usually focuses on local resources and impacts in relation to the provision of basic services and livelihoods. Coping strategies are developed to deal with short-term water shortages. Scarcity is viewed as one of many barriers to service delivery and no special attention is given to it. It has for the most part been argued by this sector, that scarcity is human induced and that distribution is the problem that retards the access as was discussed in the previous section (Figure 6 has specific reference).

Climate impacts on sustainable development policies have been limited to those induced by climate variability such as flooding and periodic droughts that result in localised water shortages and are dealt with through disaster management interventions. Longer term impact due to climate change, such as the gradual change in rainfall patterns, do not as yet fit into the planning horizons which are usually politically and financially constrained.

Coping strategies are seen as short-term interventions that are undertaken to manage these short-term stresses. It is often difficult to determine a specific factor since people react to a range of stresses and factors at any given time and hence it is difficult to identify the part of the strategy that reacts directly to the climate impact (Ziervogel et al. 2005). It would seem logical therefore that climate impacts be intrinsically bound in the sustainable development approach. However, little reference is made to climate impacts in development plans other than disaster management plans for droughts and floods. In South Africa there is a requirement that Water Services Development Plans and Integrated Development Plans be prepared by local governments, however very few acknowledge the potential impact of climate variability and change or have any plans to deal with the consequences. There is little mention of adaptive strategies that involve a permanent change in an approach to a more permanent or recurring stress and that consider the incremental impacts on livelihoods (Mukheibir & Sparks 2006).

Water Resources Management

The relative short-term view of the sustainable development response has been contrasted by the longer term view of the water resources management response. The predominant focus of water planners and managers has been to meet growing demands for water by augmenting the supply through usually large technical solutions, based on long-term demand projections. As these large infrastructure solutions have become less attractive, the development of new, and the revival of traditional, ideas such as integrated water management and rainwater harvesting have come to the fore (Gleick 2003).

Molle (2003), as well as Turton and Ohlsson (1999), have observed a three stage progression of water management, starting with augmenting supply with infrastructure, then moving to water conservation and demand side management and finally shifting to re-allocation of water from one user to another by shifting to a higher value use. Globally these responses to water scarcity have been implemented at both national and local level. The authors acknowledge that in practice, however, these stages do not always occur in a successive fashion and often occur concurrently or in a different sequence, depending on the level of strategy development. Interlinked with this, is an understanding of the socio-economic context and the political economy of water resources development and the specific response of communities that face water scarcity. There are trade offs between sectors that need to be taken into consideration (Turton & Ohlsson 1999; Molle 2003).

Despite the fact that *Integrated Water Resources Management* (IWRM[10]) has been put forward as the most sustainable way of incorporating multiple competing and conflicting demands for water resources since the first UNESCO International Conference on Water in 1977, the most common criticism is that there is still a large gap between theory and practice. The concept of IWRM remains a normative theory and the set of principles underpinning it have not found their way into the socio-economic development policies and legislation of many countries (Maganga et al. 2002; WEHAB 2002; Jeffrey & Gearey 2006).

The key relevant principles of IWRM are summarised as follows (Kenabatho & Montshiwa 2006):

- Efficient use of water through water demand management, conservation and reuse;
- Integration of water supply, sanitation and health and hygiene education programmes;
- Integrated people centred planning (including poverty alleviation, equitable access to affordable safe water);
- Capacity building;
- Effective public consultation, education and the involvement of users in the management of the resources;
- Recognition of the environment as a legitimate user of water; and
- Protection of the environment.

At a national level in South Africa, IWRM is embraced politically and institutionally, with the responsibility for IWRM vested in the Department of Water Affairs and Forestry (DWAF) (Mackay & Ashton 2004). However, Ballwebber (2006) points out that a strong formal IWRM framework in a country which does not have a history of informal technical collaboration faces challenges, as in the case of South Africa, where the horizontal integration between state departments is difficult to achieve. DWAF still need to co-ordinate and integrate their IWRM efforts with the Department of Environmental Affairs and Tourism's Strategic Region-based Management approach under the National Environmental Management Act, NEMA (Mackay & Ashton 2004). Also, despite having a sound top-down framework to support catchment management agencies (CMAs), vertical integration challenges are still being experienced in effectively empowering local collaborative partnerships. This is contrasted, for example, by the experience in the USA (Ballweber 2006), where a wealth of ad hoc collaborative watershed management efforts reflect a high degree of technical co-operation at a local level. However,

[10] IWRM has been defined as " a process which promotes the co-ordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Pahl-Wostl et al. 2005).

there is a serious need for higher political and institutional leadership and guidance due to the lack of a national IWRM strategy.

Further, although listed as a key principle, recent formulations and applications of IWRM have not focused sufficiently on poverty reduction or livelihoods. Given the vast analytical literature on poverty, IWRM has yet to develop a coherent analysis of the relationship between poverty and the access to water, specifically with regard to the productive use of water. The role of water access and use in livelihoods of the poor needs special attention (Maganga et al. 2002; GWP 2003). The message from the 2006 World Water Forum (IISD 2006) was that the water crises was largely a governance crises typified by poorly organised institutions, weak legal frameworks, limited human and financial resources, corruption and lack of transparency, and a limited involvement of stakeholders in decision-making. Current methods of drought management was viewed to be largely crisis-driven and there was an expressed need for a more risk-based management approach to planning at national and regional levels. There was a general call for a new approach to water management, including decentralisation and increased public involvement and the development of IWRM as part of broader national and local planning. Specific recommendations made by the Global Water Partnership (2003) to ensure that IWRM addresses poverty reduction included, amongst others, the need to abandon sectoral approaches to water management, the need to shift the paradigm from thinking about water for drinking only to include the productive use of water and the recognition that competition over scarce resources should not discriminate against the poor. However, despite these suggestions, the debate generally still remains silent on ensuring basic access to water services for the poor.

Current water management systems are also characterised by low adaptive management capacity due partly to *sectoral fragmentation*. The lack of communication and planning between spheres of government, horizontally as well as vertically, can result in disjointed policies and planning. This is compounded by the fact that people have not been involved in planning and decision making at a local level (WEHAB 2002). The integration of IWRM with development planning is crucial to achieve integration and resolve resource conflicts and equity problems. Adaptation management strategies in the water sector could have impacts on other sectors both positively and negatively, and hence there is a case for both trade offs and synergies, especially in terms of cost (Lasco et al. 2005).

Based on the concept of adaptive capacity as discussed earlier, the notion of *adaptive management* has also been advocated by some as the paradigm within which natural resource planners and managers should operate, since resource management systems, like ecosystems, need to be able to adapt to sudden changes in the system (Jeffrey & Gearey 2006). The main objective of *adaptive water management,* as defined by Pahl-Wostle et al. (2005), is to enhance the adaptive capacity of a water system based on a good understanding of what determines *resilience* and *vulnerability* in that system. The focus of the adaptive capacity should be on the management of socio-ecological systems, while vulnerability refers primarily to the exposure to adverse impacts. The IUCN[11] emphasises that water management should shift from technical solutions to building the capacity of communities and institutions. Water managers will need to adopt an "adaptive management style" that engages with social learning and increases the social capital of the society (Bergkamp et al. 2003).

Therefore Gleick (2003) proposes that a new "*soft path*" be pursued, one that relies on small-scale decentralised facilities and strives to improve the productivity of water use rather than to endlessly seek new sources of supply. He argues that the goal should not be the use of water as a resource, but rather the improved social and individual well-being per unit measure of water used. However, there is little theoretical or practical experience regarding how this could be achieved or the consequences of cases where attempts have been made to achieve it (Pahl-Wostl et al. 2005). One of the core recommendations of this *soft path* is to improve the productivity of water use by diverting it to higher value-added areas. This approach, however, raises two problems. Firstly, it is not easy to separate the value of water from other inputs in the production of high value-added manufactured goods and secondly, there is surprisingly little evidence that the development of higher valued-added industries has been held back because of the competition with agriculture for example. Further, in countries where the vast majority of the population depend on agriculture for their livelihoods, losses of allocated water could translate into a major human development threat.

Adaptive management has therefore been viewed as the timely extension of IWRM to cope with these challenges, since it is aimed at increasing the adaptive capacity of water management areas based on the good understanding of key factors that determine its vulnerability. This would also take into consideration the environmental, technological, economic, institutional and cultural characteristics of catchment and supply systems. It is the encompassing paradigm for adaptation to contemporary climate variability and the prerequisite for coping with the still uncertain impacts of climate change on the water cycle (Turton 1999b; Pahl-Wostl et al. 2005; Schulze 2005a; Jeffrey & Gearey 2006; Kundzewicz et al. 2007).

Regrettably, the adoption of this adaptive management approach to climate change around the world does seem far off at this stage. Observations by Rayner et al. (2005), indicate that currently there is some, but limited, use of climate forecasts in the operation and maintenance of water supply industry, which generally relies heavily on large infrastructure to deal with irregular weather events and to ensure reliability of supply. There is little infrastructure planning based on the greater predictability of short-term climate fluctuations. This limitation is due mainly to contractual constraints, regulations and economic considerations. They further found that the principal factors affecting the use of new weather and climate information was the

[11] IUCN - The International Union for the Conservation of Nature and Natural Resources (The World Conservation Union)

conservatism on the part of the technical personnel and the complexity of the climate information. Water resource managers rely on traditional planning methods so as to avoid exposure if improved outcomes are not met. Probabilistic forecast information is relatively complex and not well understood as yet by many water resource managers and viewed as unreliable. This is exacerbated by institutional resistance to externally generated information (Rayner et al. 2005). It is not surprising therefore that water resource managers have until now been reluctant to engage with the climate discourse and have paid little attention to and are often unaware of the projected impacts of climate change on future water resources.

Projected climate change will force a change in traditional water resource management and planning, which is currently based on the premise of static long-term climate. The projected global warming is likely to have a substantial destabilising effect on the hydrological cycle, resulting in greater variability in precipitation, and therefore stream flows, as well as the magnitude, duration and intensity of extreme events such as droughts and flooding. These projections currently come with great uncertainty, however, and therefore current risk management approaches and tools will need to also incorporate climate scenario analysis and vulnerability assessments thereby leading to a systems approach to water resource management and planning (New 2002; Bergkamp et al. 2003). The *Integrated Water Resource Management* approach currently does not include approaches and methods towards adaptive water management strategies under these uncertain climate conditions. Despite its misgivings as discussed earlier, Kabat et al. (2002) argue that Integrated Water Resources Management should be the approach for coping with natural climate variability and the precondition for adapting to the highly uncertain consequences of global warming and associated climate change. By coping with present-day climate variability in water resources management, which is already a formidable challenge, resilience to any further impacts of climate change will be improved. The role of the climate change discourse in water resource management is discussed further in Chapter 4.

2.3 Summary

In summary, the distinction between poor access to water and scarcity of water has been made. *Scarcity* can be defined as a quantitative concept, requiring quantitative supply side solutions. It is driven by a combination of three principal forces, viz. depletion and degradation of the resource, population growth and unequal regional distribution of rainfall and runoff. On the other hand, the underlying cause of poor access is largely institutional and political, i.e. a more structural cause. *Access* as defined in this thesis, is the receipt of safe water to meet basic human requirements of 50 litres per person per day as proposed by the World Health Organisation.

Whilst some inroads have been made in many countries towards achieving the Millennium Development Goals, Africa has lagged somewhat behind other developing regions. South Africa is close to meeting its 2015 target of 80% access. However this figure may be misleading since it does not reflect the actual number of people receiving safe water, but rather the installed capacity for delivering the required amount. In some cases the systems are no longer operational. The key elements discussed that affect the equitable *access* to water have been identified as:

- Local institutional capacity in the form of both financial and human resources,\;
- Pricing of water services and its affordability (this is taken up further in Chapter 3 as well as in the case study described in Chapter 7);
- Water markets and the allocation of water resources to competing demands; and
- Privatisation of water services and how this has in some cases marginalised certain parts of the population in term of access and affordability to water.

Based on the available literature, two responses relating to water access and climate change have been discussed in this chapter viz. sustainable development and integrated water resources management. The third response, adaptation[12] to climate change, is discussed in Chapter 4. It can be seen that the first two responses currently do not overlap much and hence do not provide a holistic approach to the issue of water access and scarcity at community, catchment or country level. They both seem to operate in their own autonomous fields, with little or no integration.

Table 4. Different attributes between Sustainable Development and Integrated Water Resources Management responses

	Sustainable Development	**Integrated Water Resources Management**
Basis	Social and economic	Engineering and natural science
Perspectives	Social & economic	Environmental
Approaches	Bottom up – community based	Top down
Focus	Programmes & projects	Policy & infrastructure
Temporal scale	Short/medium term	Medium term
Spatial scale	Local scale	Regional scale / catchments
Political & institutional scale	Micro & Macro	Meso & Macro
Access	✓✓	**X**
Scarcity	**-**	✓✓
Climate impacts	**-**	✓

Table 4 has been developed by the author to summarise the attributes of the two responses. IWRM can be best described as conceptual in nature, having been developed to describe and direct planning approaches mostly at a catchment level in a top-down fashion. It does not really address physical implementation and ongoing service delivery in any meaningful way. It does deal effectively with water resource allocation at catchment level and has recently begun to develop responses to potential climate impacts, but should be used as a practical planning tool rather than merely a school of thought.

Sustainable development is also a conceptual objective, but is grounded in political policies and programmes. These often do not have the necessary resources to follow through with the implementation or to deliver at scale. The sustainable development agenda is motivated by the issue of basic rights and through locally based initiatives is able to give a voice to local concerns and needs. The discussion around livelihoods has begun to incorporate vulnerability and resilience to climate change impacts. The approach here is a bottom-up approach that defines vulnerability as the susceptibility to climate impacts as determined by socio-economic factors. The vulnerability of a society therefore determines its adaptive capacity.

The notion of *adaptive capacity* is discussed in the context of diminishing water supplies and it is evident that countries such as Israel, with strong social and economic resource bases, have higher adaptive capacities than developing countries with lower resource base levels, such as Namibia for example.

Neither of the responses todate integrate climate change into their mainline planning and management. IWRM probably comes the closest, since it has recognised that this is an important input into sustainable water resource management, but has yet to incorporate it into day to day operations. There is a need to encourage IWRM to embrace the concept of adaptive capacity in its planning as it relates to climate change impacts and the issues of water access.

The case study presented in Chapter 7 brings together these two discourses in order to assess the impact of water scarcity on the delivery of sustainable water services, specifically under projected climate change conditions. The role that reduced rainfall and the consequent reduction of water supplies has on achieving the MDGs is demonstrated.

The discussion in the next chapter moves the focus from water resource management to the challenges of water service delivery, specifically in the small urban context. The complex issues of water access are further discussed in this context. The issues related to climate change are addressed again in Chapter 4.

[12] Adaptation – the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2001b: 72)

CHAPTER 3

3. Small towns: geography, service delivery & water access

Having established the distinction between water scarcity and poor water access, the focus of this chapter shifts from resource management to basic service provision. Specifically, the focus is on small towns since they have traditionally been marginalised both in a geographic sense, as well as institutionally, yet they are charged with the responsibility of ensuring the provision of basic services (van der Merwe et al. 2005). They often find themselves in a policy vacuum, where funding and resources are either directed to the agricultural sector or large urban centres. In South Africa, for example, inequity in access and service provision, and the difficulty of transforming the urban landscape from the racially and economically separated suburbs set up under the previous apartheid government, have proven to be big challenges (Jaglin 2004).

Cities in developing countries are further faced with the socio-economic problems of informal settlements and fragmented spaces, big disparities between the wealthy and the poor, unemployment and lack of social capital, as well as difficulty in service provision. The fact that the state in these countries is often poorly constituted at the local level further compounds the problem. Administratively, the management of water supplies falls on local municipal bodies which face multiple challenges in planning for urban water supplies, some of which can be traced to a scale mismatch (Satterthwaite & Tacoli 2003).

More than 50% of the world's population is now urban, and urbanisation is rapidly taking place, particularly in the cities of developing countries, which often struggle to cope with the increasing number of people they need to support and service (UN-HABITAT 2006b). Cities and towns in the dry regions of the world are currently witnessing some of the highest rates of urbanization. According to Lebel (2005) urbanisation is a mix of biophysical, demographic and social changes. No universal definition of urban exists, but it often implies proximity and access to diverse services and livelihoods. This issue is discussed further in section 3.3, but the notion of access is not always a given and marginalised communities within an urban context (however defined) are often denied basic services because of economic and physical barriers.

Small town public services are usually geared to the needs and capacities of the urban middle class and so neglect the needs of the rural and urban lower-income groups. In addition, small towns often located at the lower end of the urban hierarchy with very low investment in infrastructural and public facilities. It is difficult, however, to generalise about small town geographic and economic trends, because of their wide diversity – and because of the lack of national information about this sector (Hinderkink & Titus 2002). Research by the Centre for Development and Enterprise (CDE 1996) revealed that in 1996 more than half the small towns in South Africa were in economic decline. The towns in the former homelands are generally in greater economic decline than those in former white and commercial agriculture areas. Whilst the research by the CDE is somewhat dated, since no new published data is available on this topic, the overall trend of widespread degeneration provided the motivation for focusing this research on small towns.

The first two sections of this chapter raise the dilemma of scale, since the question of which tier of government should take the lead in service delivery, specifically water, depends on the specific institutional and governance arrangements in that country. Having dealt with the institutional barriers the focus of the final section shifts to how individuals are assured of access to water services. In developing countries, urban centres are already struggling with providing access to potable water supplies to their growing populations. The available literature indicates that the introduction of rising block tariffs, free services and indigence policies have only marginally protected the poor in South Africa, and have disproportionately benefited the rich.

3.1 Small towns and the issue of scale

Literature on urban development purport cities primarily as engines of economic growth, where sustainable development is used to justify the trends already in place in the urban context. This business-as-usual approach continues to be supported, despite the mounting environmental and social crises generated by the concentrated and extensive urban economic growth currently being pursued. In addition, most literature it would seem, has focused on issues of urbanisation in large cities or on the other hand on rural subsistence livelihoods at communal level. Satterthwaite (2006) has described the distinction between rural and urban settlements in Table 5. The villages and small towns falling into the "ambiguous" category are the most neglected by the research literature. Little of which is focused on small towns and the issues of unemployment, cross-subsidisation, service delivery, financial and technical capacities and resources.

Table 5: The continuum of settlements from rural to urban (Satterthwaite 2006)

Rural	Ambiguous	Urban
Unambiguously rural settlements with most the inhabitants deriving a living from farming and/or forestry	Large villages, small towns, and small urban centres. Depending on each nation's definition of urban, varying proportions of these are classified as rural and as urban	Unambiguously urban centres with much of the economically active population deriving their living from manufacturing or services
Populations or rural settlements range from farmsteads to a few hundred inhabitants	Populations range from a few hundred to 20 000 inhabitants	In virtually all nations, these include settlements with 20 000+ inhabitants. In most they include many settlements with far fewer than 20 000 inhabitants
Increasing in population size Increasing importance of the non-agricultural economic activities		

It is estimated that by 2001 approximately 61% of urban Africans lived in towns and cities of less that 500 000 people (UN 2004). In South Africa there are almost 500 small towns with less than 50 000 people and make up 10% of the country's population. However, there is very little known or said about the current or future situation of these urban centres. Small towns have seldom been viewed as key elements in South African national development, and have been ignored in favour of rural development in terms of agriculture and land reform and urban development in the large cities (CDE 1996). Further, the fate of these small towns often rests on the unpredictable and unstable condition of the surrounding agrarian economy and, as such, should be the focus of rural development and economic programmes to hold back migration to large urban centres. The lure of basic services, housing and potential jobs, together with people being forced off the land through poverty and layoffs has led to urbanisation in both large centres and small towns (RSA 1997b; Lemon 2001).

Montgomery et al. (2004) suggest that in recent years small cities and towns have tended to grow more rapidly than larger ones. Sattherwaite (2006) warns, although, of making these generalisations because not enough is known about these smaller types of settlements since census data shows great diversity both is size and characteristics. There is a critical gap in the literature because researchers do not fully understand how the economic health of these settlements is sustained (Hardoy & Satterthwaite 1986). In addition, recent census data show a drop in growth rate of many of the world's largest cities, which calls into question the assumption that increasing proportions of the world population will be found in large urban centres, especially mega-cities (Satterthwaite & Tacoli 2003). Further, the most rapid growth within cities, both large and small, is happening in developing countries and at rates far in excess of the historical rates recorded in the global North (Simon 2007b). This growth in smaller urban centres has led to infrastructural and social problems, especially in developing countries. In general, small urban areas, especially those with populations under 100 000, are underserved by their governments, often lacking in piped water, adequate waste disposal and electricity supply. As illustrated in Table 6, people living in small towns in developing countries have lower levels of service and need more time on average to collect water from water points than those living in large cities. However, these levels of service are still an improvement on those experienced in rural areas.

Table 6: Water service levels in developing countries (Montgomery et al. 2004)

	Urban centres		Rural villages
	Under 100 000 people	1 – 5 million people	
Piped water on site	35%	55%	7.8%
Minutes need to collect water	19.1	13.5	29.4

In demographic terms, the level of urbanisation is conventionally defined as "the proportion of the total population of a country living in settlements designated as urban" (McGranahan & Tacoli 2006). Urbanisation can be defined as the net increase in the urban population due to the urban natural increase, urban net migration and/or the reclassification of rural populations as urban due to urban sprawl. A key factor that contributes to urbanisation is not only population growth, but rather changes in economic structures and service delivery systems. Changes in climatic conditions such as prolonged droughts, as in the case of Senegal, can also be a significant catalyst for migration to urban centres (Satterthwaite & Tacoli 2003; Gueye et al. 2007).

However, the distinction between urban and rural is becoming more difficult to define since there is no clear line between these two types of settlements (Kok & Collinson 2006; Satterthwaite 2006). According to McGranahan et al. (2006), there is no accepted way of defining an urban area, since these change from place to place and over time. Population size thresholds, density, administrative status and boundaries, or census status are some methods used by governments to determine urban areas. These various methods suggest that caution is needed when making comparisons internationally. Further, a number of commentators on urban issues recognise that it will not be possible in the near future to conceive of a developing country as being mainly rural, but rather made up of many small urban centres.

Sub-Saharan Africa's (SSA) urban population is growing at a higher rate than that of any other region in the world and is doing so in the context of generally declining economic performance. This, combined with poor planning and governance, increases the level of urban poverty. 72% of all urban residents in SSA live in informal settlements (UN-HABITAT 2006b). By 2030 it is estimated that the developing world as a whole will most likely have become more urban than rural and more specifically in Africa, where more than 50% of the population will be living in urban areas (Montgomery et al. 2004). A report by the United Nations (2004) suggested that the rural populations of Botswana, Lesotho and South Africa could be expected to decline. However, this does not seem to be due to urbanisation, but rather to low fertility rates and rising mortality rates among some age groups (Kok & Collinson 2006).

Urban change in South Africa is closely related to the racial discrimination that was formally embedded in the previous government policies. The 2001 census data showed that 56.3% of the South African population was urbanised (SSA 2003). A large increase in urbanisation from 1994 to 2001 was as a result of the former homelands being previously excluded from the census (Crankshaw & Parnell 2002). The average annual growth rate of urban population for 1970-1990 was 2.5%. This has increased to 2.8% for the period 1990-2005 (UNICEF 2007). 95% of the rural population is classified as African. Although the urbanisation of Africans lost momentum between the 1950s and 1980s, due mainly to the effects of apartheid influx control measures, it has been increasing in recent years (Kok & Collinson 2006).

In response to there being little research into the urbanisation patterns over the past 10 years, Stats SA conducted a survey in 2007 to bridge the 10 year gap between national censuses (SSA 2007). They observed that a growth over the past decade of between 14-17% had taken place in the more urban provinces of Gauteng and the Western Cape, while the predominantly rural provinces of the Eastern Cape, Free State and North West, had only grown by less than 5%. The two key drivers for this growth are births and migration. The boom in the Western Cape and Gauteng has been attributed to migration. The migration patterns are important for planning infrastructure and services.

Atkinson and Marais (2006) concur with the observation that there is a vast amount of migration to dense settlements, but adds that these occur across both large urban and rural towns. Joblessness is so prevalent that employment prospects in large urban centres are no longer a motivation for migrants. It would also appear that government expenditure in rural areas may also create incentives to stay due to better infrastructure and services there, even where there is low economic activity. It would seem, therefore, that there is a general migratory trend from the poorer provinces to the wealthier ones, but that both large and small urban centres are attracting migrants.

Another interesting phenomenon in South Africa is the development of small towns as venues for second homes, essentially weekend holiday homes for the wealthy. In the main the benefits to local residents relate to job creation and the development of leisure industries. However, the ensuing rising housing prices have made it difficult for local entrepreneurs and residents to enter the property market (Hoogendoorn & Visser 2004).

Since 1994, the issue of urbanisation and migration in South Africa has been indirectly addressed by different government departments, whose sectoral programmes have had unintended spatial consequences. Programmes aimed at providing improved service delivery have become implicit spatial programmes. The main focus of government policy has been poverty mitigation and the promotion of development though local nodes, since the major problem facing South Africa is poverty and the creation of livelihoods. However, the sectoral approach has had little success in addressing these problems in either the urban or rural context (Atkinson & Marais 2006).

The development of small centres has been a priority in developing nations, but in many cases they have failed to play a significant role in balanced rural-urban development. The potential of small towns to contribute to local economic development has not been sufficiently recognised in rural development strategies (van der Merwe et al. 2005). The main reasons for these failures are firstly, the discrepancy between local economic development policies and national development strategies that concentrate resources and infrastructure in a limited number of growth areas, secondly, the failure to give sufficient attention to agricultural and other natural production systems in surrounding rural regions and thirdly, the limited capacity and financial resources of local governments in providing essential infrastructure and access to external markets (Satterthwaite & Tacoli 2003). Hinderkink and Titus (2002) have observed that small towns rarely play a prominent role in starting rural development in their areas. They recommend that to stimulate local development, efforts should be focused on a sectoral basis and not on a regional one. The mechanical planning models allocating public service facilities according to rules based on central government theory should be avoided. By investing in sectoral infrastructure such as water or agriculture, the implementation will be easier and the achievements are more predictable and achievable.

This trend has also been observed in South Africa, where in the Rural Development Framework (RSA 1997a) it was noted that small rural towns should be the focus so as to benefit people in the surrounding areas as well. In response to this, the South African government created an overarching fund, the Municipal Infrastructure Grant, MIG (RSA 2004) to facilitate the direct investment in municipal infrastructure and introduced the National Spatial Development Perspective, NSDP (RSA 2003b) to guide the nodal development. Whilst the NSDP cuts across the well established, but badly organised rural agenda, it still emphasises a commitment to an urban bias for state led investment (van der Merwe et al. 2005). The NSDP is based on the argument that public investment should target spaces where there is a combination of poverty and greatest potential for economic growth most rural areas. Therefore many small towns have been excluded due to their low potential brought about by low levels of human capacity and declining economies. This has resulted in the targeting of new growth areas and the marginalisation of existing small towns. Satterthwaite (2006) has observed this as a global trend where governments often push investment into unsuitable locations, or the choice of where public investment is concentrated is determined by political considerations and not economic potential. This directly contradicts the recommendations of Hinderkink and Titus (2002). The intention of reducing migration to large urban centres is therefore not achieved. Further, there is no evidence, according to Swilling (2006), that the MIG or the NSDP have taken into account the underlying sustainability of ecosystem services that urban infrastructures depend on. Swilling presents the absence of a national sustainable development strategy as the reason why South Africa's infrastructure planning has not taken sustainability into account.

Satterthwaite and Tacoli (2003) put forward that earlier views of the role of small urban centres in regional and rural development fell within the general modernisation and dependency theories, viz. that innovation and modernisation would trickle down to rural populations via a spatial rural development strategy of hierarchical urban centres. This has an inherent urban bias and does not place any emphasis or importance on rural and small urban centres. More recent views, in their opinion, have adopted a wider perspective and have described the root of regional inequalities to be the uneven development processes. However, the underlying problem facing small urban centres is the dependency on the power relations and development strategies at the national and global levels. Even though small urban centres are viewed as central to local development, there is little evidence to confirm their capacity to trigger or maintain any developmental initiatives. In order for local government to meet its developmental challenge, at both the large and small urban scale, Pieterse et al. (2007) have put forward five critical focus areas. Firstly, the funding cycles and revenue flows must be clear. Secondly, the technical standards required to ensure an adequate level of service must be published. Thirdly, the necessary human capacity must be in place to ensure the smooth delivery of the service. Fourthly, an appropriate institutional interface with customers must be set up. Finally, the geographic scale must be defined to ensure both economies of scale as well as effective area-level co-ordination.

The growth, or stagnation and decline, of small urban centres, and their relationship with the neighbouring rural region are often influenced by macro-economic strategies or sectoral priorities that make no mention of spatial dimensions. In most small urban centres in the developing world, urban poverty is not only linked to low incomes, but also to poor quality housing, lack of infrastructure and services. Whilst the lack of access to infrastructure and services in rural areas may be attributed to distance from major urban centres, low densities and financial resources, in an urban setting access may be denied due to high cost, informal settlements or poor governance. Satterthwaite and Tacoli (2003) argue further that concentrating public funds in the hands of central and regional government, and limiting the role of local governments to raise revenue, often limits improvements in infrastructure and services in small urban centres. Policies intended to support more successful local economic development outside the larger cities, need to ensure that they are not being undermined by the structure of government and the non-spatial policies and priorities of higher levels of government (Hardoy & Satterthwaite 1986).

According to the UN-HABITAT (2006a) small urban centres, especially those in poor countries, are unable to secure long-term finance for urban development, specifically for water and sanitation projects. This is further exacerbated by low levels of consumer affordability, inadequate revenue to cover operational and maintenance costs and political and foreign exchange risks associated with getting short-term funds from external sources. Globally, international finance contributes a third of the annual budget requirements for water and sanitation. However, over half of the international aid for water and sanitation in the past has gone to only ten recipients. Countries with the largest populations without access to water receive very little aid. Further, only 10% of the international aid funding for water and sanitation goes to small urban centres. Small towns tend be overlooked since they fall between large urban and rural areas (UN-HABITAT 2006a). These constraints make it difficult for small urban municipalities with low incomes to meet the Millennium Development Goals (MDGs) without some form of subsidy. Therefore, in some countries, small towns rely on some form of cross-subsidisation from the national government. In South Africa for example, the Equitable Share grant was introduced to provide local municipalities with an external subsidy based on the number of indigent households. This is discussed further in section 4.4.

The management and resourcing of small urban based water systems is a major challenge in ensuring sustainable and equitable delivery of basic services. The issues related to small water systems are discussed in the next section.

3.2 Small scale water systems

The issues related to water supplies for small towns are a complex combination of both those found in rural subsistence communities and large urban centres and are hence marginalised, since they fall between the cracks of policy and funding priorities. Water use in small urban centres is dynamic and differs across high and low income users. In general the demand tends to increase over time with increased population growth and migration from rural to urban centres. Initial installed supply infrastructure often does not keep pace with the increased water demand. Water managers are confronted with the high cost of new infrastructure, demand side management and the social obligation to provide water services to the poor (Dube & van der Zaag 2002).

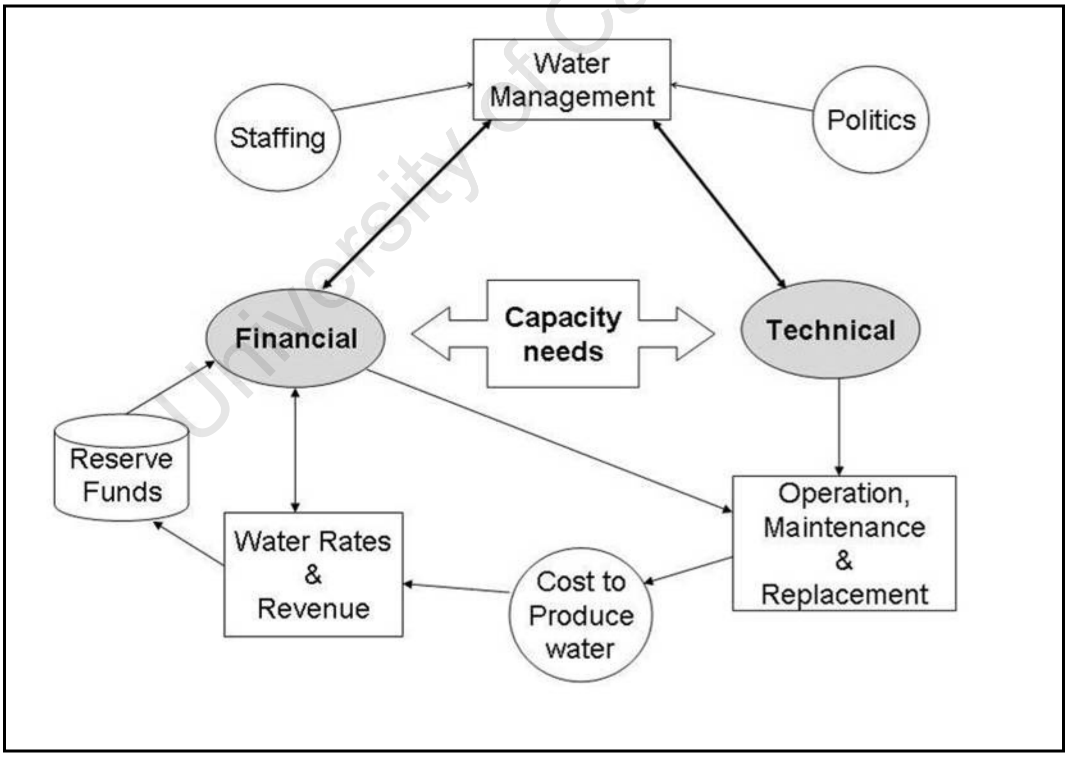

Figure 8: Overview of a small town water system (modified from Braden & Mankin 2004)

By referring to Figure 8, the operational entities of a small town water system can be identified. The development goals and policies are driven by political agendas and these are implemented through the management structure, which requires staffing. The management is typically divided into two main thrusts, viz., financial and technical. On the financial side, the setting of affordable tariffs determines the revenue stream, which is divided into direct costs and reserve funds. The direct cost are those that cover the operation, maintenance and equipment replacement to produce the demanded water supply. The reserve funding is needed to deal with shocks to the system in the form of droughts or other unexpected damages as well future expansion. On the technical side, technical capacity is need to operate the system and do forward planning to avoid future water shortages due to increases in demand and decreases in supply through drought.

In the United States of America for example, where 94% of the population is served by safe water, the burden of achieving this level of service falls most heavily on the small systems[13]. In addition to facing numerous social and environmental challenges, these small systems are at a distinct economic disadvantage (Dziegielewski & Bik 2004). Without adequate measures to increase revenues and reduce costs, water systems of small towns experience serious financial upsets that may result in their closure or seriously affect the operations of other users due to down stream pollution or over utilisation of a local source. According to Brown (2004), a number of studies revealed that between the years 2000 and 2020 small water systems in the US would experience a cumulative operating and capital shortfall of between 500 and 750 billion dollars. Small systems will be disproportionately affected since they lack economies of scale and are poorly funded and hence commonly operate at loss. They also mostly lack the necessary technical capacity. Braden and Mankin (2004) noted that the overall number of small water systems in the USA decreased by 8% from 1993-2002, due to bankruptcy. The picture is not too different for South Africa, since as Wall (2006) points out, municipalities have a large responsibility for water service provision. Over a ten year period, municipalities received grant and loan finance to install more than R30 billion worth of water infrastructure.

Since 1998, the provision of water services in South Africa became the responsibility of the local municipalities by virtue of their roles as statutory Water Service Authorities (WSA) in terms of the National Water Act (RSA 1998b). The Water Services Authority (WSA) is the local authority that has jurisdiction over the area. In most cases this will be the District Municipality. The WSA controls who gets water and for what purpose. The WSA has the right to limit or discontinue services if reasonable conditions (such as tariff payments) are not met. The WSA may appoint a Water Services Provider (WSP) to actually provide the water service and be responsible for the operation and maintenance of the water scheme.

The role of the WSP is clearly spelt out in the Water Service Act (RSA 1997c) and includes the following:

[13] The US Environmental Protection Agency defines small systems as those serving 3300 people or less. In the USA nearly 6000 very small systems serve populations of less than 500 (Dziegielewski & Bik 2004)

- Operate and maintain the water services provision system so that customers are satisfied with the level of service;
- Handle customer relations;
- Collect revenue payments for water services;
- Enter into a contract with Bulk Water Service Providers (e.g. Water Boards);
- Contract in any support agencies if necessary;
- Prepare business plans;
- Manage human and technical resources; and
- Prepare budgets and manage funds.

The capacity of many of these municipalities, mostly the smaller ones, to provide even the basic levels of service through attending to this list of activities is relatively low, as has been discussed in the previous section. These inherent stresses which small towns already have to cope with, also decreases their potential resilience to the climate impacts such as drought on the water supply system. Drought stress is traditionally experienced first in rural areas and small cities lacking in multiple water resource options and financial resources. A number of key issues that point to the limited capacity of small water supply systems to maintain an adequate level of water supply service have been identified (Braden & Mankin 2004; Dziegielewski & Bik 2004; Everatt et al. 2007; Mukheibir 2007c) viz.:

- The political imperative to deliver new infrastructure and target obscures the need to spend funds on maintaining exiting infrastructure, with the result that aging equipment and infrastructure cause stoppages.
- Poor record keeping, co-mingling of accounting systems, and the use of water revenues to fund other service needs is often prevalent. External grants are not ring-fenced and are used for other pressing concerns.
- There is a lack of local capacity to operate and maintain the systems and manage the implementation of viable water resource management strategies. It is difficult to recruit and retain trained engineers and operators due to migration to larger centres and aging communities. Existing staff tend to be overworked as a result of low numbers of employees. There is a reliance on outside consultants to perform many of the internal functions.
- The low financial resource base to cover the capital and running costs results in expenses exceeding revenue, since income and revenue bases are limited due to low population densities. In addition, local decision makers prefer to keep rates as low as possible, which results in the under-pricing of water; The low financial base often results in an absence of reserve funding for difficult periods.
- Poor cost recovery from water supply systems in small towns and poor communities is often cited as being the key obstacle to the longer sustainability of these systems and the

potential increase the service coverage. Coupled with high water losses, the economical viability of these systems becomes doubtful.

According to Hazelton and Kondlo (1998), the literature is inconsistent with respect to estimating different poor communities' ability to pay for the full cost of operation, maintenance and capital redemption. In some cases only the operation and maintenance costs are paid for by the consumers and in others the full cost of refurbishment or part thereof is paid for. This is due, in part, to ignorance of sound financial costing and to the actual ability of the community to pay for the basic amount of water they consume.

Setting water tariffs therefore requires that a balance be struck between four key objectives as outlined by Whittington (2003) viz. revenue sufficiency, economic efficiency, equity and poverty alleviation. He found that in South Asia, for example, water utilities were not generating sufficient revenues to ensure that they recover their financial costs. Cost recovery is the main objective to ensure revenue efficiency from the water suppliers' point of view, i.e. revenue should be sufficient to cover the operation and maintenance costs and any capital costs for refurbishments and expansion. The revenue steam should be fairly stable so as not to cause any cash flow or capital financing difficulties. In order to ensure economic efficiency, volumetric charges should be set at the marginal cost of supplying water. When capacity is constrained and water is scarce, it is usually assumed that the marginal cost of supplying water is the average incremental cost (A more detailed discussion on pricing is made in section 3.3) Equity means that the tariff charged for water treats all customers fairly and that customers in different situations are treated the same, i.e. users are charged the proportionate cost of the service that they demand. An increasing block tariff is often proposed as a mechanism to promote conservation through higher rates, which discourage high end users from wastage (Baumann et al. 1998). As a way to address poverty alleviation, they are also used to provide cheaper water for low income households who generally use low volumes of water. However, Eberhard (2001) found that very few water demand studies reported in the literature discussed equity issues. In some cases, water is provided free to poorer households to ensure some form of poverty alleviation.. This issue is discussed in more detail in the next section.

3.3 Equitable access to adequate safe water

It has been declared by the former United Nations Secretary-General, Kofi Annan, that access to safe water is a fundamental human need and, therefore, a basic human right (WHO 2003). Urban poverty reduction literature has focused generally on two generations of rights, namely the right to vote and the second generation right of access to basic services. The focus of this section, and this thesis, is on the second generation right which is achieved through sustainable delivery of affordable urban services to households and through viable administrative and finances services as well as infrastructural investment. However, as will be illustrated, the poor are often trapped in a "second class" urban status that may allow for voting rights, but does not always ensure the second generation rights. Whilst often these household rights are assured by national policy, they are typically guaranteed only by actions outside of national government, such as municipal rebates, water or electricity subsidies, pro-poor housing and transport etc. In developed countries many of these public good interventions are provided to the poor at subsidised rates. Urban services demand some form of subsidisation to facilitate access based on need and not ability to pay; hence providing services hinges on the level of state capacity to provide public good benefits (Parnell & Pieterse 2007).

As was illustrated in Table 6, access to water services is lowest in rural and small urban centres. In order to meet the Millennium Development Goals of halving the number of people without safe drinking water by 2015 compared with 1990 (UN 2006), a considerable portion of the effort will need to be focused on these rural areas. A policy shift in the 1970's saw the redirecting of development funding from urban to rural areas. Satterthwaite and Tacoli (2003) warn that this approach does not take into consideration the poor who live in peri-urban and small towns.

It is difficult to ascertain exactly what the global, national or even local level of water access is. International databases on access to water service provision are based on official government reports, but it is not clear whether these reports are reliable, since what accounts as "adequate" provision may vary from one country to the next. For example, a communal standpipe operating for a few hours a day would have the same weighting as a reliable house connection. Therefore, in this thesis, a narrower definition to "safe water" is used as compared to that put forward by the United Nations Human Settlements Programme (UN-HABITAT 2006c). Here "safe water" does not include water drawn from private wells, communal standpipes, water delivered by tankers or water purchased from vendors because these sources not only carry greater risk of contamination, but also require time and resources to obtain. Having a tap a few hundred meters away does not mean that the water is accessible since it is difficult to carry sufficient water over such distances and it may only be intermittently available, not be potable or be managed by a company or individual who charges high prices for it, with the result that most people only use around 10 litres per day (RSS 1997). Many households do not receive water from a private metered connection, so the service provision is inequitable on two aspects - the volumes that people are able to use and also the time taken to collect water, with these two aspects being inversely proportional (Whittington 2003). For this reason "safe water" is considered in this discussion as potable water that is supplied through a piped network, via either household or yard connections, and at an affordable price.

In South Africa, the right to water (and sanitation) has its roots in the Reconstruction and Development Programme (RDP) where it is explicitly stated that "the fundamental principle of our water resources policy is the right to access clean water – 'water security for all'" (ANC

1994: 28). The RDP goes on to add that to ensure that every person has an adequate water supply, the national tariff structure must include the following:

- A lifeline tariff to ensure that all South Africans are able to afford water services sufficient for health and hygiene requirements;
- In urban areas, a progressive block tariff to ensure that the long-term costs of supplying large-volume users are met and that there is a cross-subsidy to promote affordability for the poor; and
- In rural areas, a tariff that covers operating and maintenance costs of services, and recovery of capital costs from users on the basis of a cross-subsidy from urban areas in cases of limited rural affordability.

While it may have been reported by the South African government that two million households had been provided with access to water via mostly communal standpipes between 1994 and 1999 (Kasrils 2003), inefficient cost recovery measures and institutional arrangements have made many such projects unsustainable and have resulted in small scale water systems becoming uneconomical and inoperative (RSS 1997). Wellman (1999) estimated that by 1999 at least 50% of the installed systems were no longer operational. This was due mainly to poor cost recovery and a lack of operation and maintenance capacity, as was found in a study of the Eastern Cape (RSS 1997) and reconfirmed in the recent evaluation of the DWAF Masibambane II programme (Everatt et al. 2007), but Wellman also reports that vandalism of water meters was often cited by government officials as the cause for system failure.

Cost recovery is usually achieved by charging users the full short-run marginal cost of production plus a portion of the long-term operation and maintenance costs. This notion of "cost recovery" influenced levels set by Government for basic services. These service levels were based on "you get what you pay for" under Operation Masakhane. Communal standpipes were installed in villages and townships, with the understanding that collectively the costs would be covered by monthly household payments (Pape & McDonald 2002). Assessments of affordability were based on the communities agreement and "willingness to pay", rather than their "ability to pay" or actual affordability. Since communities were desperate to receive services, they would agree to household tariffs, without the full knowledge of what this entailed or where the funds would come from. This has resulted in systems failing and consumers, mainly the poor, being denied an equitable access to a basic service such as water.

Water provision in the city of Cancún (Mexico) illustrates this point (Aguilar & De Fuentes 2007). The introduction of the market system for urban water supply resulted in the heavy water users opting to install private desalination plants. The implications of this is an uncertain revenue stream for the main public supply and tariff increases, which in turn inhibits the ability to cross-subsidise low income households. The dichotomy between wealthy high volume users who can afford their own private supplies on the one hand, and the lack of access and high cost of water to residents of peri-urban settlements on the other, is representative of the socioeconomic inequity in this city and others globally.

Water services are generally accepted as affordable when the cost of the service is less than 5% of the household income – this is known as the “5% rule” (Eberhard 2001). However, Eberhard calculated that a poor household using 66 litres/person/day would spend about 8% of its income on water, but a wealthier household using 350 litres/person/day would only spend about 1% of its income. Cairncross and Kinnear (1992) show that poor households spend up to 20% of their income on water, and in some cases even more. For example, in two squatter communities in Khartoum, Sudan, the portion of income spent on water was 17% in the one case and up to 57% in another, while in Uganda expenditure in excess of 10% are not uncommon (Eberhard 2001). And in South Africa it has been found that poor households can pay up to between 25-40% of their incomes on basic municipal services (McDonald 2002). Water in these households has become an essential good necessary for survival. Pricing can discriminate against poor households because at low subsistence levels of consumption, the price elasticity of demand may be zero (Cairncross & Kinnear 1992; Jansen & Schulz 2006). In other words, poor people will pay anything for the basic amount of water and forgo other household items.

Warford (1997: 18) appears to be alone in his analysis of the affordability of water for the poor. He argues that the resistance to price increases for water is often based on the argument that the poor must have access to supplies which are sufficient to meet their basic health needs. However the real economic cost of water is usually a very small fraction of the household income. He believes there is much evidence to show that poor people have the “willingness to pay” water vendors much higher prices for lower quality water that than which is supplied through the municipal system. Cairncross and Kinnear (1992) argue that this comes at a cost and that where prices are inflated or increased, poor households sacrifice other household goods, usually food, for basic water supplies. This is corroborated by the USAID’s International Labour Organization programme in Madagascar (Minten et al. 2002), where it was found that a sizeable potion of both the urban and rural population indicated that they were willing to pay additional money for improved water quality. On this basis it was assumed that cost recovery was indeed feasible. Yet, household income and expenditure surveys have revealed that a significant portion of the population in the small towns and rural areas would not be able to pay for even small increases in the prices for water. A step tariff was thus proposed.

In some cases, low income households find it difficult to keep up with payments and are eventually cut off from the service. This leads to sub-standard living conditions and raises public health concerns (Martin & Wilder 1992). Research by Martin and Wilder suggest that between 5-7% of total customers in small cities get cut off each month. They argue that the marginal price should be high enough for upper levels of consumption so that overuse and wastage are discouraged, and the average price for basic consumption levels should be low to allow access to basic water services by poor households.

In a survey of case studies in South Africa, Loftus (2004) found that the central theme was the pressure being placed on households to restrict their demand since they have been unable to meet the payments. He found that water restrictions and flow controllers had been installed on individual households to “help” them manage their water bills. The flow restrictors consist of a simple disc with a narrow hole in the middle, which dramatically reduces the diameter of the pipe at the meter, thereby restricting the flow to a daily level that approximates the free water allowance set by government. Such a method is notoriously unreliable since the flow is dependent on the pressure in the system, which varies depending on the other users in the system.

Another technical innovation was the introduction of prepaid meters in South Africa as an answer to the cost recovery difficulties. A prepaid meter is a device that not only measures the exact amount of water consumed, but also forces consumers to pay for the service in advance. They do not allow the consumer to go into default and therefore require no punitive measures. The pre-paid meters are installed at communal points and in some case at household connections. A survey of the Northern Cape by Deedat (2002), confirmed that the prepaid system is generally not accepted by consumers. In the past, they could settle their accounts with the municipality by arrangement. Under the pre-paid system however, they often went without water or used unsafe sources.

These two examples illustrate that poor people are typically deprived their right to access to clean safe water, whilst at the same time being the only people in the world who suffer from life threatening water scarcity. Schreiner and van Koppen (2002) identified two relevant key reasons for this. Firstly they lack the technical and financial assets to access sufficient clean water. Secondly, under growing competition for scarce water resources, high income users of high volumes of water have the socio-political power to assure their permanent access to water. Commercial agriculture is a case in point. The exclusion of the poor and subsistence farmers from water governance is reinforced by their general social exclusion from public governance due to their low levels of education, literacy and access to information. Institutional exclusion from decision making over water allocation further erodes poor peoples access to water and also further decreases their water demand.

To avoid this, the South African National Water Act (RSA 1998b) shifted the locus of formal water control from riparian water title holders, consisting mainly of the white minority, to the national government as custodian of the nations’ water resources for all its citizens. Under the Act, compulsory licensing has resulted in the cancelling of past licensing and the re-issuing of them on the basis of a new allocation schedule that redresses the inequities of the past. Under this legislative framework, an amount of water is reserved for human needs that is provided free to Water Services Authorities (WSA), as well as for ecological needs, as determined by water management plans. Further, there are specific components of the National Water Act that contribute specifically to poverty eradication. The water reserve includes an ecological reserve and a basic human water need and is allocated before any other allocation is made.

The South African "basic" level of water supply to promote a healthy standard of living is 25 l/p/d at a walking distance of less than 200m as specified in the RDP (DWAF 1994). This equates to 6 kilolitres per household per month for a household of 8 people and is regulated as part of the national strategy in terms of the Water Services Act (RSA 1997c). However, the number, size and structures of households in South Africa have undergone dramatic changes during the past decade. The total number of households in South Africa has increased through government housing programmes and has resulted in the average household size declining from about 4.48 in 1996 to about 3.69 in 2005 (van Aardt 2007). The monthly volume therefore would equate to an average of just over 50 litres per person per day, which would be more in line with the WHO recommendation for on-site water delivery (Howard & Bartram 2003). However, this is a generalisation. Some large poor households (10 to 20 people), who receive their free water through a prepaid system, often reportedly exhaust their free household water allocated well before the end of the month. The result is they are unable to access further free water and have to resort to using unsafe sources or sacrifice other parts of the household budget to buy water (Dugard 2007). The allocation of a free basic level of service at the household level is based on an average number of residents and hence can discriminate in two ways: not only do large households receive markedly less than the 25 litres per person per day, as proposed, but small household units receive more free water person than was intended by the policy.

In response to the concerns about access and equity, many countries (including South Africa) have introduced rising block tariffs in an effort to make the initial levels of consumption more affordable and, in some cases, free, thereby addressing accessibility for the poor. Increasingly higher tariffs are charged as consumption levels increase, effectively taxing the wealthy to curb their consumption and to make cross-subsidisation financially sustainable. The general acceptance of these measures in South Africa stems from the African National Congress' Reconstruction and Development Programme (1994) which states that tariffs are intended to "ensure that every person has an adequate water supply" and must include a lifeline tariff to ensure that all South Africans are able to afford water services sufficient for health and hygiene requirements. It also states that in urban areas, a progressive block tariff could be implemented to ensure the long-term costs of supplying large volume users are met and that there is a cross subsidy to promote affordability for the poor.

Hermanus, one of the first municipalities to implement the block tariff system in South Africa, reduced consumption by 32% over the first three year period and also increased revenue by 20% (Deedat et al. 2001). However, residents in the poorer areas, i.e. townships, were subjected to punitive measures, such as cut-offs, for non-payment. The progressive nature of this form of tariff structure is incompatible with intensified measures of cost recovery which result in large numbers of people going without water. As Whittington (1992) also illustrates, equity and fairness are not always achieved. The use of block water tariffs is widespread throughout developing countries. There are two commonly accepted justifications for using increasing block tariffs (IBTs). The first is that of equity. It should help low-income households to afford water and ensure an equitable allocation of the costs of water production and distribution. Since low-income users use low volumes of water, the IBT results in higher marginal prices to the higher income households who use larger volumes of water. The price of the first block is usually set very low or in some cases is free for a volume of water essential for basic human needs (typically 25-50 litres/person/day). The second justification is that the higher prices charged for the higher consumption blocks acts a deterrent for extravagant water use and hence promotes water conservation. However, this form of tariff system does not always have the desired effect. Shared water connections and indirect purchases from water vendors result in higher unit costs per household. Households often live in dense settlements without house connections and usually share a communal tap. They either pay a flat rate per month (which is not linked to volume used) or the tap is metered, with the result that the joint use pushes the volume into the higher tariff blocks resulting in higher average unit cost being paid by the community. Households who do not have household taps often resort to purchasing water from neighbours with metered taps, who use this as a business opportunity and hence charge unit costs which would be higher than the first block tariff.

Research by Saleth and Dinar (1997) shows that the steeper the blocks under increasing block structures and the higher the marginal prices, the more likely it is that customers on the higher end will respond to marginal price increases since the price-elasticity at this end is higher. Warford (1997) concurs and reports that empirical analysis has shown that in developed countries such as Israel, Canada, USA, Australia and UK, the price elasticity of demand for water by households is between -0.3 and -0.7 (i.e. a doubling of the price of water would reduce the consumption by between 30-70%). He also found a similar trend for developing countries in Asia and Latin America, which have much wider income distributions. He warns that such generalizations are no substitute for actual local analysis of the specific water system, since a host of variables may be very location specific, such as quality of housing, per capita income and its distribution.

Also, the actual blocks have been found to be arbitrarily set and influenced by political factors. There is a mismatch between the blocks and the marginal cost of the water and there is a conflict between revenue sufficiency and economic efficiency. In some cases the subsidy for the low end users exceeds the revenue received from the high end users and operating expenses surpass revenues (Eberhard 2001). In response, Boland and Whittington (2004) propose a uniform price with a rebate that would meet the same objectives, while avoiding most of these problems. It accomplishes the intended income redistribution, makes it easier to predict future revenue and is more likely to appear fair and equitable.

Historically South Africa has had one of the most unequal distributions of income in the world, and by all accounts it is getting worse. South Africa's Gini[14] coefficient rose from 0.69 in 1996 to 0.77 in 2001 (HSRC 2004). To address this issue of affordability, the Government committed itself to providing a life-line amount of 6 000 litres per household per month free, implemented by local authorities. Initially no additional finance was provided to local governments to implement this policy. The idea was to cover the cost through cross-subsidisation within the municipal area.

With regard to Free Basic Water provision, the Implementation Strategy (PDG 2001) document notes that the legal framework for implementation of free basic water is essentially that of tariff setting which is guided by:

- The Constitution of the Republic of South Africa (RSA 1996);
- The Local Government: Municipal Systems Act (RSA 2000a); and
- The Water Services Act (RSA 1997c).

The Strategic Framework for Water Services (DWAF 2003a) also sets out a number of targets related to the provision of free basic water. These include:

- All people in South Africa should have access to a functioning basic water supply facility by 2008[15]; and
- Free basic water policy should be implemented in all water services authorities by 2005.

The policy finds its clearest expression in DWAF's Implementation Strategy Document for Free Basic Water (PDG 2001). The purpose of this policy document was to set out an implementation strategy for the policy with respect to the provision of free basic water. This document, whilst noting that much of the ultimate responsibility for delivering free basic water rests with local government, points out that they will have to operate in a context which enables them to provide subsidized services effectively. This includes appropriate national subsidy arrangements and guidance and support from other spheres of government. The document focuses on how government can provide the context for the detailed implementation strategies of local government. The Implementation Strategy Document is accompanied by a practical guideline for local authorities which outlines the specific steps that can be taken at a local level to implement to free basic water policy.

[14] To measure inequality the Human Sciences Research Council in South Africa have used the Gini coefficient, which can vary from 0 in the case of a highly even distribution of income, to 1 in the case of a highly unequal distribution (HSRC 2004).

Yet, in practice the capacity of local authorities to implement this policy is limited. Pape (2002) points out that for small rural towns and areas, there is little scope for mobilising funds through a block tariff, since most have relatively few industries or large scale users to subsidise the water costs to the poor. Further, few small urban centres have sufficient wealthy consumers to subsidise the poor. Those who cannot pay for their water are still cut off, since fees are still charged to cover the operational costs of providing the water service (Mehta & Ntshona 2004; Mosdell & Leatt 2005). As can be seen in the example of Cape Town (Figure 9), the portion of consumers in the upper income group is getting smaller while the projected percentage of low income consumers is projected to increase by 2020 due to unemployment and migration from the Eastern Cape (Gasson 2002). If the internal cross-subsidisation through the block tariff is unable to ensure access to water for all, then there is a motivation for increasing funding from central government.

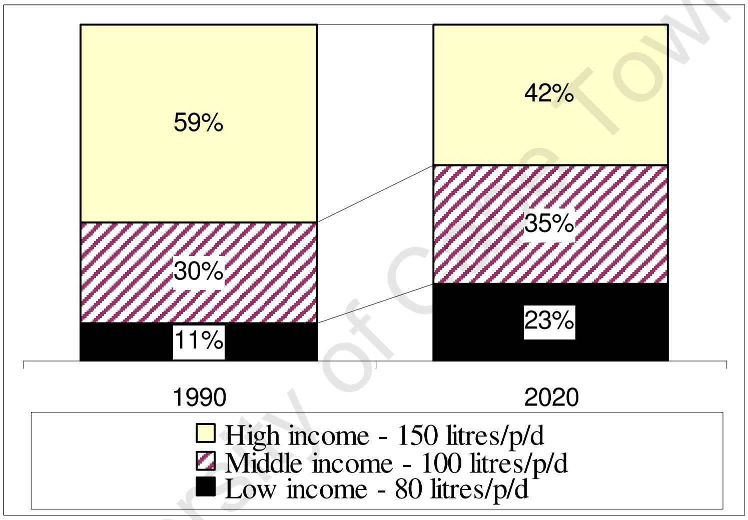

Figure 9: Cape Town annual water consumption by income group (after Gasson 2002)

A severe cholera epidemic in 2000 in several provinces and towns, including parts of Johannesburg, was linked by some to the Government's policy of full cost recovery for water and the ensuing lack of access to water in sufficient quantity and quality by the poor (Budds & McGranahan 2003). This, together with the fact that in 2003 it was reported that only 57% of the population had access to free basic water services (Kasrils 2003), led to introduction of the Equitable Share policy.

Subsidies in the water sector in South Africa take the following forms (DWAF 1997; DPLG 2004):

- Capital subsidies to assist the development of bulk infrastructure;
- Capital subsidies to assist with household access to water and sanitation services; and

[15] Recent field research reveals that at current levels of funding and rates of services delivery, the elimination of water backlogs by 2008 will not happen (Everatt et al. 2007).

- Operating subsidies from the Equitable Share policy.

The capital subsidies were mainly delivered through the Consolidated Municipal Infrastructure Programme and Local Economic Development programme which have now been amalgamated under the Municipal Infrastructure Grant (RSA 2004).

The Equitable Share is currently composed of two parts. Firstly, the I-grant component which is to ensure that each municipality has sufficient funds to ensure a functioning administration. Secondly, the S-grant, which is the largest portion, is structured to ensure that low income households in all municipalities receive access to basic municipal services, viz. water, sanitation, refuse removal and electricity (RSA 2005). This is based on specific weightings, viz. water (23.3%), electricity (41.9%), sanitation (11.6%) and refuse removal (23.3%) (Whelan 2004).

Internationally, most countries have some form of social assistance programme to ensure service delivery to the poor. In higher developed countries these programmes are generally in the form of a comprehensive social security system which is provided by central government, while public service delivery assistance lies with local governments (PDG 2001). Most systems have some mechanism for central government to assist the local level to meet its regulated duties. A common approach is to use some form of equalisation grant, such as the Equity Share funding in South Africa, which recognises that local governments have differing capacities to raise revenue within their boundaries, as well as differing expenditure needs. These often do not correspond. This equalisation funding is aimed at addressing this mismatch (Parnell et al. 1998).

Two international examples of national scale water subsidies in Chile and Colombia were investigated by the Palmer Development Group (PDG 2001). They found that in Chile, an individual means tested subsidy was introduced, in which households were screened using a socioeconomic classification system based on an interview in the homestead. Eligible households were awarded a subsidy that covered between 25-85% of water and sanitation bills for a period of three years. The revenue for subsidisation came from national taxation funds. In Colombia, the subsidy was based on a geographical classification of households. Based on guidelines developed by central government, all dwelling were classified into six socioeconomic groups based largely on neighbourhood characteristics. Households in the lower three groups received a subsidy, while the upper three paid a surcharge to cover the subsidy. This local cross-subsidisation was supported by regional and national transfers as required. The targeting systems in both cases showed large errors of inclusion, where consumers not eligible had also received a subsidy. The Colombian system has much lower levels of exclusion however. These examples illustrate the need for three key areas to be addressed for ensuring equitable access, especially to the indigent. Firstly, it is not possible to provide access to people who are “invisible” to the municipality. All potential recipients need to be registered with the municipally in order that they be factored into the supply plans. Secondly, the provision of the services should be based on the need and not the ability of the recipient to pay. Finally, targeting mechanism should be developed to distinguish the indigent from the paying customers (Parnell & Pieterse 2007).

In developing countries, i.e. middle and low income, there is seldom a similar comprehensive social security net; however, the need is much greater. Since poor local authorities are less able to mobilise additional local revenue to support the delivery of services, especially to the indigent, well designed intergovernmental transfers are particularly important. In South Africa the National Indigent Policy (DPLG 2004) has been developed to assist the calculation of the Equitable Share. It would seem to follow the Chilean example, and is based on the household income. Each municipality receives a share of subsidy funding based on the number of indigent inhabitants under its authority. This policy works on the notion that all households can afford to pay for services unless they can prove otherwise. Yet this is not a simple method. There is no common criteria as to what indigence is. Each municipality has had to develop its own guidelines and administrative procedures, resulting in different levels for different municipal areas. For example, the City of Cape Town set their indigent level at R1 640 per month, whilst the Cape Agulhas Municipality (which has jurisdiction over Bredasdorp) set theirs at only R1340 per month (City of Cape Town 2006a; Visser 2007b). At the same time a national standard income poverty indicator is used by the Department of Provincial and Local Government (DPLG), based on the National Treasury guideline for calculating the equitable share. This is based on household expenditure with the limit currently set at R1 100 per month. This disparity further illustrates the financial flexibility that a large urban centre has over the smaller municipalities.

As will be illustrated in the case study in Part 4, projected climate change will place an additional stress on small towns, especially in their role of ensuring the delivery of basic services. The increased costs, and hence unit prices to be charged to customers, will put undue financial strain on the low and middle income consumers.

3.4 Summary

In this chapter the glaring gap within the literature on small towns and small scale water systems emerges. The focus to date has mainly been on large cities, addressing the problems of urbanisation and service delivery, and on the rural areas where economic development projects have been developed to reduce the migration to the large urban areas. The issues facing small towns appear to be relatively absent from the debates. This is partly due to the problem of inconsistent definition, where different countries view small urban centres either as urban or as rural, and also due to a lack of synergy between different government departments which has resulted in uncoordinated infrastructure planning. Small towns, through their lack of representation at the higher tiers of government, become further marginalised through exclusionary policies both economically and in terms of service provision.

In the developing world, poverty in small towns is not only linked to low incomes, but also to low levels of service delivery as defined by the Millennium Development Goals. The delivery of water services in small towns is a case in point. Whilst the figures internationally for people with access to safe water in small towns are better than for those living in villages, they are still a long way off the large cities levels of access. Small towns are hampered by low levels of human and financial capacity to both plan and manage water services. Whilst the situation in South Africa shows many similarities with the international experience, this problem is not confined to developing countries only. The literature also provides examples of similar limited technical capacity in small water service providers in developed countries.

Poor cost recovery coupled with high water losses in these small systems, threatens the financial viability and has in some cases resulted in the disruption of service delivery. When water is viewed as a commodity, the water service is assessed on financial terms and not social ones. Yet, health benefits are more important for the individual as well as for the state in terms of health care outbreaks of water related epidemics such as diarrhoea and cholera. On the other hand, the concept of "public goods" stresses the developmental aspects of the services. However, this does not imply that the service comes at no financial or social cost. A balance needs to be struck between covering the cost of service delivery and ensuring that all people have adequate access to clean water. This may involve cross-subsidisation between users as well as across sectors and tiers of government.

Rising block tariffs are consistent with cost recovery, since they allow for cross-subsidisation from high end users to low end users and also introduce conservation incentives for the top end users. However, they have their own set of problems. The most obvious is that small towns generally do not have the higher end users to pay the high block tariffs required to subsidise the lower end users. The result is that the poor either use far less water than what would be described as sufficient for basic needs, or they get cut off from the system due to non-payment. The notion of affordability of water services is further explored in Chapter 7, where a case study of a small town and the impact of projected climate change on the cost of water supplies is investigated.

South Africa, as in other countries, has introduced an indigent policy through the Equitable Share grant, which is designed to provide local municipalities with a subsidy for each indigent household to ensure that they receive the basic amount of 6 kilolitres per month. However, it was found that local municipalities have differing definitions and measures of indigence, which results in the implementation of the free basic water being inconsistent across the country. Large urban centres are able to provide a larger social subsidy than smaller centres and this bring into question the notion of equitable water access. People living in small towns are discriminated against due to their geographic location, size of settlement and scale of their water provision system. The lack of financial and human capacity results in a limitation of the delivery of basic services, resulting is a dependence on external grants.

The discussion on the issues of access appears to be confined to physical infrastructure and cost recovery, but the literature is generally silent on how access will be affected by climate change. The impact of projected climate change on these small systems will no doubt provide an additional stress, where reduction in the available water resources will most probably increase the cost to deliver water and hence make it more difficult to cross-subsidise the basic free water supplied. This is investigated in the next chapter.

CHAPTER 4

4. Climate change: urban water resources

In Chapter 2 it was shown that one of the key threats to water security is water scarcity. However, beyond scarcity, water security is also about risk and vulnerability. This notion of *vulnerability* is a term used in research communities dealing with natural hazards and disaster management, poverty and development, livelihoods, land change amongst others and has been conceptualised in different ways (Fussel 2007). This has become particularly problematic in global climate change research, since it bring together researchers from all these communities. Vulnerability for the purposes of this study is defined as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity" (IPCC 2001b: 995). Climate change poses a threat to water security especially for many of the poorest countries and households. Of course, this threat is not limited to poor countries since wealthy countries will also experience the impact of changing climate and weather patterns. However, it is poor people and countries which lack the financial resources to reduce the risk through firstly preventative action, and secondly through adaptation to impacts or restoration if damage is inflicted by extreme weather events.

Current projections by the Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC) indicate that the global average surface air temperature is projected by models to increase by 1.4 to 5.8^{O}C by 2100 relative to 1990 and will be accompanied by regional variations in precipitation. In addition, there would be changes in the variability of climate, and changes in the frequency and intensity of some extreme climate phenomena. Both natural and human systems are vulnerable to climate change and the impacts on some ecosystems may be irreversible. Developing countries, because they generally have least resources to adapt to these changes, are the most vulnerable to the impacts of climate change, with Africa being identified as the most vulnerable continent (IPCC 2007b).

Current climate modelling scenarios suggest that there will be significant climate change impacts in South Africa, even under a "business as normal" global emissions scenario (Kiker 2000). Climate change is expected to alter the present hydrological resources in southern Africa and add pressure on the adaptability of future water resources (Schulze & Perks 2000). South Africa's rainfall is already variable in spatial distribution and unpredictable, both within and between years. Much of the country is arid or semi-arid and subjected to droughts and is rated as one of the twenty most water deficient countries in the world (Ashton & Haasbroek 2000; DEAT 2004). Since water is currently a limiting resource for development in South Africa, a change in future water supply could have major implications for sectors of the economy, such as agriculture, forestry, power generation etc.

Although climate change issues seem minor compared to the pressing needs of poverty alleviation, health, hunger and economic development, it is becoming increasingly clear that the achievement of development goals, such as those related to food and water, can be seriously impeded by climate impacts. Infrastructure decisions made today lock us into inappropriate patterns of behaviour for many years to come, especially water infrastructure with long life spans operating under new climate patterns. It is for this reason that the linkages between climate change and development are receiving more attention in political and scientific circles. Development can be planned in such a way that that development goals are achieved, while at the same time, vulnerability to climate change is reduced, facilitating a sustainable development that realises economic, social and environmental (local and global) benefits (Markandya & Halsnaes 2002; Davidson et al. 2003; Huq et al. 2003; Argrawala 2005; Munasinghe & Swart 2005; Grubb 2006; OECD 2006; Reid & Vogel 2006; Stern 2006).

The collective opinion in recent literature on adaptation is that it is essential that the impacts of climate change be moderated in the poorer parts of the world, where projected levels of poverty will be exacerbated under future by climate change scenarios. It is the countries with the fewest resources that are most likely to bear the largest burden of climate change in terms of loss of life, adverse effect on income and growth, and damage to general living standards, such as access to safe water, energy and shelter (Stern 2006).

At a political level in South Africa it has been acknowledged that "it is possible that the effects of global climate change will influence the availability of water and patterns of use during the next few decades" (Kasrils 2002). Further, research suggests that water resource planners should account for climate change when planning to meet South Africa’s development objectives and that the management of water resources at a local level needs to be closely integrated into the development plans of local governments. There is currently a disjuncture between the integrated development plans and water service development plans, since the former is focused on poverty alleviation and access to services, while the latter on availability of and demand for water. This is discussed further in Chapter 5.

This chapter investigates the linkages between climate change and the previous two chapters. The first part of this chapter introduces the approach taken by the climate change academic and policy communities in assessing the impact of climate change on water resources and the resultant impact on individuals, communities and countries.

The second section of this chapter considers the approach by urban planners to concerns of climate change and how urban environments are located in the climate change discourse. This is addressed both in terms of mitigation and adaptation, and specifically draws attention to the fact that climate change is a source of uncertainty that will become increasingly relevant to urban service infrastructure planners in the future. Climate change is widely reported to lead to more extreme weather events, but perhaps more importantly, in many areas it is expected to have incremental impacts on the natural resource base on which urban areas depend. Local governments build costly infrastructure to meet expected future demand and therefore, just like other uncertainties such as demographic and socio-economic changes, climate change uncertainty should also be factored in. Most poor countries have short-term priorities and hence focus primarily on poverty reduction and development and not on the risks of longer term climate change impacts (Davidson et al. 2003).

4.1 The climate change response and its role in the water sector

Human induced climate change arose as an issue of international concern in the early 1970's. It was not until 1988 that the Intergovernmental Panel on Climate Change (IPCC)[16] was established to develop a scientific assessment of the problem and possible responses. While there is a level of uncertainty around the extent of human-induced climate change, the IPCC (IPCC 2007a) concluded that the balance of evidence suggests a discernable human influence on global climate.

The natural greenhouse effect is due to outgoing long wave radiation which is trapped by certain gases and then warms the earth. These gases are known as greenhouse gases and include water vapour, carbon dioxide, methane, nitrous oxide, chlorofluorocarbons and ozone. Water vapour has the largest "greenhouse potential" and, together with carbon dioxide, is one of the main causes of the greenhouse effect (Shackleton et al. 1996).

Over the past few decades, the global temperature has been increasing due to anthropogenic GHG emissions. Human activities release greenhouse gases (GHGs) into the atmosphere, which include carbon dioxide from energy production, methane and nitrous oxide from land use change and agriculture, and three trace gases. A combination of intensive agriculture, the burning of fossil fuels and industrial processes have raised the levels of CO_2 in the atmosphere resulting in an enhanced greenhouse effect. The concentration of these gases has increased by 34% from 1750 to 2005. This has resulted in the average linear warming trend over the past 50 years (0.13 °C per decade) being nearly twice that for the past 100 years (IPCC 2007b).

[16] The major activity of the IPCC is to prepare comprehensive and up-to-date assessments of peer reviewed policy-relevant scientific, technical, and socio-economic information relevant for understanding the scientific basis of climate change, potential impacts, and options for mitigation and adaptation. The First Assessment Report was completed in 1990, the Second Assessment Report in 1995, the Third Assessment Report in 2001 and the Fourth Assessment Report in 2007. The reports are comprised of three working group volumes and a synthesis report. Working Group I assesses the scientific aspects of the climate system and climate change; Working Group II assesses the vulnerability of socio-economic and natural systems to climate change, potential negative and positive consequences, and options for adapting to it; and Working Group III assesses options for mitigating climate change by limiting greenhouse gas emissions.

According to the IPCC's Fourth Assessment Report (2007b), a warming of 0.4 ^{0}C is projected for the next two decades for a range of emission scenarios. Even if the concentrations of all greenhouse gases had been kept constant at year 2000 levels, a further warming of 0.2 ^{0}C would be expected. Rising levels of GHGs are expected to continue in the future, which will cause global temperatures to increase by between 1.4 and 5.8 ^{0}C by the end of the 21^{st} century. This is two to ten times the observed global warming of the past century. This warming is likely to have a significant impact on the global environment. Mean sea level is expected to rise 15-95 cm by 2100 due to the melting of the icecaps, causing flooding of low lying areas and other devastation. Extreme climatic events are expected to become more frequent. The Stern Report (2006) calculates that these projected impacts are likely to reduce global living standards by between 5-20%. Because atmospheric changes have cumulative and lagged responses, the effects of what is happening at present will be felt increasingly over the coming decades, even if emissions are stabilised at current levels.

Long-term trends spanning 1900 to 2005 have been observed indicating changes in precipitation over many large regions, specifically recent drying in the Sahel, the Mediterranean, southern Africa and part of southern Asia (IPCC 2007b). Climate impacts are transforming the nature of global water security; firstly, through climate variability and, secondly, in the future through projected climate change impacts. Callaway (2004) argues that there are more conceptual similarities than differences between the adjustments that are made to cope with climate variability[17] and those made to adapt to climate change[18]. The obvious similarity is that the aim of both types of action is to avoid meteorologically induced damages when predicting them is subject to some error. Both actions have the potential to improve society, whilst making decisions under some risk, both involve reallocating scarce resources to make the adaptive adjustments. The major difference, according to Callaway, between variability and change is that historical records are more reliable for planning for variability than the reliability attached to climate prediction models, in other words, the variability in the existing climate is more easier to plan for than the variability associated with alternative climates. Notwithstanding that, many poorer countries are unable to manage even their current variability, not because the necessary strategies are unclear, but because they lack the means to implement them. Muller (2007) questions why they should consider future impacts, when they are unable to manage their current droughts or floods.

While the threat due to rising temperature is firmly established on the international agenda, the role that this will play in future climates is less certain. Global warming will transform the

[17] Climate variability – variations in the mean state of the climate on all temporal and spatial scales beyond the individual events of the weather (IPCC 2001a).

[18] Climate change – any natural change in climate over time, whether due to natural variability or because of human activity (IPCC 2001a).

hydrological patterns that determine the availability of water. Global modelling projections indicate complex outcomes that will be shaped by micro-climates. Managing uncertainty will therefore become a key issue in ensuring sustained water supplies. Water infrastructure is crucial for reducing the impacts of climate unpredictability and mitigating related risk, and has a major influence on the capacity of households to absorb shocks. However, globally there are large inequalities in access to infrastructure. For example, the USA stores about 6000 cubic metres of water per capita, whereas Ethiopia only 43 cubic metres. Even wealthy countries are exposed to climate impacts and risks, but they have the resources and capacity to ensure a lower vulnerability to climate induced impacts. It is usually the poor who bear the brunt of water related shocks. For example, the 2000 floods in Mozambique reduced the country's GNI[19] by 20%. (Watkins 2006).

In order to minimise and cope with these climate induced impacts, adaptation is therefore required at national, community and at the individual level. Various types of adaptation measures can be distinguished to identify the response measures, including anticipatory, autonomous and planned adaptation (IPCC 2007a):

- *Anticipatory adaptation* – Adaptation that takes place before impacts of climate change are observed. This has also been referred to as proactive adaptation.
- *Autonomous adaptation* – Adaptation that does not constitute a conscious response to climatic stimuli, but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. This has also been referred to as spontaneous adaptation.
- *Planned adaptation* – Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change, and that action is required to return to, maintain, or achieve a desired state.

The IPCC (2001b: 18) defines adaptive capacity as "the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences". However, this definition of adaptive capacity explicitly confuses the less predictable aspects of climate change with the more predictable gradual changes, and is evidence of how the failure to separate them out when addressing vulnerability has spread to the level of developing practical responses. Midgley (in Midgley et al. 2007) proposes that this confusion be resolved by separating out the adaptive capacity needed for impacts of and vulnerability to unpredictable extreme events from the more predictable and gradual changes in climate. Two types of adaptation are therefore suggested, viz.:

[19] GNI: Previously known as Gross National Product (GNP), Gross National Income comprises the total value of goods and services produced within a country (i.e. its Gross Domestic Product), together with its income received from other countries (notably interest and dividends), less similar payments made to other countries.

- *Resilience-type adaptive capacity* aimed at reducing system sensitivity and increasing system resilience, especially in anticipation of extreme climate events; and
- *Acclimation-type adaptive capacity* aimed at reducing system sensitivity to gradual changes in average climate conditions, in anticipation of predictable trends in stimuli, or key thresholds in climate drivers.

Owing to climate variability and the incidence of extreme events a need currently exists for resilience-type responses, such as disaster management and insurance approaches, to cope with this risk. This would involve enhancing the capacity of responses (infrastructure and human capacity) that are already in place. However, under normal climate conditions no need would exist for acclimation-type adaptation. For example, in the agricultural sector, initial phases of climate change might be adapted to by varying the date of planting, row spacing and other inexpensive shifts. Key thresholds of change that would indicate the need to shift crop genotype or even crop species would be identified, i.e. acclimation-type adaptation. The research agenda and/or technology transfers (such as crop varietal breeding or import) required to support farmers through a series of anticipated shifts could then be scheduled, and the appropriate capacity developed. This splitting of two major adaptation types facilitates a focus on two distinct sets of practices, and could even allow strategies and finance for them to be prioritised in a more logical way.

Mitigation and adaptation are the two prongs of the strategy for tackling the threat posed by climate change (as is illustrated by Figure 10). Mitigation is an imperative and concerns the reduction of the global GHG emissions generated by the development paths followed initially by developed counties and now more recently by some developing countries (such as South Africa, India, Brazil, China and Mexico). If the international community fails in this regard, human development in the 21st century will suffer a severe setback. Even if countries meet the goals of the Kyoto Protocol, the world is committed to some warming and hence the need to adapt to climate change induced impacts is very real. Adaptation[20], on the other hand, is about recognising that some climate change is inevitable and that many of vulnerable countries and communities have least resources to adapt. Adaptation seeks to reduce the vulnerability of human and natural systems to the impacts of climate change at a local level. Adaptation is necessary to ensure that development goals are achieved under these impacts. However, constrained by limited capacity and sometimes weak governments, few developing countries have initiated country strategies for adaptation.

[20] Adaptation: defined as the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC 2001b)

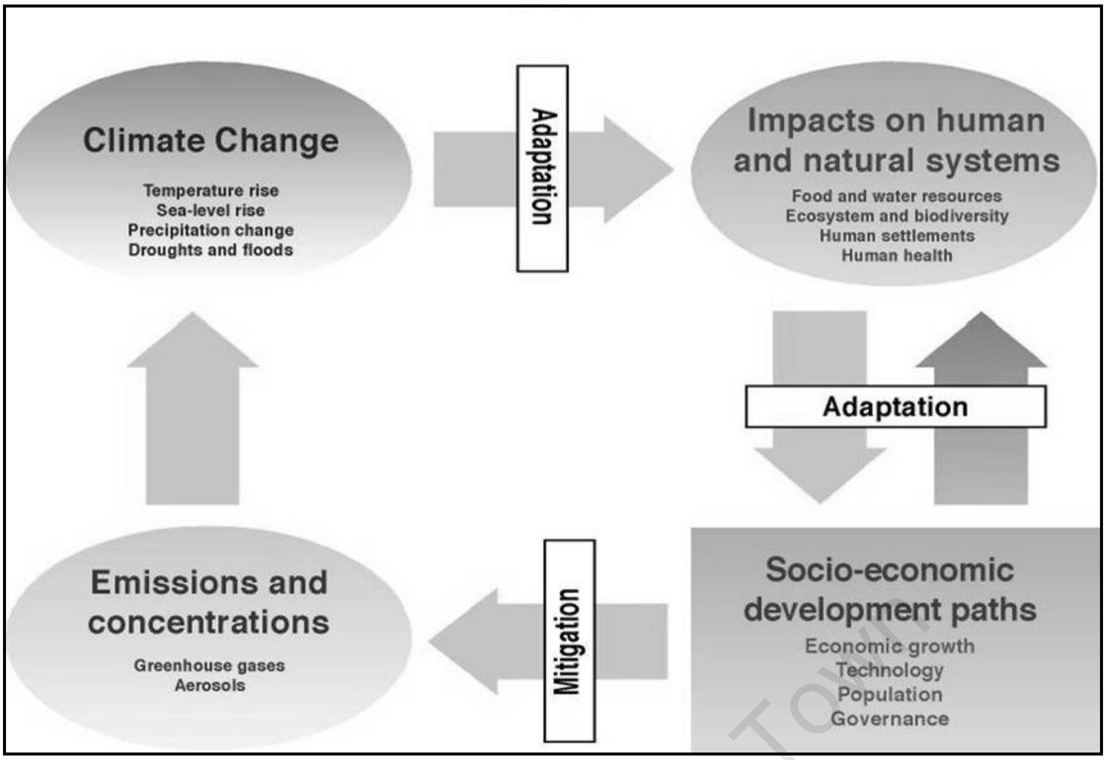

Figure 10: Climate change as an integrated framework (IPCC 2001a)

The need to consider both adaptation and mitigation as essential components of climate policy has raised questions as to how they may be combined or traded off against one another, and whether or not synergies can be created between the two options. In response, Klein (2006) suggests that:

- Trading off adaptation and mitigation is not a zero-sum game. Climate policy does not involve allocating a single fixed budget between adaptation and mitigation. For example investments by energy intensive industry to reduce GHG emissions, will have very little to do with budget allocations by water resource managers;
- Real synergies between adaptation and mitigation are few and far between. Synergistic measures would involve many different role players who would not normally work together, thereby reducing the efficiency of the measures; and
- Research on the links between adaptation and mitigation needs to go beyond economic and integrated assessment modelling.

Tol (2005) and Klein (2006) argue, that adaptation and mitigation should be kept largely separate in the policy debate due to three distinct mismatches:

- **Scale:** Primarily mitigation is a matter of national governments in the context of international negotiations, whereas adaptation is a matter for local managers of natural resources and services, in the context of a regional economy and society. This issue of scale was taken up in the context of small towns and their access to resources in section 3.1.

- **Client:** Economic evaluation of mitigation is addressed, first and foremost, at ministerial level whereas economic evaluation of adaptation is addressed at local water managers, health officials, coastal zone managers etc. This implies that decision criteria, parameters and reporting are different for adaptation and mitigation;
- **Time scale:** Economic evaluation of mitigation considers short-term actions because of the potentially detrimental long-term developments, whereas economic evaluation of adaptation looks at short-term action in the context of short- to medium-term developments.

The focus to date has mainly been on mitigation of GHG emissions in terms of policy development and financial support and has been structured under the UNFCCC[21]. Stern (2006) therefore argues that an equitable international response to climate change should not just include action on mitigation, but also on finding ways of working with vulnerable countries to ensure that their growth and poverty reduction goals are not compromised, since the adverse effects will be felt most acutely by poor people in developing countries. This is mainly due to their geographic and climate locations, their high dependence on agriculture and natural resources, limited human capacity and financial resources to cope with climate impacts. However, support for adaptation in developing countries has to date been fragmented and piecemeal. Very few countries have prioritized adaptation in key planning documents such as poverty reduction strategy plans (PRSP), integrated resource management plans or urban development plans (Watkins 2006; Mukheibir & Ziervogel 2007).

The response of the international community to this problem of climate change is organised under the UNFCCC, which was adopted at the 1992 Rio Earth summit. All countries that have ratified or acceded to the convention are parties to the UNFCCC. Whilst developed countries (Annex I Parties to the convention) have more specific commitments under the convention, all parties have agreed to adopt national programmes for mitigation and adaptation and describe these in “national communications”. Specific mitigation commitments for industrialised countries were negotiated and included in the Kyoto Protocol[22], which binds them to reduce their collective GHG emissions during the period 2008-2012 by at least 5% compared with 1990 levels (UNFCCC 1997).

In terms of adaptation to climate impacts, the convention and protocol already embrace many commitments on adaptation. All parties to the convention have agreed that “the specific needs and special circumstance of developing country parties, especially those that are particularly vulnerable to the adverse effects of climate change should be given full consideration”. There are currently four global funds for financing adaptation viz. the Global Environment Facility

[21] UNFCCC – United Nations Framework Convention on Climate Change

[22] The Kyoto Protocol came into force in 2005.

Trust Fund, the Least Developed Countries Fund, the Special Climate Change Fund and the Adaptation Fund (Mohner & Klein 2007). Parties have agreed that a share of the proceeds from certified mitigation activities, from for example the Clean Development Mechanism (CDM), be used to assist developing country parties that are particularly vulnerable to the effects of climate change to meet the costs of adaptation. To date adaptation funding has been channelled through the Global Environment Facility (GEF). More recently an Adaptation Fund has been set up under the protocol and is financed by a 2% share of the CDM projects (GEF 2004).

The core mandate of the GEF has been to fund the incremental costs of global environmental benefits. Unlike mitigation where the benefits are of a global nature, climate impacts are localised and on different geographical scale. Adaptation does not fit into this core mandate. So the benefits of this funding mechanism will not be realised for most vulnerable areas and communities. Further, the incremental benefits of adaptation are often not as clear as for mitigation projects, with many project activities requiring better development planning or consideration of the long-term effects of reduced or enhanced rainfall.

The present approach by the UNFCCC and other UN agencies it to separate climate adaptation from the normal development and management activities. The result is that much of the adaptation funding has been allocated to capacity building around climate change and has not included the provision of adequate funding for the implementation of adaptation strategies (Bouwer et al. 2006).

In addition, international aid has in recent times fallen in both absolute and relative terms (IPCC 1996; Gleick 1998a). Developing countries and poor communities cannot therefore rely on these sources of funding to improve their resilience to climate impacts. As adaptation activities can be capital intensive and the benefits highly localised and immediate, the real challenge will be the development of secure, adequate and predictable funding to meet priorities. Local actions and initiatives will need to be harnessed to improve their resilience.

The following general categories of adaptive responses could be considered by decision makers and planners (after Allen Consulting Group 2005):

- **Inaction and bear the loss:** This occurs when those affected have no capacity to respond, or where the costs of adaptation measures are considered to be too high in relation to the risk.
- **Share the loss:** In large societies losses are shared through public relief, rehabilitation, and reconstruction paid for from public funds or insurance.
- **Modify the threat:** It may be possible to exercise control over the pending environmental threat such as flood-control measures in the form of dams and levees.
- **Prevent effects:** Examples in agriculture include fertiliser application, new crop varieties and pest and disease control.

- **Change use:** This should be considered where the continued practice of an activity is impossible or extremely risky.
- **Change location:** Relocation is a more extreme response, but may be necessary where there is a high risk of incurring large losses and costs.
- **Research:** The process of adaptation can also be advanced through research into new technologies and methods of adaptation. The documentation of historical impacts and responses may highlight trends and appropriate response measures for replication.
- **Educate, inform and encourage behavioural change:** This would ensure mainstreaming and integration of adaptation policy into ongoing sectoral planning, budgeting and decision making processes.

Whilst mainstreaming of adaptation is already happening in developed countries, it is not always evident in developing countries. Institutional change and the development of local government adaptive capacity is sadly lacking. Efforts made to mainstream adaptation to climate change have proven relatively successful in the agriculture sector, a sector which has a long history of working at mitigating drought impacts. At the national policy making and planning level in other sectors such as the water sector, this has not been the case (Huq et al. 2003). Climate change adaptation measures are often difficult to separate from other issues especially with respect to natural hazards and climate variability. Current policies for climate risk management, tend to be divided between the agriculture and water sectors and therefore adaptation policies would be best if implemented in these sectors, rather than set up new institutions.

Adaptation actions should be integrated into development policy and planning at every level. It should not be an add-on or an after thought. Development itself is key to adaptation, since adaptation should be an extension of good development practice and should reduce vulnerability. All levels of government should ensure that policies, programmes, budget frameworks and projects take account of climate change and adaptation strategies.. However, there is little evidence of this (Burton et al. 2002; Mukheibir & Sparks 2006; Stern 2006). Many development practitioners view climate change as a long-term problem that does not compare with the urgent needs such as food security, HIV/AIDS or air pollution. The climate change discourse is based on long-term projections, typically 50 - 100 years, whereas most development scenarios are for a much shorter period, for example the Millennium Development Goals are set for 2015 (Huq et al. 2006).

The linkages between access to water and climate impacts on water supplies are less known or understood by decision-makers and planners, particularly in developing countries, due to the fact that they normally focus their attention on conventional development strategies like growth, employment and poverty alleviation. As shown in Figure 11, sustainable development is considered to be a special (and rather obscure) subset of conventional development by most development practitioners and decision-makers. The environmental aspects of sustainable development, and ultimately climate change, are themselves perceived as a minor subset of the environment (MIND 2006). Therefore adaptation strategies to climate impacts, will only be taken seriously by decision makers if they are successfully integrated into national and local sustainable development goals and should not be seen as an add on.

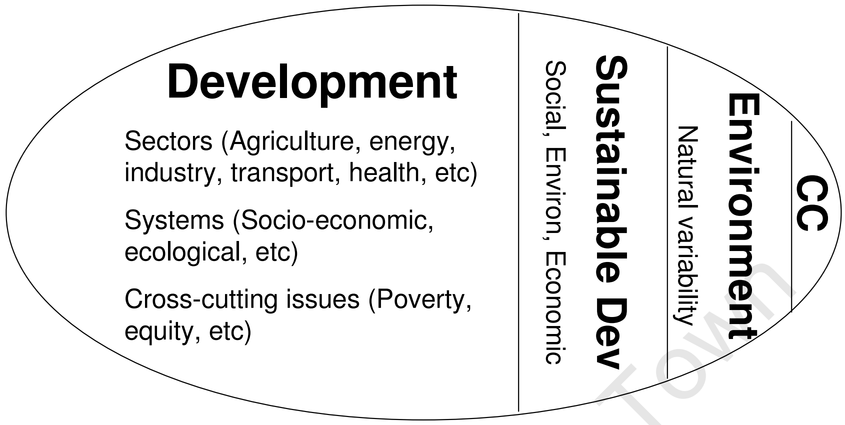

Figure 11: Linking climate change to development (MIND 2006)

Whilst climate change forms a small subset of sustainable development, it has to a large extent been pursued by a different community and has had a different scientific and political discourse. The two communities have different priorities and often operate on different time and space scales (OECD 2006). The climate change scientific discourse has revolved around the Intergovernmental Panel on Climate Change (IPCC), through its first to fourth assessments The political discourse has been debated through the United Nations Framework Convention on Climate Change (UNFCCC), but the agenda has mainly focused on mitigation of greenhouse gas emissions. There has been a shift in focus in recent years, where policy makers and academics have begun to debate the issues surrounding adaptation to future climate impacts and to consider the implications for the future (IPCC 2001b; Burton & May 2005). However, this has mainly been focused at the national or regional level. National Adaptation Plans of Action (LEG 2004) are developed at national level, for example, but the resources and capacity at local level to deal with the implementation and operational issues are not always considered.

The climate change agenda is largely driven by the scientific community, who by broad consensus, believe that global climatic change is a real problem and that it will alter the hydrological cycle in a variety of ways. Previously water planning and management relied on the assumption that the future climate would be similar to that of the past. The IPCC therefore urges water managers to begin a systematic re-examination of engineering design criteria, operating rules, contingency plans and water allocation policies and emphasises that water demand management and institutional adaptation are the primary components for increased system flexibility to meet the climate change uncertainties (IPCC 2001b; Burton & May 2005).

Present perspectives of the scientific community on adaptation deficit, specifically in the water sector, are described by Burton and May (2005) as a view of the climate change increment rather than an assessment of the problem as a whole. Focus to date has been on the direct impacts of climate change on water flows, but little attention has been paid to the secondary effects on food security, natural ecosystems, health, poverty and economic development. The cautious assessment of the impact on water resources avoids painting an alarming picture of large scale development interruptions due mainly to climate change impacts. This sentiment is supported by other researchers in the fields of subsistence agriculture, municipal water supply and regional conflict (Bergkamp et al. 2003; Miller & Yates 2004; Niasse 2005; Reid et al. 2005; Schulze 2005a; Ziervogel et al. 2005).

When the problem of climate change is disaggregated into potential impacts on specific sectors, there appears to be a lack of any sense of urgency. If one considers the United Nations Framework Convention on Climate Change (UNFCCC) the source of this frame of mind can be found. Article 2 of the Convention (UNFCCC 1992) has had two profound consequences. Firstly it developed the simplistic assumption that the solution to the climate change problem lay in the reduction of greenhouse gas emissions through mitigation. Secondly, it presents the problem as one-directional relationship in which climate change is the cause and the impacts on human society is the result (Burton & May 2005). Burton and May (2005) argue that it is misleading to refer to climate change impacts, since the consequences of climate impacts are a result of an interactive process between human activities and climate. Therefore, failure to adapt urban water management systems well enough and quickly enough account for larger portions of water problems than the actual or projected climate impacts.

The recent IPCC Fourth Assessment Report now shows signs of recognising the importance of climate change on local water resource management. Chapter 3 of the Impacts, Adaptation and Vulnerability report specifically mentions that current water management practices are unlikely to be adequate in reducing the negative impacts of climate change on water supply reliability. It suggests that improved incorporation of current climate variability in water related management would improve the resilience to future climate change impacts (Kundzewicz et al. 2007). However, the focus of the IPCC is still at a regional and national scale, leaving local issues such as equitable access and sustainable institutional capacity to manage climate impacts unaddressed.

At other forums outside of the UNFCCC and IPCC, the issues of declining water resources, lack of access to safe drinking water, efficiency of use, water rights and water management are receiving a lot of attention. The message that contrasts with that of the IPCC is that the world's water resources are already overstretched, and therefore further climate impacts will bring major crises where rainfall is projected to decrease. Many of the actions required now to deal with current water scarcity are being advocated by the UNFCCC as adaptive measures for future climate impacts. The development community however, argues that these measures should be funded and implemented now to avert the current crises and thereby minimising any future crises (Burton & May 2005).

Burton and May go on to explain that in recent times, developing country parties to the Convention have started to push for financial assistance for adaptation and to attempt to focus the climate debates on issues such as poverty, equity and development. In their opinion, two perspectives on adaptation have emerged, viz. adaptation is a secondary issue under the Convention and has a role in determining the urgency for greenhouse gas emission mitigation actions, and secondly adaptation is made to stand for all that is currently wrong in the development sector. For example, all the deficiencies in the water management sector are implicitly attributed to the lack of adaptive capacity or financial support for adaptation under the Convention (Callaway 2004).

Planners in climate sensitive countries have the right tools for assessing the costs and benefits of various climate change options, but Callaway argues that they have little guidance on how to characterise climate change in ways that are useful to them, since they believe the climate change information has low statistical confidence levels. However, he adds that society is quite likely already adjusting to climate change, since a gradual change in the climate will induce society to make small inexpensive changes without having to differentiate the source of the climate variability. The extent to which a society is able to adapt to these climatic changes will depend on its relative adaptive capacity or resilience. The specific relationship between urban environments and climate change impacts is discussed further in the next section.

4.2 The urban environment and climate change

Until recently, there has been a conspicuous gap in the policy and research literature in relation to the urban environment and climate change[23] (Sánchez-Rodríguez et al. 2005; Parnell et al. 2007; Simon 2007a). There has been no consideration of the full extent of the interaction between urban areas and biophysical processes. The major emphasis has been on the impacts of urban areas, mostly mega-cities, on the climate in the form of global warming and the mitigation of greenhouse gases mainly from the industrial, energy production and transport sectors (ICLEI 1993). Despite urban centres being important for economic growth and social wellbeing, much less attention has been focused on the impacts of climate change on urban areas, and even less on the welfare and rights of the urban citizens, especially the poor. There has been little distinction given to crucial climate related issues facing middle and low income cities.

[23] In the urban and geographical studies literature "climate change" is often referred to as "global environmental change".

Those studies relating to cities and climate impacts have been confined to disaster mitigation and management of predominately extreme weather events such as heavy storms, cyclones and hurricanes and, to lesser extent, pending sea level rise. This is not surprising, since, as can be seen in Figure 12, the global cost of economic losses due to extreme weather events has increased more than ten fold over the 50 years up to 2005. The insurance industry too has seen an increase in the weather related damage claims made over this period (Munich Re 2005). A comparison of the disaster and the climate change discourses illustrates the commonalities and differences. Disasters tend to be one off events within a relatively short time frame, whereas climate change impacts would include more frequent and intense disaster type events as well as slower events such as sea level rise (IPCC 2007a). In section 4.1 reference was made to acclimation-type and resilience-type adaptation (Midgley et al. 2007). This distinction is useful since it facilitates a focus on two distinct sets of practices. Resilience-type adaptation would likely involve enhancing the capacity of responses that are already in place to deal with current climate variability and disasters. The emphasis would more likely be on increased funding for infrastructure, equipment, skilled staff or insurance and/or disaster relief. A focus on improving the prediction of extreme events, and their consequences would increase in importance with their increasing frequency. For acclimation-type adaptation, by contrast, there is likely to be a far higher requirement for research of appropriate responses as the climate system moves towards a new state.

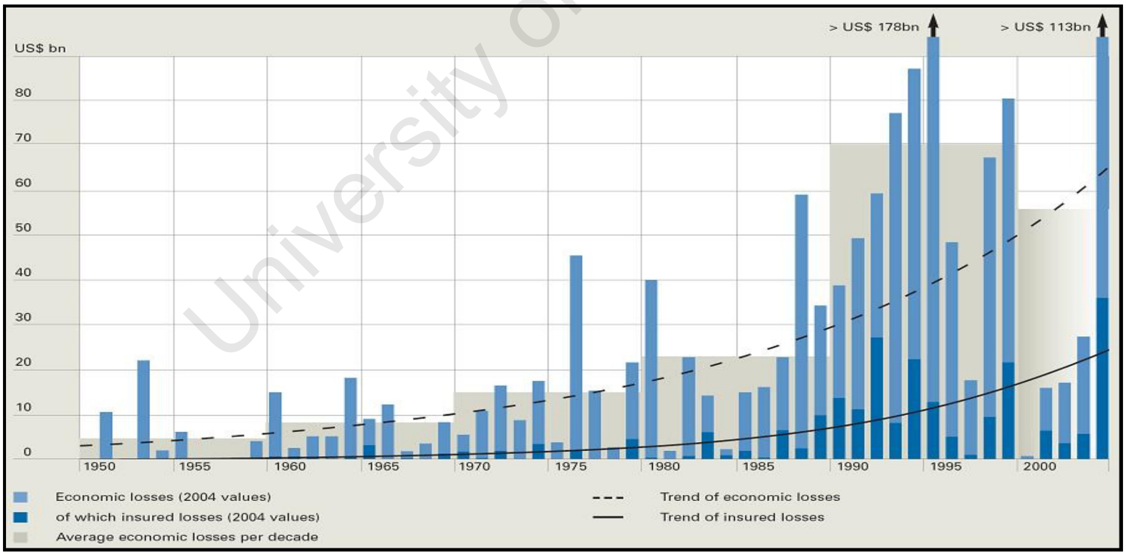

Figure 12: Rising costs of global weather-related losses (Munich Re 2005)

Even if GHG emissions are successfully reduced, societies will still need to adapt since much of the change that will occur in the first half of this century has already been pre-determined by past and current GHG emissions. To date most studies on peoples' vulnerability and adaptation to climate change have been done in rural areas and on a household level. This is true generally of the urban development agenda, which has lagged behind that of the rural agenda. Thus urban settlements have been neglected despite the fact that they may be more vulnerable as the high concentration of people makes urban settlements both particularly vulnerable to climate induced disasters and can stress limited social, financial and environmental resources. The impacts of drought are confined by the literature to mostly rural and agricultural areas. Despite urban systems' reliance on vast resources for the supply of critical ecological services such as energy, building materials, food and water, reduced availability of water, whilst acknowledged as a climate related threat, has not received much attention in the urban context. Climate change has the potential to impact on all these resources. The study of these services for urban areas is still in its formative stage and has not been fully incorporated into the climate change discourse. The converse is also true, where the failure by the urban sector to adequately address climate change on either the mitigation or adaptation fronts will result in disasters in vulnerable urban areas. More specifically adaptive efforts will require structural changes in how urban centres are planned and managed. Therefore the climate change concerns will need to be incorporated into disaster management practices as well as the broader urban planning and policy. Given the absence of information on adaptation to climate change on an urban scale, studies at other scales and contexts would need to be assessed critically to find out whether the methods are applicable to the urban scale and context (Sánchez-Rodríguez et al. 2005; Parnell & Pieterse 2007; Parnell et al. 2007). Urban climate resilience will depend on hard and soft engineering solutions together with improved climate forecasting (Wilby 2007b).

The higher concentration of people in urban areas in comparison to rural areas, makes them particularly vulnerable to two known effects of climate change:- the increase in extreme weather events and the more gradual stress on environmental resources through changes in weather patterns. The urban poor are often worse affected in extreme weather events as they tend to occupy marginal land; however, gradual degradation of the environmental resources of a city affects all (Parnell et al. 2007). Some aspects of the urban physical infrastructure such as buildings, transport systems, energy supply systems, may be affected, as is illustrated in Table 7. For example, settlements may be affected by coastal and river flooding, where stormwater drains, water supply and waste management have not been designed to meet the projected impacts. A decrease in rainfall may result in reduction of available urban water supply, with a resultant increase in the unit supply cost. Energy demand may even increase due to the need for space cooling due to an average temperature increase or more frequent heat waves.

Table 7: Key infrastructure and service impacts due to projected climate change (after LCCP 2002; and Mukheibir & Ziervogel 2006)

Decreased rainfall	More frequent drought conditions	• Reduced soil moisture and groundwater replenishment • Reduced available water for domestic and industrial uses • Potential for health impacts • Increased cost of supplying water • Increased competition for local water allocations.

Increased rainfall	More frequent and intense rainfalls resulting in flooding	• Riverine flooding and flooding of urban drainage systems • Water quality problems associated with discharges from storm water outflows • Increased likelihood of building subsidence on clay soils • Increased ground movement affecting underground pipes and cables • Increased disruption to transport systems by extreme weather • Damage to infrastructure through buckled rails and rutted roads • Increased exposure of insurance industry to extreme weather claims • Increased cost and difficulty for households and business of obtaining flood insurance cover
Sea level rise	Rising sea levels, storminess and tidal surges	• Damage to coastal beaches and low lying property
Higher temperatures	Intensified urban heat island (UHI), especially during summer nights	• Increased demand for cooling (i.e. energy) in summer • Reduced demand for space heating in winter • Heightened water demand in hot, dry summers • Water quality problems associated with increased water temperatures

Adaptation measures are difficult to plan and implement, since they require longer time horizons than the political time horizon of politicians. According to McEvoy (2007), climate scenarios indicate that climate impacts will become starkly evident by 2050. These time scales are not in the mind set of most policy makers and planners, who usually plan 15-20 years ahead at most. It is increasingly recognised, however, that infrastructure is built to last for long periods, especially in urban environments. Therefore, the major challenge for planners and policy makers is to ensure that climate change impacts are considered and fully integrated into urban planning in order to pre-empt them or at least manage the residual impacts. Autonomous adaptation on the other hand is to some extent already happening as societies react to experienced or perceived change.

Huq et al. (2007) have observed that there is a dramatic difference in the speed in which climate change has transformed the assessment of risk as compared with the speed of actual adaptation to those risks. Risk can be fairly quickly identified, adaptation is much slower. Cities in general are not easily relocated, even if threatened with sea level rise as is the case with Venice and Alexandria. Coping strategies are developed over time, especially if the threat develops gradually. Huq et al. argue that generally cities in high income countries have reduced their risks through decades of investment into housing and infrastructure, although they point out that Hurricane Katrina, over New Orleans, illustrated that these cities too are vulnerable to extreme climatic events. The important thing to observe is that whilst the inner city of New Orleans has been able to rebuild itself, the poor have suffered the largest losses since they do not have the same access to resources to rebuild their homes and livelihoods.

In addition, institutional responses to climate change are in their infancy. The literature lacks examples of state funded structural adaptation. Watershed management plans have been prepared in some cases, but according to Pelling (2003), the implementation has been slow because of broad institutional inertia, financial constraints, lack of human resources and, in some cases, the influence of powerful vested interests. In addition, the dynamic nature of linkages between levels of governance is not well understood. Ad hoc institutional responses at different scales to climate impacts are the outcome of the varied understanding of the benefits of action and costs of inaction (Adger et al. 2005). In South Africa, both adaptation and mitigation is happening in an ad hoc fashion, often driven by pressures other than climate change. The task of integrating climate change into South African settlement policies is yet to be addressed at any level of government (du Plessis et al. 2003).

In the water sector, this is aptly illustrated by Arnell and Delaney (2006) in their mapping of the competing necessity for adaptation across scales in the context of water supply in England and Wales. Firstly the national government requires that water providers put in place plans to deal with climate change to ensure the reliability of the supply and the sustainable use of the water resources at a national level. The next level of regulation are the environmental and economic regulators who require that water providers consider climate change to ensure the sustainable use of the environment and safe guard the customer against supply stoppages respectively. At the local scale, water supply institutions ensure supply under climate change by changing the management systems or instituting demand side management at the consumer level. Individual customers adapt to climate change by modifying the consumption habits by mostly responding to tariff pricing and consumption restrictions.

The trend of most international agencies and development banks has been to reinforce the control over resources by central government. In addition to this, many city planners and policy makers see climate change as a global issue or at the very least a national issue. In contrast, many climate change experts understand urban changes as a local issue that they need not understand let alone address. However, it is at this micro level that adaptation efforts are critical. As discussed further in section 5.3 a number of frameworks have been developed which are either at a national or regional level in scale or are project focused. There appears to be a gap at the city level. There is a complete vacuum in the published literature when is comes to urban climate adaptation planning, except for a few isolated initiatives such as the adaptation planning framework published by the City of Cape Town (Mukheibir & Ziervogel 2006).

Burton et al. (2002) put forward three requirements to ensure that impacts are managed effectively, viz. reducing the sensitivity, altering the exposure and increasing the resilience of a system. Attention to any of these decreases the vulnerability, but as discussed before, the level to which this is achieved depends on the adaptive capacity. Large cities may have more resources and hence a higher adaptive capacity than a small town. Under low adaptive capacity, small towns may find themselves faced with fewer options than the larger urban centres.

The capacity for municipal governments to contribute to building resilience is largely determined by their organizational structure and relationship to national government. In the past the significance of municipalities has been downplayed and failings were generally attributed to budget shortfalls and capacity shortages, rather than questioning the basic institutional framework within which they operate. A new agenda can be seen emerging in urban governance which puts it in the optimum institutional position to oversee the privatisation of local public services, on the one hand, and to strengthen the engagement of urban citizens in the democratization process on the other. However, this decentralisation is often accompanied by a lack of financial support (Pelling 2003).

Countries and urban regions are seen as vulnerable through their inability to generate the financial resources required to offset increasing vulnerability and climate induced impacts, however capacity to manage risk should not be reduced to the size of the economy alone. Other factors also play a part. However, there are few policy recommendations for reducing risk especially in urban centres from low-income countries. De Sherbinin et al. (2007) attribute this to a number of factors which are of a political, social, institutional and financial nature. They argue that climatic disasters are more likely to adversely affect poorer, more vulnerable sub-populations with the least political influence. They are unable to lobby for resources to ensure resilience against these impacts. Adaptation and mitigation measures require substantial investment and adequately functioning institutions. The low tax collection capacity of institutions and low income bases constrain the available financial resources for government to make institutional and/or infrastructural investments. Further, wealthier classes may choose to self insure instead of contributing to the public resources.

Pelling (2003) sees this problem slightly differently. In his view, cities of the global South are already pursuing risk aversion measures, but in a response to individual sectoral environmental risks, which are not integrated with economic or socio-political risks. Planning at municipal level would be further enhanced if climate information was available and integrated into a holistic planning process. The types of changes needed in urban planning and governance to climate proof a city are usually supportive of the local development goals and the policies and programmes in pursuance of the Millennium Development Goals. A municipal adaptation planning process as described by Mukheibir & Ziervogel (2007) would ensure that vulnerability to climate impacts be identified, especially those that undermine the development goals. This process is explained further in section 5.3, but involves identifying the vulnerable sectors by overlaying an assessment of the vulnerability to socio-economic stresses and of the vulnerability to climate change impacts. Specific strategies and actions can then be developed that not only safeguard infrastructural services, but also focus on building the resilience of the poor.

The application of such a municipal adaptation planning process is also applicable at the small urban centre scale, since it is at this level that people are more likely to be vulnerable due their low levels of resilience. However, the problems of political, social, institutional and financial capacity are even more apparent in the small urban context and forward planning and insurance are difficult to achieve. It is at this scale that the following chapter focuses.

4.3 Summary

The climate change response to water resources management describes the notion of vulnerability in the context of climate change, but from a top-down approach. It views the problem as one starting with climate change which results in expected damage for a given level of global climate change. However, the implications for local water management under these conditions have not been clearly articulated in the literature. This is a serious omission since an analysis of the local level, as opposed to a global or regional one, is equally important in small towns with weak fiscal and human capacity. Charged with the mandate of ensuring equitable access of clean water to all, the responsibility is compounded by the imperative of cross-subsidisation to achieve the national development goals. These local capacity issues are equally important as those additional ones which become evident through climate change impacts.

The *adaptive capacity*[24] as defined by the climate change response determines the vulnerability to the damages due to climate change impacts. It can be viewed as a methodological approach based in a scientific community that has little knowledge of how to operationalise its concerns at a local level and rather engages at an international and national level. The difficulty has been how to distinguish between *adaptation*[25] and normal business as usual development projects. It is not always easy to identify or measure the incremental resilience to climate impacts, i.e. what is the adaptation component and what is the additional cost? Communities with low levels of social, technical and financial capital, will have low levels of resilience and will therefore be unlikely to address current climate variability impacts let alone those due to predicted climate change. Whilst the issue of access has not been dealt systematically by the climate change

[24] Adaptive capacity - the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences." (IPCC, 2001b:6)

[25] Adaptation - the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2001b: 72)

community, the current literature and policy papers have developed well articulated concerns and strategies around physical water resource scarcity.

A gap between climate impacts research and urban environmental planning was highlighted. Until recently the main focus has been on the mitigation of greenhouse gas emissions and disaster management for climate induced damages at an urban level, and on agriculture and livelihoods at a rural level. The research agenda has largely missed out on the impacts on small towns and villages, especially as they relate to reduced rainfall, flooding, sea level rise and higher temperatures.

The distinction between resilience-type and acclimation-type adaptation strategies has been presented, where the former is aimed at increasing system resilience in anticipation of extreme climate events, whereas the latter aims to reduce system sensitivity to gradual changes in average climate conditions. The main focus of this thesis in on the latter type, where for example a gradual reduction of rainfall due to climate change will result in reduced available water resources to meet the projected demands of urban centres. Small cities are particularly at risk due to their limited financial and human resources. This in turn has a potential impact on access to basic water supply

At an international level, climate change impacts are largely perceived to affect only water scarcity, whilst the development sector to date has primarily focused on the access to basic services. The linkage between the two has not explicitly been made. The inter-linkage between climate change impacts and water service provision to the indigent raises the concern, therefore, that as water becomes more scarce and therefore more expensive to provide, more poor households will have their supplies restricted to avoid escalating domestic costs and arrears. This hypothesis is examined in the case study in Chapter 7. It will be demonstrated that in addition to internal cross-subsidisation and intergovernmental transfer, international adaptation funding may also need to be leveraged to compensate for the additional water service delivery costs due to climate induced water shortages

Much as in the urban debates where there is general focus on large urban centres and very little focus on small towns, the same could be said for the general focus of the climate policies and interventions. There is a disconnect between the policy makers and the people who feel the impacts of climate change. The approach to climate change has been determined and focused at the national and regional level. Funding and policy development is driven by international government bodies such as the UNFCCC and hence do not have the tools or frameworks to operate at the local level. On the other hand, municipalities operating at the local level do not have the financial or human capacity to develop or implement resilience building programmes and projects.

The absence of an integrated approach to projected climate change impacts provides a key motivation for undertaking this study. In Part 3 of this thesis, a framework and methodology for identifying vulnerabilities in the water provision system and approach is introduced, along with a tool for selecting robust strategies that are both resilient to climate change in the long-term and that also meet the development goals of the local authority and the country.

PART THREE

MUNICIPAL WATER: CLIMATE RESILIENT STRATEGIES FOR EQUITABLE ACCESS

It is wise to bring some water, when one goes out to look for water – Arab Proverb

CHAPTER 5

5. A framework for municipal adaptation to climate change in the water sector

As discussed in Part 2, the political response to climate change has been debated through the United Nations Framework Convention on Climate Change (UNFCCC). The agenda has in the past focused mainly on mitigation of greenhouse gas emissions, but recently there has been a shift in focus, where policy makers and academics have begun to debate the issues surrounding adaptation to future climate impacts and to consider the implications for the future. In addition, all parties to the Convention, including South Africa, agreed to adopt national programmes for mitigation and adaptation and have described these in their "national communications" (DEAT 2004). However, this has been focused on issues at the national level, whereas the impacts are at the local level. It is at this level that the resources and capacity to deal with the implementation and operation of adaptation strategies is required.

A number of methodologies have been developed which are either at a national level in scale, such as the National Adaptation Plans of Action (NAPA), or are project focused, such as the SSNAPP methodology developed by SouthSouthNorth and the USAID Adaptation Guidance Manual (LEG 2004; Alam & Mqadi 2006; USAID 2007). However, these methodologies do not institutionalise and integrate the approach at a local municipal level or sectoral level such as water provision. They generally start with an existing project or initiative in mind and then proceed to test it for robustness against climate impacts and then develop adaptation strategies to alleviate the identified vulnerabilities. A holistic approach is needed where the likely impacts of climate change are integrated into development planning. The climate impacts should be overlaid with existing areas of vulnerability, both physical and socio-economic. Munasinghe (2007) proposes an national approach to sustainable water resources management and policy (SWAMP) to be applied to the water sector. Whilst this is a sectoral approach, it is aimed at integrating with the national development goals and plans and not at the municipal level.

In response to the gap in the planning literature, a framework is presented in this chapter for the integration of potential climate impacts into water resources planning at a municipal level. Together with Ziervogel a framework for municipal adaptation planning was developed for the

City of Cape Town (Mukheibir & Ziervogel 2007). Drawing on this framework, a process is proposed for water resources adaptation planning, with a view to integrating it with the municipal adaptation planning tool.

In developing a framework for adapting to climate impacts at a municipal level, this chapter first outlines the obligations for countries that are signatories of the UNFCCC. An analysis of the existing legislation in South Africa, specifically the water sector, is undertaken to identify enabling regulations and potential gaps. This is followed by a proposed framework to facilitate the development of an adaptation programme and the ultimate selection of water related adaptation strategies. Finally, the issue of uncertainty, as it relates to the water sector and climate information, is considered.

5.1 International obligations and frameworks

As has been illustrated in chapter 4, while a substantial body of knowledge exists regarding climate change impacts, information on adaptation policies and strategies are limited. The discussions about climate change adaptation have not moved much beyond the identification of possible adaptation measures (Gagnon-Lebrun & Agrawala 2006). All countries, as signatories to the UNFCCC, have to fulfil certain obligations in terms of adaptation. Yet, little guidance is provided as to how practically these obligations should be met. The obligations include the following (DEAT 2004):

- Cooperate in preparing for adaptation to the impacts of climate change;
- Take climate change considerations into account in the relevant social, economic and environmental policies and actions with a view to minimizing adverse effects on the economy, public health and on the quality of the environment;
- Promote and cooperate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system intended to further the understanding and to reduce or eliminate uncertainties;
- Promote and cooperate in the full, open and prompt exchange of relevant scientific, technological, technical, socio-economic and legal information related to the climate system and climate change; and
- Promote and cooperate in education, training and public awareness related to climate change.

In response, two United Nations initiatives have been developed to assist with the development of climate impact responses. The first is the Adaptation Policy Framework (APF) which aims to provide guidance to developing countries for formulating national policy options for climate change adaptation (Spanger-Siegfried & Dougherty 2003), although the approach also has applicability for developed countries. The process begins at the project or programme level and assesses the climate risk of that specific intervention and then develops strategies to adapt to the potential climate threats. It is structured around four major principles from which actions to adapt to climate change can be developed (Lim et al. 2005), viz.:

- Adaptation to short-term climate variability and extreme events is included as a basis for reducing vulnerability to longer-term climate change;
- Adaptation policies and measures are assessed in a developmental context;
- Adaptation occurs at different levels of society; and
- Both the strategy and the process by which adaptation is implemented are equally important.

The second, the National Adaptation Programme of Action (NAPA) framework, was developed to provide a process for Least Developed Countries (LDCs) to identify priority activities that respond to their urgent and immediate needs with regard to adaptation to climate change (UNFCCC 2002). A different approach is provided here that focuses on enhancing adaptive capacity to climate variability, which in itself will help address the adverse effects of climate change. The NAPA takes into account existing coping strategies at the grassroots level, and builds upon these to identify priority activities, rather than focusing on scenario-based modelling to assess future vulnerability and long-term policy at state level. In the NAPA process, prominence is given to community-level input as an important source of information, recognizing that grassroots communities are the major stakeholders. A process for undertaking the preparation of NAPAs includes:

- assembly of a multidisciplinary integrated assessment team;
- synthesis of available information on adverse effects of climate change;
- participatory assessment of vulnerability to current climate variability;
- identification of key climate change adaptation measures;
- identification and agreement on country driven criteria for selecting priority activities to address the adverse effects of climate change;
- development of proposals for priority activities to address needs arising from the adverse effects of climate change, including national/ sub-national consultations for the purpose;
- public review of the draft NAPA document;
- final review of the NAPA document by government and civil society representatives, followed by endorsement by the national government; and
- public dissemination (including translation as necessary).

While using different processes, both of these frameworks are located at the national level. The APF is a top down approach, whilst the NAPA can be seen as a bottom up approach. The NAPA draws on local activities, but it does not house the expertise or programmes at this level. The drivers for implementing these two approaches at the national level can be understood in the context of the international climate regime. International funding for adaptation can only be leveraged through national representation at the UNFCCC and hence these tools have been designed to assist developing countries to prepare national plans and budgets for addressing local adaptation needs.

The UNDP suggests that international adaptation financing should be seen as “new and additional” commitments, which supplement and not divert existing aid commitments. Current commitments fall well short of what would be required annually to climate proof development investments (Watkins 2008). There are currently four global funds for financing targeted adaptation viz. the Global Environment Facility Trust Fund, the Least Developed Countries Fund, the Special Climate Change Fund and the Adaptation Fund (Mohner & Klein 2007). Despite this, little adaptation funding[26] has actually reached developing countries. A key obstacle to scaling up the implementation of adaptation programmes is that the core mandate of the GEF has been to fund the incremental costs of global environmental benefits. It has been difficult to prove this global benefit for local climate induced impacts, since the line between development and adaptation is fine one. It is therefore important that the planning and implementation of adaptation programmes take place at the local level and are integrated into existing planning systems. The notion of mainstreaming has been put forward by a number of academics and policy makers (Huq et al. 2003; Agrawala 2004; Eriksen et al. 2005; OECD 2006). Efforts to mainstream climate change into sectoral planning have been relatively successful for the agricultural sector due to its long history of working in drought prone environments, but the same can not be said for the water sector (Huq et al. 2003).

Specifically the OECD (2006) has raised some key opportunities for making the integration of climate change adaptation with development activities more effective. They suggest that climate information should be made more relevant and that appropriate entry points for this information should be targeted. The language used to convey this information should be appropriate for the sector that is intended to use it. In order to clearly identify climate vulnerability, relevant climate risk screening tools should be developed and applied. These should be incorporated into existing planning tools. And finally, the actual implementation of the adaptation projects and programmes, rather than the continual development of new plans, will further institutionalise the approach to adaptation within a development paradigm. A framework for this is suggested and discussed in section 5.3.

5.2 Climate related legislation for South Africa

In 1997 a national climate change policy for South Africa was identified as an urgent requirement and was coordinated under the auspices of the National Committee for Climate

[26] As of May 2007 a total of 34 adaptation projects were either listed in the pipeline, approved or under implementation with funding from the GEF totalling US$110.92 (Mohner & Klein 2007)

Change (NCCC). The climate change response strategy focused on both mitigation and adaptation aspects and identified the key climate change adaptation issues in the country to be health, water, agriculture, rangelands and biodiversity (DEAT 2004).

South Africa has a number laws and regulations that relate to the protection and management of the environment. National legislation that is relevant to a framework for adaptation to climate is mentioned below:

- *The Constitution of South Africa (108 of 1996)*

  The Constitution (RSA 1996) presents an overarching obligation to sustainable environmental management, which requires that amongst others, local government provide services in a sustainable manner.

- *National Environmental Management Act (107 of 1998)*

  The over-aching legislation contained in the provisions of the National Environmental Management Act (RSA 1998a), which states that local government should develop strategies to protect natural and cultural resources, but at the same time proactively address poverty.

- *Municipal Systems Act (32 of 2000) and Integrated Development Plans (IDP)*

  The Municipal Systems Act (RSA 2000b) has certain implications and obligations for environmental management by local government, which must be accommodated and reflected in the institutional framework and policies of the local Government authority. It provides the core principles, mechanisms and processes that are necessary to enable municipalities to move progressively towards the social and economic upliftment of local communities.

  In terms of the Municipal Systems Act (RSA 2000b), municipalities are required to lead and manage an integrated plan for development. This IDP includes the allocation of resources, for the provision of fundamental municipal services.

- *Environmental Conservation Act (73 of 1989*)

  The objectives of this Act (RSA 1989) are to reduce potential negative environmental impacts of activities related to development, and to promote sustainable development. Specific sections of this Act set out procedures for Environmental Impact Assessmentsthat must be complied with in order for activities such as water supply and wastewater treatment works, to commence, as defined in the Act.

- *Disaster Management Act (57 of 2002)*

  This Act (RSA 2003a) focuses on preventing and reducing risk of disasters, mitigating their severity, emergency preparedness, rapid and effective response and post-disaster recovery.

- *National Water Act (36 of 1998) and Water Services Act (108 of 1997)*
  In response to the National Water Act, DWAF (2004b) developed a first version of South Africa's National Water Resource Strategy (NWRS) to address the management of the water resources to meet the development goals of the country. This is discussed further in the next sub-section.

5.2.1 South African water policy and legislation

Significant transformation in the field of water resources management policy in South Africa has been driven by two key aspects. Firstly, the democratisation of South Africa brought about the need to eliminate disparities between various sectors of South African society with respect to access to resources, among which water is a primary resource. Secondly, the awareness that the increased exploitation of water resources to meet rising water demands in South African catchments, as well as the intensification of associated impacts on water quality, needed to be addressed (Backeberg 2005). The South African Constitution provides the primary legal framework for the government's water policy, as discussed below, and is the basis for formal legislation. Amongst other socio-economic rights, the constitution confers on 'everyone the right to have access to water' (RSA 1996).

The White Paper on Water Supply and Sanitation published by the Department of Water Affairs and Forestry (DWAF 1994) states that water and related policies are important issues for all South Africans. Not only is water central for development, but it is an essential basic human need for physical survival. The policy principles around which the policy was based are:

- demand-driven and community-based development;
- that basic services are a basic human right;
- the principle of 'some for all' rather than 'all for some';
- equitable regional allocation of development resources;
- that water has an economic value;
- the 'user pays' principle;
- integrated development; and
- environmental integrity.

The National Water Act (RSA 1998b) replaced the 1956 Water Act with the following relevant core objectives:

- meeting the basic human needs of present and future generations;
- promoting equitable access to water;
- redressing the results of past racial and gender discrimination;
- promoting the efficient, sustainable and beneficial use of water in the public interest;
- facilitating social and economic development;
- providing for growing demand for water use;

- protecting aquatic and associated ecosystems and their biological diversity;
- reducing and preventing pollution and degradation of water resources; and
- managing floods and droughts.

The National Water Policy White Paper (DWAF 1997b) and National Water Act (RSA 1998b)are based on the principles of equity, sustainability and efficiency. The country's new laws have instituted a macroeconomic and environmental reform process in the sector in which water rights have been separated from land rights and a water right is limited to a 'use-right'. Water is now deemed common property owned by the people of South Africa and managed by the Government (Goldblatt et al. 2002). In addition, as discussed in section 3.3, basic adequate water services are defined by DWAF as potable water supply of 25 litres/person/day within a walking distance of 200 metres (DWAF 1994). This is considered sufficient for cooking and drinking. To address the issue of affordability, Government committed itself to providing 25 litres per day, free of charge (the life-line tariff), to be implemented by local authorities (Majola 2002).

The National Water Resource Strategy, NWRS, (DWAF 2004b) was developed to address the management of the water resources to meet the development goals of the country. It will be reviewed at least every five years. One of the key objectives of the NWRS is to identify areas of the country where water resources are limited and constrain development there as well as development opportunities where water resources are available. Climate change has the potential to impact very significantly on both the availability of and requirements for water in South Africa and thus will also be monitored every five years.

In an attempt to redress the past imbalances, the NWRS has identified some specific linkages with the Integrated Rural Development Programme and the Urban Renewal Strategy (DWAF 2004b) by:

- Ensuring that rural development features strongly in water catchment management strategies;
- Identifying rural water needs and opportunities and making specific allowances for rural development and livelihoods in re-allocating water by compulsory licensing;
- Ensuring community representation on the management bodies of water management institutions; and
- Contributing to the planning and development of urban river floodplains to ensure public safety, and the safety of infrastructure, during floods.

Whilst attention in the past was mainly focused on the development of new resources, the issue of efficiency of water use has not been as well developed to date. With the current high degree of water resource utilisation in the country, the efficiency of water use needs to be substantially improved. With this in mind, the Department of Water Affairs and Forestry is currently developing a programme for water conservation and water demand management.

A policy framework to deal with projected climate change impacts on the water sector is already in place in South Africa through the National Water Act (RSA 1998b), with its emphasis on Integrated Water Resource Management, and more particularly the National Water Resource Strategy. Substantial potential changes to available surface and groundwater resources may occur in future. The existing policy framework therefore requires more direct focus on adapting to potential impacts of climate change on formal water management structures as well as on the vulnerabilities of many communities and the environment to their water requirements under conditions of perturbed climates. The NWRS (DWAF 2004b) emphasises that the climate change projections are estimates of how the global climate system may possibly evolve in the future. Nevertheless, it is important that no development or investment decisions are made that neglect to take into account the actual or potential affects of climate change on water resources. Hence it is necessary that a common framework be developed that ensures that climate change impacts are consistently considered by water resource planners.

5.3 Development of an appropriate adaptation framework

Climate scenarios have been widely used in the assessment of climate change impacts and vulnerability. However, relatively few studies have attempted to identify vulnerabity to potential climate change impacts on urban water resources and these have for the most part not followed a consistent framework for the analysis or the planning of the response (Boland 1997; Dessai et al. 2005; Muller 2007; Taviv et al. 2007). Developing a framework for adaptation to climate change at the municipal scale is therefore necessary to prioritise the most urgent local adaptation activities and identify the required local human and financial resources. If climate variability is to increase it is important to understand how climate will impact on the different sectors and what their resultant vulnerabilities are likely to be. This process should focus attention on where priority intervention might reduce the impacts of climate change and help cities to be pre-emptive, rather than reactive.

In order to develop an appropriate local level or municipal adaptation plan, the following ten steps were presented by Mukheibir and Ziervogel (2007) to guide the development of urban adaptation strategies (see Figure 13 further on):

1. Assess current *climate trends* and *future projections* for the geographical region.
2. Undertake a *climate vulnerability assessment* of the municipal area. This is an assessment of whether climate variability or change could compromise the integrity, effectiveness and longevity of the development goals of the municipality. Many cities will not have this information collected and analysed and would therefore have to develop this assessment from scratch, as follows

   a. Identify *current* sectoral and cross-sectoral vulnerabilities based on current climate variability risks and trends;
   b. Identify *future* potential vulnerabilities based on future projected climate scenarios and future climate risks; and
   c. Capture this information on local vulnerability maps using GIS and other tools. The climate impact assessment would include sea level rise, drought and flood prone areas.

3. *Review of current development plans* and priorities. Most municipalities would be able to find this information in their various strategic plans.

4. *Overlay* of development priorities, expected climate change, current climate vulnerability and expected future climate vulnerability, using GIS for spatial interrogation and other participatory and quantitative assessments for further analysis. These various overlays will assist in identifying hotspots of concern in order to focus adaptation activities.

5. *Develop adaptation options* using new and existing consultative tools. These options should integrate climate-sensitive responses with development priorities as well as focusing on areas that are highly vulnerable to climate variability.

6. *Prioritise the adaptation actions* using both qualitative and quantitative tools. Examples of these are discussed in section 6.2.

7. Develop programme and project scoping and design documents together with associated budgets. This should be integrated in the Water Services Development Plans.

8. *Implement* the prioritised interventions.

9. *Monitor and evaluate* the interventions on an ongoing bases.

10. Regularly *review* and modify the plans at predefined intervals.

Unlike most tools, this process starts with an assessment of current climate trends and future projections for the whole municipal area and all municipal functions, rather than focusing on a specific project. Assessing vulnerability to current climate variability is challenging because of the range of factors that contribute to vulnerability in addition to climate. Although some attempt to evaluate adaptive capacity provides an indication of the ability to adapt to future change, it is impossible to definitively define future vulnerability. Although some tools, such as scenarios, may help to evaluate future pathways of vulnerability. This process should also include an assessment of the local government's capacity to implement adaptation actions in terms of budgetary and personnel constraints, with and without explicit climate change adaptation strategies (Smit & Pilifosova 2001).

Once the key vulnerabilities are identified, it is necessary to formulate an adaptation strategy consisting of a range of adaptation actions. These adaptation actions need to be developed for the local context in conjunction with key stakeholders, including those directly impacted, experts in the sectors and climate specialists who can comment on the nature of the climate variability. This is necessary in order to assess the secondary impacts of pursuing certain adaptation actions and to ensure there is equity and sustainability given the complex institutional arrangements of the town and its inhabitants. A stakeholder engagement process is also necessary to bring politicians and decision makers on board and to give them insight into the projected impacts and potential adaptation actions. Since some of the actions may be capital intensive or politically unpopular, it is necessary to build political will to fund and support adaptation measures. Further, some actions may require some tradeoffs that the stakeholders would need to negotiate.

Once adaptation actions have been identified, they need to be prioritised. One method of evaluating which actions might be pursued first, is multi-criterion analysis (MCA). The purpose of using MCA is to aid decision-making rather than to evaluate options on monetary terms only. It is useful for assessing options for adapting to climate change as there are many factors that need to be considered, including equity, efficiency, short or long-term benefits as well as many other non-monetary factors. Other tools such as cost-benefit analysis (CBA) and the social accounting matrix (SAM) are useful when determining the financial implications of an intervention, both in terms of cost and benefit to society. Issues such the impact on GDP and employment can be assessed. At the same time, the limitations of these methods should be addressed. For example, although MCA might enable non-cost factors to be assessed, the stakeholders defining the criteria and evaluating them may have biases.

One of the first steps towards developing an adaptation plan would be to consolidate and integrate existing adaptation initiatives to avoid duplication and to work within budgetary and capacity constraints. A holistic approach to developing a municipal level adaptation plan should also include reviews of both the direct impact on natural resources, as well as the secondary impacts on the socio-economic environment and the livelihood of communities. Through stakeholder consultation and prioritisation, these and other affected sectors could be included.

A key component of a framework for the climate change strategy is the ongoing monitoring of the programmes and the projects that are prioritised and implemented. The effectiveness of the interventions should be assessed regularly and modifications made if necessary. Adaptation to climate change is not an event, but rather it is an ongoing process of social learning. The development of the adaptation plan should lead to adaptation actions being integrated into development policy and planning at every level. It should not be an add-on or an after thought. Development itself is key to adaptation, since adaptation should be an extension of good development practice and should reduce vulnerability. All levels of government should ensure that policies, programmes, budget frameworks and projects take account of climate change, since critical economic, social and ecological challenges can only be effectively addressed on a regional scale. However, there is little evidence of this since low- and middle-income countries face two key barriers to integrating climate change into developing planning, viz. institutional constraints and technical capacity (Burton et al. 2002; Stern 2006; Mukheibir 2007c).

However, the adaptation implementation plan should not be seen as a once-off process. It should initially be used to educate planners of these potential impacts and develop interventions that are sectorally based as well those that are cross-sectoral. With time, the integration of climate-sensitive actions into development planning should become commonplace in all municipal departments and their strategic plans.

Having considered the holistic approach to developing an adaptation plan at the municipal level, the focus now shifts to the water sector. The SWAMP methodology by Munasinghe (2007) has been designed to address water resource problems within a national sustainable development strategy. It successfully integrates the social, environmental and economic interaction into one tool, using the following criteria for assessment: economic efficiency, social equity, financial viability and environmental sustainability. While the SWAMP is primarily country focused, it starts by considering the international and cross-boundary linkages. It then considers the interactions of a multi-level institutional arrangement within the country as well as the policy instruments that operate at these levels. Finally it is able to identify the impediments to successful water resources management, such as uncertainties in climate impacts, financial costs and technology development, lack of human and infrastructural capacity, weak institutions and finally weak political will. A criticism of this tool is that it is a country level tools and requires integration with the socio-economic developments of the country. This may be beyond the scope of a regional or municipal water planner.

By drawing on the methodologies discussed above, a process for developing a water resources adaptation plan (WRAP) is proposed, which can be implemented at both regional and local levels. This plan could be used as a sectoral plan for national and regional water planning, or as an input into a local development plan at a municipal scale, as illustrated in Figure 13 overleaf.

The approach does not differ too much from the municipal adaptation planning framework discussed above, but is focused more around the water sector. The process begins with an initial assessment of the water resource vulnerability both to climate variability at present as well as the projected impacts due to climate change in the long run. This would involve an analysis of the water balance taking into consideration the future projected water demand and climate impacts (both positive and negative). Kabat et al. (2002) suggest the criteria listed in Table 8 for identifying vulnerability to water stresses.

Table 8: Criteria for identifying areas highly vulnerable to water stress (Kabat et al. 2002)

Environmental Stress		Susceptibility	
Quantity	**Quality**	**Access**	**Ability**
Magnitude Variability Temporal aspects Domestic food production Natural resources protection	Human health Ecosystem health	Distance Legal rights Price Infrastructure	Technical Financial Social Institutional Demographic

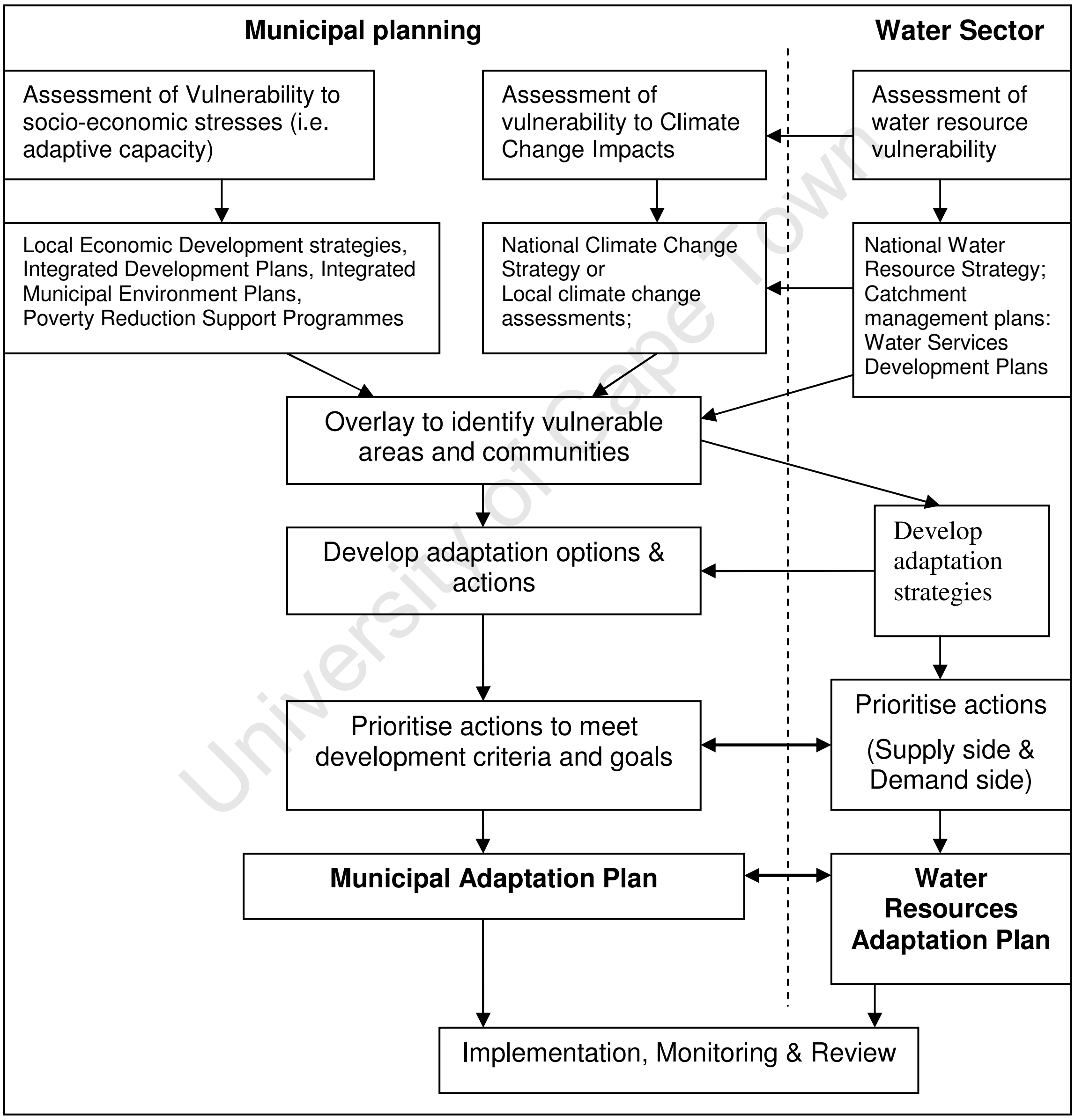

Figure 13: Process for developing a Water Resources Adaptation Plan, WRAP (modified from Mukheibir 2007d; and Mukheibir & Ziervogel 2007)

The suggested criteria for environmental stress are subdivided into indicators related to the quantity of water (i.e. too little or too variable) and its quality. "Susceptibility" is broken down into indicators of 'access' to actions and infrastructure that can help individuals or ecosystems to cope with climate change, and indicators related to their 'ability' to manage water resources in the face of increased climate change. 'Ability' is a function of financial resources, strong management institutions, and other factors. The accuracy of this analysis is based on the reliability of the data. In large urban centers in general, the socio-economic and physical environmental information is up to date and reliable. However, the availability of such data is a major barrier in small towns where the lack the resources to collect statistics and physical information is prevalent (Adger & Vincent 2005). Sattherwaite (2006) further warns that making generalisations where data are missing can be misleading, since not enough is known about these smaller types of settlements.

The assessment of vulnerability should be integrated into national water resources strategies and at a local level into the catchment management planning. Given the uncertainty associated with future projections, these could be incorporated with the use of scenarios, illustrating high and low impact cases. The resource impacts and areas of high stress should be overlaid with the key development and water demand priorities as identified through the parallel development planning process. Vulnerable communities and infrastructure which will be impacted by increased water stress should be specifically identified.

Once the vulnerable physical and social areas have been identified, strategies should be identified that build resilience to the potential impacts of climate change and ensure that the development objectives are met. These strategies can be drawn from a suite of supply side options ranging from new dams and groundwater sources to the reduction in supply losses, or from demand side options such as higher tariffs, regulations or domestic leak reduction. The strategies should be prioritised using screening criteria such as cost (capital and unit), employment creation, long-term applicability and real additional volume created. These strategies should reduce the vulnerability to water stress and in the case of water, ensure an equitable access to supply, especially for the poor.

The identification of these strategies culminates in the development of a Water Resources Adaptation Plan (WRAP). The WRAP should be a stand alone document and give guidance and direction to the water sector implementation planning. But more importantly, it should also inform and be integrated with municipal adaptation plans to provide a holistic development strategy that encompasses climate change considerations and builds the local resilience and adaptive capacity. Adaptation plans for other sectors such as health and infrastructure should follow the same process. This process can also be undertaken for national or regional development planning.

During and after implementation, it is important to conduct monitoring and evaluation of the plan and the specific interventions suggested. Adaptation planning frameworks are not events and should be viewed as ongoing processes, where the cycle is repeated at regular annual intervals. This ongoing process should result in the modification of the plans and strategies to take into account changing climate projections, levels of resilience and socio-economic demands.

A number of potential barriers to developing an adaptation plan do, however, exist. Issues such as low local human capacity to undertake this kind of planning and the limited knowledge and understanding of climate issues and scenarios at local and municipal level are some of the more obvious obstacles (Dessai et al. 2005). Constraints in climate science data and scientists have been observed for Africa, but these would be true of most developing countries (Washington et al. 2006). Reliable, long-term and well distributed climate information is essential to informing any development policy aimed at addressing the consequences of climate induced impacts . Limited financial resources and competing priorities often result in medium to long-term planning being sidelined and the implementation of projects that do not fit into the short political life of decision makers do not get implemented (Denton et al. 2001). Further, it is difficult to convince decision makers to consider the need for a climate strategy when the climate projections cover a longer time horizon than the political and development framework and are associated with high uncertainty. And finally, without a legislative framework, comprehensive and consistent adaptation planning will not be done by all municipalities.

5.4 Assessing vulnerable water resources under climate change

Having outlined the framework for developing an urban based water resources adaptation plan, it is relevant to discuss the steps required to assess the nature and extent of the vulnerability of the local water resources under future climate conditions, specifically the impact on stream flows and groundwater yields.

Although there is wide acceptance that water resources are sensitive to climate change in a number of different ways, water resource planners have delayed accounting for climate change in their planning until the risks are better known. It still remains standard practice, therefore, to project water use on the basis of population and other factors, but not as a function of climate. Although the long-term climate projections maybe too uncertain to meet the operational needs of today's water managers, short and medium term forecasts are available. These forecasts have improved considerably. However, they are not being used in water management in many parts of the world due mainly to a lack of capacity and understanding of their potential

There are a number of reasons for why conventional planning does not currently consider climate change. In the past, lengthy departures from "normal" weather conditions were viewed as random deviations around a stationary mean. Conventional planning practice leads to large infrequent capacity expansions. Water supply planning is based on a static climate assumption that has worked reasonably well in the past and hence there is no convincing evidence that they will not work in future. Any trend resulting from climate change would simply cause a change in the timing of the next capacity expansion, without a loss of reliability. Further, the water sector has postponed adaptation due to climate change uncertainty and as a result, a no regrets approach to water resources planning and management is perceived to be necessary (Boland 1998; Kabat et al. 2002).

In keeping with the framework outlined in the previous section, and in order to move this debate forward, the following approach is advocated when considering climate impacts and local water resources. The following should be determined:

- the future projected water use and demand;
- the future projected climate change impact on rainfall and temperature; and
- the future climate impacts on water resources

This approach incorporates both top-down and bottom-up approaches. The projection of future water use and demand and the development of management strategies are developed using local knowledge and information, whilst the assessment of future climate impacts is usually done by outside agencies with regional and scientific information. These three key components are discussed below and make specific reference to South African conditions in order to illustrate the complexities and methodological approaches. The development of future water resource management strategies in response to the projected impacts is discussed in detail in Chapter 6.

5.4.1 Forecast of future urban domestic water use and demand

Population growth introduces some uncertainty to the projection of future water use and demand. Researchers differ on their projections of future population growth in South Africa. More recent estimates are much lower than those undertaken before 2000. The Development Bank of Southern Africa (DBSA) has based population projections on differentiated low and high impacts of HIV/AIDS (Calitz 2000b, 2000a)..Dorrington et al. (2006), for example, have included the consequences of HIV/AIDS in their projections, which results in a growth rate of less than 0.5% by 2015, whereas the those projections made by Roux (1998), are in the region of 1% (See Table 9).

Table 9: Projected annual population growth rates for South Africa

Years	Projected annual population growth rates	
	Business Futures 1998 (Roux 1998)	**CAR (2006)** (Dorrington et al. 2006)
1999-2015	1.92 %	1.6-0.4 % (0.95 %)
2015-2030	1.06 %	0.4 %

Further, water use patterns differ markedly between urban and rural areas. Rates of water access are much higher in urban areas and urban population growth rates for earlier periods were substantially higher than those for rural areas. Urban population growth from 1946-1970 was 3.45% per year and 3.09 % for 1970-1996 (SACN 2004). Overall, this gives a picture of a growing population, but growth slowing down to lower rates. Further, there have been some suggestions that rural populations have peaked and will stabilise or even decline (Calitz 1996). This will put further pressure on urban centres due to migration.

Given the uncertainty associated with population growth, one can simply multiply the historic consumption per capita by the projected population to establish the estimated future demand for water. However, this method does not take into account the increased use of water as the population becomes more affluent and the level of poverty is reduced. The approach taken in this thesis when considering the growth in demand for the case study in Chapter 7 assumes that no inroads are made into the increase consumption of poorer households. Ideally the forecast should be spatially and sectorally disaggregated and be dependent on realistic population and water demand growth figures.

When considering the impact of climate change on urban water demand the projected increase in temperature could increase evaporation in swimming pools and result in increased watering of gardens. Work by Steiner (1998) and Boland (1997), however, showed that over a forty year period up to 2030, climate change impacts on water use were calculated to be relatively small in comparison with the increase in use due to population growth. They argued that water managers did not need to plan for any increases in demand due to future project climate impacts, which was consistent with the recommendations made by the then US Department of Interior. They argued that normal demand side management strategies would be sufficient to deal with these increases under various climate change scenarios. For the case study (Chapter 7), these recommendations have been used as the basis for the demand growth assumption.

5.4.2 Current climate assessments and future projections

Over the past few decades, the global temperature has been increasing (IPCC 2007b). A combination of intensive agriculture, the burning of fossil fuels and industrial processes have raised the raised the levels of atmospheric CO_2 concentrations resulting in an enhanced greenhouse effect. The concentration of these gases has increase by 34% from 1750 to 2005. This has resulted in the average linear warming trend over the past 50 years (0.13 °C per decade) being nearly twice that for the past 100 years. Long-term trends spanning 1900 to 2005 have been observed to show changes in precipitation over many large regions, specifically recent drying in the Sahel, the Mediterranean, southern Africa and part of southern Asia (IPCC 2007b).

Historically major droughts have had significant impacts over the past 200 years in southern Africa, resulting in famine and social dislocations of people (Vogel 1989). Climate variability, and especially variable rainfall, is a characteristic of southern Africa and other dry regions, where the sequencing of wet and dry years is not distributed evenly and no clear trends can be identified (Kabat et al. 2002), as is illustrated in Figure 14. Whilst this distribution definitely tells a story, it may not be entirely accurate for all areas of South Africa. The eastern side of the subcontinent experiences higher MAP than the western side, and hence one should be wary of , considering generalisations over such a wide area with a range of rainfall patterns. Rainfall variability is particularly pronounced over the dry western parts of South Africa, where a sequence of dry years can have significant repercussions for reliable water supplies..

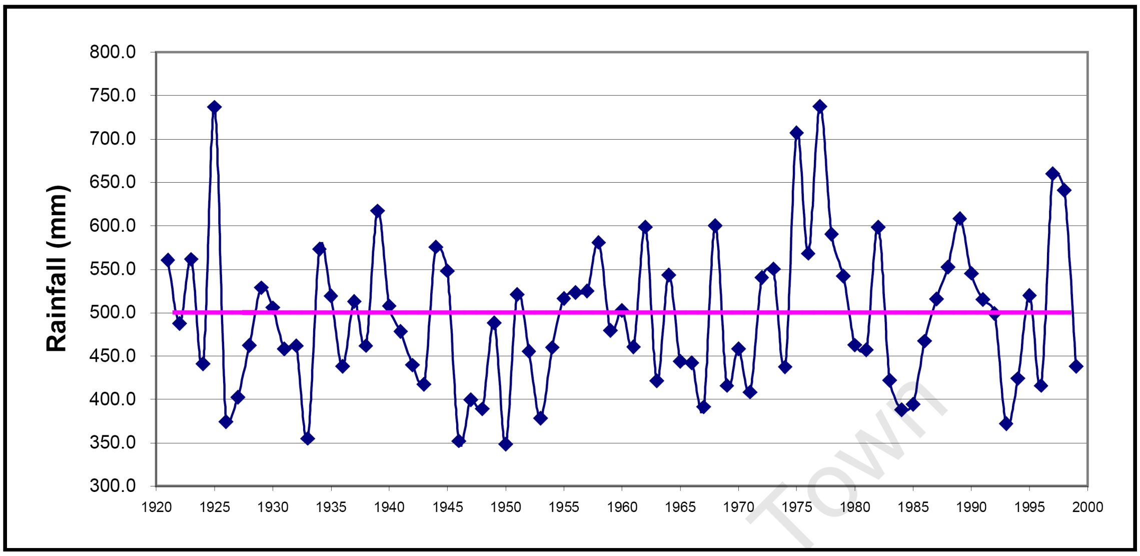

Figure 14: Annual averages of rainfall over South Africa (in Kabat et al. 2002)

Climate variability occurs at varying spatial and temporal scales and magnitudes (Bradley & Diaz 2007). Weather is variable on sub-daily and daily scales, this includes precipitation, temperature, humidity and wind direction and speed. Seasonal changes are also variations in climate that we have become accustomed to and have adapted our behaviour and agricultural practices to accommodate these changes. Gradual variation or change also occurs in the median or average climate over a medium to long-term period. This has been termed *climate change* and would require acclimation adaptation, as discussed in Chapter 4.1.

Inter-annual and extreme events are more difficult to predict, particularly the increase in the intensity of extreme events resulting in droughts and floods. It may be the case that the same amount of annual rain falls, but it may be concentrated over a shorter period of time, resulting in floods on the one hand, and more drier than normal months on the other. Coping capacity and resilience often does not extend to these events and result in disasters (DiMP 2000). The response would be to build adaptive resilience or to take out insurance against similar events.

The frequency of smaller events with short recovery intervals can cause equally as much damage to socio-economic structures as it can do to physical ones. A combination of extreme and recurrent events over a period of time can lead to catastrophic impacts and result in the adaptive capacity not being resilient enough to deal with the prolonged event (Bradley & Diaz 2007). A society may have resilience for a one year drought, but if it persists for two to three years, then the adaptive capacity will be stretched. Design parameters and factors of safety would need to reviewed in response to such events.

As can be seen in Figure 15 and Figure 16, the examples of Calvinia (winter rainfall region) and Kenhardt (summer rainfall)[27], precipitation displays a high degree of inter-annual variability, with periods of more plentiful rainfall followed by periods of drought. The intermittent single extreme events skew simple analyses, and this makes precipitation difficult to analyse in terms of trends. Extreme events make planning for times of drought difficult, yet essential, since with large inter-annual variability there are no guarantees of adequate rainfall in any year (Mukheibir 2007c).

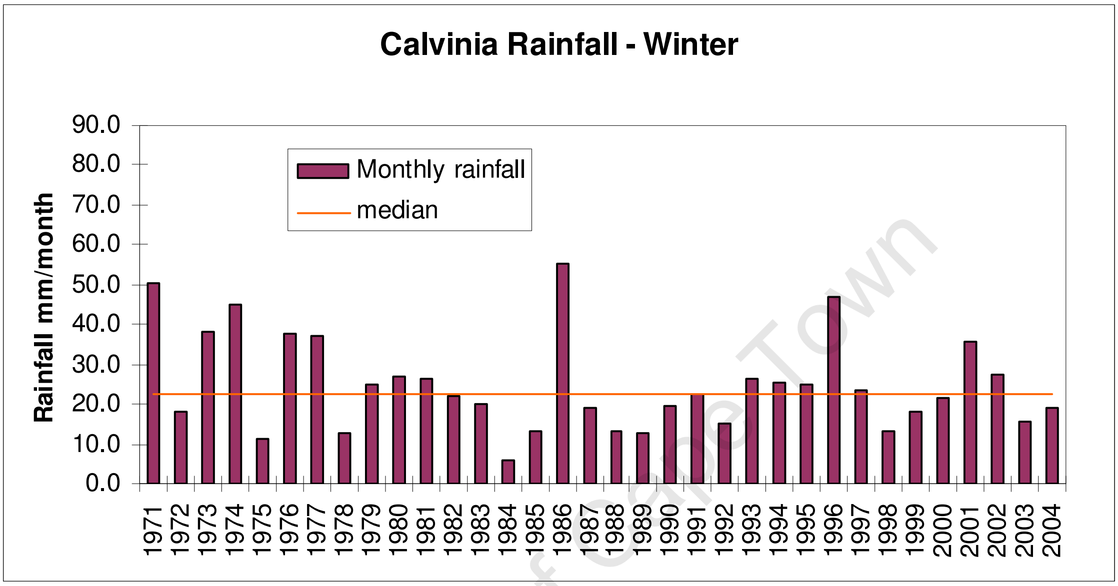

Figure 15: Average winter monthly (JJA) rainfall trends for Calvinia between 1971 and 2004 (Mukheibir 2007a)

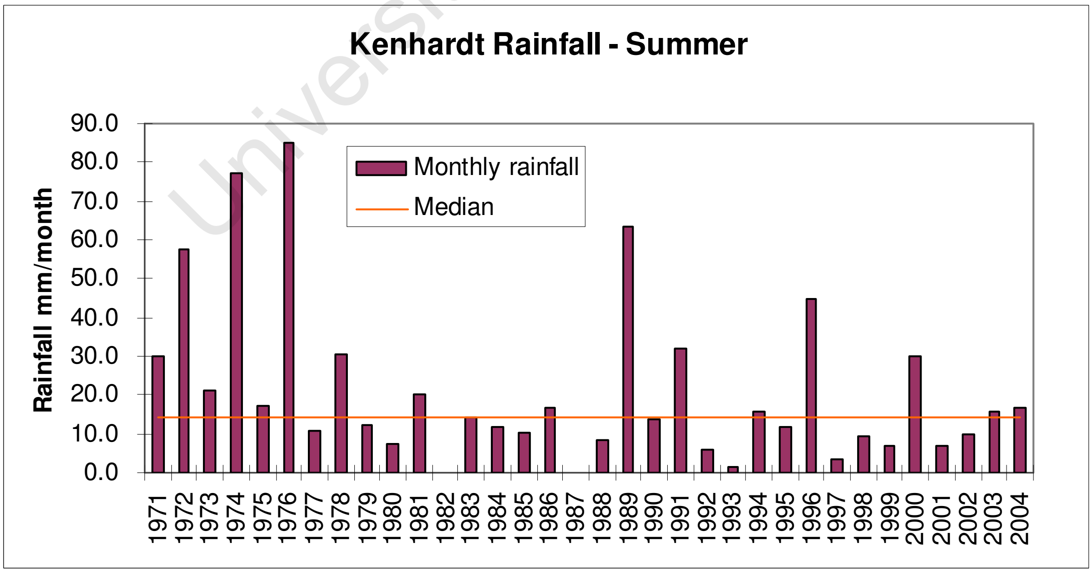

Figure 16: Average summer monthly (DJF) rainfall trends for Kenhardt between 1971 and 2004 (Mukheibir 2007a)

[27] Calvinia (population size = 6500) and Kenhardt (population size = 3600) are small towns in the Northern Cape Province (Element Raadgewende Ingenieurs 2001; Ninham Shand & Octagonal Development 2004a)

Wet and dry phases appear in some cases to be relatively strongly influenced by sea surface temperature anomalies in the Pacific (the El Niño/Southern Oscillation phenomenon), in the south-west Indian Ocean (the Indian Ocean Dipole) and the Southern Annular Mode i.e. the pressure and wind systems around the southern ocean and Antarctic (Chapman & Midgley 2007). Suggestions by Alexander (2005) that a 21-year periodicity is evident in a multi-year rainfall cycle in South Africa due to forcing by solar output as manifest in the Wolff number (sunspot number) are shown by Midgely and Underhill (2007) to be unfounded.

Statistically significant trends of increased maximum temperatures for the period 1960-2000 have been established for western and southern Africa (New et al. 2006) and more specifically the western and southern parts of South Africa (Warburton & Schulze 2005). The region centred on the Limpopo Province has also become warmer. Fewer frost days are occurring than thirty years previously, particularly in the Highveld and inland plateau areas. Little if any change in low temperature extremes is recorded in the lower altitude coastal regions, with the exception being the KwaZulu-Natal coast (Warburton & Schulze 2005).

Current projections by the Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC) indicate that the global average surface air temperature is projected by models to increase 1.4 to 5.8 ^{o}C by 2100 relative to 1990 and will be accompanied by regional variations in precipitation. In addition, there would be changes in the variability of climate, and changes in the frequency and intensity of some extreme climate phenomena (IPCC 2007b). More specifically a steepening of the rainfall gradients can be expected, i.e. the wetter areas will tend to get wetter and the dry regions will receive less precipitation (Hewitson 2006/7). Furthermore, extreme dry years tend to be more frequent in the driest regions of the country (Tyson 1986).

General Circulation Models (GCMs) have been used to project changes in precipitation and temperature globally. This is done by accounting for the changing levels of CO_2 and other greenhouse gases in the atmosphere, and by determining the resulting atmospheric conditions brought about by changes in circulation patterns under different climate regimes as defined by the IPCC emission scenarios, typically the A2 and B2 scenarios[28] (IPCC 2001b). The GCMs are skilful at low spatial resolutions (grid size of 300km by 300km). It is important to note that GCM grid cells are not points, but area averages. Hence variance and magnitudes will be reduced compared to point data. Single grid cell data are not appropriate for assessing small regional catchments, since precipitation projections at a single cell is one of the least robust

[28] A2 and B2 refer to the IPCC scenarios for a future world under different driving forces, as follows:

A2: A differentiated world with self reliance and preservation of local identities. Economic development is primarily regionally orientated and per capita economic growth and technological change are slower than the other story lines.

B2: A world in which the emphasis is on local solutions to economic, social and environmental sustainability. This is a world orientated towards environmental protection and social equity.

attributes of a GSM simulation (Hewitson 2006/7). Applications, such as urban drainage design, demanding finer spatial scales often require finer temporal resolution. To address this, dynamical downscaling methods have been developed, such as Regional Climate Models (RCMs) which simulate climate features dynamically at high resolutions of 10-50 km over limited areas. Atmospheric fields simulated by a GCM are fed into the boundary of the RCM at different vertical and horizontal levels. The RCM uses this information to generate patterns of climate change that differ from those of the host GCM (Wilby 2007a). The most recent, regionally-downscaled climate change scenarios provide for more improved spatial resolution and allows for more precise estimates of the impact of such change on run off. This is an important driver in the management of urban water supplies (Hewitson & Crane 2006; Meadows 2006).

However, despite steady improvements in the various Global Circulation and Regional Climate Models (GCM and RCM) the results form the various models gives varying results. No one model is right or wrong. All models project a plausible time evolution of the climate. The models have a high degree of consensus over the direction of change, and how the large scale circulation features respond to greenhouse gas (GHG) forcing, however ascribing probabilities to a magnitude of change is still problematic. The uncertainties in projecting change are centred primarily on the magnitude of the change. The projections are therefore presented as the median change of a range, and the 10th and 90th percentiles. The median is considered as the likely change, while the 10th and 90th percentiles represent the lower and upper bounds to be taken into account in developing adaptation strategy and policy (Tadross & Hewitson 2007).

Therefore, for planning and developing response strategies, it is best to consider the bounds of the envelope of possibilities, and consider the median[29] of this envelope. The median of a number of GCMs can be scaled linearly to a selected year to establish the percentage change in precipitation as compared with the model control period. The projected percentage change in rainfall can then be applied to the historical Mean Annual Precipitation (MAP) for the model control period to establish to potential monthly and annual rainfall in the selected future year (Hewitson 2006/7). The case study presented in Chapter 7 uses this approach and for simplicity does not consider climate variability over the short-term.

A number of studies captured in the IPCC Third Assessment Report (IPCC 2001b) suggest that changes in climate variability and extremes are likely to be as important as changes in the mean climate condition in determining climate change impacts and vulnerability. Predictions involving short-time-scale events can be used to formulate short-term adaptation actions for any negative impacts, such as reinforcing sea walls, preparing for flooding, or increasing local disaster-relief funds. Anticipated variations in conditions from one season or year to the next

[29] Median is used because sometimes a model is an outlier, and would skew the results if using the arithmetic mean.

could be taken advantage of through short-term adaptive measures, such as adjusting water-resource management strategies.

On longer time scales, climate variations can lead to prolonged droughts, or can alter the frequency and distribution of severe weather events for many years (Bradley & Diaz 2007). They also can influence the nature of shorter term events, such as the frequency with which El Niño occurs, or their duration and severity. Such long-term changes have the potential for greatly exceeding shorter-term variations in their physical, societal and economic impacts. Water resources and quality, human health, and natural ecosystems could be impacted on positively or negatively. Consequently, responses to climate changes on decade-to-century time scales may involve investments in infrastructure and changes in policy. These response measures are discussed further in Chapter 6.

5.4.3 Impact of climate change on water resources

The impact of climate change on water resources, including groundwater, acts through a modification of the water balance, ranging from the micro to the macro-scale. This includes factors such as surface conditions, the soil column, aquifers and catchments (Braune 1996). This was confirmed, in a more recent review of the current hydroclimatic setting in southern Africa, where Schulze (2005c) motivates that there is a highly variable and highly sensitive natural hydrological system over southern Africa. He argues that even when considering average present climatic conditions, a high risk hydroclimatic environment in southern Africa is evident, since the high inter-annual rainfall variability is amplified by the natural hydrological system. He notes that different components of the hydrological system differ markedly in their responses to rainfall variability. For example, streamflow variability is high in individual external sub-catchments, but a river system becomes relatively more constant in internal and main-stem catchments. In addition, land use change often increases flow variability because it changes the partitioning of rainfall into stormflow and baseflow components. Negative degradation of the landscape can further amplify any hydrological responses, resulting in flooding and erosion.

The effects of any decrease or increase in precipitation may be amplified through the hydrological system, where both runoff and groundwater recharge, especially in semi-arid and arid regions, will decrease at a much higher rate than the underlying decrease in precipitation.

The extent to which runoff and recharge are affected has been termed in this thesis as the *Climate Impact Factor* (CIF). The CIF is expressed as a change in available supply for the specific period of analysis. Therefore the expression that can be used to determine future water resources under a future climate change scenario is as follows:

$$CIF = \left(\frac{S_{Future} - S_{Current}}{S_{Current}} \right)$$ **Equation 1**

where: CIF = Climate Impact Factor for the study period

S_{Future} = Future supply (either runoff or recharge)

$S_{Current}$ = Current supply in the base year (either runoff or recharge)

If the CIF is positive, then we can expect an increase in future water supplies under future climate impacts due to an increase in rainfall, and visa versa. The CIF can be calculated for either groundwater or surface runoff. By using this factor, the future available water supply can be established. The shortfall or surplus can be established by comparing the available future water supplies with the expected future demand. Where the demand exceeds the projected available supply, additional sources should be sought and demand side management measures should be introduced. This is discussed further in the next section.

The key impact of climate change is on rainfall, but the other important dimension is temperature. Temperature changes are generally included in climate change modelling studies via a change in potential evaporation. Increasing temperature generally results in an increase in the potential evaporation and given that temperature is expected to increase globally it can be expected that evaporation on large open waters would increase. For example, evaporation losses per annum from dams have been calculated to be on average 1.1 meters of depth per square kilometre of surface area. This could be much higher depending on the climate of the region (Gleick 1994). Deep dams with smaller surface areas would be less affected that those with large surface areas. In addition, changes in other meteorological controls may exaggerate or offset the rise in temperature, such as wind speed and humidity (IPCC 2001b).

5.4.3.1 Impact on Runoff

Milly et al. (2005) show that an ensemble of climate models projected 10-30% decrease in the runoff in southern Africa by 2050 due mainly to a decrease in precipitation. When considering the impact of reduced precipitation on runoff in sub-Saharan Africa, work done by de Wit and Stankiewicz is of interest, since it shows that for a hypothetical 10% reduction in rainfall, regions with 1000 mm MAP[30] would experience a 17% reduction in catchment runoff and for areas that have 500-600 mm MAP would have 50-30% less runoff respectively (de Wit & Stankiewics 2006). Whilst using an average precipitation reduction for the continent is a gross simplification, since summer and winter variations are evident, and projections using climate models on a regional basis should be used, the related runoff reduction is of interest here.

The South African Country Study on Climate Change (Kiker 2000) found that when running GCM and ACRU models, runoff was found to be highly sensitive to changes in precipitation.

[30] MAP – Mean annual precipitation

Under one of the hotter drier GCM scenarios, decrease in runoff of up to 10% in some areas could be experienced. A decrease of this magnitude could occur in the western area of the country as early as 2015 (Schulze & Perks 2000).

Studies by Chapman (2007) reveal that percentage reduction in runoff is greater than the reduction in rainfall. He cautions that the use of simple trend-lines to arrive at these figures can be misleading, and that the absolute figures should not be used. Yet the clear trend that a percentage reduction in rainfall results in a greater percentage reduction in runoff is important. Historical data and in-situ measurement should be taken for a specific site being investigated.

Table 10: Reductions in runoff due to reductions in rainfall (Chapman 2007)

Site	Annual Rainfall	Rainfall reduction	Runoff reduction	period
Cathedral Peak	> 1500 mm	19 %	45%	50 years
Jonkershoek	> 3000 mm	14%	20%	60 years

These studies reveal that the magnitude of the runoff reduction is between 2-4 times greater than the reduction in the precipitation, for a 50-60 year historical period. Historical data is required to establish the direct relationship for a site specific analysis.

A modelling study conducted by Bari et al. (2005) of the impact of future climate change on runoff in a catchment in Western Australia revealed that for an 11% decrease in precipitation between 1990 and 2050, a 31% reduction in annual catchment yield would likely be experienced. Therefore the impact of the reduction in rainfall on runoff in the Western Australian catchment would equate to:

$$\mathrm{CIF}_{\mathrm{runoff(1990\text{-}2050)}} = \left(\frac{\mathrm{Runoff}_{2050} - \mathrm{Runoff}_{1990}}{\mathrm{Runoff}_{1990}} \right) = -0.31 \approx -31\%$$

5.4.3.2 Impact on groundwater recharge

Groundwater recharge was found to be even more sensitive than surface water runoff (Kiker 2000; Schulze & Perks 2000). Groundwater in South Africa usually occurs in secondary aquifers. Recharge of the aquifer depends on its type, since some are more responsive to rainfall and recharge is closely linked to higher and persistent rains. Others, such as deep aquifers, are slow to respond and require consistent rain over a period of time (Visser 2004). Studies by Kirchner et al. (1991) have shown that before any recharge takes place, a rainfall and soil moisture threshold must be overcome. The bulk of the recharge takes place in the years in which the average annual rainfall is exceeded and during periods of high rainfall persistency. It stands to reason then, that the areas that are dependent on groundwater will be vulnerable to decreases in rainfall and/or variability. In addition, low storage aquifers are vulnerable to changes and variability in recharge. This is the situation in 90% of the country (Braune 1996).

Groundwater recharge estimation is a key factor in determining the suitable management of groundwater resources. A wide range of techniques is used for estimating groundwater recharge as well as direct and indirect estimation methods with which recharge is calculated, inferred or simulated (Beekman & Xu 2003). However, using long-term records of past climate-recharge interactions is difficult to apply in southern Africa, since there are very few locations where records of climate and groundwater have been kept in sufficient detail to allow for this analysis (Selaolo et al. 2003).

A comparison of studies conducted in many disparate locations using different methods, revealed that in areas with annual precipitation less than 500 mm/year, large differences exist between the recharge values found. As is illustrated in Figure 17, recharge becomes negligible for precipitation lower than about 400 mm/year. Using this information, predicted long-term changes in annual rainfall can be translated into longer term changes in groundwater recharge (Beekman et al. 1996).

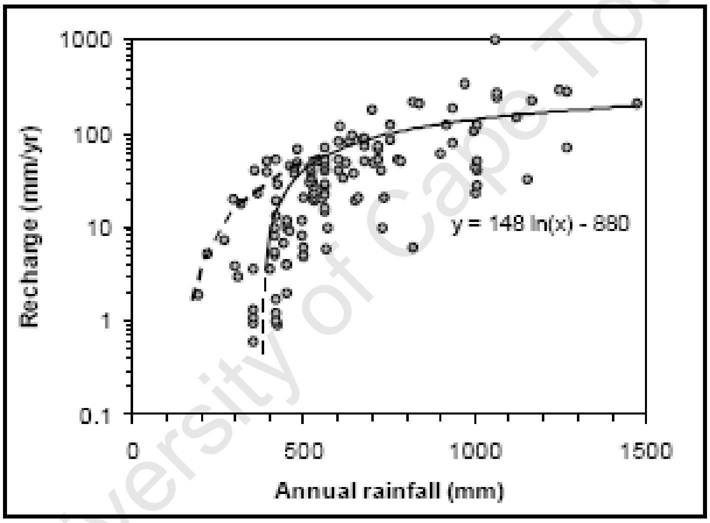

Figure 17: Annual recharge rates in southern Africa (Beekman et al 1996 in Cave et al. 2003)

Based on this information, Beekman et al. developed the following equation:

$$\text{Recharge} = 148 * \ln(\text{MAP}) - 880 \qquad \textbf{Equation 2}$$

where: MAP = Mean Annual Precipitation for that catchment in mm

Therefore, when considering the impact of drought on the available groundwater for a specific aquifer, it is necessary to determine the recharge regime of the aquifer. The historical recharge data plotted against climate trends for the past 50 years would provide an understanding of the type of rainfall needed to ensure adequate recharge. With this knowledge it will be possible to develop a management system for that specific aquifer. Continual monitoring of the aquifer against climate conditions will provide some knowledge of the future potential recharge under projected climate conditions.

In general, decreasing precipitation will cause decreasing recharge and hence depletion of the groundwater resources which are being abstracted at present rates. Changes in recharge will result from changes in rainfall as well as a change in the timing of the rainfall season. The rainfall-recharge relationship may therefore be used in a first cut assessment of climate change impacts on the groundwater resources. Cave et al. (2003) argue that short-term predictions of climate change are not necessarily more accurate than long-term predictions. Human-induced climate change will occur against a backdrop of natural climate variability. Forcing in the short-term are weak in comparison to long-term ones and so the short-term signal is more difficult to separate from that of climate variability (Cave et al. 2003).

Using Equation 2, changes in longer term groundwater recharge due to predicted long-term changes in annual precipitation can be calculated. Applying this equation to a MAP of 500 mm would result in a recharge of 39.8 mm/year. If reduced by 10% to 450 mm, recharge would be 24.2 mm/year. This would equate to a 39% reduction in groundwater recharge or a CIF of -0.39:

$$\mathrm{CIF}_{\mathrm{recharge}} = \left(\frac{\mathrm{Recharge}_{\mathrm{Future}} - \mathrm{Recharge}_{\mathrm{Current}}}{\mathrm{Recharge}_{\mathrm{Current}}} \right) = -0.39 \approx -39\%$$

Therefore recharge is reduced by a greater percentage than the reduction in rainfall and the groundwater storage would be thus affected accordingly, i.e. the magnitude of the recharge reduction is almost 4 times greater than the reduction in the precipitation.

5.4.4 Dealing with uncertainty

A key issue raised by planners when planning based on scenarios of future climate change is the uncertainty associated with projections of climate variables at specific geographical locations and spatial scales. This has been cited as a reason for the difficulty in using climate scenarios for adaptation planning beyond “no regrets” measures (Gagnon-Lebrun & Agrawala 2006). The water resources planning community has been dealing with variability in a formal sense for many decades which has facilitated the application of risk management methods such as conjunctive use of different resources, incremental construction, designing for extreme events and demand management measures. In considering the application of these techniques it is useful to distinguish between risk, where a probability distribution is known or can be assumed, and uncertainty, where no probability distribution can reasonably be assumed (Major 1998).

Introducing climate change into the water planning process involves a sequence of models and techniques that result in a cascade of further uncertainties. A number of commentators have addressed the issue of uncertainty under climate change (Frederick 1998; Jones et al. 2007; Schelling 2007). Climate change studies inherently have to consider the significance of uncertainty. This does not mean that there is no confidence in the understanding, or that the understanding is not certain enough to allow for the development of appropriate adaptation strategies and policies for resource management. Rather, current research would suggest that the political and planning response is lagging the understanding of climate change. Four sources of uncertainty currently limit the detail of the regional projects, viz. natural variability, the understanding of the climate system, future emissions and the downscaling of the global circulation models (Midgley et al. 2005). Owing to the finite historical records from which the range of natural variability at different scales of time and space has been defined, it is not possible to set the definitive limits of natural variability nor to establish how much of the change in variability is due to anthropogenic factors. In addition, the current understanding of the regional dynamics of the climate system of the African sub-continent is limited.

Given than much of the projected change is dependent on how society responds to reducing the emission of greenhouse gasses, these projections will need regular updating. The amount of CO_2 that will be emitted into the atmosphere if no, or only partial, global mitigation takes place is unknown. This will depend on population and economic growth, energy technology development and the level of commitment by national governments to meet Kyoto Protocol type targets (Schelling 2007). This will have an impact on the amount of average global warming which can be expected from specified increases in the concentration of CO_2 and other GHGs. The IPCC are preparing to update the emissions scenarios based on the data and trends of the past few years. The increase in warming will translate into changing climates around the world. The intensity and frequency of extreme climatic events will be affected - exactly how is not certain (Schelling 2007).

The modelling tools for projecting these trends are subject to certain levels of uncertainty which are driven by the structure of the global circulation models (GCMs) and the parameters that have been used. No single tool for projecting future climate is perfect and a range of projections needs to be taken into account. It is important to note that the pattern of regional change is more robust than the absolute magnitude of the projected change (Tadross & Hewitson 2007). One needs to also consider the natural variability of the climate being studied, which adds an additional uncertainty through unpredictable droughts and scarcity. Downscaling the GCM to a regional scale using RCMs also has its own inherent uncertainty due to the structure of the RCMs and their parameters, as do hydrological models.

There also exists an uncertainty attributed to the response measures. It is not a perfect science as to how these projected climatic changes will affect livelihoods and productivity in sectors such as agriculture, fishing and forestry, or how they will affect health in terms of vectors and pathogens. People, communities and large urban settlements will all adapt to these physical and resource impacts in different ways with differing levels of adaptive capacities.

The financial cost to firstly build resilience to adapt these impacts, and secondly the cost of damages and how this will affect the insurance industry is largely unknown. Specifically in the water sector, the elasticity of the high end users to pay higher prices per unit of water in order to cross subsidise the poor through a progressive block tariff is not easy to determine. The actual level of price elasticity is difficult to predict in the high end users (Martins & Fortunato 2007). The level of subsidisation varies from place to place and over time. Specifically in South Africa, where a subsidy in the form of the Equitable Share is used to ensure access to a basic level of service of 6kl of water per household is provided, the issue of population growth and the increase in the number households is of concern.

While the uncertainties associated with the prospect of climate change may not provide sufficient basis for building new projects, they do provide added justification for developing water management institutions that are more flexible and responsive to change in supply and demand.

5.5 Summary

In this chapter the regulatory environment was discussed and based on this background, a process framework has been proposed for the development of a Water Resources Adaptation Plan (WRAP), as well as its integration into a municipal integrated development planning process. While the available literature contains planning frameworks for either national or project specific adaptation planning, this thesis has presented a municipal level planning tool for integrating water resources planning and climate change impacts into municipal development plans.

Whist this thesis focuses on the water sector, all municipal sectors could use this framework to develop specific adaptation plans following the steps developed for the municipal water sector. These sector plans should be integrated with each other to ensure that full advantage is taken of any synergies than may exist, especially those related to health and water access and consumption.

In the absence of sophisticated population growth models and the uncertainty associated with HIV/AIDS, municipal water planners are advised to simply use the historic growth in population due to migration and natural population growth. Ideally the forecast should consider population growth in a spatially and economically disaggregated manner. The growth in water demand should be reviewed regularly to ensure that the plans for future supplies are still adequate.

The integration of climate projection information into water resources planning is all too apparent. In general a decrease in precipitation will cause a decrease runoff and recharge. As has been illustrated, a 10% change in future rainfall can result in change in runoff or recharge of up to 30-40%. For comparison purposes the impacts of climate change on recharge and runoff can be expressed as the proportion of the available water under normal climate conditions. In this thesis this ratio has been termed the *Climate Impact Factor* (CIF), and it can be simply expressed as:

$$CIF = \left(\frac{S_{Future} - S_{Current}}{S_{Current}} \right)$$

where: CIF = Climate Impact Factor for the study period

S_{Future} = Future supply (either runoff or recharge)

$S_{Current}$ = Current supply in the base year (either runoff or recharge)

Finally, attention is drawn to the fact that adaptation is complicated by uncertainties in both the probabilities and consequences of climate change and in the adaptive responses of affected systems. In the same manner that water planners have had to accommodate the uncertainties associated with population growth, climate variability, consumption patterns and cost recovery, so too should climate change be included into planning in a systematic manner. The WRAP framework provides such a tool and allows for the integration of the water resources management information at each stage of the municipal planning process.

An integral part of the WRAP framework is the section of robust strategies to overcome future projected climate change impacts. The next chapter provides a methodology for selecting such strategies, incorporating both qualitative and quantitative selection criteria.

CHAPTER 6

6. Adaptation strategy planning for small urban water systems

The focus of this chapter now shifts from the use of an overarching framework to a discussion of tools for identifying specific water sector strategies for coping with or avoiding climate impacts. This proposed methodology is applicable at any scale, i.e. catchment level, large urban and small towns, and can be adapted for use in other sectors. It is particularly useful for small towns where limited technical capacity and financial resources exist. The selection of viable strategies can be quite daunting and complicated, especially when trying to satisfy competing demands and development goals.

Building resilience to the impacts of climate variability is the day to day business of water supply managers. Traditionally water infrastructure, such as dams, reservoirs, household tanks, wells etc, around the world reflects the local climatic conditions. However, the strategies for addressing variability are not restricted to infrastructure, institutional and social mechanisms are equally as important. This, too, is applicable when building resilience to future climate change impacts.

Climate impacts are transforming the nature of global as well as local water security, firstly through current climate variability and secondly in the future through projected climate change impacts. Callaway (2004) argues that there are more conceptual similarities than differences between the adjustments that are made to cope with climate variability and those made to adapt to climate change. The obvious similarity is that the aim of both types of action is to avoid meteorologically induced damages when predicting them is subject to some error. Both actions have the potential to improve society, whilst making decisions under some risk, both involve reallocating scarce resources to make the adaptive adjustments. The major difference, according to Callaway, between variability and change is that historical records are more reliable for planning for variability than the reliability attached to climate prediction models. The variability in the existing climate is much easier to plan for than the variability associated with alternative future climates. It is also agreed by most in the climate change field that existing water resources management coping strategies geared to cope with present day climate variability and large climate anomalies already place us in a good position for coping with further climate change impacts (Kabat et al. 2002; Washington et al. 2006).

A key challenge will be the reconciliation of water demand and supply, both for the medium and longer term. Short-term responses might be seen as coping strategies, whereas longer term actions that help to deal with future variability could be collectively called adaptation strategies. By applying an initial filtering tool (as is illustrated in Figure 18) which is qualitative, the responses to climate variability can be evaluated for their long-term suitability to ensuring resilience to future climate impacts, and also ensuring that the local development goals are achieved. The highest ranked options should then be evaluated against quantitative criteria such as capital and operational costs, cost effectiveness in R/kℓ and volume water actually provided or saved. The most commonly used tools for this are cost benefit analysis (CBA) or cost effective analysis (CEA).

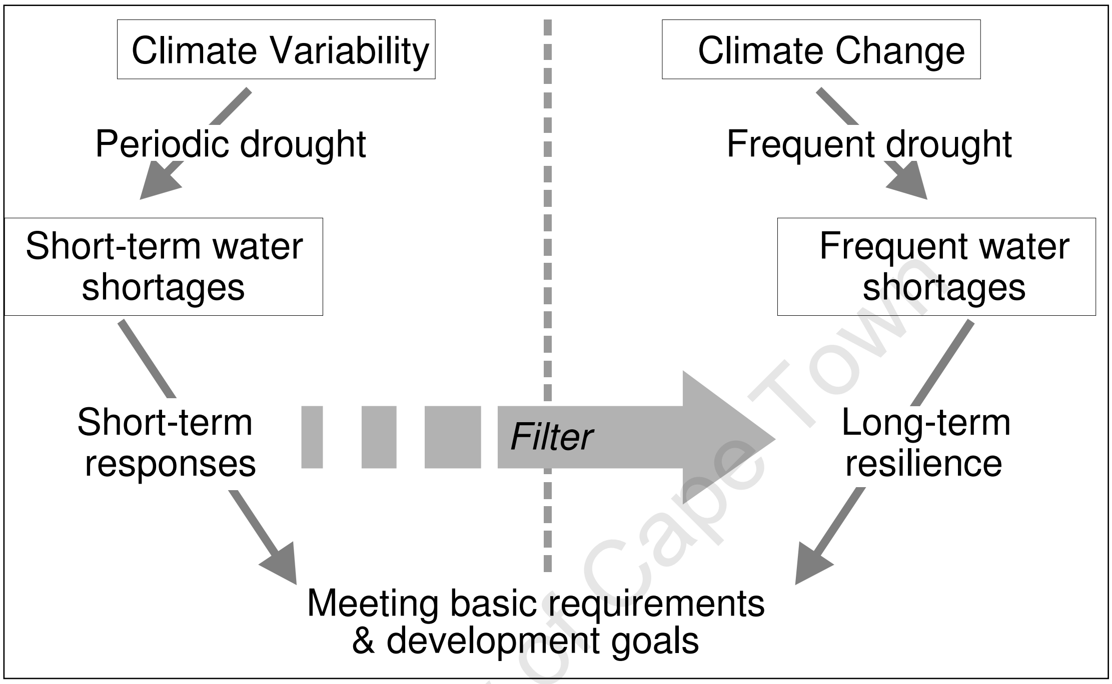

Figure 18: Diagrammatic view of the linkage between climate variability and climate change, with a specific focus on drought (Mukheibir 2007c)

In this chapter, a number of potential strategies for small town water systems are presented and their appropriateness for building resilience to climate induced impacts is discussed. A set of qualitative criteria for initially screening the strategies are suggested and the view points of different constituencies on these criteria examined. The set of quantitative criteria for further assessment of the short-listed strategies are proposed. Finally, appropriate climate adaptation indicators are offered for evaluating the effectiveness of the water security strategies in terms of financial implications and in meeting development goals.

6.1 Water resource management strategies

Short-term responses to climate variability, especially drought, could be viewed as coping strategies, whereas longer term actions that help to deal with anticipated future variability could be collectively called adaptation strategies. Two basic areas of adaptation strategies for water resources are proposed, viz. supply side and demand side. These are, however, not being implemented in a structured and planned manner across all municipalities. The strategies, listed in Table 11, are discussed in the following sub-sections, with a specific focus on their applicability in the drier areas of South Africa. As discussed in section 5.4.2, the western and north-western regions of the country are likely be most affected by reduced rainfall. The examples of these strategies in small towns is drawn from a study by the author (Mukheibir & Sparks 2006) on municipalities in the Northern and Western Cape provinces of South Africa (See location map in Figure 1). These strategies are later analysed to assess whether they are suitable for long-term applicability as well as meeting the development criteria of the country.

Table 11: Municipal water supply management options (Mukheibir & Sparks 2006)

Supply Side Strategies	Demand Side Strategies
Advantages	
• General economic development can proceed unaffected • Maintain scope for serving all users with adequate water	• Relatively low investment required • Incentives to improve efficiencies • Raw water supplies are preserved for alternative and future uses • Less sewage treatment capacity is required
Disadvantages	
• High capital investment is required • Low opportunity cost – Raw water becomes unavailable for other and future uses • Risk of adverse environmental impacts	• Excessive demand management could affect general economic development
Examples	
• Construction of new infrastructure • Artificial groundwater recharge • Conjunctive use of surface and groundwater • Desalination • Local and regional water resource planning, management and monitoring • Rainfall enhancement • Rainwater harvesting • Reduction of leaks programmes on supply lines • Standby relief under critical conditions e.g. tankering of water • Control of alien vegetation • Control of water pollution	• Dry sanitation systems • Dual flush toilets • Education programmes • Reuse of grey water • Reduction of leaks by the consumers • Saline water for toilets • Tariff structures i.e. pricing • Water restrictions • Water efficiency

6.1.1 Supply side management strategies

As part of the ongoing planning and management of the local water resources, it has been suggested by van Dyk et al. (2005) that each local authority be in a position to guarantee an assurance of water supply to its users under existing climatic conditions. As is illustrated in Figure 19, for example, approximately 25% of the towns in the Northern Cape were using more than 80% of their available groundwater resources in 2000. It is proposed that the peak demand should be 80% of the available yield of the resource. The would allow for a buffer against drought and climate variability. It would also allow the aquifers time to recharge (van Dyk 2004).

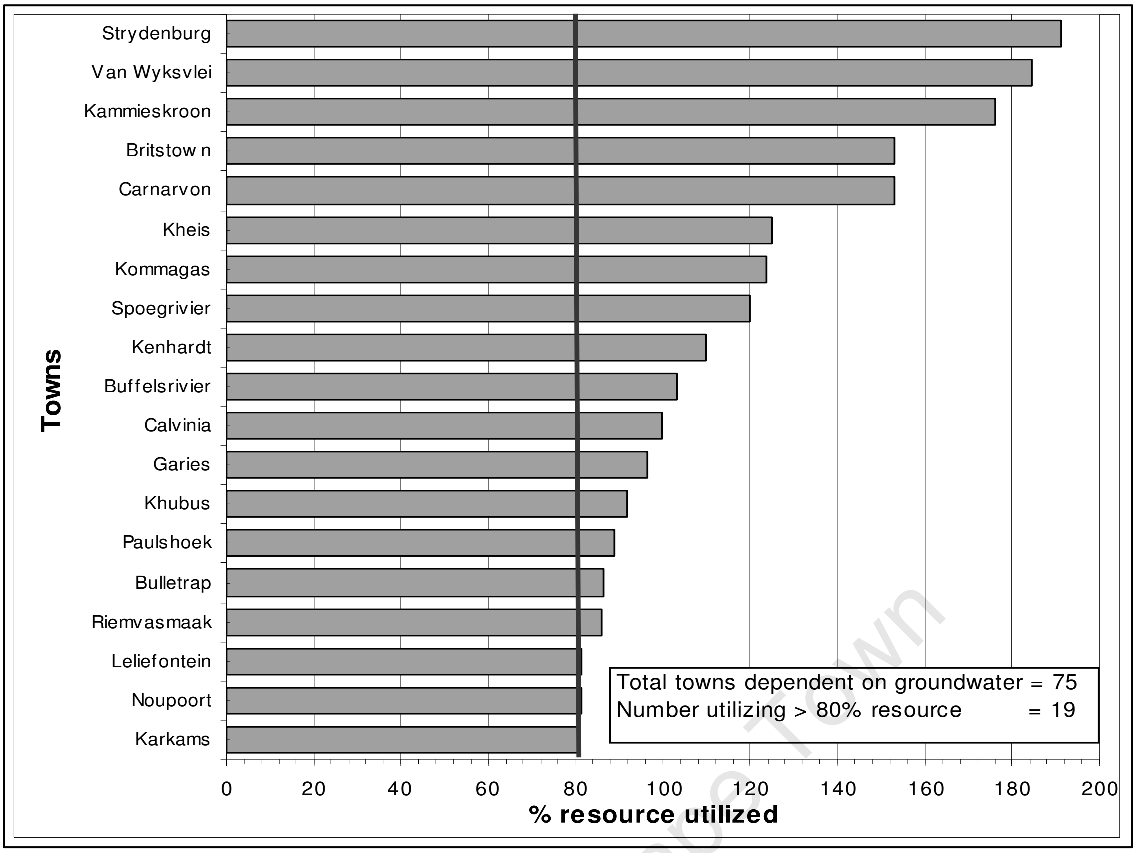

Figure 19: Example of groundwater resource utilization in 2000 in the Northern Cape (van Dyk et al. 2005)

Adequate water resources planning and management is key to meeting the suggested assurance of supply. This, along with the conjunctive use of different water sources, can provide an assurance of supply to provide some resilience to climate variability, especially in the form of droughts. Together with these approaches, contingency plans should be developed to address prolonged and unforeseen drought conditions. A number of unconventional alternative sources of water should be investigated and these include rainwater harvesting, artificial groundwater recharge, and cloud seeding. The reduction of supply line leaks, control of water pollution and the removal of alien vegetation provide the opportunity to secure "additional" water from the available sources. These options are discussed further.

6.1.1.1 Water resources planning and management

At a national level, DWAF has developed a National Water Resource Strategy, NWRS (DWAF 2004b) to address the management of the water resources in order to meet the development goals of the country. It will be reviewed at least every five years (Kasrils 2002). One of the key objectives of the NWRS is to identify areas of the country where water resources are limited and constrain development, as well as development opportunities where water resources are available. In addition, industrial users are required to develop and submit a water management plan if they draw their water directly from a water source (DWAF 2004b).

DWAF have further stated that they will assist municipalities to anticipate drought cycle conditions and prepare contingency plans for their specific areas through the Water Services Development Plan support (DWAF Northern Cape 2005). During these periods, DWAF state that they will assist municipalities to identify and initiate actions to mitigate the impacts of drought in affected areas. Whilst this support is not monetary, DWAF state that they are able to provide technical and planning expertise to the province. With this in mind, in the Northern Cape a database of water resource information is being established by the Water Service Division of DWAF. Currently this information is being housed by a Kimberley-based consultancy. In conjunction with this, DWAF plans to roll out a programme to ensure measuring, storing and interpretation of this water resource information (van Dyk et al. 2005). This information would ultimately be used by local authorities when doing their Water Service Development Plans.

At a local level, the Kgalagadi District Municipality has prepared a proposal for the development and implementation of a water resource management system within their district (Africon Engineering 2003; Kgalagadi DM 2004). This initiative has been developed by their health department. To ensure the sustainability of the water resources in their area, they proposed the protection of groundwater resources against over utilization and pollution and the implementation of awareness programmes at different levels.

Long-term planning at local level is essential to ensure future supply meets future demand. Forward planning of services provides local authorities with better options, as in the case of Garies, where it would not have been possible for them to utilize salt water for the sewage system if the dual infrastructure had not been installed from the start. This has enabled Garies to save the available fresh water for drinking and cooking (Ninham Shand & Octagonal Development 2004b).

In addition to planning, co-ordination of activities and sharing of information at a local level is important if a water resource management system is to function adequately. It is important that water authorities be actively involved in the management of water information in order that they deliver a consistent level of service to the beneficiaries. At present, a number of meetings are convened at local and provincial level, viz.:

- The South African Local Lovernment Association (SALGA) chairs a Provincial Water Sector committee which meets every two months;
- the Department of Housing and Local Government holds regular (monthly) Provincial Drought Task Team meetings; and
- each District Municipality hosts a District Water Sector Forum every month.

At a local level municipalities are required to prepare a Water Services Development Plan in terms of their function as a Water Services Authority (RSA 1997c). In order to inform these plans, water resources plans have been prepared by most local authorities. However, in some cases (such as Sutherland) the studies have been driven by political promises such as the promise of waterborne sanitation to replace dry sanitation systems (SRK Consulting 2004). In the case of Sutherland water saving practices should ideally be considered since the town experiences water shortages.

Groundwater is likely to be severely affected by projected climate change, with the groundwater table dropping due to reduced aquifer recharge, particularly in the western parts of the country (Cave et al. 2003). Strict groundwater management systems should therefore be put in place with early warning mechanisms to report depleted groundwater reserves. The DWAF's long-term goal is that local authorities manage their own water supply and demand. This can only be attained if they are informed of the possible supply resources, monthly abstraction volumes and water quality and aquifer levels (van Dyk et al. 2005). In response, the NORAD assisted programme for the sustainable development of groundwater sources for the Community Water and Sanitation Programme of South Africa (managed by DWAF), has prepared a groundwater management framework for rural water supplies (Murray & Ravenscroft 2004). This framework identified the key reasons for managing groundwater as the prevention of over-abstraction of the aquifer, the optimisation of the individual pumping rates and the minimisation of groundwater contamination from surface sources. The best example to date of groundwater resource management is the Local Government and Housing funded water management programme in Namakwaland where a database stretching over 10 years was established (Visser 2001). Unfortunately this project was terminated in 2002 due to a lack of funding.

An adequate and well functioning groundwater management system should be locally based with the necessary capacity housed within the local municipality. Borehole tests should be conducted to determine maximum pump rates and safe yields. All boreholes should be installed with volume meters on all pumps outlets to measure hourly pump yields and dip meters to measure water levels. A recording system for monitoring groundwater levels, pump rates and abstraction volumes should in place. This could be aided by a computer programme for capturing data and drawing graphs to monitor the groundwater levels. The monitoring data records should be reviewed every six months by a geohydrologist (Murray & Ravenscroft 2004).

Conjunctive use of surface water and groundwater

The use of surface water or groundwater should not be considered independently. The increasing intensity of water scarcity problems worldwide, requires the adoption of an approach that avoids the dependence on only one source or type of source. Some local authorities have therefore made use of multiple water sources (conjunctive use) by, for example, using both groundwater and surface water (Schulze & Perks 2000). This is often found in small towns which depend on both groundwater and surface water (Toens et al. 1998), since they usually do not have the resources to invest in large infrastructure and rely therefore on small integrated schemes, such as in the Bredasdorp case study of this thesis. This practice is also very common where groundwater is found to be too saline for domestic use. One way to increase the available supply is to dilute the saline water with fresh water to acceptable concentrations. Alternatively, the saline water can also be used for flush toilets, whilst the treated water can be used for drinking and cooking (Mvula Trust 2001). This type of system requires a dual water supply and dedicated plumbing for each source, and hence could be costly to install. If identified at an early stage, the infrastructure can be installed in new developments to reduce the reticulation costs.

Water transfers between basins can also be considered as conjunctive use, and may result in more efficient water use under the current and future changed climate. Inter-basin transfers are considered an effective short-term measure for addressing drought and water supply on a regional scale (Schulze & Perks 2000). This, however, is an expensive option and not likely to be affordable to small urban centres and would therefore require an intervention by the national Department of Water Affairs.

6.1.1.2 Contingency planning for drought

Much research has been conducted into coping with drought due to climate variability and specifically measures that could be taken to prevent or minimise the disruption and damage caused by such occurrences. In the past, most of this research has been conducted in the agricultural sector; more recently research has been focused on the impacts of drought on people and their livelihoods (Ziervogel et al. 2005; Huq et al. 2007). The lessons from this research, as well as resilience strategies of vulnerable communities, need to be taken into consideration when developing strategies to deal with the impacts of future long-term climate change. If the development goals of the country are to be achieved despite the impacts of climate change, then the appropriate lessons need to be incorporated into national and local water management policy.

Planning for the most vulnerable water supply areas should be such that proper monitoring can provide early warning of variations in climate, including global change impacts. As has been suggested previously, it is likely that climate change will affect the frequency of droughts. Seasonal forecasts have been shown to be useful as an adaptive strategy to respond to climate variability in the agricultural sector, especially in determining the planting and harvesting times. The forecast information is currently available on a monthly basis. However, there is still a need for improved support to enable seasonal forecast information at the national and district level (Ziervogel et al. 2005).

The cost of developing contingency plans to adapt to water shortages and mitigate droughts is relatively small compared with the potential benefits (Schulze & Perks 2000). Contingency planning would typically include standby relief under critical conditions, bringing in water via tanker, as well as drought relief aid from a national disaster fund. A brief discussion of each follows.

Standby relief under critical conditions:
Standby relief forms part of the National Disaster Management plan, which is co-ordinated by provincial governments. The Disaster Management Act (RSA 2003a) states that each province is charged with the responsibility of preparing a disaster management plan for the province as a whole, coordinating and aligning the implementation of its plans with those of other organizations of state and multi-national role-players and regularly reviewing and updating its plan. Likewise, each metropolitan and each district municipality is responsible for establishing and implementing a framework for disaster management in their municipalities, which is aimed at ensuring an integrated and uniform approach to disaster management in their respective areas. These relief measures should, however, be seen as the exception and not be implemented on an ongoing basis. Additional infrastructure to provide water under these drought conditions can be quite costly for small municipalities to install and maintain purely as an emergency measure, with the result that very few undertake this insurance measure. The consequence is that the provincial government is tasked with delivering water to drought prone areas by tanker.

Water tankering:
Water tankers are used to bring freshwater from other sources during times of drought or breakdown in critical domestic water supply. Although this forms an essential part of standby relief, it has in some cases become a regular form of municipal water supply. This is illustrated by the case of Van Wyksvlei, where in 2003 water was supplied by tanker from Carnarvon (60 km away) and Copperton and it was proposed to continue with this practice until a more permanent solution had been developed (Department of Housing and Local Government 2005).

Drought relief funding and aid schemes:
In addition, various national and provincial departments allocate relief funding to the Department of Housing and Local Government (DHLG) to administer in times of drought. The DHLG hosts regular Provincial Drought Task Team Meetings which are attended by Department of Housing, DWAF, Department of Agriculture, Department of Health and Social Services and the local district municipalities. This Task Team co-ordinates the drought relief efforts for the province and keeps track of the allocation of relief funding from the different departments. However, analysis of the meeting minutes revealed that in a large number of cases, the drought relief funding had been used to expedite the delivery of basic services and provide co-funding for bulk infrastructure to remote areas (DHLG 2005a, 2005b). These projects would normally have been funded under the Municipal Infrastructure Grant, but administrative delays had kept these projects on hold.

6.1.1.3 Alternative sources and storage

A number of potential sources of water could be considered to supplement the main source, such as rainwater harvesting, artificial groundwater recharge and desalination, and these are discussed below.

Rainwater harvesting:

Whilst acknowledging the agricultural benefits of surface water harvesting, there are also benefits of improving the recharge of underground water, either by natural infiltration of the soil or by artificial recharge methods. The effectiveness of this does, however, depend on the aquifer type. In the southern tributary catchments of the Lower Orange Water Management Area, the unique use of soil embankments has been employed as a means of rainwater harvesting (DWAF 2004b). This practice enables additional recharging of the aquifer and reduces runoff. Appropriate measures are required to manage the impacts of these “soomwalle” on downstream users (BKS (Pty) Ltd 2003).

Rainwater collection is one of the oldest means of collecting water for domestic purposes. At a domestic level, rainwater harvesting from roofs is an effective way of augmenting drinking water, watering gardens and filling up swimming pools. In Western Europe, the Americas and Australia, rainwater continues to be an important water source for isolated homesteads and farms (Agarawal & Narain 1997) In the Northern Cape a number of towns have implemented domestic rainwater harvesting schemes (Visser 2004; DHLG 2005b). It does, however, have limitations in drought prone regions, where the primary use would be to provide safe drinking water.

Artificial groundwater recharge:

This is the process of transferring surface water, which could be in the form of rainfall runoff, treated wastewater and urban storm runoff, into an aquifer The surplus runoff is often lost due to evaporation from dams and rivers. The main reasons for artificial recharge include the provision of security during drought and dry seasons and to reverse the negative dewatering trend (lowering of the groundwater table). Artificial recharge provides storage of local or imported surplus surface water and therefore also enables the management of both surface and groundwater reservoirs. In some cases it improves the quality of the groundwater, specifically the when it is saline. During years of good rainfall, the recharge of the aquifer is enhanced by injecting additional water into the aquifer. (Murray 2004b).

Examples of this technology in South Africa have been implemented in Atlantis (over 20 years in operation as of 2007), Polokwane (over 10 years of operation), Karkams (over 5 years operation) and Calvinia (over 2 years in operation). These examples have demonstrated that this strategy is effective and applicable to both large scale schemes as well as small scale operations.

It does require basic maintenance to ensure that the injection rate is optimised. Also, the quality of the water being injected needs to be of a high quality (Murray 2004b).

As can be seen for Karkams in Figure 20, groundwater recharge allows the aquifer to replenish itself and increase its resilience to dewatering during times of low rainfall. During periods of recharge, which coincide with periods of good rainfall, the groundwater level rose by between 10-25 metres (approximately 25-50%). The recharge potential for the Karkams aquifer for an injection over a one to six month period could increase the available yield by 0.6 to 3.9 times (Murray & Tredoux 2002).

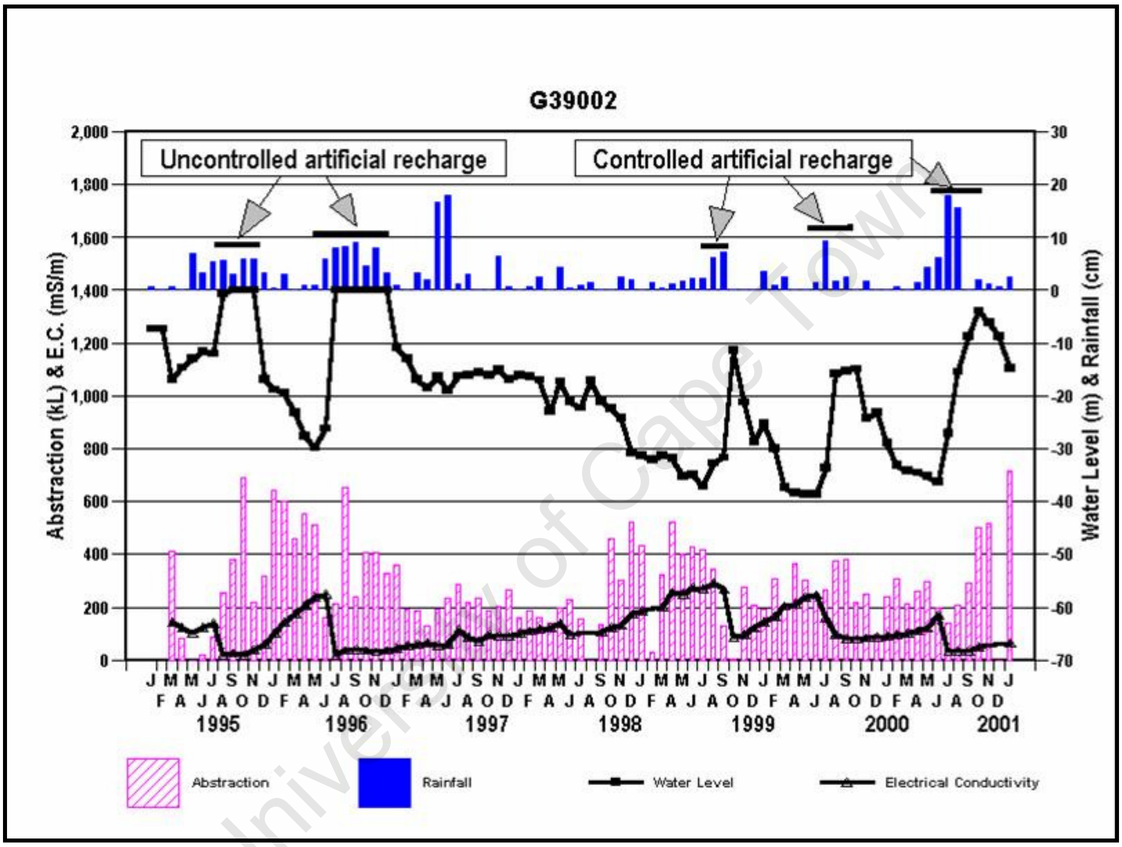

Figure 20: Water level responses to artificial recharge at Karkams (Murray 2004a)

The great difficulty in using artificial recharge, however, is the difficulty in keeping the wells in good operating condition due to clogging. This is due to suspended matter which reduces the pore space in rock, or the high levels of organic matter present in the water which results in bacterial growth (Mather 1993).

Desalination:

Desalination offers an opportunity for coastal municipalities to convert seawater into freshwater. Presently this technology is both a capital- and energy-intensive source of freshwater that would make the cost of water out of the reach of most local municipalities – in some case 3-4 times the cost of conventional sources (Eglal et al. 2000). However, the unit price of desalinated water is dropping continually as technology improves (ATSE 2002). In places such as the Middle East, where there is no alternative for fresh water, this technology provides a solution. In Dubai, for example, 95% of the drinkable water is derived from the sea (Makin 2005).

There are specific locations within South Africa where small-scale desalination has proven to be more cost-effective than transporting fresh water over long distances. In these instances, groundwater with a high saline content is desalinated using small plants, especially at schools and clinics (van Dyk 2004).

6.1.1.4 Reduction of leaks

Water losses in the water supply system are due mainly to high static pressures, burst pipes, leaking valves and reservoirs and water treatment processes. Lambert et al. (1999) show that leakage is a function of inline pressure, length of pipe lines and the number of consumer connections, and not of per capita consumption. Extensive study of physical losses from water supply systems has led to the conclusion that a certain amount of leakage is unavoidable and has been termed the Unavoidable Annual Real Losses[31] (UARL) by Lambert et al. (1999).

In South Africa, the level of unaccounted for water in urban distribution systems is between 15 and 20% of the bulk volume supplied, which is viewed as high by international standards (Goldblatt et al. 2002). For example, the average for water losses in Australia was reported in 2003 as 9.6%, due mainly to UARL and water meter inaccuracies (Girard & Stewart 2007).

Still (2006) warns that confusing comparisons can result from expressing leaks as a percentage of the bulk water supplied or the volume actually consumed. Using the latter would result in a higher percentage for the same volume of water lost. He calculates typical real losses in South Africa cities at 30% of the consumed volume as compared to rural villages, which are typically between 80-240% of consumption and 50-70% of volume supplied. This is not too different to municipal systems in the MENA[32] countries, where about 50% of water supplied is unaccounted for (World Bank 1996).

Unaccounted for water not only amounts to losses in usable water, but also in potential revenue due to additional treatment and distribution costs. These losses are often passed onto the consumer, who are required to pay higher tariffs to offset these losses. With the stress on available water supplies, consumers cannot be expected to increase the available water resource through a reduction in demand alone. Losses in the system need to be addressed as part of supply management. Service providers should see this as one of their main target areas for "creating" more available water. Just as any viable business would aim to reduce their commodity losses in order to maintain their competitiveness, so too should water service

[31] The UARL is expressed as function of the length of mains and supply piping, number of service connections and the average operating pressure.

[32] MENA – The Middle East and North African region – Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Malta, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, Yemen, and the West Bank and Gaza.

institutions aim to run an efficient operation. It has been estimated that a saving of up to 15% of demand can be achieved by implementing effective distribution management measures (DWAF 2004c). This could be achieved through leakage detection and repair, pressure reduction, pipe replacement programme, cathodic protection of pipelines against corrosion, changes to the methods for mains flushing and reservoir cleaning and installing peak balancing capacity.

In addition, the introduction of pressure management systems, where water lost from undetected leaks is reduced by reducing the off peak water pressure in the pipes, would also reduce the water lost through leaks within the piping on private property. It has been estimated that if static pressures are reduced by about 35%, losses due to leaks could be reduced by 7% (Dube & van der Zaag 2002). In Khayalitsha (South Africa), the introduction of pressure management systems reduced water lost from undetected leaks by reducing the off peak water pressure in the pipes. This also reduces the water lost (not used) through leaks within the piping on private property (City of Cape Town 2005a). The initial water saved by this project was 9 million kl/year, 40% of the original amount supplied to the area (McKenzie et al. 2004).

6.1.1.5 Control of invasive alien vegetation

It has been reported (Cullis et al. 2007) that invasive alien plant species (IAPs) lead to an undesirable reduction in streamflow and water yield. IAPs have been reported to cover some 10 million hectares, about 8%, of South Africa (Kasrils 2000). It is the invasion of the riparian zones and mountain catchments areas that are the most important from a streamflow reduction perspective. They currently cause the loss of some 4% of the current registered water use from these catchment areas and it is estimated that this could go up to as much as 16% of registered future use if unchecked (Cullis et al. 2007).

In response, DWAF have initiated the 'Working for Water' programme to remove invasive alien tree species (wattles, pine etc) from catchments in South Africa as part of local catchment management strategies (DWAF 2004e). Through the modification of the vegetation in various catchments, where water-thirsty vegetation with high transpiration rates has reduced the stream flow, the available water supply can be increased. Through the Working for Water Programme it is estimated that approximately 750 000 hectares will need to be cleared each year over a 20-year period (Kasrils 2000). While this programme is funded through the national government, the implementation is undertaken by local authorities. This programme provides a real opportunity for local employment creation as well as a means to release additional water into the supply system.

6.1.1.6 Rainfall enhancement

Research has shown that only 10% of moisture in atmospheric systems passing over South Africa falls as rain (Shippey et al. 2004). By using cloud seeding, i.e. the artificial introduction of additional condensation nuclei into clouds around which raindrops can form, the ability of the clouds to produce rainfall is enhanced. Rainfall enhancement can only stimulate raindrop formation where clouds already exist and meet specific physical criteria.

However, these areas are limited to the eastern and north-eastern parts of South Africa, as is indicated in Figure 21. This coincides with the area due to get wetter under future climate projections and hence does not provide a viable solution for the drier western regions of South Africa. Furthermore, the cost implications may make this practice prohibitive for small municipalities (Otieno & Ochieng 2004).

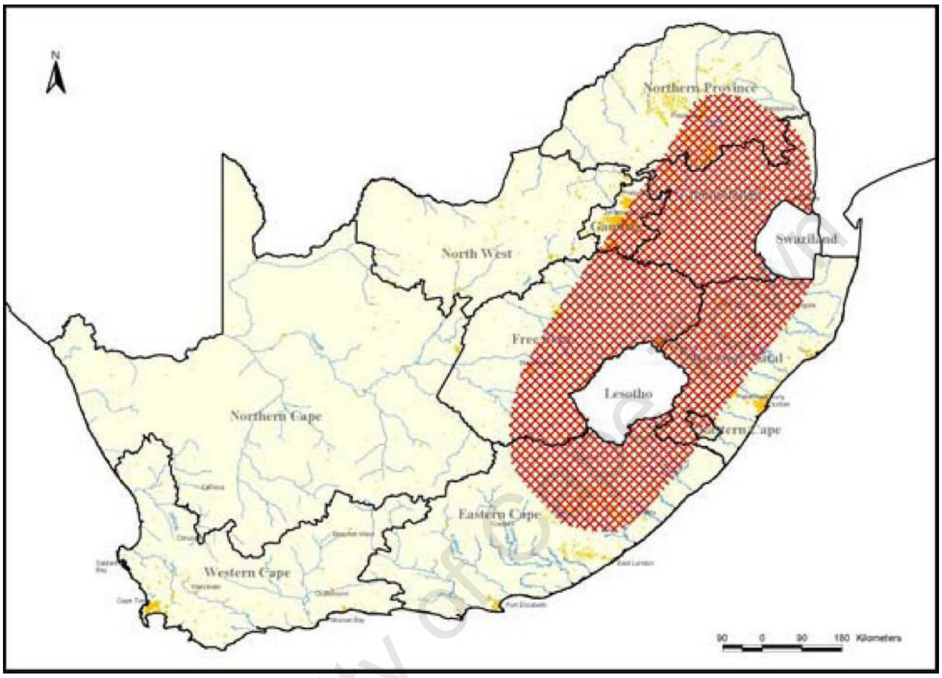

Figure 21: Likely target areas for future operational cloud seeding (Shippey et al. 2004)

6.1.1.7 Control of water pollution / water quality

Polluted water that is unfit for drinking or other uses can have a similar impact to reduced water supply. Reducing water pollution effectively increases the supply of water, which in turn increases the safety margin for maintaining water supplies during droughts (Schulze & Perks 2000). The protection of water quality presents a major challenge to water policy in South Africa.

The above supply options offer limited strategic choices for small towns, since they lack the necessary financial and technical resources to implement capital intensive infrastructure. Basic groundwater capture and small surface water systems are generally the limit of the investments by these small urban centres. Artificial groundwater recharge and rainwater harvesting can offer some relief, but this is not as effective during time of sustained drought. Desalination is appropriate for very small towns, where potable water is provided separately, but is relatively costly to operate and maintain in larger systems.

Recently supply options have not been as prevalent in recent times and many more utilities are introducing demand side management strategies. Just as in the electricity industry, where “least cost planning” and “integrated resource planning” were developed to compare energy conservation to increased supply, so too have these principles been transferred to the water sector. Resource conservation and demand management are central to integrated resource management and planning. Least cost planning involves several elements: end-use analysis, demand forecasting, the design and modelling of demand management programmes, evaluation of conservation costs and savings, estimating supply costs, cost benefit analysis and multi-criteria analysis and final choice of options. It is more cost effective to implement demand side measures than to invest in large supply side infrastructure (DWAF 2000; White & Fane 2002). The following section therefore considers a number of these strategies that may be appropriate in the small urban context.

6.1.2 Demand side management strategies

Reducing growth in demand can result in postponing large infrastructure requirements and can thus result in significant financial savings (DWAF 2000). Reduced demand also creates a greater margin of safety for future drought periods. It is calculated that the total opportunity for reducing water demand in the water services sector is approximately 39% of the total existing demand (DWAF 2000). There are a number of ways to reduce the water demand by consumers. The first is to influence their consumption behaviour. This could be done through education programmes as well the provision of incentives or assistance projects. The second would be through persuasive means such as water restrictions and tariff structures. The implementation of urban water demand side management (DSM) will not make any significant impact on the availability of water on a catchment-wide scale. However, it is a crucial intervention that must be implemented by all local authorities, so as to prolong the life of existing urban sources of supply. To encourage this at local level, DWAF has stated that it will not consider the licensing of new water resource developments for any local supply schemes unless water demand management has been implemented (Ninham Shand et al. 2004).

In Australia, for example, a number of water utilities have invested large amounts of money in demand management programmes because of the high costs of bulk water supply, economic benefits of deferring large capital works, but most notably in some cases regulatory requirements. In Sydney, the Sydney Water Corporation was regulated to reduce demand per capita by 25% in 2001 and 35% by 2011 from 1991 levels (White & Fane 2002). However, Turner and White (2006) report that even with a long history of demand side management in Australia, there is limited evidence of real long-term commitment through adequate budgeting and staffing. The result is that water planners are led to believe that DSM has been applied and that supply side options are better to pursue. Further, the most prominent lesson from the demand management literature is that programmes to encourage DSM activities do not guarantee that the desired activities will actually take place. Many programme plans will assume a hundred percent uptake of an initiative, when in reality DSM programmes have very low installation rates (Terrebonne 2005). A shift in behaviour patterns is difficult irrespective of the level of education, wealth or size of the domestic unit. All water saving measures are not applicable to everyone, since their attitudes towards water differ (Yurdusev & Kumanhoglu 2007). Therefore the probability of success is a very important consideration in determining the cost effectiveness of an intervention.

White & Fane (2002) have reviewed a number of DSM initiatives in Australia and have developed a list of options with related savings and associated unit costs. These are listed in Table 12, with the unit costs converted to 2005 Rands. The sub-sections that follow discuss some of these strategies in relation to their applicability to small towns, viz. tariff structures, sanitation savings, water restrictions, reduction of on-site leaks, water-use efficiency, re-use of grey water and education programmes.

Table 12: Examples of demand side options (after White & Fane 2002)

Measures	*Saving (l/p/d)*	*Cost (2005 R/kl)*
Shower head performance standard	8.6	0.01
Active leakage control	7.2	1.71
Clothes washer performance standards	3.5	0.23
Residential indoor audit and retrofitting - with discount	3.4	1.08
Industrial and commercial audits	2.9	2.40
Industrial reuse project 1	2.3	3.02
Price increase (R0.57/kl over 2 years)	1.9	0.01
Outdoor water use restriction	1.8	0.36
Industrial reuse project 2	1.8	3.71
Residential indoor audit and retrofitting - free for low-income	1.5	1.43
Hotel audits	1.3	2.40
Shower head rebate (R56.89)	0.7	0.80
Washing machine rebate (R853.28)	0.4	3.99
Outdoor irrigation system audits	0.3	3.82
Outdoor water use promotion	0.2	2.79

6.1.2.1 Tariff structures

Most policy papers dealing with natural resource management in South Africa recognise the need for economic instruments and market mechanisms for efficient utilisation and allocation of natural and environmental resources (Eberhard 2001). The provision of water at prices below the true economic value is considered the main reason for inefficient use of water and allocation in South Africa. Further, in the context of water scarcity, an argument can be made for the introduction of economic incentives in water-stressed catchments to encourage the conservation of water and its shift from low to higher value use. This can be done administratively or by using market-related mechanisms. The Department of Water Affairs and Forestry has implemented a water pricing strategy which includes abstraction, storage of water for recreational purposes and stream flow reduction for the purposes of afforestation. Water use charges have been divided into four sections, viz. municipal, industrial, mining and energy, agriculture and stream flow reduction activities (DWAF 2004b). Unit charges per kilolitre will be determined for each user sector and water management area. The charges are based on recovering costs of managing the total volume of water that may be allocated for use in each Water Management Area.

One of the most effective ways being used by local authorities to encourage consumers to use water more efficiently is through tariff mechanisms. Market-based allocations are able to respond more rapidly to changing conditions of supply and also tend to lower the water demand, conserve water and consequently increase both the robustness and resilience of the water supply system (Schulze & Perks 2000). Nevertheless, before any form of tariff system can be implemented, meters for measuring consumption should be installed. This allows for transparency and trust in relation to charging per volume consumed. Maddaus' (2001) review of the literature indicates that the installation of water meters typically reduces consumption in range of 10-30% and in some cases as much as 50%. It is advisable therefore that consumption needs to be metered before any DSM activities are implemented,.

Hassan et al. (1996) raise a number of issues to be considered when reviewing the pricing of water to reduce demand. Marginal cost pricing is more appropriate than average cost pricing, since it sends the right pricing signal to both efficient and inefficient water users. Variable tariff rates, as opposed to flat rates, are more effective to provide for periods of scarcity and peak demands. This can be done by implementing rising block tariffs, as opposed to the declining block tariffs implemented in some cases which encourage resource use. Quality return flows from waste streams should be rewarded and encouraged. Finally, as discussed in section 3.3, access equity through lifeline tariffs should be assured at all times, since income distribution in South Africa is highly skewed. Therefore a pricing policy that exacerbates this inequality is likely to be undesirable, since the price elasticity of water is very low in low income households (Eberhard 2001). Hence any pricing mechanism should target higher earning households and ensure that water service remain affordable to lower income households.

It is evident from most urban studies (see section 3.3) that demand for water is price inelastic, at least in the short run. Research conducted in Cape Town by Jansen and Schultz (2006) found that consumption is insensitive to price changes among the poor, while the richer households react to price changes more. They found that a 10.0% price increase facing the marginal consumption of the high-income group would trigger a 9.9% reduction in their water consumption. This has policy implications. Price mechanism can only work on the higher income households, who generally have the higher consumption volumes. Other mechanisms need to be used for low income households where wastage of water in apparent, such as quantitative restrictions, low pressure valve installation and education.

In most cases a rising block tariff has been used to curb excessive use of water. This mechanism is designed along the principle of “the more you use, the more you pay”, as illustrated in Table 13. Rising block tariffs are promoted on the basis that they promote equity by forcing companies and wealthier households to cross-subsidise the poorer households, discourage wastefulness, implement marginal cost pricing principles thereby promoting economic efficiencies. Rising block tariffs can be used to improve the living standards of the poor, while at the same time curb the consumption of the wealthy, and still provide sufficient revenue for the water service provider (Bailey & Buckley 2004). By using the elasticity of demand of the higher income group, the rising block tariff can be structured accordingly (Jansen & Schulz 2006). This mechanism does not usually require additional staffing or resources, but merely an adjustment to the billing system. An education campaign is also advisable in this instance to make people aware of the new billing systems and also to make them aware of water saving practices. As can be seen from the example for Cape Town (Table 13), the local authority increased the water tariffs substantially in an attempt to curb excessive water use. The two top tiers were increased by 87% and 191% respectively in order to reduce high end consumption. This measure was implemented as a result of the very low water levels in the dams due the prevailing drought conditions during 2005 and 2006.

Table 13: Example of domestic consumption rising block tariff (City of Cape Town 2005b)

Consumption in kl per household	*Tariff per kl*		
	2004/5	*2005/6*	*increase*
0 – 6	R0.00	R0.00	R0.00
7 – 12	R2.32	R2.46	6%
13 – 20	R6.15	R6.52	6%
21 – 40	R10.41	R11.04	6%
41 – 60	R13.34	R25.00	87%
61 +	R17.20	R50.00	191%

Another approach would be to use incentives and rebates, in order to encourage water saving initiatives, installation of rainwater tanks and household boreholes, retrofitted dual-flush toilets and the installation of waterwise gardens with indigenous plants, which have low water needs.

6.1.2.2 Water restrictions

In a some towns and cities water restrictions have been implemented as means of curbing water demand (Department of Housing and Local Government 2005). This has been done either through rising block tariffs or the restriction of certain water uses, such as the watering of domestic gardens. In severe cases, users are restricted to a certain volume of water per day. Those exceeding the limit are fined.

In areas with high water consumption, the contribution of outdoor water use such as landscape irrigation, gardening, car washing and topping up of swimming pools, can account for as much as 50% of the urban consumption (Hanemann 2000). Therefore the pricing of water and water restrictions can be very effective in reducing these outdoor consumptions. Renwick and Archibald (1998) observed that middle income households were more price responsive than higher income households, primarily due to their water bill constituting a larger portion of their household budget. Non price policies are more effective in reducing consumption in the higher end users, for example, water allocations and irrigation restrictions shift the conservation burden onto households with large landscaped areas. The impact of water restrictions can be clearly seen in the variation of the season demand (influenced mainly by gardening) for Cape Town in 2001 and 2006, as illustrated by Figure 22 (Sparks 2007).

Instituting water restrictions requires additional personnel capacity to police the interventions and to prosecute those who are offenders. The implementation of an education campaign to both inform users of the new measures and to make them aware of water saving practices also requires capacity and funding. Unfortunately water restrictions do not always permanently reduce the demand for water, and restrictions on watering times often merely shifts the peak water use, rather than reducing the overall demand (White 2001).

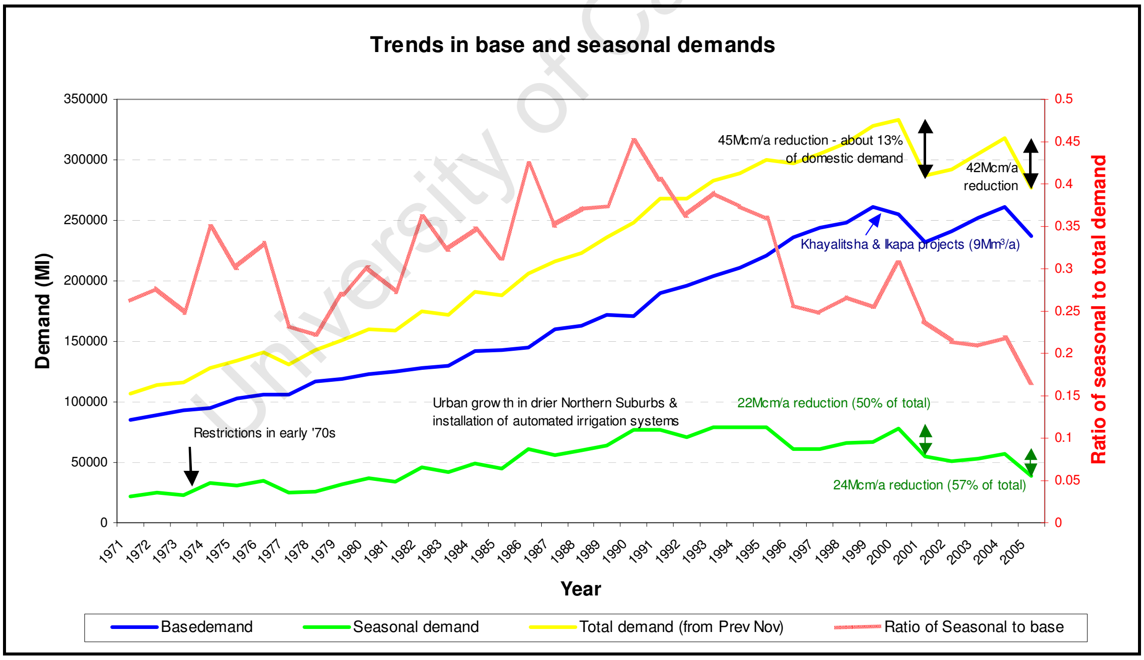

Figure 22: Seasonal demand for water in Cape Town for the period 1971 to 2006 (Sparks 2007)

6.1.2.3 Changes in agricultural management practices

Agriculture is by far the largest user of water in South Africa, as shown in Figure 4, while urban and rural requirements make up 25% and 4% respectively. Agriculture and forestry together use two thirds of the available water resources.

Currently, losses through irrigation range between 30-40% of the demand, and is indicative of the potential for water demand management in the agricultural sector (DWAF 2004d). Whilst out of the direct control of municipal managers, small towns do compete directly with agriculture for their supply of water. A reduction in the demand for water by the agricultural sector would release additional water for use by the urban sector. The Draft Water Allocation Reform Framework (DWAF 2005) suggests methods that could be used to take proactive steps to meet the water needs of historically disadvantaged individuals, women and the poor; ensure participation by these groups; and establish partnerships to build capacity to use water productively. To balance the many demands for water for production, it might be necessary to re-allocate water between users, where some water may be taken from existing users to give to those who have none. However, it is likely to be a slow process, since the agricultural lobby is unlikely to willingly give up its allocation for redistribution to municipalities and subsistence farmers (van Rooyen 2007). It would also be prudent for the agriculture sector to consider efficient irrigation techniques in any event, given the likelihood of future water scarcity.

6.1.2.4 Sanitation systems

Studies have shown that flush toilets account for approximately 30% of total residential indoor water use (Gumbo 1998). A number of options exist to reduce this volume, ranging from dual flush, saline water flush, low flow and dry toilets.

Dual flush toilets:

This strategy reduces the demand for water when providing waterborne sanitation. Some models of dual flush toilets use six litres of water to flush solid waste but only three litres of water to flush liquid waste. These toilets save an average of 26% more water over the single-flush six litre toilets. In places such as Australia and Singapore, this technology has been made mandatory (Soroczan & Baynes 2003).

Saline water for toilets:

As discussed under conjunctive use of surface and groundwater, saline water can be used for flush toilets. A dual system can be adopted where the salt water is used for the sewage system and the fresh water is used for drinking, as is the practice in the town of Garies (Mvula Trust 2001). This type of system requires a dual water supply and dedicated plumbing for each source. If identified at an early stage, the infrastructure can be installed in new developments to reduce the reticulation costs, which can be costly if implemented at a later stage.

Dry sanitation systems, low-flow systems:

In areas where there is a lack of water to allow conventional flush toilets, dry sanitation, pour flush and low flow systems should be considered. In areas that are dependent on groundwater, care must be taken to avoid contamination of groundwater source when installing VIP latrines. Composting latrines or lined chambers should be considered if there is a potential for contamination. However, sometimes it is difficult to get buy-in from consumers in South Africa who have aspirations for flush toilets. In 2003 the planned flush toilet project for Carnarvon (Kareeberg) was stopped by the Minister of Water Affairs and Forestry, and dry sanitation was specified due to the shortage of water in the area (Karoo District Municipality 2003).

6.1.2.5 Water use efficiency

The development and enforcement of minimum water efficiency standards for new appliances such as dishwashers and washing machines would enhance water use efficiency. Regulations for rated shower heads and efficient flushing toilets for new developments would result in less resources being used for the same service. This could be encouraged by offering incentives for water efficient purchases and installations (White & Fane 2002). The passing of municipal by-laws would ensure that new buildings comply with such a policy.

Retrofitting of plumbing fittings such as low or dual flush toilets, tap flow regulators and low volume shower roses have been shown to reduce overall water use. This has been as much as 25% for domestic demand (Martindale & Gleick 2001).

6.1.2.6 Leak reduction

The average water wastage due to plumbing leaks in the household is estimated at 20% of the total indoor household water use (DWAF 2004c). Consumers should be encouraged to maintain their internal reticulation systems. Whilst no revenue may be lost to the service provider due to these leaks, unused water is being wasted through leaking taps, pipes and faulty toilet cisterns. Together with the education programme and pressure control systems, these internal leaks can be reduced.

Initiatives such as the Water Leaks Project in Cape Town aims to repair household leaks in Khayelitsha to reduce water and financial wastage (City of Cape Town 2006b). This approach initially costs money to set up, but the long-term savings and delaying of new supply options makes this strategy economically viable.

6.1.2.7 Re-use of grey water

Grey water utilisation at a domestic level can be beneficial for irrigating small gardens, and to lesser extent assisting in the recharge of groundwater resources. This practice not only reduces the water demand, but also relieves the volume on the waste water treatment works. Municipal byelaws are required to regulate this practice to avoid the contamination of the groundwater and to ensure that pooling of grey water does not take place, as this could lead to the spread of diseases. The use of properly constructed French drains should be regulated.

6.1.2.8 Water education programmes

Public information and school education programmes are key to highlighting the need and benefits of initiating water demand strategies. These programmes could include brochures, advertising, newsletters or magazine and newspaper inserts, exhibits and informative billing.

All the options listed above require a behaviour and perception shift by users as well as the water supply institutions. Whilst these options still require some financial input, they are generally cheaper than investing in new large infrastructure, which require longer investment periods. These options are best managed at a local level and need to be designed with local conditions and practices in mind. Hence, demand side options are best implemented at the municipal level, specifically in small urban centres.

However, political buy-in for some of the strategies such as water restrictions and dry sanitation will need to be obtained through education programmes, but much like the supply side options, these also require human and financial resources. There is a general lack of technically qualified people to plan and implement water demand management measures. It has been reported that in developing countries additional political and economic barriers result in little or no time and energy to address water savings. A shift in behaviour patterns is difficult, irrespective of the level of education, wealth or size of the domestic unit. All water saving measures are not applicable to everyone, since their attitudes towards water differ (Yurdusev & Kumanhoglu 2007).

6.2 Sustainable development indicators for assessing and prioritising options

There are several possible methods to select and prioritise the strategies that would satisfy developmental needs and allow adjustments to longer-term climate change impacts. The NAPA programme (LEG 2004) considers both qualitative and quantitative assessment criteria for an identified strategy for a projected climate induced impact. These include the expected level of damage due to inaction, the potential poverty reduction due to enhanced adaptive capacity, the potential cost savings due to synergies with other adaptation initiatives and the cost effectiveness or investment costs associated with the intervention.

The challenge is to use tools that deal with decision making involving conflicting priorities in a structured and systematic manner. The most commonly used are cost benefit analysis (CBA), cost effective analysis (CEA) and multi-criteria decision analysis (MCDA) (LEG 2004). The first two require that costs and benefits be expressed in absolute monetary terms. However, in this study numerous criteria may be included which do not have monetary values. Resource management usually involves variables which cannot be fully quantified, but are nonetheless determinant factors in the decision making. In such cases MCDA is considered to be the quickest and most appropriate method for addressing vulnerability strategies. MCDA has inherent properties that make it appealing and practically useful to planners. Belton and Stewart (2002) describe it a taking explicit account of multiple and often conflicting criteria. It helps to structure the management problem by providing a model that can serve as a focus for discussion, and it offers a process that leads to rational and justifiable decisions. This is possible since it is conveniently structured to enable a collaborative planning and decision-making environment. This participatory environment accommodates the involvement and participation of multiple experts and stakeholders (Mendoza & Prabhu 2003). Pietersen (2006) cautions however, that the application of MCDA methods in water resource management should be used circumspectly by planners and decision-makers and should not be viewed as a "black box".

Mendoza and Martins (2006) suggest that in terms of practice, MCDA should adopt a more participatory approach at all levels of the analysis process. Stakeholders or decision makers must be able to participate and contribute actively to process—from identification of strategies, formulation of relationships, and including the actual decision-making process. This calls for a more transparent, simple, and easily accessible participatory analysis approach and process. Hence the approach used in this thesis is a two stage one. Firstly the proposed strategies should be assessed qualitatively against a pre-selected set of criteria. This process can be done relatively quickly and does not require much in the way of quantitative analysis of costs and yields. Once a smaller suite of options has been identified, it can then be evaluated quantitatively. This method allows for stakeholders to be involved in the identification of strategies, as well as being able to articulate unquantifiable concerns and obstacles, without necessarily having to be armed with the associated technical knowledge. The following two sections address the qualitative and quantitative assessment criteria associated with water resources management and urban supplies and draws on examples of processes conducted by the author to illustrate the process.

6.2.1 Qualitative screening tools

In order to rank the appropriate strategies and interventions discussed in section 6.1, a set of criteria needs to be developed for the comparative analysis of the inputs and the impacts of the strategies. At a national level in South Africa, DWAF have set a number of objectives against which strategies by water institutions or consumers to influence the water demand and usage of water should be measured (DWAF 2004a), viz.:

- economic efficiency;
- social development;
- social equity;
- environmental protection;
- sustainability of water supply and services; and
- political acceptability.

In a study of the Northern Cape province conducted by the author, these were further expanded through consultation with stakeholders from local municipalities and members of the Provincial Drought Task Team, and are described in Table 14. A scale against which to rate each of the criteria was also established in consultation with the stakeholders attending the Provincial Drought Task Team meeting (DHLG 2005b; Mukheibir & Sparks 2006). A retrospective comparison of these criteria with those proposed by the USAID (2007) revealed that they were consistent with international approaches.

Table 14: Definitions of criteria for strategy analysis (Mukheibir 2007c)

Criteria	Description	Ranges for scores against the criteria
Additional yield / saving	How will the intervention impact on water supply through additional yield and/or savings? Is it effective in creating water supply resilience?	1 = None 2 = Low 3 = Significant 4 = Very high
Required technology	Is the technology for the intervention readily available?	1 = Not available 2 = Must be imported 3 = Available in SA 4 = Locally available 5 = Already installed
Local capacity to implement	What level is the institutional capacity currently at with respect to the intervention?	1 = Very low 2 = Low 3 = Adequate 4 = High
Additional capital expenditure	Will the intervention require additional capital expenditure?	1 = High cost 2 = Medium cost 3 = Low cost 4 = No cost
Additional running costs	Will the intervention incur additional running costs?	1 = High costs 2 = medium costs 3 = Low costs 4 = No O&M costs
Local employment	To what extent will the intervention impact on job creation?	1 = Loss of jobs 2 = Neutral 3 = Few jobs (<10) 4 = Many jobs (10-30)
Acceptability to local community	What is the consumer acceptability of this intervention in terms of additional cost to them and convenience? Does it improve access to and affordability of water services?	1 = None (high additional costs) 2 = Low (added costs / inconvenience) 3 = Neutral 4 = High (no additional costs)
Impact on local water resources	What impact will the intervention have on the water resources and the environment in the area?	1 = Negative 2 = Neutral 3 = Positive 4 = Highly positive
Long-term applicability	What is the period of impact of the intervention? (short to long term)	1 = <2 years 2 = 2-5 years 3 = 5-15 years 4 = 15-25 years 5 = >25 years

The potential for additional resource yield or savings should be established for each intervention, even if it is established intuitively. The intervention should only be pursued if it will have a positive impact on available supplies and no adverse affects on the local environment and water resources. The local availability of the proposed technology is a prerequisite for sustainable implementation. Spare parts and technical assistance should be close at hand. The local institutional capacity to properly operate and maintain the equipment or manage any demand reduction programmes should be in place. The cost implications, both capital and running costs should be intuitively estimated, These can be confirmed later when doing a quantitative assessment. The socio-economic considerations should be assessed, such as job creation, affordability, equitable access and convenience. The ninth criterion, long-term applicability, was included as a final screen to establish which strategies have the potential to address long-term climate change impacts. This could be used as a "killer" criterion with which to eliminate any strategy that does not meet the long-term requirement. For example, delivering water by tanker could be seen as an interim or relief measure, but not as a sustainable long-term option to deal with impacts due to climate change. This is relevant for both resilience-type adaptation and acclimation-type adaptation as explained in section 4.1, where building resilience to extreme events such as droughts and reducing the system sensitivity to gradual changes in the average climate conditions is important over the longer term.

It is important to weight the criteria since some will carry more significance than others. The criteria were weighted by the stakeholders from *1-5*, where *1* was deemed to have a low importance, and *5* a high importance[33]. In Figure 23 the average weighting per criterion is provided and was used when evaluating the strategies. As can be seen, different sectors placed varying importance on the different criteria for evaluating the strategies. A good example of this would be local employment, where the local government officials placed a higher priority on this weight compared to the officials from DWAF, whereas almost all parties agreed that additional yield/saving, additional capital expenditure, impact on local resources and long-term applicability were of highest importance.

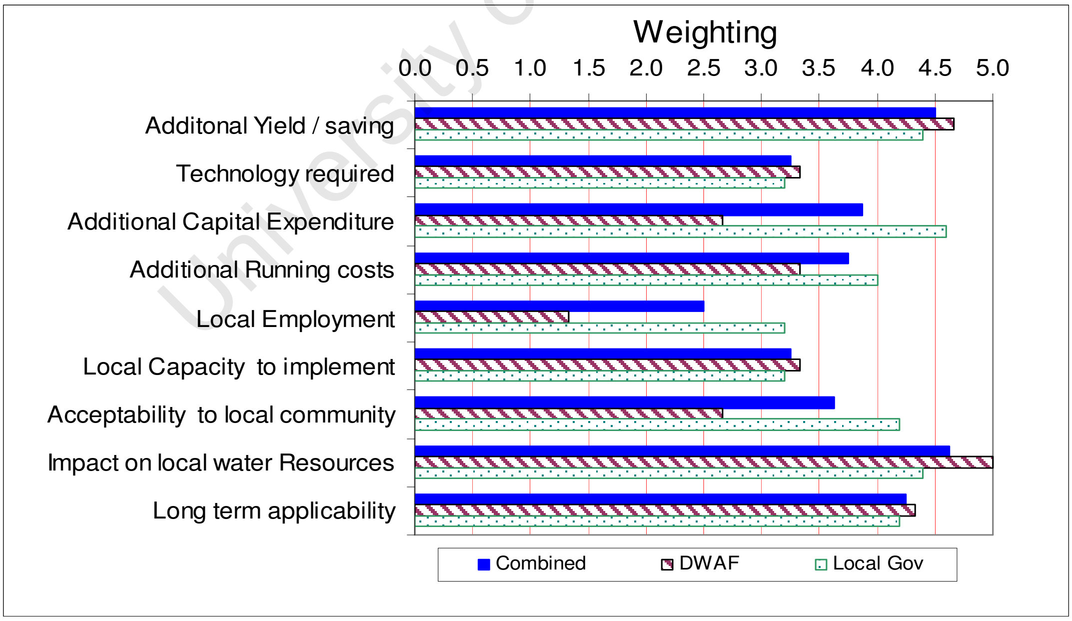

Figure 23: Weighting of criteria for strategy analysis by various stakeholders (Mukheibir 2007c)

[33] It should be emphasised that the responses received from the stakeholders were their own views and not those of their respective organisations.

Therefore the ranking of the strategies will be assessed by establishing a ranking score per strategy by considering the strategy against all the criteria and their associated weightings. This is best illustrated by the following formula:

$$RS = \sum_{x=1}^{n} CS_x * CW_x$$ **Equation 3**

where: RS = Ranking Score for the strategy

CS_X = Criterion Score for each criterion

CW_X = Criterion Weight for each criterion

n = the number of criteria

Analysis of a sample of strategies against the combined criteria:

By using the MCDA methodology and the weighted qualitative criteria discussed above, a sample of strategies most likely to be appropriate to the Northern Cape were identified and assessed. This was done in consultation with representatives of the Northern Cape Provincial Drought Task Team (Mukheibir & Sparks 2006). The Ranking Score for each strategy was calculated by multiplying the related Criteria Score with the corresponding Criteria Weighting and summing all the weighted criteria scores for each strategy. As can be seen from Figure 24, the different stakeholders rated the strategies differently. Except for *resource planning and management, water restrictions* and the *reuse of grey water,* the overall trend is not too dissimilar.

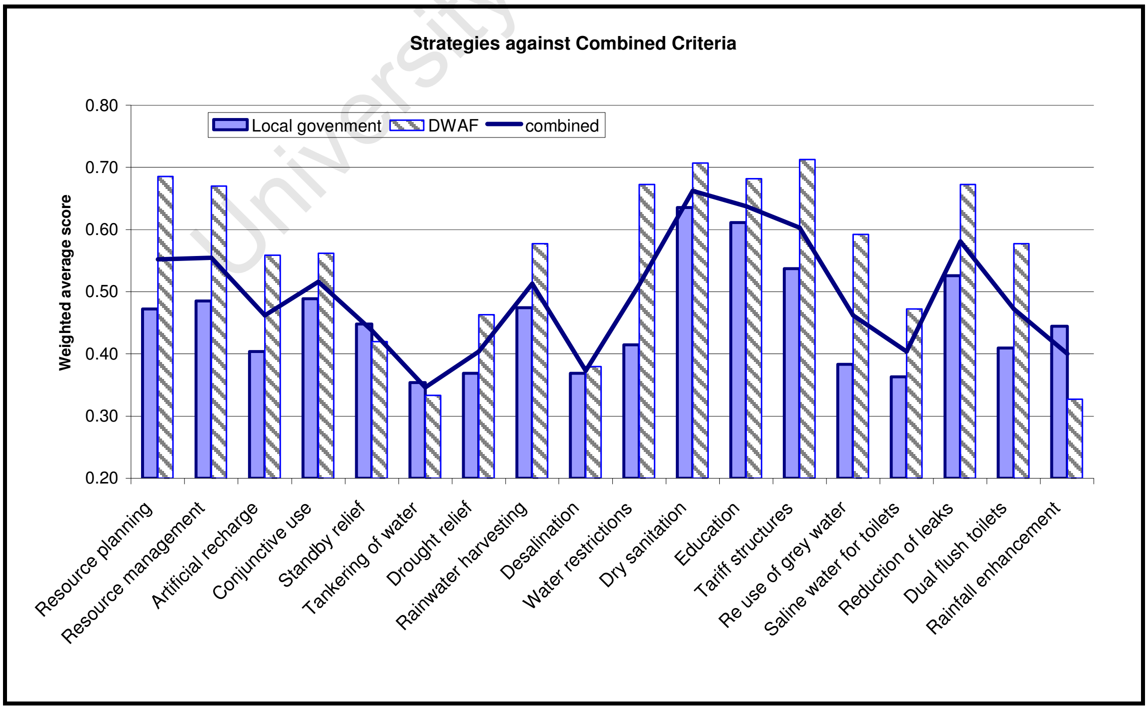

Figure 24: Graphical representation of strategy comparison using weighted average for all criteria (Mukheibir & Sparks 2006)

Based on the combined ratings, the following nine strategies were ranked above 0.50:

- Dry sanitation systems (1)
- Education programmes (2)
- Tariff structures (3)
- Reduction of leaks programmes (4)
- Regional water resource planning (5)
- Local water resource management and monitoring (5)
- Conjunctive use of surface and groundwater (6)
- Rainwater harvesting (6)
- Water restrictions (6)

The use of saline water for toilets, rainfall enhancement, water delivered by tanker, drought relief and aid funding and desalination of saline water were not considered appropriate strategies by this group of stakeholders.

By further analysing the scores of the top nine strategies for each individual criterion, the potential barriers to implementing these strategies were identified. The criteria with low scores indicated areas of deficiency or potential barriers (See Table 15).

Table 15: Summary of obstacles and limitations for the top nine water adaptation strategies (Mukheibir & Sparks 2006)

Strategy	*Local capacity*	*Capital expenditure*	*O&M expenditure*	*Acceptability*	*Employment*	*Technology*
Dry sanitation systems				X		
Education programmes	X		X			
Tariff structures	X				X	
Reduction of leaks programmes	X	X	X			
Regional water resource planning	X	X	X		X	
Local water resource management	X	X	X			
Conjunctive use of surface & groundwater	X	X	X			X
Rainwater harvesting	X					
Water restrictions				X	X	

The strengths and weaknesses for the first six strategies ranked by the stakeholders can be illustrated by using a spider web diagram as can be seen in Figure 25.

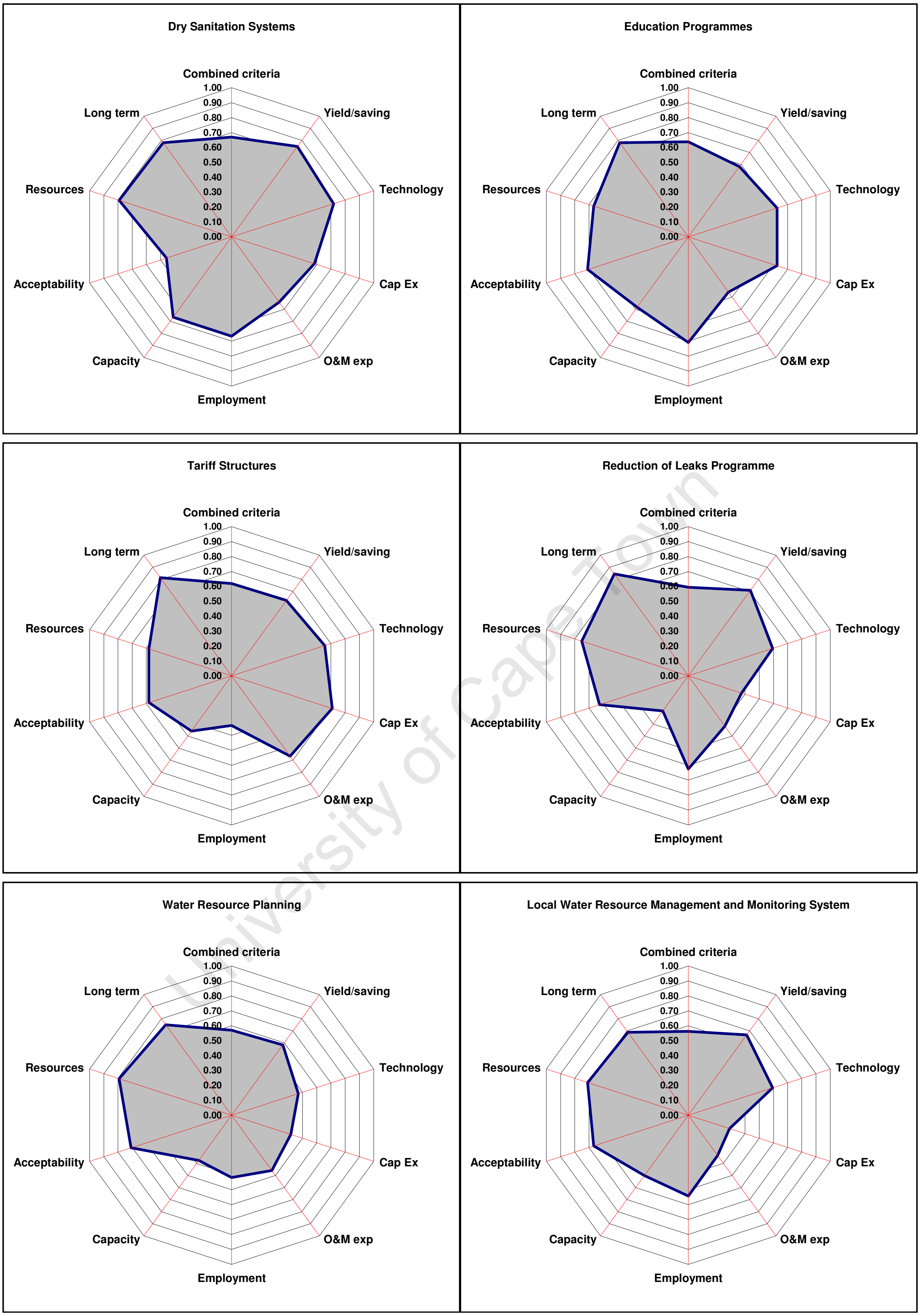

Figure 25: Graphical representation of the first six strategies as ranked by the stakeholders against all the selection criteria (Mukheibir & Sparks 2006)

As can be seen, the *dry sanitation systems* strategy scores particularly high for almost all the criteria except for local community acceptability. It is viewed as having long-term applicability and has a positive impact on the local water resources, since it contributes significantly additional water saving. The local skills and technology are available locally to implement such a strategy and it will provide local employment. It is surprising that this strategy ranked on top, given the general low acceptance for non-flush latrines. This type of technology is usually considered a poor person's solution. There is a real tension between the demand for flush toilets in poor communities and the vulnerability of having scarce water resources. Given the political pressures being faced by local authorities it is unlikely that this strategy will be given any serious thought, despite its top ranking.

The *education programme* strategy was ranked second in this list of proposed strategies since it has long-term applicability and does not cost the consumers in a direct manner and therefore would have a high local community acceptability. It is also perceived to contribute favourably to employment creation and impact positively to local water supplies. This strategy has a relatively low running costs rating, since it would have medium level operating costs to sustain an education programme.

A *structured tariff* that curbs high water consumption would have long-term applicability. Once the system is in place, the tariff calculations are automatically generated. It would also require low capital and operating costs. It would in the long run increase the available volume of water for further usage by other consumers. It is unlikely, however, that any new local employment would be generated.

A *leak reduction programme* has the potential to provide local employment, and significantly increase the useable volume of water and hence will have a positive impact on the local water resources. It has good long-term applicability. The local capacity to implement such a leak reduction programme is, however, perceived to be low and the high capital investment to set up the programme is also perceived to be a burden.

Regional water resource planning has good potential for long-term applicability. Its impact on local water resources is also positive. It is envisaged that the community would have a neutral response to such an intervention, since they would not be directly affected. Such an intervention would have a positive influence on their water security, although there may be an increased financial burden that gets passed onto the price of water for the region. Local municipalities do not have the personnel resources to implement such a strategy since it is perceived that the local capacity is low. It also does not have much scope for local employment opportunities as it is likely that skilled personnel would need to be imported to address the low capacity levels in this field. This strategy has relatively medium-level costs, but these should be quantified to obtain a realistic idea of the actual capital investment required and ongoing running costs.

Local water resource management and monitoring would be interlinked with the previous strategy. Ongoing management and monitoring of this resource would be important to ensure that they are sustainably utilized. The key strength of this strategy, similar to the regional water resource planning strategy, is the long-term applicability and the positive impact on local water resources. In addition, it has significant potential to improve the yield and reduce consumption. Once again the local acceptability of the strategy is neutral, even though such an intervention would have a positive influence on their water security. There may be a increased financial burden that that gets passed onto the price of local water. This is significant given that the capital and running costs are perceived to be of medium importance

Table 15 and Figure 25 provide useful tools to identify the potential obstacles and limitations to implementing these strategies at a local level. For example, the most notable factor affecting the viability of these strategies is the perceived lack of local capacity to implement them. This is further exacerbated by the low financial resource base to cover the capital and running costs of most of the strategies. Implementing water restrictions and dry sanitation would require the local authority to address user acceptability of the strategies. Some of these strategies do not contribute much to local employment and this would need to be addressed in some other ways.

6.2.2 Quantitative assessment criteria

In order to quantitatively compare the shortlisted strategies, it is useful to use quantitative criteria that measure the financial implications of the intervention as compared with benefits of increased water availability and the impact on water services access, especially for the poor. For policy purposes it is important to distinguish between the costs of managing "normal" climatic variability and those for managing the new impacts of climate change. Changes in rainfall patterns and the resultant water availability will have some obvious cost impacts on cities. Water supply is generally costly and if availability of water is reduced by climate change, consumption patterns will need to change or additional water will need to be brought from further away. Wastewater standards that specify dilution standards may also be costly to meet under climate change conditions (Muller 2007). A list of some potential indicators is provided in Table 16 and are discussed in more detail below.

Table 16: Quantitative assessment criteria

Broad Criteria	Specific indicators	Unit
Volume of water	Additional water supplied or saved	Kilolitres
Access to clean water & level of access	Urban households with onsite access	% of total households
	25 litres from a communal standpipe	No. of people, % of total
	25 litres from a yard tap	No. of people, % of total
	Access to 50 litres on site	No. of people, % of total
	Access to > 50 litres on site	No. of people, % of total
Access to water subsidy	25 litres free	No. of people, % of total

Cost of water	Capital cost of intervention Unit operational cost Unit price to consumer	Rands, Rands/kilolitre Rands/kilolitre Rands/kilolitre
Employment	No. of additional jobs created or lost	No. of jobs (- or +)

6.2.2.1 Volumetric criteria

The primary criteria for assessing the comparative effectiveness of a strategy is the additional water that it would provide or save. The additional yield per day would be a key item for a comparative analysis of the options available.

Where a large infrastructure option, which would satisfy demand for a longer time period, is compared with a number of smaller options over the same period, it is sometimes common practice to discount the actual water used over that period to a present day value as illustrated in Equation 4. The estimated annual safe yield could be a fixed amount each year where the option provides the full yield from day one, or it could be a variable yield over the period where the demand placed on the option increases with time until full capacity is reached. Fane et al. (2003) supports this approach by emphasizing that the supply or saving to be discounted should not be viewed as being a physical quantity, but rather the demand satisfied or reduced. This is the volume that should be discounted to account for the consumers time preference for consumption.

$$PV_Y = \sum \frac{Y_t}{(1+r)^t} \qquad \textbf{Equation 4}$$

where: PV_Y = present value for volume in base year

Y_t = estimated annual safe supply or saving in year

r = discount rate (discussed in 6.2.2.3)

t = time between today and the future supply or savings year

6.2.2.2 Socio-economic criteria

Access to clean drinking water can be measured in a number of ways and is usually expressed as a percentage of the total population in the municipal area. The most common way is to measure the number of households with onsite access from a piped source. This can be further disaggregated into the actual volumes used per person. The intervention should show some improvement to these statistics for it to be favoured.

Local employment opportunities due to the intervention should also be evaluated. At the very least, no jobs should be lost as this would undermine the poverty alleviation efforts underpinned by the local development goals.

6.2.2.3 Financial criteria

The bottom line of any strategy would be the cost implications. These include both the capital investment cost as well as the ongoing operating costs. For any strategy to be viable, it would need to be financially sustainable. The related impact of the financial costs on access and affordability of service is a specific financial criteria that is important when considering the impact of the interventions on the poor.

A detailed discussion of specific financial concepts follows and specifically emphasises the financial tools that are needed when comparing different supply- and demand- side options to meet future water demands.

6.2.2.3.1 Present value

Present value (PV) is the cash value today that is the equivalent value to a future stream of cash flows. For a single future value (FV) the present value PV is defined by:

$$PV_C = \frac{(C_c + C_{om})_t}{(1+r)^t} \quad \textbf{Equation 5}$$

where: PV_C = present value of cost in base year (R)

C_c = initial capital cost (capital, labour, administration cost) in year *t*

C_{om} = cost (operation & maintenance cost, fuel, tax and interest) in year *t*

r = discount rate

t = time between today and the future payment year

Discounting refers to a process that allows for the comparison between the value of economic resources (or consumption) at different points in time and takes into account the time value of money. The *discount rate,* or *social discount rate,* refers to the rate at which discounting is undertaken. Since adaptation cost studies involve comparisons over long periods of time, the discount rate is an extremely important parameter in economic calculations. The *financial discount rate* is a market-related rate which reflects the cost of funding (often a weighted average of a required rate of return on equity capital and interest rate on loans), uncertainties and risks (Clark & Spalding-Fecher 1999).

According to Du Preez (2004) one aspect of cost-benefit analysis, which is often neglected, is the choice of the social discount rate. A relatively high social discount rate favours projects with low capital costs and high operation costs, and the converse is also true. The World Bank normally uses a social opportunity cost of capital of 10% per annum as a theoretical basis for their choice of the discount rate. In South Africa the most commonly used rate is 8% (Conningarth Economists 2002).

6.2.2.3.2 Life-cycle cost

The *life cycle cost* (LCC) is the total discounted (present value) cash flow for an investment with future costs during its economic life. In other words, the LCC is the *present value* of all the costs associated with an investment. It generally includes the initial capital cost, the sum of discounted annual maintenance and operating cost and any other future capital payments (Clark & Spalding-Fecher 1999). The formula for life cycle costing is as follows:

$$LCC = \sum \frac{(C_c + C_{om})_t}{(1+r)^t} \qquad \textbf{Equation 6}$$

where: LCC = life-cycle cost (R)

If the annual costs were not constant, then we would have to discount the value in each year to the appropriate present value (PV) (see section 6.2.2.3.1), and then add them together. Life cycle costs would also include any implementation or overhead costs associated with projects and in some cases a credit for any salvage value for the investment at the end of the project.

6.2.2.3.3 Annualised cost

The concept of *annualised cost* (AC) is recommended as a standard for comparison of cash flows which occur at different points in time. It involves calculating a stream of equal cash flows whose net present value is equal to that of a given stream of variable cash flows. The purpose of this method of is to be able to show the equivalent annual costs of an investment, as opposed to the total costs over the life (Clark & Spalding-Fecher 1999). Annualised costing is a means of spreading the LCC, i.e. the initial capital cost of an option and the estimated operating and maintenance costs, across the life time of the option while accounting for the time value of money by using a discount rate or interest rate. This is useful when comparing different investments that achieve the same yield.

$$AC = LCC\left(\frac{r}{1-(1+r)^{-n}}\right) \qquad \textbf{Equation 7}$$

where: AC = annualised cost (R)

n = number of periods in the life of the investment (years)

This method also can be used to express a constant future annual cost of supplying a estimated safe constant annual yield from the option and would be expressed in currency per kilolitre e.g. $/kl or R/kl (Fane et al. 2003). The equation for transforming the present value/life cycle cost to a series of equal annual payments for the period covering the first year of operation to the last year in the scenario to give the annualised unit cost (AUC) is as follows:

$$AUC = \frac{LCC\left(\frac{r}{1-(1+r)^{-n}}\right)}{Y} \qquad \textbf{Equation 8}$$

where: AUC = annualised unit cost (R/kl)

Y = estimated annual safe yield or consumption

Some literature refers to this method as "levelised costs", however, in this thesis, "annualised unit cost" is defined as the discounted cost of supply or saving divided by a fixed annual water yield, while "levelised cost" takes a variable annual yield into account. This is discussed further in the next section.

6.2.2.3.4 Levelised cost

A limitation of Equation 8, is that it only allows for a unit cost based on a fixed estimated annual yield. Applied to both conservation measures and bulk supply, this method does not account for the fact that large scale measures will produce significant over capacity in the short-term. To overcome this, Dziegielewski et al. (1993) and the NSW Water Demand Management Forum (1996 in Fane & White 2003) define *levelised cost* (LC) of conserved or saved water as:

$$LC = \frac{LCC}{\sum Y_t} = \frac{\sum C_t/(1+r)^t}{\sum Y_t} \qquad \textbf{Equation 9}$$

where: C_l = levelised cost per unit of yield or saving ($/kl)

C_t = the cost (capital and operating) of the option in year *t*

Y_t = estimated annual safe supply or saving in year *t*

This approach allows for the variation in both cost and water demand over the life time of the option or programme. The estimated annual safe yield could be a fixed amount each year where the option provided the full yield from day one, or it could be a variable yield over the period where the demand placed on the option increases with time until full capacity is reached.

Fane et al. (2003) argue however that the method is biased towards large schemes and does not allow for the advantages provided by incrementally meeting demand. The LC approach must be applicable to both supply and conservation options and provide a fair comparison of relative costs across scales. The period over which an analysis is conducted will have a significant impact on the cost outcome due to the lack of discounting of the supply or saving. For example, if a long period is taken for the life of a dam, then not discounting the supply or the saving will give an inappropriately low unit cost of supply. Conversely, for a shorter assessment period, large scale water supply projects would not approach their design capacities and would have significant overcapacity in the short-term.

There has been some opposition to the idea of discounting the supply or saving, since it does not make conceptual sense to discount a volume of future water. Fane et al. (2003) dispel this by asserting that the variable of the supply (or saving) to be discounted is not a physical quantity, but rather the demand satisfied or reduced. This is a quantity that should be discounted to account for the consumers time preference for consumption. By using *consumption* instead of *capacity*, the real cost of the service provided is calculated over the life time of the option.

Discounting can lead to misleading comparisons when comparing supply and conservation projects that are dramatically different in size or timing of future flows of money or water. Therefore Skeel et al. and White (1999 and 1998, in Fane & White 2003) defined the *levelised cost* of conserved water as the discounted cost per unit of discounted demand or saving. In this thesis this has been termed the *discounted levelised cost* (DLC) for a supply or conservation option and can be expressed as:

$$DLC = \frac{PV_C}{PV_Y} = \frac{\sum C_t / (1+r)^t}{\sum Y_t / (1+r)^t}$$ **Equation 10**

where: DLC = discounted levelised cost (R/kl)

Here the numerator is the present value of all initial and future costs incurred by the intervention and the denominator is the discounted amount of all initial and future water savings or supplies. The numerator is a financial value, the denominator is a quantity of water and the ratio itself is a discounted cost per discounted unit of water. This ratio scales both money and water quantities according to the times they occur. This feature is not usually incorporated in present value calculations and it is therefore especially appropriate that DLC be used when comparing unit costs of projects with radically different sizes or durations.

The *average incremental cost* (AIC) of a specific water supply system is generally used in the literature to represent the marginal cost of future supplies for both existing supply systems and the planned bulk augmentations (Fane & White 2003). AIC is estimated in the same way as DLC, by dividing the discounted incremental costs of meeting future demand by the corresponding discounted volume of incremental output over the same period (Warford 1997), as illustrated here:

$$AIC = \frac{\sum_{t=1}^{T} (I_t + R_t - R_o) / (1+r)^t}{\sum_{t=1}^{T} (Q_t - Q_o) / (1+r)^t}$$ **Equation 11**

where: AIC = average incremental cost (R/kl)

I_t = the investment cost in year t

R_o = the recurring cost in the base year (i.e. operating & maintenance cost)

R_t = the recurring cost in year t (i.e. the operating and maintenance cost)

Q_o = the consumption in the base year

Q_t = the consumption in year t

The AIC should represent the true least cost options available to the water service utility for additional water supply over and above the base year supply and cost. The key difference between DLC and AIC is that the former includes the base year values, whereas the latter only considers the additional volumes and costs. Potential other water saving or supply options should be compared to the current AIC to determine their relative cost effectiveness. AIC is important for decision making, since the costs of supplying water are rising over time due to the more difficult water supply conditions in some cases, while prices have failed to keep up. Often AIC of urban water supplies are commonly 2 to 3 times greater than the cost of existing water supply schemes (Munasinghe 2007). If options under consideration have lower AICs, then they should be implemented immediately. Fane & White (2003) warn that only resources with a fixed or long-term capacity impact can be compared in this way.

6.2.2.3.5 Water pricing and subsidies

Typically water pricing would be based on the revenue objective of the institution and would be derived from an analysis of the capital and operating costs and the required surplus. There is no one correct approach to determining the overall *unit selling price,* $P_{U,}$ (or tariff). However, one approach that is put forward by most scholars and practitioners is the marginal costing approach (Baumann et al. 1998; PDG 2000). This is a forward looking approach in which the unit selling price is based on estimates of future marginal costs rather than on historic costs. Whilst marginal costs are more difficult to collect and calculate, they do send the correct cost signal to the consumer. In the case of water supply, infrastructural investment often takes place in large increments and hence the marginal cost of supply varies considerably over time. According to Eberhard (2001), in addition to large infrastructural supply costs, there are three different types of marginal access costs:

- The incremental local distribution infrastructure costs;
- The incremental cost of a new connection to the network; and
- The incremental cost of the administrative and management of a new consumer.

In addition, there are two types of marginal consumption costs:

- The marginal capital costs of extending the capacity of the system; and
- The marginal operating costs to deliver another unit of water.

These cost are likely to vary spatially and temporally. The cost may also differ per customer. Therefore, developing a pricing strategy by using the marginal cost approach, requires a sophisticated economic system and may discriminate against some consumers who live far away or may have joined at a different time. To address this problem of spatial and temporal differences, urban water price policy makers advocate (in Eberhard 2001: 66) a long-run marginal cost[34] pricing approach based on the *discounted levelised cost* (DLC), which would include both current costs and future planned costs and where the costs and the available capacity are discounted to the base year. It is interesting to note that in a survey conducted by

[34] Long-run marginal cost – The cost of providing the next unit "in the long run", that is, when investments in supply capacity are not fixed.

Eberhard (1999a), no instances were found of full marginal cost pricing in which the long-run marginal cost price had been applied to all units of water sold. His research showed unequivocally that political and economic factors mitigate against the implementation of full long-run marginal cost pricing, especially where these prices were significantly higher than the historical prices. Increases in the marginal price of water above the historic average have been resisted by water service providers. The long-run marginal cost of supply is useful as a rough estimate of the magnitude of the tariff to be charged (Eberhard 1999b). In practice, the *average unit cost* (C_U) is calculated using the levelised cost (LC) formula, where the present value of the capital and operating costs are divided by total volume consumed or sold over the period. Therefore, without considering profit mark up, the C_U would represent the tariff (P_U) to be charged to consumers and would normally include all costs associated with providing the future service viz. operating and maintenance costs, refurbishment and capital costs for existing and planned new infrastructure. The tariff is therefore represented as:

$$P_U = C_U = \frac{\sum C_t / (1+r)^t}{\sum Y_t}$$ **Equation 12**

where: C_U = average unit cost (R/kl)

P_U = unit selling price or tariff (R/kl)

P_U here would represent a simple flat tariff structure. In practice, block or step tariffs have been used. Usually a simple two step block tariff is proposed, where the first block is set at the average unit cost and the second at the long-term marginal cost. The second block would be aimed at the luxury consumption consumers in order to encourage conservation at this consumption level.

A number of municipalities have also opted to use a rising block tariff to make up the lost revenue from providing a free basic supply (CCT 2007; Joburg 2007; Ravenscroft 2007; Visser 2007b). The rising block tariff forces high end users to cross-subsidise even more. However, block tariffs provide an added complication due the arbitrary nature of their setting, as illustrated in Figure 26.

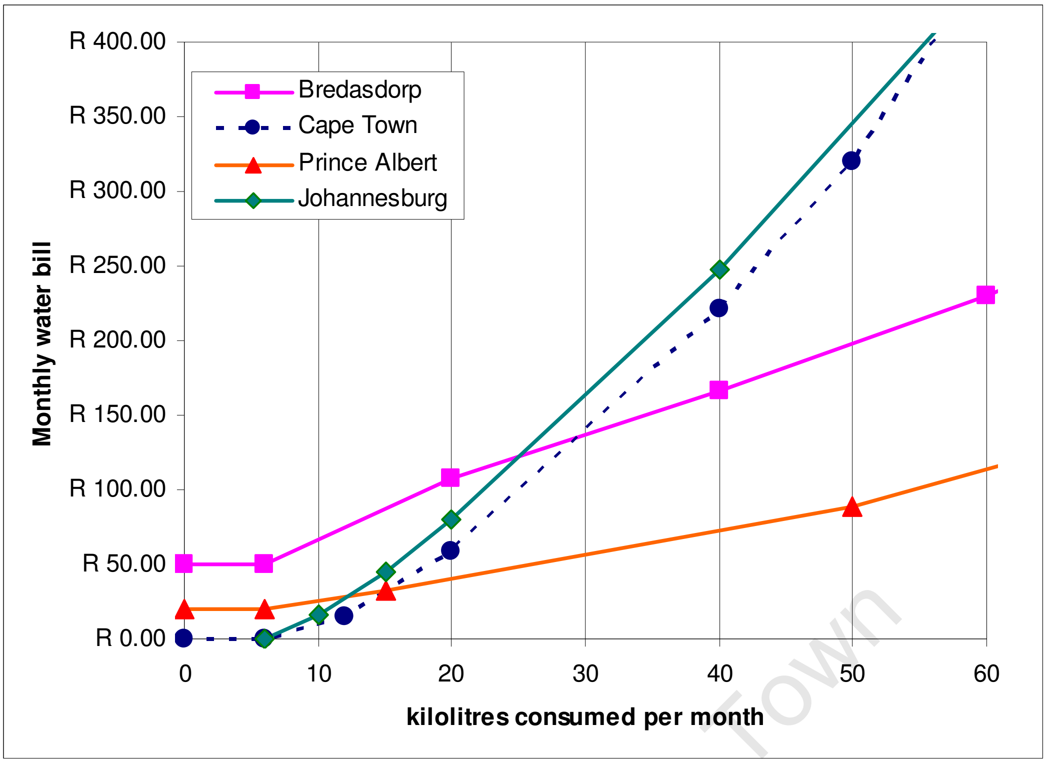

Figure 26: Monthly water bills based on rising block tariffs for 2006/07 (CCT 2007; Joburg 2007; Ravenscroft 2007; Visser 2007b)

A number of municipalities have also opted to use a rising block tariff to make up the lost revenue from providing a free basic supply (CCT 2007; Joburg 2007; Ravenscroft 2007; Visser 2007b). The rising block tariff forces high end users to cross-subsidise even more. However, block tariffs provide an added complication due the arbitrary nature of their setting, as illustrated in Figure 26.

In the examples illustrated, the two small towns of Bredasdorp and Prince Albert charge an access fee across the board and then apply a block tariff to consumption. The larger metropolitan centres such as Cape Town and Johannesburg do not, but the cost of water for the higher end users is much higher than for the smaller centres. The large urban centres are able to provide a bigger subsidy to the lower end users than the smaller centres can offer, possibly due to there being fewer high end users in the small centres, making cross-subsidation more difficult to achieve.

Owing to inconsistent application of the block tariff, the approach in this thesis has been to simply balance the actual cost of supply with the net revenue received. A simple two tier system has been used, i.e. free basic supply of 6 kl per household per month and a fixed rate for consumption in excess of the free volume based on the levelised cost (LC) approach. Under this cross-subsidy scheme the P_U would need accommodate both the C_U and the cost of the subsidised free water (V_F), as illustrated in Figure 27. The P_U of water is therefore calculated as follows:

$$P_U = \frac{C_U * V_T}{(V_T - V_F)}$$ **Equation 13**

where: V_T = total volume of water supplied

V_F = volume of water provided for free

Based on this formula, it can be seen that as the indigent population increases, the total volume of free water consumed will also increase, resulting in a higher tariff (P_U) being charged to non-indigent consumers in order to match the supply cost. The converse is therefore also true.

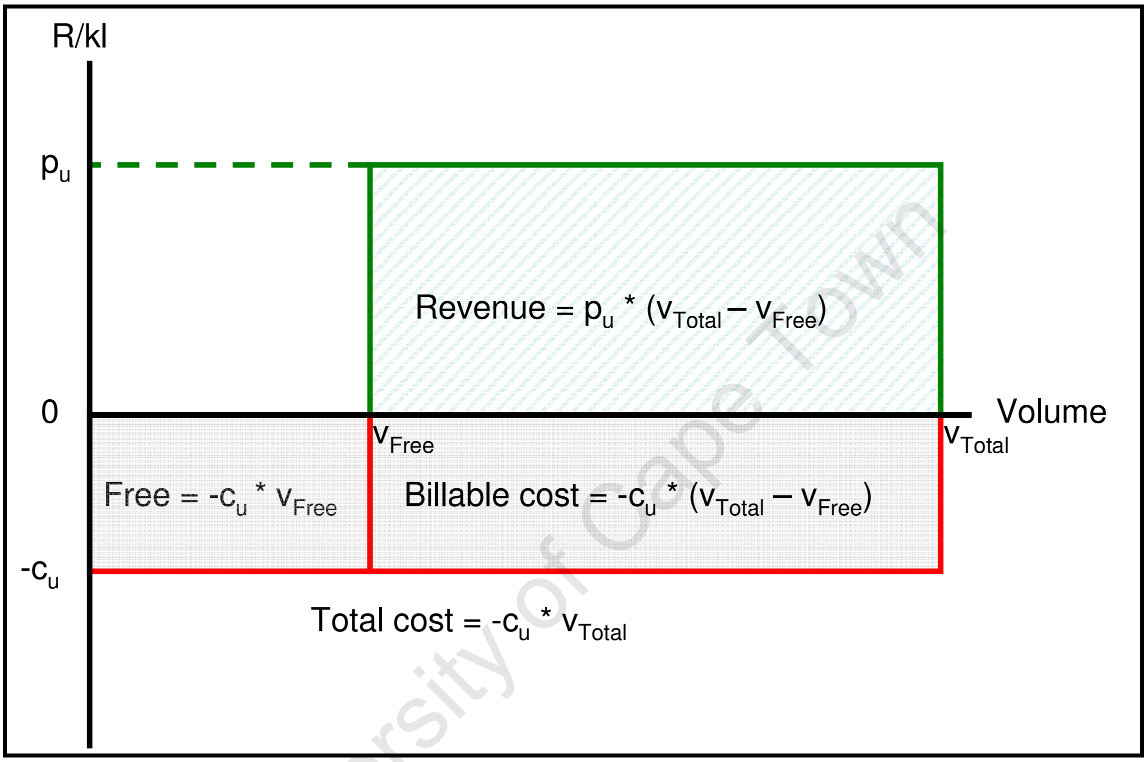

Figure 27: Schematic representation of simple cross-subsidisation, without an external subsidy

As discussed previously, some countries such as South Africa have introduced an external subsidy from national government for all local municipalities based on the number of indigent households in their geographical area. In South Africa this is known as the Equitable Share Grant. This external subsidy has the function of reducing the burden of internally cross-subsidising the free basic water service. This is graphically illustrated in Figure 28 and has the overall effect of reducing the P_U.

The Unit Price of water is therefore calculated as follows:

$$P_U = \frac{(C_U * V_T) - S_E}{(V_T - V_F)}$$ **Equation 14**

where: S_E = external subsidy

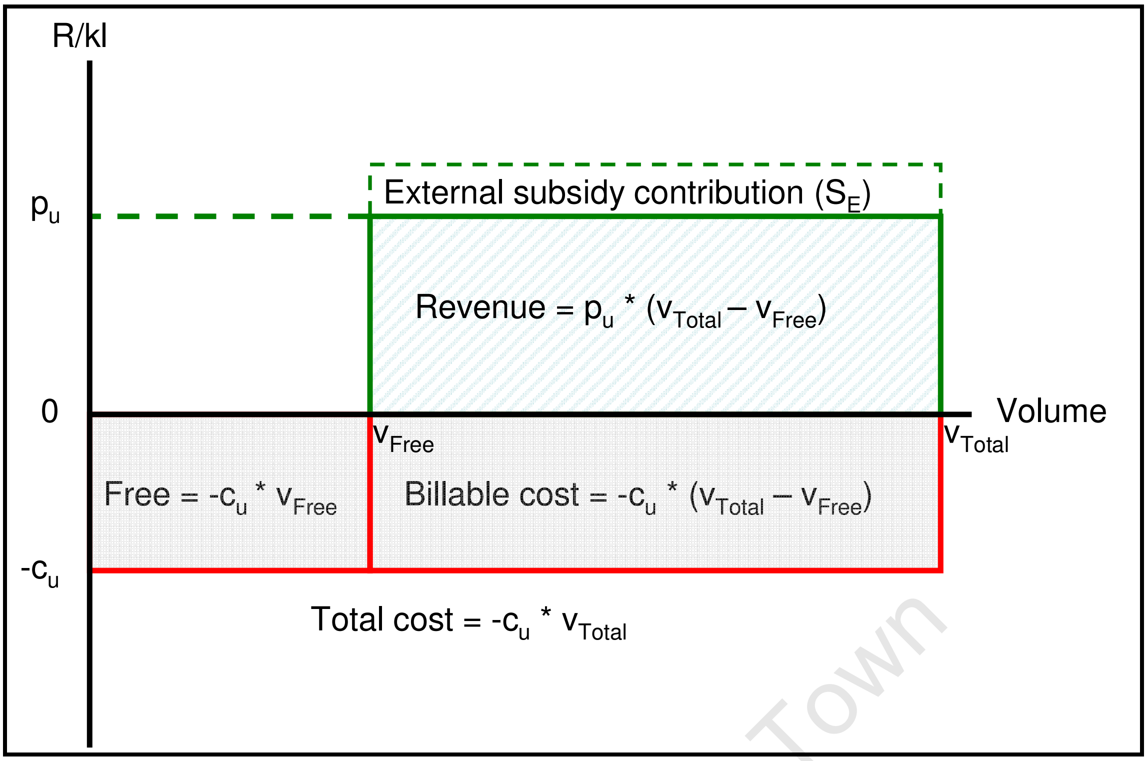

Figure 28: Schematic representation of cross-subsidisation with an external subsidy

Depending on whether an external subsidy is available or not, these two formulae can be used to calculate the additional cost to the paying consumer for the various strategic options being evaluated. The P_U for each one can be included in the multi-criteria decision analysis when assessing them against the quantitative criteria.

Financial sustainability of a water adaptation strategy will be dependent on the following:

- The cost of providing the water is less than or equal to the revenue received including any external subsidy, i.e. $C_U * V_T \leq P_U * (V_T - V_F) + S_E$.
- The internal subsidy (P_U-C_U) is acceptable to the paying customers.
- The internal cross-subsidy and the external subsidy actually cover the free basic supply costs.
- The external subsidy (S_E) is actually paid to local government by the national government.
- The subsidies are sufficient under climate change to keep the P_U at an acceptable level for the paying customers.

In addition, the formulae are also appropriate for assessing the change in unit selling price for future climate impacts as compared with present averaged/normal climate conditions. Increasing unit costs of water with time tends to be the rule, as sources close to urban areas become fully utilized and under climate change conditions the sources will be needed sooner than originally planned. This will have the effect of increasing the unit selling price to paying customers. The ratio between these two prices can be termed the *climate impact factor for unit selling price* (CIF_{Pu}) and can be expressed as:

$$CIF_{P_U} = \frac{CCP_U}{NCP_U}$$ **Equation 15**

where: CIF_{Pu} = climate Impact Factor for unit selling price

CCP_U = unit selling price under future climate change conditions

NCP_U = unit selling price under present average/normal climate conditions

6.3 Measurement of successful adaptation

Having identified the appropriate measure or intervention, the local municipality should set in motion the logistical and administrative arrangements to implement the adaptive water strategy. In order to assess the effectiveness of the strategy to meet the development objectives and mitigate the impacts of climate change, a monitoring and evaluation system should be put in place. The purpose for this is two-fold. Firstly by monitoring the implementation, modifications to the approach or design can be effected before the completion of the project. Secondly, by evaluating the strategy after implementation at predetermined intervals, lessons can be learned for ensuring more effective implementation in future and these lessons can be passed onto other small centres with similar water and climate characteristics. Each indicator should have associated with it a performance target against which actual performance is compared. In simple terms, indicators show problems before they get too bad and help you identify the cause and what to do to fix them. The indicators for the monitoring and evaluation should be set before the project is implemented though a stakeholder process so that all expectations for the strategy can be measured.

As was discussed in Chapter 4, the definition of successful adaptation depends on the spatial and temporal scale. However, as emphasised by Adger et al. (2005), it is not sufficient to define success in terms of effectively meeting the objectives, since the action may impose externalities at other spatial and temporal scales. For example, what appears to be successful in the short-term may not necessarily be so in the long-term. An action that addresses intermittent drought such as tankered water may not be adequate under more frequent dry periods. Or, an action may have spatial consequences such as the case of coastal reinforcement against erosion which often results in impacts such as sediment deposits on other areas. For this reason, Adger et al. (2005) suggest that the generic principles of equity, efficiency, effectiveness and legitimacy should be used to evaluate the success of adaptation measures.

Effectiveness:

Effectiveness relates to the capacity of an adaptation measure to achieve its intended objective, through either reducing the impacts or avoiding the risk of climate change. However, this is not always easy to measure. The effectiveness of the measure may be dependent on the action taken by other institutions or individuals. The effectiveness of the climate change measure is dependent on the spatial and temporal scales. The future state of the climate and economic environment may alter unpredictably and further influence the effectiveness. The measure may be effective in one place, but may induce further hazards and adverse outcomes in others. Evaluating the effectiveness can present two problems in actual measurement. The intervention may have been designed to reduce vulnerability to infrequent extreme climate events. However, if these events do not occur, the effectiveness can not be specifically measured. And secondly, the strategy may have been designed to incorporate long-term risks from climate change. However, the long-term change may not yet be evident when the intervention is evaluated after implementation. The time horizons may not coincide. The USAID (USAID 2007) warn that these two problems should not be used to prove that the investment was unjustified, nor should the lack of immediate payoff be used as a factor for decision analysis, since the intervention can still be measured for other local benefits and cost effectiveness, especially in the light of climate variability.

Financial Efficiency:

An assessment of the financial efficiency requires consideration of the distribution of the costs and benefits of the strategy, the non-market costs and benefits and the timing of the adaptation strategy. At the local scale, the direct financial costs are those for implementation and the benefits would be financial savings due to reduced impacts. These financial costs and benefits can be measured and evaluated. However, at a national level the response of government is to provide planning scenario information and risk assessments, but to avoid financial contributions to private adaptation actions (Callaway 2004). Government led adaptation initiatives stress the public good elements which often do not have market value and are hence difficult to measure.

The issue of timing is important when considering the planning horizon. For short planning horizons, the capital turnover rates are high and systems are flexible enough to adjust to climate variations. However, where the planning horizons are long, the systems are not so flexible and therefore longer term climate changes need to be factored in to avoid costly planning errors and, therefore, financial inefficiency.

Equity and legitimacy:

The available studies on this topic (in Adger et al. 2005) show that present day adaptations to climate impacts have reinforced existing inequities and in some cases exacerbated the vulnerabilities. In developing countries especially, the equity and legitimacy of an adaptation strategy is of critical importance. In ensuring equitable outcomes of climate change options, the extent to which decisions are acceptable to both participants and non-participants is important.

The legitimacy of an adaptation decision can be ensured through proper consultative process, which can be monitored during the planning process.

Much has been written about monitoring and evaluation of water projects, programmes and strategic interventions (Mukheibir 2000; Morrison et al. 2001; Walmsley et al. 2001; Atkinson & Wellman 2003; UNICEF no date). The purpose here is not to reinvent the wheel in terms of generic methodology, but there is a dearth of literature on specific adaptation monitoring and evaluation. Much of the relevant climate and water literature focuses on indicators for drought vulnerability (Eriksen & Kelly 2006). Monitoring and evaluation of climate change adaptation is much the same as would be done conventionally, except for an additional test for resilience to climate impacts. In addition to testing the strategy for its support of the local development goals, its contribution to avoiding or addressing the climate impacts is important in this context. It could be argued that resilience to climate impacts should be part of any sustainable development project, however the evidence is to the contrary. As discussed previously, only the agricultural sector has really considered future climate variability in its planning. Most development projects consider only the historical climate data for their planning. Including climate related indicators in the monitoring and evaluation process of municipal water projects, should ensure that these issues are considered during the planning phase. If not, the projects will likely fail the climate resilience test and be ineffectual in the long-term.

In order to monitor and evaluate a strategy, project or programme a pre-implementation baseline should be set. This will assist is establishing the adaptation benefit, which is the pre-implementation situation less the post-implementation situation. The baseline would include specific climate related indicators such as information on the climate science and local climate impact resilience or adaptive capacity. This is necessary firstly to be able to measure if the climate has actually changed in relation to the baseline, as was originally projected. Secondly, it is necessary to establish the level of improvement in the vulnerability at the municipal level to climate impacts. The intervention needs to build resilience to climate change. Various tools prescribe methods for collecting this information such as the NAPA and SSNAPP (LEG 2004; Alam & Mqadi 2006).

When setting indicators, one should ensure that they follow the 'SMART' approach i.e. They are simple, measurable, achievable, realistic and time bound (Ticehurst 1996):

Simple: The indicators should be simple and not to complex to assess. It is better to have fewer indicators than a complex set. This should minimise the amount of data that needs to be collected and the amount of data analysis required.

Measurable: The indicators must be measurable e.g. in numbers, days or money. Indicators that require an answer of "good" or "a lot", are difficult to analyse and compare. Information should be easily verifiable.

Achievable: It must be possible to actually measure the indicator. Assessing how many households have paid their tariff is much more achievable than trying to assess what percentage of the household income is spent on water.

Realistic: The indicators should provide realistic information. Collecting information that reflects how much water is used by children versus adults is not a realistic indicator to measure the sustainability of the scheme, however interesting the results may be.

Time bound: Ensure that the indicator can be measured at regular intervals and is specific to a measured period of time.

The types of climate and water related indicators that would best fit these criteria are listed in Table 17.

Table 17: Climate and water related monitoring and evaluation criteria

Indicators	**Units of measure**
Climate data: -rainfall -temperature	 mm/day, mm/month daily Max, Min in degree Celsius
Daily runoff and recharge, in order to establish a change due to climate impacts.	m^3 per day and per month
Access to basic levels of services	No. of households and no of people per month (disaggregated into the various levels available)
Numbers of indigent people in the municipal area	No. of people per month or year
Financial costs: -the additional capital investments -the additional operating and maintenance costs.	 Total Rands Rands /month
The additional volume of water provided or saved	kl/day and kl/month
The change in unit cost of supply	R/kl per month
The change in unit selling price	R/kl per month
Local capacity to manage the water strategy	No. of qualified staff vs the industry norm

Whilst there is a need for the indicators to be time bound, it may be difficult to establish long-term impacts of climate change and the related benefit of the strategy given the long periods required for this. Staff turnover and the loss of institutional memory could be barriers to this process. For this reason good record keeping is needed to ensure that a reliable historical data base is maintained.

It is important that all relevant stakeholders participate in the setting of the indicators and are present when the results of the monitoring and evaluation processes are reported. Stakeholders would include individuals and groups directly affected, local and national government officials and any relevant agencies. Any corrective action should be prescribed collectively.

Drawing on the outputs of the case study by Mukheibir & Sparks (2006), the obstacles and limitations to implementing these strategies successfully at a local municipal level were identified. Two key limitations stand out:

- ***Local capacity:*** The most notable issue affecting the viability of these strategies is the perceived lack of local capacity to implement the strategies. The former Director-General of DWAF, Mr Mike Muller, has stated that there is a severe shortage of qualified water managers in small to medium-sized municipalities which has resulted in 63% of municipalities not complying with drinking-water quality standards. There is an urgent need for formal training in this sector (Venter 2005).

- ***Financial resource base:*** This is further exacerbated by a low financial resource base to cover the capital and running costs of most of the strategies. Local government competes for nationally allocated funds for capital expenditure. Running costs are mostly covered from local revenues, which for the smaller and remote local municipalities are insufficient to ensure water security at this local level.

In addition, political buy-in for some of the strategies such as water restrictions and dry sanitation will need to be obtained through education programmes, however these also require human and financial resources.

6.4 Summary

This chapter has mainly focused on the development of specific climate change related strategies for small towns. A wide range of supply side and demand side options have been presented. There is often a choice from a suite of hard and soft instruments which could be used to enhance the resilience to climate variability. A screening tool to assess the available strategies firstly against qualitative criteria has been introduced to develop a short list of viable strategies for further quantitative assessment.

The qualitative criteria incorporate social, environmental and financial considerations. The key criterion that has been introduced is the one to assess the long-term applicability of the strategy. It is important to distinguish between strategies that address climate variability from those that would be suitable and robust under future project climate change impacts. This qualitative process allows all stakeholders to engage in the process since it does not rely on technical knowledge and also considers socio-political issues such as acceptability, equity and accessibility. This tool is essentially a simplified multi-criteria analysis tool and hence requires that the participants weight the criteria before the options are scored and analysed.

The use of quantitative assessment tools to consider economic cost, actual volumes supplied or saved and employment opportunities is the next step of the strategy analysis. White & Fane (2002) suggest that average incremental cost (AIC) be used to rank supply side and demand side options. AIC has been defined in this thesis as unit cost of an option by dividing the present value of future incremental costs of the option by the present value of the future incremental water saved or supplied. The denominator is a physical quantity so the ratio measures discounted units of money per discounted unit of water. This methods is an appropriate and effective measure for comparing incremental unit costs of projects with differing sizes and payback periods.

The economic principle, that as the scarcity of a resource increases price adjustments will alter the demand in order to be balanced with supply, is not always true in the water sector. As discussed, water demand is an inelastic commodity for the lower end user and also the correction of prices does not always address the issue of equity and access. The price may be increased to cover increased costs of supply due to both increased demand through population growth and climate induced shortages.

There is no one correct method for calculating the unit tariff for water supply system, but in this thesis the discounted levelised cost (DLC) is proposed and has been used. Using this method, the future tariff under normal climate conditions can be compared with that under climate change conditions.

In order to ensure a basic level of water access the poor, most countries have adopted some form of free water or subsidised delivery to the poor. This is mostly accommodated through a cross-subsidy system within the municipal water tariff structure, using the rising block tariff method. In some instances an external subsidy is also provided by the national government to cover this social benefit. In order to accommodate this, a simple equation has been proposed where the unit tariff takes these amounts into consideration.

The impact of projected climate change on the future unit tariff can be expressed using the Climate Impact Factor ratio, where the tariff under climate change conditions is divided by the tariff established under present averaged normal climate conditions for a specific period. This is useful for comparison purposes or when deciding which water supply system is potentially financially unsustainable.

The sustainability of these strategic choices, under projected climate change conditions, will need to be monitored and evaluated. Using the indicators provided in Table 17, the effectiveness of the strategic choices can be tracked and modified if necessary. This is extremely important in a field which has to incorporate a number of uncertainties into its planning and implementation.

PART FOUR

THE ECONOMIC IMPACT OF CLIMATE CHANGE: A SOUTH AFRICAN CASE STUDY

'Til taught by pain, men really know not what good water is worth - From Don Juan by Byron

CHAPTER 7

7. The impact of climate change on the water supplies of the small town of Bredasdorp

7.1 Purpose of the case study

This case study has been undertaken to investigate the hypothesis that climate change is also an economic issue and not primarily an environmental one. Climate change directly impacts on sustainable development through physical and financial stresses. In small towns these resources are generally in short supply and a negative impact on either can adversely affect the achievement of and sustained delivery of services related to the local development goals, specifically the supply of clean safe water. The combination of water scarcity and poor adaptive capacity directly test the resilience of a local community to external shocks, be they economic or climatic. As discussed in Part 2, it is generally the poor who bear the brunt of these shocks.

The methodology outlined in this case study has particular reference to other small towns located in arid and semi-arid regions. The methodology is not complex and could be implemented by a municipal engineer with access to climate projection information. Of specific interest to other small municipalities is the impact of the projected climate on their mandate to ensure water supplies to all residents. The key objective of this case study is to demonstrate the projected impact of climate change on the local water supply of a small town and the related socio-economic consequences. This case study considers the first step of the Water Resources Adaptation Framework discussed in Chapter 5, viz. the assessment of the impact of climate change on development goals and considers only a limited number of solutions to ensuring adequate supplies of water. In so doing, it assesses the potential impact of projected climate change on affordability and access to water services. The methodology that is applied aims also to provide an illustration of how the incremental cost of climate change can be established through firstly establishing the current baseline of the water resources and then determining the additional impact due to future climate change.

While the delivery of basic water services, free for the first 6 kl per household per month, is driven by a national development goal, it is incumbent on local government to ensure this right.

For this, the local municipality needs to ensure that water supplies meet the consumption demand, present and future. Technical and financial planning are therefore required to ensure that an undisrupted service is provided. The impact of climate change needs to be included in this planning.

In general, small towns do not have many high end users to fully subsidise the provision of a free basic supply to indigent and poor households. Whilst an unconditional external grant has been provided by the national government in South Africa in the form of the Equitable Share (see section 3.3), it is not sufficient to fully cover this free service, usually due to the other priorities attracting a larger portion of the budget allocation. It will be illustrated through this case study, that under future projected climate change conditions the need for additional funding to cover the incremental unit cost is evident, since the increased burden on the paying customers is not sustainable in the long-term. This increase in unit supply cost is due mainly to the additional cost of securing water from sources that are further away and hence more costly, both in terms of investment and operating costs.

This study draws on climate projection information from the Climate Systems Analysis Group (CSAG) at the University of Cape Town. The intensity and frequency considerations of future rainfall patterns have not been taken into account when determining the future runoff and recharge, since this involves fairly technical calculations and this was considered beyond the scope of this study. Rather, the projections are presented as the median change of a range of outputs.

A conservative approach was employed in this specific study to illustrate the methodology and to not get distracted by the various alternative scenarios that could be considered, such as reduced poverty levels, more aggressive drying, the impact of abrupt drying and longer inter-annular drought cycles and the compound impact of climate change on other basic human needs.

Further information and results for this chapter have been largely drawn from two case study reports conducted by the author, viz. *The impact of climate change on small municipal water resource management: The case of Bredasdorp*, *South Africa* funded by the Korean Environmental Institute (Mukheibir 2007b), and *Access to water - the impact of climate change in small municipalities* funded by the C^{3}D programme of UNITAR (Mukheibir 2007a).

7.2 Process for identifying the specific town

Based on a Water Research Commission study of small towns in the Northern Cape (Mukheibir & Sparks 2006), a number of potential towns were investigated. These included towns that had experienced water shortages in the 2000 drought (see Figure 19), where the extraction rates for groundwater had exceeded 80% of recommended yield (van Dyk et al. 2005). However, after interviewing practitioners in the water sector, it became evident that the issue of available historical supply and demand records was key (Murray 2006; Groenewald 2007; Visser 2007a; Woodford 2007). Whilst other small towns with chronic water problems exist, based on the advice received, the author decided to use the small town of Bredasdorp as an illustrative example, due mainly to the availability of rainfall, groundwater extraction and water consumption and billing records. A number of water related reports and a water services development plan (Afri-Coast 2003) had been prepared for the municipal area. In addition the downscaled climate projection information for the catchment area was available (Hewitson & Johnston 2006).

The key basis for the choice was the willingness of the Cape Agulhas municipal engineer to provide relevant information and financial records for the Bredasdorp areas. Without this cooperation, the information required to make the projections for supply and demand would not have been possible, nor the assessment of climate change on the water pricing.

Western Cape towns are generally characterised by racially separated areas and little success has been achieved in changing this pattern in the new political dispensation (CNdV Africa 2005). In many cases, extensions to the existing areas which house the lower income groups are located even further from services and work opportunities than before 1994. The Provincial Government of the Western Cape has expressed concern over the increase in poverty and the role that the changes in agriculture and tourism have played in these settlements. Van der Merwe et al. (2005) found that most small towns in the Western Cape had a negative development potential.

Bredasdorp is an example of such a settlement in the Western Cape province of South Africa, as illustrated by Figure 1. The specific location of Bredasdorp is 34°32′ S and 20°02′ E.

7.3 Background to Bredasdorp

Bredasdorp is located approximately 200 km south-east of Cape Town in the Overberg district. It falls in the Cape Agulhas municipal area and has an approximate population of 13000 (Afri-Coast 2003). Approximately 18% of the households have been classified as indigent i.e. earning less than R 1,340 per household unit (Visser 2007b).

The area experiences a Mediterranean climate with warm, dry summers and cool, wet winters. The monthly means of daily maximum temperature range from 17^{O}C to 28^{O}C in winter and summer respectively. Typically about 60% of the rain falls between April and August, as can be seen from the average monthly rainfall graph in Figure 31 further on. The mean annual precipitation (MAP) is approximately 500 mm (Visser 2002).

Bredasdorp is located at the geological interface of the Bokkeveld Group (BG) and the Table Mountain Group (TMG). The faulted and fractured quartzite of the TMG hosts numerous perennial springs which feed into a wetland south of Bredasdorp. Both primary and secondary aquifers are present in the area. The secondary aquifers are more common and are associated with fracture sets in the hard, consolidated sediments of the BG and TMG. Groundwater quality is usually determined by the host rock type and, in the case of Bredasdorp, the groundwater from the BG has a high electrical conductivity of between 150 and 300 mS/m and is thus brackish For the TMG this value is less than 60 mS/m and hence the water is not brackish (Visser 2002).

Bredasdorp has been subject to a number of climate induced disasters, including widespread flooding in April 2005 which caused five million Rands worth of damage (Vogel 2007). Whilst most of these disasters have been related to extreme events involving high precipitation intensity, Bredasdorp is also located in a relatively dry region. The focus of this case study is on the projected gradual reduction of annual precipitation in the Bredasdorp catchment.

7.4 Methodology

7.4.1 Data collection method

The data and information used in this study were extracted from written reports, as well as interviews and correspondence with practitioners with specialised knowledge of Bredasdorp and the Cape Agulhas Municipality. Specific reference is made to the following reports:

- Toens P, Visser D, Van Der Westhuizen C, Stadler W & Rasmussen J 1998. Overberg Coastal Water Resources (Volume II): A report to DWAF on the groundwater resources, current and future water requirements of the coastal strip and adjoining hinterland between the Potberg and Quoin Point. Toens & Partners. Feb 1998, T&P 980148 (Toens et al. 1998);
- Visser D 2002. Cape Agulhas Municipality: Bredasdorp - Report on the 1999-2002 groundwater investigation to augment the towns water supply. Toens & Partners. May 2002, T&P 2002278 (Visser 2002); and
- Afri-Coast (Afri-Coast Engineers SA (Pty) Ltd) 2003. Water Services Development Plan 2003: Volume 1 Cape Agulhas Municipality. Overberg District Municipality. June 2003, P2402/1 (Afri-Coast 2003)

Personal communications were conducted with:

- South African Weather Service for historical weather records (SAWS 2007);
- Prof B Hewitson of CSAG for climate projections (Hewitson 2006/7);
- Mr S Visser - Financial manager for the Cape Agulhas Municipality (Visser 2007b);
- Mr P Groenewald – Municipal engineer for the Cape Agulhas Municipality (Groenewald 2007); and
- Mr D Visser – Geohydrologist for Ninham Shand Incorporated (formerly of Toens & Partners) (Visser 2007a).

7.4.2 Step by step process

The following steps were followed when undertaking this case study:

1. A literature review of the available water related studies for Bredasdorp and the Cape Agulhas areas was undertaken.

2. Historical rainfall data for Bredasdorp was obtained from the South African Weather Service, specifically for Station No. 0003062/7-Bredasorp Police Station.

3. Climate projection results for seasonal precipitation for the region were obtained from the Climate Systems Analysis Group (CSAG) based at the University of Cape Town. The projections are presented as the median change of a range of GCMs, since the median is considered as the likely change. The intensity and frequency considerations of rainfall have not been taken into account when determining the future runoff and recharge, since this involves fairly technical calculations and this was considered beyond the scope of this study.

4. A field trip was made to Bredasdorp to meet with the Cape Agulhas municipal engineer and obtain further relevant documents and computer based spreadsheets.

5. By using MS Excel, the historical rainfall data, water supply and domestic demand patterns were analysed.

6. The MS Excel spreadsheets were also used to project the supply and demand patterns from a base year of 2005 up to 2035. This was done for both the present average/normal climate (NC) conditions (based on historic climate records) and the projected climate change (CC) conditions (based on the CSAG projections). These two scenarios have been termed in this thesis as the NC Scenario and the CC Scenario respectively.

7. Based on these scenarios, the related investment costs for each scenario in present value were calculated. Under each scenario the volume of water demanded was the same. Only the investment costs for additional supply sources to meet the reduction in supply due to climate change were compared. The costs for the additional supply augmentations were based on the supply costing options presented by Toens et al. (1998). The costs were escalated from 1998 to 2005 using a CPIX index of 155.4 (SSA 2006).

8. To assess the total cost of supply under the two scenarios, the *discounted levelised cost* (DLC) was calculated by using the approach outlined in section 6.2.2.3, and is depicted by the following equation:

$$\mathrm{DLC} = \frac{\sum C_t / (1+r)^t}{\sum Y_t / (1+r)^t} \qquad \textbf{Equation 16}$$

where: DLC = discounted levelised cost (R/kl)

C_t = the cost (capital and operating) in year *t*

Y_t = estimated annual safe supply in year *t*

r = discount rate

t = time between today and the future payment year

Here the numerator is the present value of all initial and future costs incurred by the intervention and the denominator is the discounted amount of all initial and future water savings or supplies.

In order to calculate the operating costs in year *t,* the additional operating costs for additional infrastructure were added to the basic volumetric operating costs. The basic volumetric operating cost was based on the 2005 unit cost per kilolitre of water supplied, as provided by the Cape Agulhas Municipality (Visser 2007b). This unit cost was then multiplied by the volume supplied and added to the additional infrastructural operating costs.

The additional operating costs of the future infrastructure supply options was calculated using the unit costs for operation and maintenance suggested by the Department of Water Affairs and Forestry for water development projects (DWAF 2003b). For maintenance costs of the additional pump stations and related new bulk lines, 4% and 0.5% of the respective capital cost was applied annually. To account for the additional operating costs to pump the water over the longer distances, an additional factor of 1.5 times the additional maintenance costs was included.

9. The impact of implementing demand side management options on the CC Scenario was assessed and this was referred to as the CC&DSM Scenario. By using the approach outlined in section 6.2.2.3, the following equation for *average incremental cost* (AIC) was used to compare the cost effectiveness of implementing the DSM options verses the supply side options:

$$AIC = \frac{\sum_{t=1}^{T}(I_t + R_t - R_o)/(1+r)^t}{\sum_{t=1}^{T}(Q_t - Q_o)/(1+r)^t}$$ **Equation 17**

where: AIC = average incremental cost (R/kl)

I_t = the investment cost in year t

R_o = the recurring cost in the base year (i.e. operating & maintenance cost)

R_t = the recurring cost in year t

Q_o = the consumption in the base year

Q_t = the consumption in year t

Average Incremental Cost (AIC) is estimated by dividing the discounted incremental costs of meeting future demand by the corresponding discounted volume of incremental output over the same period (Warford 1997). Increasing unit costs of water tends to be the rule, as sources close to urban areas become fully utilized. Under climate change the sources will be needed sooner.

10. The tariff or unit selling price (P_U) of water under the NC and CC Scenarios was calculated based on the investment costs and the annual operating and maintenance costs calculated in step 8. The levelised cost (LC) equation was used to calculate the average unit cost (C_U) of the two scenarios. For both the NC and the CC scenarios the denominator is the same, since the volume of consumed water is projected to be same under both scenarios. In Bredasdorp the cost of supplying free water is subsidised by an external subsidy (the Equitable Share) as well as internal cross-subsidisation. This is expressed with the equation:

$$P_U = \frac{(C_U * V_T) - S_E}{(V_T - V_F)} \qquad \textbf{Equation 18}$$

11. For comparison with other water schemes, the *climate impact factor for unit selling price*(CIF_{Pu}) is a useful tool. This ratio between the tariff under climate change conditions (CC) and normal climate conditions (NC) can expressed as:

$$CIF_{P_U} = \frac{CCP_U}{NCP_U} \qquad \textbf{Equation 19}$$

where: CIF_{Pu} = Climate Impact Factor for unit selling price
CCP_U = unit selling price under climate change conditions
NCP_U = unit selling price under normal climate conditions

7.5 Case study inputs and assumptions

Following the initial five steps outlined above, the available information and assumptions were assembled to prepare a baseline.

7.5.1 Water balance assessment for Bredasdorp

7.5.1.1 Present water resources:

In 2002 Bredasdorp obtained its bulk water supply from the following surface and underground water resources:

Groundwater:

Five production boreholes (BD1-5) were developed in 1985 with a combined safe yield 480 000 kl/year**.** The boreholes were located in the quartzitic sandstone of the Table Mountain Group to the south of the town. The maximum safe yield to be extracted over the summer peak demand period was 59 000 kl/year (Toens et al. 1998). During the drought conditions in 2001 BD6 was developed and in 2002 test pumping of BD7-9 was completed. The total annual available equipped yield for the groundwater in 2001 was thus 792 000 kl, as illustrated in Table 18.

Table 18: Actual annual groundwater abstractions at Bredasdorp (Afri-Coast 2003)

year	BD1-BD6 (kl)	BD7-BD9 (kl)	Average rate (kl/d)	Available yield (kl)	% of available yield
1999	418 185	0	1 146	480 000	87.1 %
2000	216 965	0	595	480 000	45.2 %
2001	444 037	131 148	1 576	792 000	72.6 %

Surface water:

Bredasdorp is supplied by two surface water sources, the Klein Sanddrift dam and the Uitvlugt springs. The Klein Sanddrift dam, situated 5 km west of the town, was commission in 1997 to capture the "surplus" run off from the catchment and has a storage capacity of 455 000 kl. The 98% yield of this source is 440 000 kl/year i.e. 1 205 kl/day (Ninham Shand 1998). Since 1974 the water in this catchment was allocated in a ratio of 4 is to 5 between Bredasdorp and the irrigation farmers i.e. a split of 196 000 kl to 244 000 kl respectively. The annual consumption from the dam for a three year period is shown in Table 19. During the drought in 2001, levels dropped to below 33% of full supply capacity (Afri-Coast 2003). As can be seen from the table, in the years preceding 2001, more than the recommended yield for this dam was used.

Table 19: Water drawn from the Klein Sanddrift dam in kl/year (Afri-Coast 2003)

Year	Bredasdorp	Farmers
1999	425 314	118 017
2000	388 447	159 581
2001	221 746	131 083

The Uitvlugt springs supply water via a pipeline over 11 km to the Vleikloof dam. The estimated sustainable yield is 160 000 kl/annum (438 kl/day). The Vleikloof dam is useful in meeting peak demands and has a storage capacity of 295 000 kl (Ninham Shand 1998).

Available water supply resources:

As can be seen in Table 20, the available allocated annual water supply is 1 257 Ml, of which 63% is dependent on groundwater. The allocation from the dam for Bredasdorp is more than the allowable amount stated above i.e. 196 000 kl. Bredasdorp has by agreement obtained a large portion of the farmers' allocation, which has resulted in a revised allocation of 305 Ml per annum.

Table 20: Summary of Bredasdorp water supply in kl/year (Afri-Coast 2003)

Year	Dam	Spring	Groundwater	Total
Allocated potential	***305 000***	***160 000***	***792 000***	***1 257 000***

7.5.1.2 Future supply options:

No surface water is available for further exploitation, but three further underground aquifers have been identified as potential supply options (Toens et al. 1998). This will increase the dependence of the town on groundwater. The De Duine West option is much more expensive in terms of unit cost since it is located 22 km from Bredasdorp.

Table 21: Future groundwater supply options (Toens et al. 1998):

Underground Supply option	Estimated safe yield	Pumping distance	Real cost in 2005	Unit cost R/kl
Golf course compartment	260 000 kl/year	2.5 km	4 870 000	18.75
Sanddrift/Napier Compartment	800 000 kl/year	8 km	12 500 000	15.65
De Duine West	720 000 kl/year	22 km	33 725 000	46.85

7.5.1.3 Future water demand:

Future demand for water is dependent on a number of factors such as the population growth, the rate of urbanisation and the increase in household consumption. Population growth presents a level of uncertainty in determining the future water demand and in developing viable strategies.

Researchers differ on their projections of future population growth in South Africa as was discussed in detail in Section 5.4.1. The projected annual growth in households for the Western Cape, for example, has been estimated at 1.56 (van Aardt 2007), which compares favourably with the national estimates shown in Table 22. Perhaps one of the most difficult assumptions about the future relates to the levels of poverty. The approach taken in this thesis is an assumption that no inroads are made into reducing the proportion of poor households, nor that there are any dramatic increases in poverty. In addition, the potential impact of future increases in temperature and evaporation on water demand have not been considered in this study.

Table 22: Projected annual population growth rates

Years	**Regional**	**National annual population growth rates**	
	Western Cape (van Aardt 2007)	**Business Futures 1998** (Roux 1998)	**CAR (2006)** (Dorrington et al. 2006)
1999-2015	1.56	1.92 %	1.6-0.4 % (0.95 %)
2015-2030		1.06 %	0.4 %

In assessing the future water demand for the Bredasdorp case study, the annual water demand growth rate until 2008 was estimated to be 2.3%, based on the historical growth in demand (Afri-Coast 2003). This is slightly higher than the population growth, but is assumed to take urbanisation and increased demand due to ease of access into account. As the urban population moves into houses with piped water, the consumption will likely increase. The household units may be smaller in future, but the consumption due to the ease of access may increase.

Based on this assumption, the annual water demand by 2035 was projected to be approximately 1 964 Ml. The demand in 2005 was calculated to be 967 Ml – slightly more than a two fold increase over 30 years. If we consider the demand for water against the existing supply (see Figure 29), we see that a shortfall can be expected around 2016. The unmet water demand by 2035 would be 707 Ml/annum (1 964 Ml-1 257 Ml).

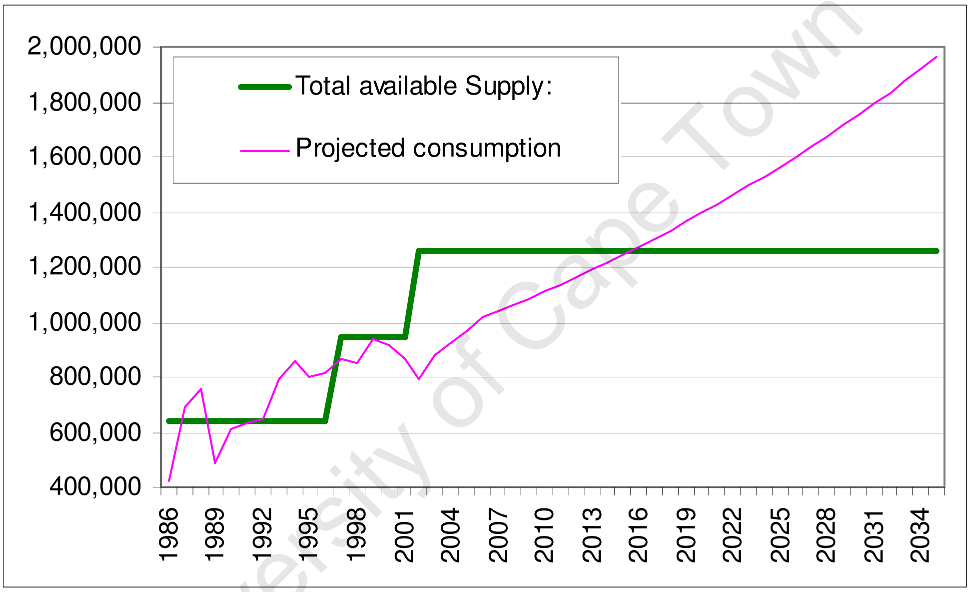

Figure 29: Current available water supply and projected water demand for Bredasdorp

7.5.1.4 Unaccounted for water / Losses

From 2002 to 2005 water losses were of the order of 15%-17% in Bredasdorp. In 1999 this was as high as 24.2%. This reduction was achieved by implementing an improved water management programme (Afri-Coast 2003). In 2005 the losses were recorded as 17%. This has been used as the assumed losses in the system for this case study.

7.5.2 Climate projections

Recent downscaled rainfall scenarios project a general drying in most March-May) and winter (June-August) months and in line with a shorter winter rainfall season as is graphically depicted in Figure 30. The projected changes in the intensity and frequency of precipitation events are less certain (Tadross & Hewitson 2007).

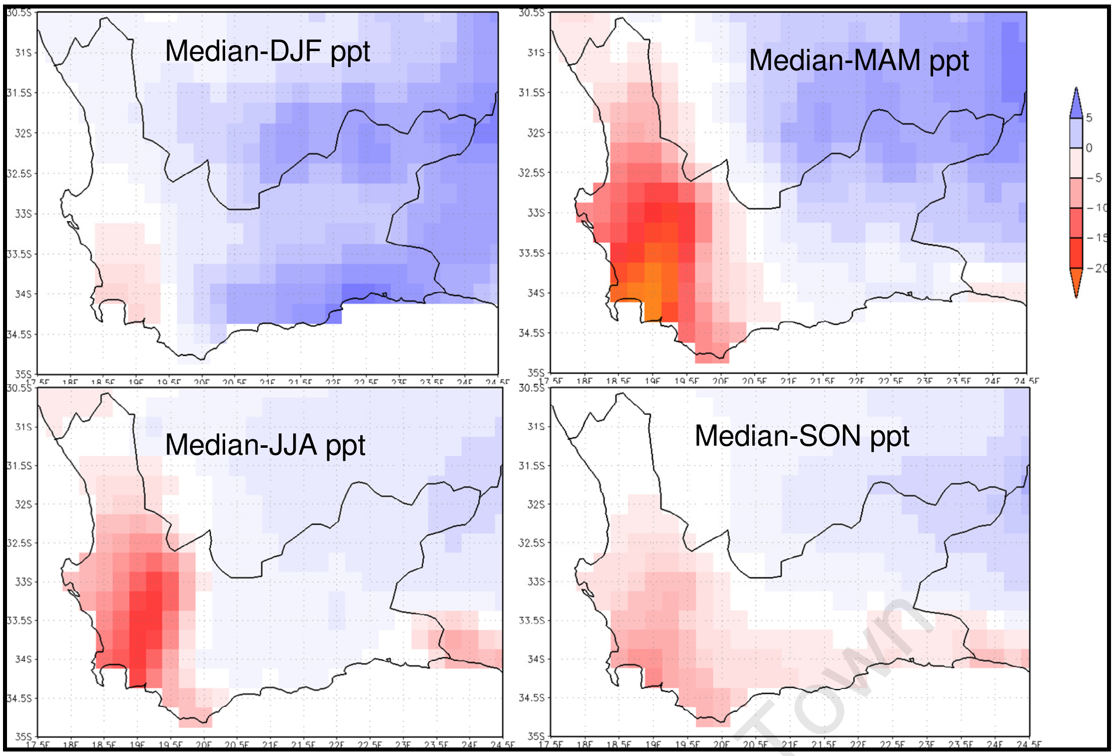

Figure 30: Downscaled precipitation anomalies between future and present climates in mm per month for the four seasons using the median of 6 downscaled GCM models (Hewitson & Johnston 2006)

Following the methodology as discussed in section 5.4.2, the median of a downscaled suite of six[35] Global Circulation Models for 2045-2064 was scaled linearly to 2035 to establish the change in precipitation in mm as compared with the model control period of 1980 - 1999 (Hewitson & Johnston 2006). By totalling the monthly changes in precipitation for the 12 months, the annual percentage reduction in rainfall for the Bredasdorp location was found to be 8% by 2035, against the historical average for 1980-1999, as shown in Table 23 and Figure 31.

Table 23: Projected change in rainfall for Bredasdorp

Months	Rainfall figures in mm			% change
	1980-1999	Projected change	2035	
Jan	23	2	25	9 %
Feb	24	2	26	8 %
Mar	30	-6	24	-20 %
Apr	67	-6	61	-9 %
May	41	-6	35	-15 %
Jun	50	-5	45	-10 %
Jul	46	-5	41	-11 %
Aug	52	-5	47	-10 %
Sept	35	-3	32	-9 %
Oct	48	-3	45	-6 %
Nov	31	-3	28	-10 %
Dec	27	2	29	7 %
Annual	**476**	**-36**	**440**	**-8%**

[35] The 6 GCMs (and whether they are from the Third Assessment Report (TAR) or the Fourth Assessment Report (AR4) archive) used for the downscaling are: CSIRO-Mk2 (TAR), HadAM3P (TAR), Echam4.5 (TAR), GFDL2.1 (AR4), MIROC (AR4), MRI_CGCM (AR4)

Therefore, for this study, we note that for the period 1990-2035, the precipitation is projected to decrease by 8%.

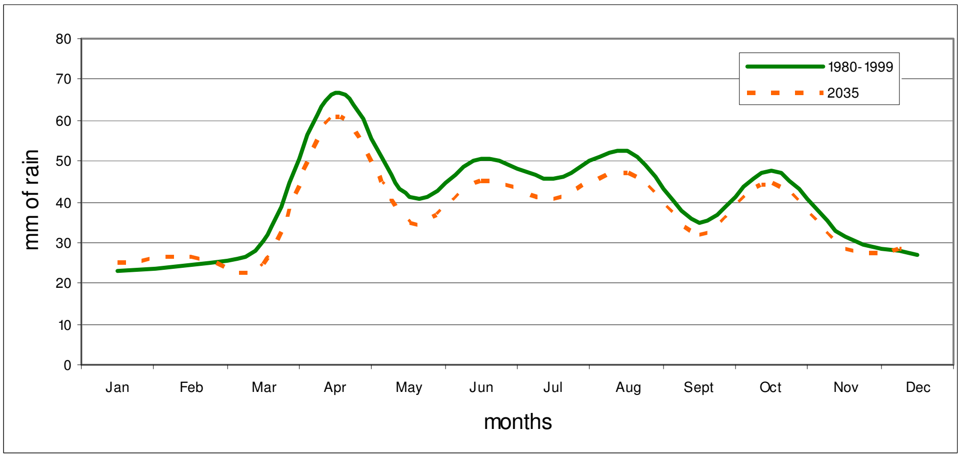

Figure 31: Average projected monthly rainfall and historical average monthly rainfall for Bredasdorp

7.6 Results: Impact of climate change on water resource management

7.6.1 Projected average annual precipitation for the Bredasdorp catchment

Most methods used to estimate future water supply resources assume that climate is stationary and that therefore mean precipitation does not change over time (Kirchner 2003). However, as can be seen by Figure 32, the long-term historical mean annual precipitation ($MAP_{historical}$) for Bredasdorp is recorded as 500 mm (Ninham Shand 1998), but the historic mean annual precipitation for the 20 year period 1980-1999 ($MAP_{1980-1999}$) is 476 mm per annum, which would possibly indicate some drying already.

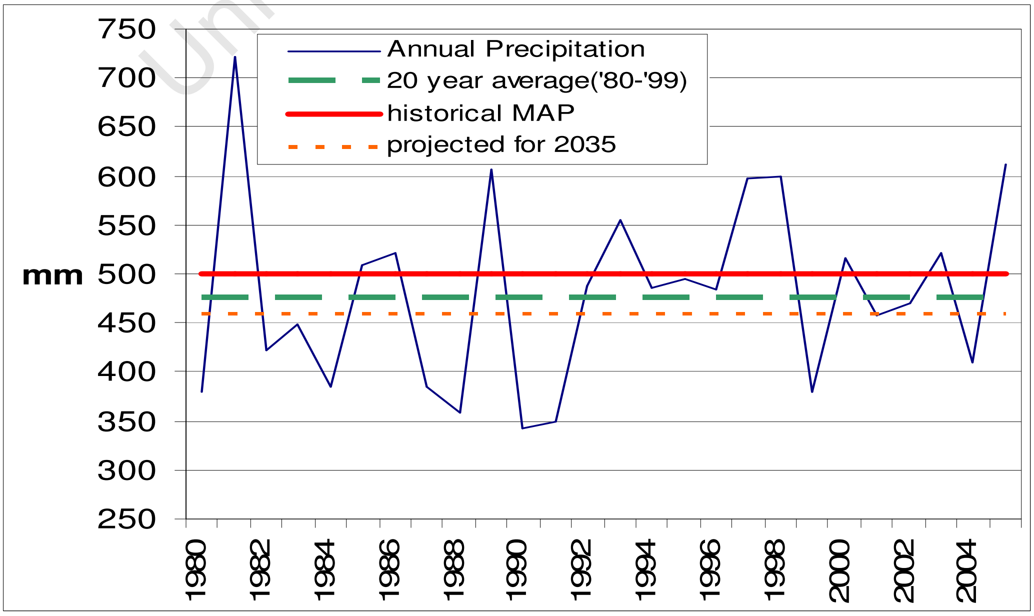

Figure 32: Annual precipitation for Bredasdorp

In the Western Cape region, precipitation is forced by large scale circulation but is significantly modulated by the topography. Future projections for winter indicate a continued winter drying in the west in both lowland and mountain regions. The winter season is likely to shorten, while for summer it will be characterised by drying in the west, with slight wetting in the north and east (Hewitson & Johnston 2006).

For the Bredasdorp catchment, the projected precipitation for 2035 decreases by 8% when compared with the $MAP_{1980\text{-}1999}$ (after Hewitson & Johnston 2006). Hydrological and engineering planning often undertaken using the $MAP_{historical}$. In future, therefore, projects for Bredasdorp with a lifespan of 30 years should be planned for using 8% less annual precipitation than the $MAP_{1980\text{-}1999}$.

The effect of climate change on rainfall amounts and patterns of rainfall, particularly on intensity and increased evaporative losses due to higher temperatures, may be more important in its impacts on runoff and groundwater recharge than the rising temperature alone. However, this was considered beyond the scope of this study.

7.6.2 Impact of climate change on future water supplies

The impact on the available water resources has been estimated on the basis that projected climate change causes an 8% reduction in mean annual rainfall from 1990 to 2035. Firstly the impact on groundwater recharge is considered for the same period, followed by the impact on surface runoff into the dam. It should be noted that only the mean annual precipitation has been considered in these calculations. No assessment has been made which included the changes in rainfall intensity and its related impact on both runoff and recharge. A detailed historic data set of daily rainfall and daily runoff and recharge values would be needed for each abstraction site to establish the relationship. This information was not available at the time of writing this thesis.

<u>Groundwater recharge</u>:

Various studies of Bredasdorp and the Table Mountain Group[36] (TMG) aquifers provide varying information on the recharge of the aquifer. Toens et al. (1998) obtained an average recharge of 19.6% from various reports citing observations from other locations (See Table 24).

This is supported by the recharge calculation of 17.4% at neighbouring Struisbaai using cumulative rainfall collectors (Weaver & Talma 2005). However, Duah et al. (2006) have estimated that recharge for TMG aquifer ranges from 0.28% to 12.6 % with an average recharge of 30 mm/year.

[36] The Table Mountain Group (TMG) consists predominately of quartzitic sandstones which, on the whole, are highly fractured and jointed (Toens et al. 1998)

Table 24: Average annual recharge estimates for sedimentary rock aquifers in mountainous catchments in TMG areas (Toens et al. 1998)

Location	MAP (mm/yr)	Recharge		Reference
		(mm/year)	(% of MAP)	
Pretoria/Rietondale	670	54-160	8-24	Bredenkamp et al., 1995
De Hoek	1852	20-290	1-16	Connelly et al., 1989
Rustenberg	749	114	15	Bredenkamp et al., 1995
Zachariashoek	1061	319	30	Bredenkamp et al., 1995
Olifant/Doring River Basin	365	102	28	Hay, 1997
Klein Karoo			10-30	Kotze, 1995
Average			19.6	Toens et al. 1998

In the absence of historical data sets of recharge for this catchment, the Beekman (1996) expression has been used to calculate the percentage change in recharge due to a change in MAP by 2035.

$$\text{Recharge} = 148 * \ln(\text{MAP}) - 880 \qquad \textbf{Equation 20}$$

Applying this equation to the $MAP_{1980-1999}$ of 476 mm results in a recharge of 32.5mm/year. If reduced by 8% to 440 mm, recharge would be 20.8 mm/year. This would equate to a 36% reduction in groundwater recharge. Therefore recharge is reduced by a greater percentage than the reduction in rainfall and the groundwater storage would be thus accordingly affected.

The *Climate Impact Factor* (CIF) for the period 1990-2035 would therefore be -0.36.

i.e., $FS_{recharge} = CS_{recharge} * (1 - 0.36)$

This would mean that groundwater abstraction would also need to be reduced by 36% so as not to dewater the aquifer.

<u>Surface runoff</u>:

In order to accurately calculate the runoff for future water resources studies for Bredasdorp, a monitoring programme should ideally be put in place to collect this data in order to calculate the historical runoff trends in relation to recorded rainfall and temperature. On the basis of this, a relationship between the three could be established. Alternatively, by using the Pitman monthly rainfall-runoff model, various scenarios can be run to compare the monthly runoff due to variations in future rainfall and temperature. The inputs required for such a modelling exercise would include the physical basin properties, soil moisture content, runoff, recharge and infiltration parameters (Kapangaziwiri & Hughes 2008). Unfortunately, reliable historical data required for both these methods was not readily available for the Bredasdorp catchment at the time of the study.

However, based on the discussion in section 6.5.1.2, we can assume that for a projected 8% reduction on a $MAP_{1980-1999}$ of 476 mm by 2035 a reduction in runoff would be in order of 50-30%. Therefore, for the purposes of this study we have chosen a conservative estimated reduction of 30%, i.e. the CIF for the period 1990-2035 would be -0.30.

Therefore, $FS_{runoff} = CS_{runoff} * (1 – 0.30)$

Whilst it is not ideal to make such an assumption, surface water contributes 24% of available water in 1990 and only 16% of the demanded water by 2035, and hence does not significantly influence the outcome of the demonstration case study as much as the groundwater source does.

7.6.3 Meeting future demand

Given that the available water resources are likely to be reduced by 30-36% by 2035, the loss of water from available sources needs to be factored into the water balance. In order to maintain the current levels of available supply (1257 Ml/annum) until 2035, an additional 434 Ml/year (marked A in Figure 33) will be needed under projected climate change conditions, as compared with the supply under present/normal climate conditions. This equates to 35% of the current available supply under normal conditions (i.e. A/total available supply).

In order to meet the projected water consumption (1964 Ml/annum) in 2035, this climate induced water supply decrease will need to accommodated. This climate induced shortfall is also 61% of the unmet demand (707 Ml/annum) for 2035 under present/normal climatic conditions (i.e. A/B). This means that by 2035, planners will need to plan for 61% more water than they would have under normal climate conditions.

Table 25: Supply and demand of water for Bredasdorp under climate change

Details	**Volume (kl/annum)**
Projected water demand for 2035	1,963,678
Current available supply	1,257,000
Shortfall by 2035 under present/normal climate conditions (B)	706,678
Future available supply under climate change	609,280
Reduction in supply due to climate change (A)	434,220
Total shortfall against 2035 demand under climate change (A+B)	1,140,898

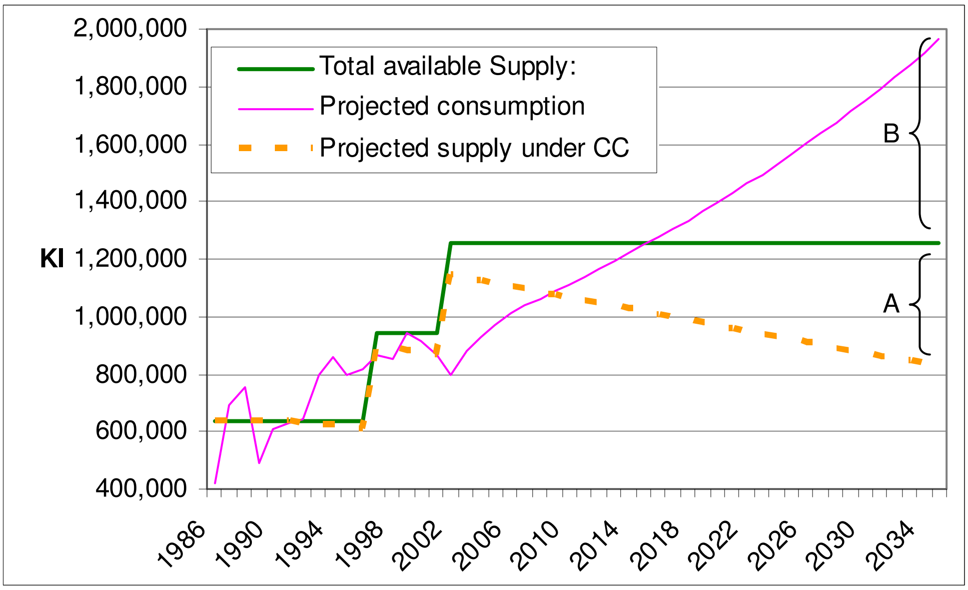

Figure 33 : Water supply and demand graph under historical and climate change conditions for Bredasdorp

Further, under present/normal climate conditions, the current water supply system would experience a shortfall in meeting the projected demand by mid 2015. The projected climate change impacts will induce this shortfall before 2009, almost seven years earlier. This will have infrastructural and financial implications and is discussed later.

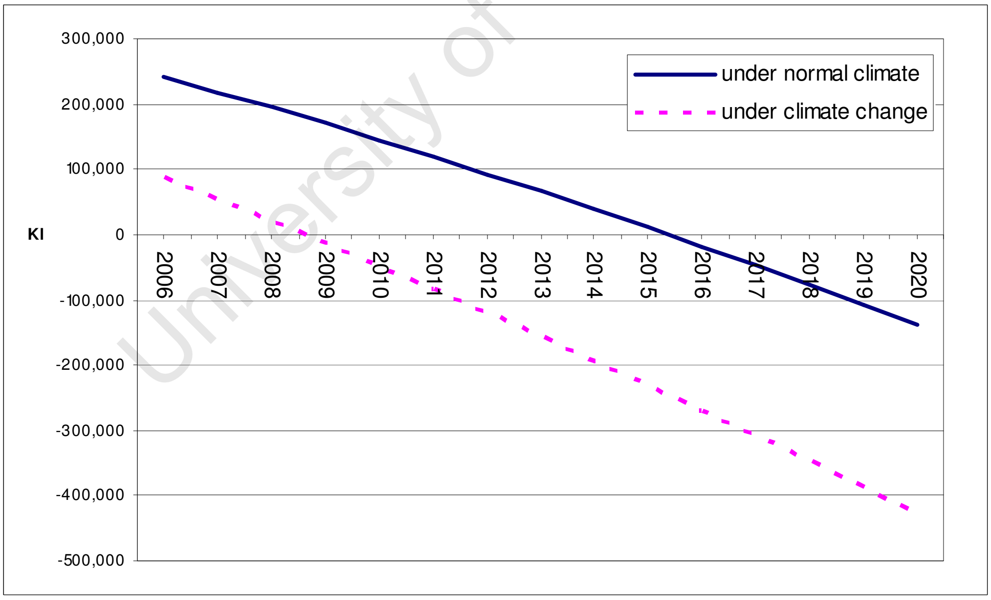

Figure 34: Timing of projected water supply shortfall for Bredasdorp

7.6.4 Analysis of water resource management strategies under climate change

A number of supply and demand side options are investigated to illustrate the impact of climate change on water resource management for the Bredasdorp case. These strategies have not been adopted by the planners of Bredasdorp and have been used in this case study to illustrate the potential financial impacts of climate induced shortages, based on the associated assumptions.

7.6.4.1 Selected supply side options

In order to meet the projected demand of 1964 Ml/annum by 2035 under normal climate change conditions, two additional supply sources will need to be augmented, as illustrated in Figure 35. These two sources are the Golf Course Compartment (260 Ml/year) and the Sandrift/Napier Compartment (450 Ml/year[37]) comprising a total of 710 Ml/year.

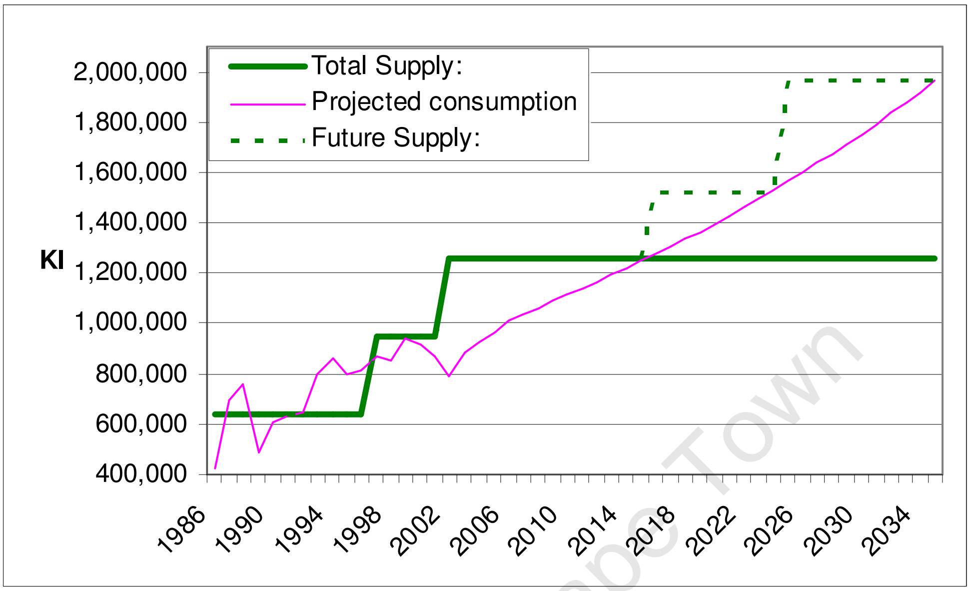

Figure 35: Projected water supply for Bredasdorp until 2035 under normal climate conditions

In order to meet the shortfall under climate change conditions, an additional 434 Ml/year will be needed from additional sources. As illustrated in Table 26, these additional sources are the balance of the Sanddrift/Napier Compartment and the De Duine West wellfield. The progressive reduction in available water supplies over the period 1990 to 2035 due to climate change, results in a 36% and 30% reduction in recharge and runoff respectively. This has been extrapolated linearly over the period (1990-2035) in order to apply the appropriate reduced volume at the intervals that they are required. As can be seen in Figure 37, the augmented supplies are also reduced over time due to the climate change impact. In other words, a potential resource in year 1990 of 400 Ml would be reduced to 320 Ml by 2015 and further reduced to 298 Ml by 2022, due to the progressive impact of climate change (see Table 26).

[37] This amounts to 56% of the full 800 Ml/year available

Table 26: Future groundwater supply options commissioned (in kl/year)

Supply option	Normal climate Estimated supply in 1990			Climate change conditions Projected supply using the annual CIF ratio (estimated supply in 1990)					
	2016	2025	2035	2010	2015	2022	2028	2032	2035
Golf course compartment	260000			218400 (260000)					
Sanddrift/Napier Compartment		450000			320000 (400000)	297600 (400000)			
De Duine West							250560 (360000)	239040 (360000)	
Cumulative additional supply	260000	710000	710000	218400	528000	788640	988320	1181920	1139200

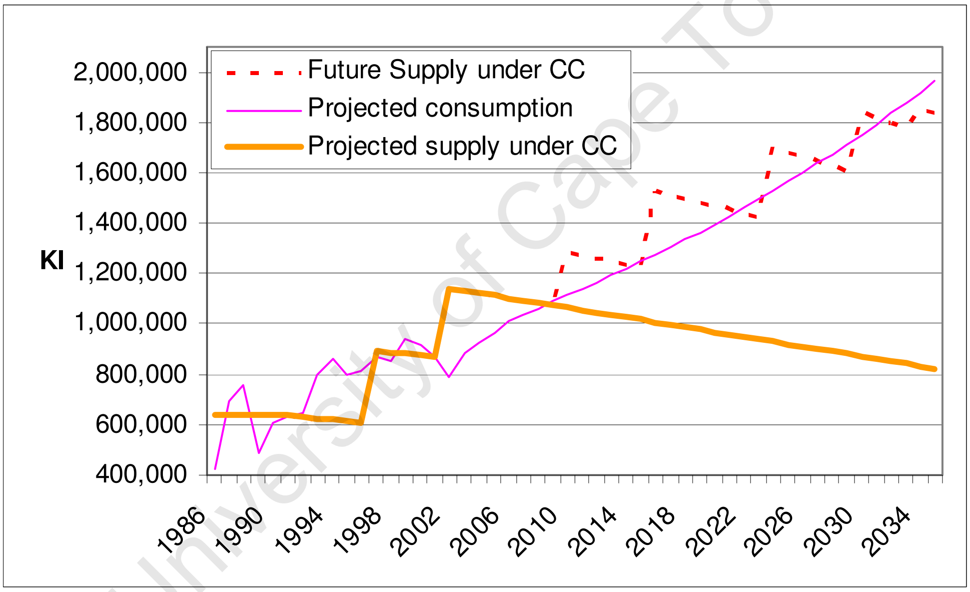

Figure 36: Projected water supply for Bredasdorp until 2035 under climate change conditions

7.6.4.2 Financial assessment of the climate change impact

Financial cost indicators are ideal for quantitatively assessing the various supply and demand reducing options, since for local municipalities' financial capital is one of the key resources that need to be managed strategically.

In assessing the financial implications of meeting the projected demand for 2035 under climate change conditions, the real present day investment cost (assumed here to be as at 2005) of additional supply has been compared with that under present/normal climate conditions. The influence of the running costs have been included under the analysis of the unit cost and price of the system. This section is confined to analysing the investment costs only. The investment intervals are provided in Table 27.

Table 27: Present value investment costs of future groundwater supply at Bredasdorp (in 1000s of R/year)

Supply option	Normal climate			Climate change conditions					
	2016	2025	2035	2010	2015	2022	2028	2032	2035
Golf course compartment	4870			4870					
Sanddrift/Napier Compartment		7032			6250	6250			
De Duine West							16863	16863	
Cumulative Supply	4870	11902	11902	4870	11120	17370	34233	51096	51096

As can be seen from Table 28, this analysis reveals that approximately an additional R40,000,000[38] will be required at Bredasdorp in present value terms. This is approximately **4¼ times** the capital expenditure under normal climate conditions. In other words, for this case study, a projected decrease of 8% MAP from 1990 to 2035 is projected to result in a 329% increase in present value investment cost.

Table 28: Investment cost comparison of ensuring water supplies under climate change conditions

Impact by 2035:	No CC	Under CC	Change		
Real 2005 investment costs of additional supply (R)	11,902,128	51,096,561	329%	4.29	Times
Additional annual water supplied in 2035 (R)	710,000	1,139,200	60%	1.60	Times
Real costs/additional water required in 2035 (R/kl)	16.76	44.86	168%	2.67	Times

Cost-effectiveness analysis is a specialised version of traditional cost-benefit analysis. All costs of a portfolio of strategies are assessed in relation to a policy goal that represents the benefits of the strategies, and all other impacts measured as positive or negative costs. The policy goal in this case is ensuring municipal water supply of 1964 Ml/annum by 2035.

The unit cost comparison has been calculated by dividing the real cost by the actual supplied volume required in 2035, expressed in Rands per kilolitre (R/kl). Therefore, under the present/normal climate scenario, the cost of meeting the 2035 demand is R16.76/kl compared with R44.86/kl under climate change conditions, which is **2.7 times** higher. This is less than the investment cost ratio (4.29), since the additional volume of water to be sourced increases by 60% (i.e. 1.60 * 2.68 = 4.29).

It is also evident from the results that due to projected climate change, the cost of finding additional water increases in real terms. This is so since as time goes on, and the impacts of climate change on runoff and recharge become more pronounced, water becomes more difficult, and hence more expensive, to secure. The unit capacity cost for the first augmentation from the

[38] Approximately US$ 5.7 million (using R:$ = 7:1)

Golf course compartment was R18.75/kl, while for the De Duine West site it was R46.85 per annual available kilolitre of water (see Table 21).

The *discounted levelised cost* (DLC) for the supply of all consumed water for the period 2006-2035 under both normal climate condition (NC) and climate change conditions (CC) has been calculated and is presented in Table 29. For discounting purposes, a discount rate of 8% was used[39]. As can be seen the total DLC for CC is 29% higher than for under climate change impacts. The increased long-run marginal cost to deliver water under the CC scenario is due to the significant increase in the capital investment costs to source the additional water to offset the reduction in supply due to climate change impacts.

Table 29: Discounted levelised cost for CC and NC scenarios at Bredasdorp

Details	Under NC (using DLC)	Under CC (using DLC)	Change
Total discounted volume consumed/supplied for the period (kl)	14,313,326	14,313,326	
Total 2005 present value investment costs of supply (R)	11,902,128	51,096,561	
Unit investment cost of consumption/supply (R/kl)	**0.83**	**3.57**	**330%**
Total 2005 present value running costs of supply (R)	140,643,709	145,658,209	
Unit running cost of consumption/supply (R/kl)	**9.83**	**10.17**	**3%**
Total unit cost of consumption/supply (R/kl)	**10.66**	**13.75**	**29%**

7.6.5 Selected demand side strategies

In order to mitigate the impacts of climate change and possibly reduce the financial burden of implementing new supply side options, demand side management (DSM) has been considered for this case study. For illustrative purposes, water restrictions and household leak detection programmes have been analyzed. The savings and related unit costs, drawn from work conducted by White & Fane (2002) in Australia, are provided in Table 12.

Table 30: Examples of demand side options (after White & Fane 2002)

Measures	Saving	Cost
	l/p/d	2005 R/kl
Active leakage control	7.2	1.71
Outdoor water use restriction	1.8	0.36

The introduction of the DSM measures in 2009 results in a delay of 1-2 years for the implementation of the capital intensive supply options (compare Table 26 and Table 31). Based on a projected population of 26150 by 2035, the volume of water saved for the year in 2035 is

[39] The real long-term interest rate in South Africa is estimated to be between 6% to 8% (DWAF 2000)

approximately 86 Ml, as shown in Table 32. This is a 4.4% reduction on the projected demand of 1964 Ml/annum by 2035. The impact of implementing demand side management (DSM) strategies is that the saved water results in a delay in the implementation of supply infrastructure, and hence saves capital investment costs. For example, there is a 7.5% increase in available water due to the two DSM options by 2035, i.e. 86 Ml. This results in a delay of the implementation of supply options by 1-2 years during the period of study, causing a net decrease in the investment cost of 7.4%, and a reduction of the unit cost by 7.4%. It can be observed that the implementation of DSM activities in 2009 results in implementing a portion the second augmentation from the De Duine West site. It is acknowledged that the reduction in demand may result in reduced revenues, but this will in all likelihood be offset by the reduced operational costs.

Table 31: Future groundwater supply options commissioned under CC and DSM (in kl/year)

Supply option	Climate change conditions Projected supply using the annual CIF ratio (estimated supply in 1990)						Climate change and DSM conditions Projected supply using the annual CIF ratio (estimated supply in 1990)					
	2010	2015	2022	2028	2032	2035	2011	2017	2024	2030	2034	2035
Golf Course Compartment	218400 (260000)						216320 (260000)					
Sanddrift/Napier Compartment		320000 (400000)	297600 (400000)					313600 (400000)	291200 (400000)			
De Duine West				250560 (360000)	239040 (360000)					224800 (360000)	146448 (225000)	
Cumulative Supply	218400	528000	788640	988320	1181920	1139200	216320	517440	771680	965600	1069200	1053440

Table 32: Capital cost comparison of water supplies under climate change conditions & DSM for Bredasdorp

Impact by 2035:	Under CC	Under CC & DSM	Change	
Real 2005 capital costs of additional supply	51,096,561	44,819,964		
Real 2005 DSM costs	0	2,493,167		
Total 2005 investment cost of additional supply	51,096,561	47,313,131	-7.4%	0.93 times
Additional annual water supplied in 2035	1,139,200	1,053,440	-7.5%	0.92 times
Additional annual water saved through DSM in 2035	0	85,906		
Total additional water secured in 2035	1,139,200	1,139,346		
Marginal cost of supply in 2035 (R/kl)	44.85	41.53	-7.4%	0.93 times

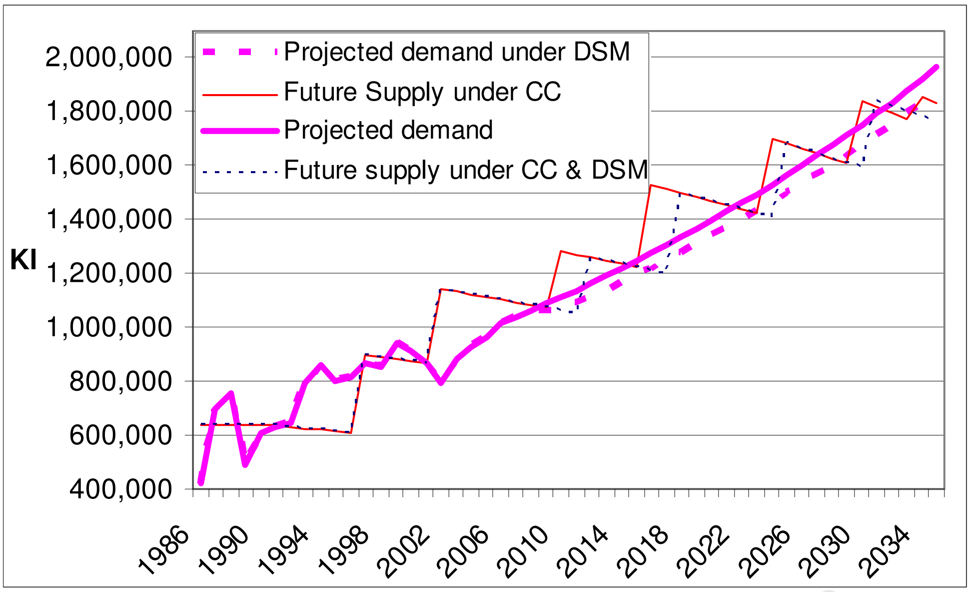

Figure 37: Projected water supply for Bredasdorp until 2035 under climate change and DSM conditions

7.6.5.1 Assessing the economic costs of DSM

Since the DSM measures effectively substitute a portion of the final De Duine West augmentation implementation in meeting the required demand, the CC and the CC&DSM scenarios are compared using *average incremental cost* (AIC) method as discussed in section 6.2.2.3. The discount rate used was 8%. While for supply limiting reasons, the DSM options are a good strategy for extending the life of the supply reserves, it is useful to assess if this is indeed an economically sound intervention. The financial costs for the options includes the investment costs as analysed above as well as the operating costs.

The results are presented in Table 33, where it can be seen that the DSM strategies under the climate change scenario are more cost effective. This is based on the long-run marginal unit cost for the additional water supplied to consumers over and above the base year supply and cost for the period 2006 to 2035. The marginal cost of DSM strategies is R5.03/kl over this period. This is less than the AIC for the whole system under the CC scenario and hence this result should indicate to planners that the DSM options be considered as an implementation strategy.

Table 33: Average incremental cost for CC and CC&DSM scenarios for Bredasdorp

Details	Under CC (using AIC)	Under CC&DSM (using AIC)	DSM only (using AIC)
Total additional incremental supply and saving over the period (kl)	5,574,539	5,095,151 (includes savings)	495,182 (saving)
Total 2005 present value incremental investment costs of supply (R)	51,096,561	47,313,131	2,493,167
Unit investment cost of supply (R/kl)	**9.17**	**9.29**	**5.03**
Total 2005 present value incremental running costs of supply (R)	13,595,932	6,850,157	-
Unit running cost of supply (R/kl)	**2.44**	**1.34**	**-**
Total unit cost of supply (R/kl)	**11.61**	**10.63**	**5.03**

7.7 Impact of climate change on equitable access

7.7.1 Water tariff structure

The tariff structure for the Cape Agulhas municipal areas is based on a rising block tariff. Table 34 shows how the tariff has been structured over the past six years. The tariffs have progressively increased over the years. The increases have been consistently applied across all blocks, ranging from 8% down to the more recent 3% increase.

Table 34: Cape Agulhas water block tariff (Visser 2002)

Rates	Tariff Rands per kilolitre					
	2002/2003	**2003/2004**	**2004/2005**	**2005/2006**	**2006/2007**	**2007/2008**
Basic fee per month	R 38.00	R 40.00	R 45.00	R 47.50	R 50.00	R 51.60
0 - 6	0.00	0.00	0.00	0.00	0.00	0.00
7 - 20	2.20	2.38	2.56	2.70	2.85	2.95
21 - 40	2.33	2.48	2.66	2.81	2.96	3.06
41 - 60	2.61	2.67	2.88	3.04	3.21	3.32
61 - 80	3.08	3.10	3.34	3.52	3.71	3.83
81 - 100	3.88	4.09	4.40	4.64	4.90	5.06
101 and more	5.28	6.47	6.96	7.34	7.74	7.98
Average increase		8%	8%	5%	5%	3%

It is interesting to note that the Cape Agulhas Municipality charges users a *Basic Fee* per month, which in 2005/06 was R47.50. For poor and indigent households, this fee is waived and recovered from the Equitable Share funding. As can bee seen from Figure 38, 53% of all the water related revenue is received under the *Basic Fee*. Consumption charges make up less than half the billed revenue. The free 6 kl/household per month is recovered through an internal cross-subsidy. All households, including the indigent, get charged for water used over the free 6 kl per month. It is also interesting to note that two thirds of the water consumed is made up of volumes metered below 20 kl per month, but that this volume only yields 21% of the billed revenue.

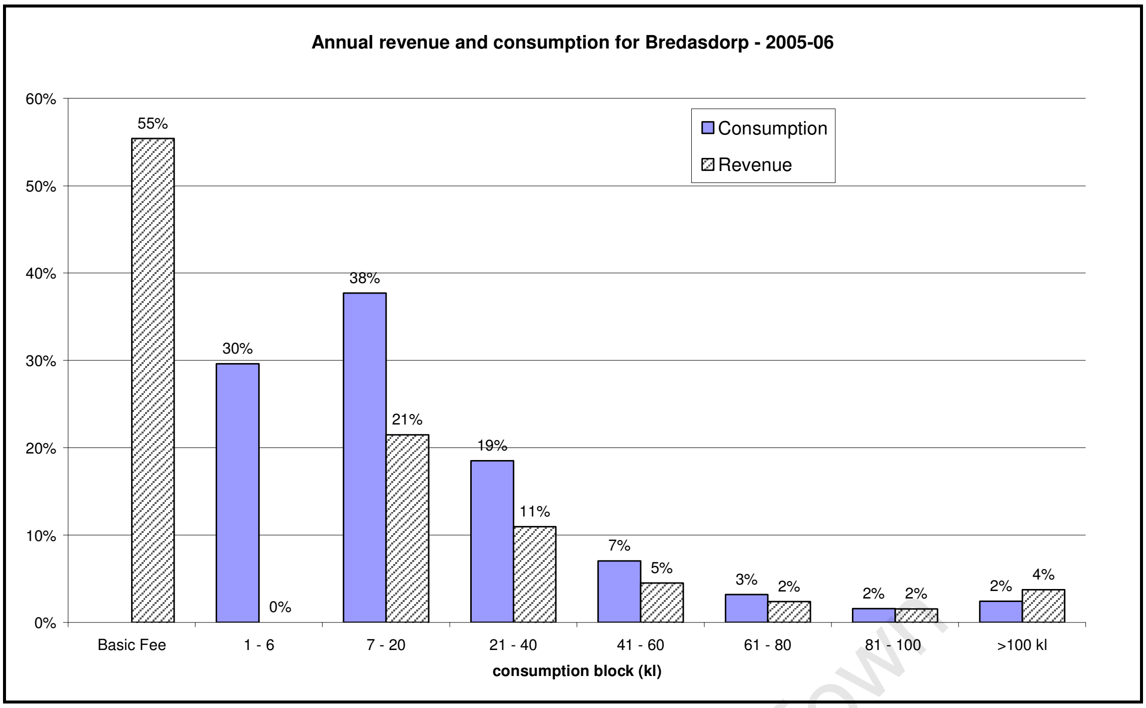

Figure 38: Annual revenue and consumption for Bredasdorp based on the consumption blocks

For the analysis of 2005 tariffs under a cross subsidising approach the consumption demand for that year has been used and not the installed capacity. The relevant consumption volumes and related financial information are provided in Table 35.

Table 35: Volumes and costs for 2005 under normal climate conditions for Bredasdorp

Average annual volumes		**Average present value finances**	
Water losses at 17%	166,989 kl	Supply cost	R 4,171,638
Free basic water	206,208 kl	Unconditional external subsidy	-R 288,587
Billable supply volume	593,823 kl		
Total volume	967,020 kl	Total recovered Revenue	R 3,883,051
		2005 unit cost (C_U)	**R 4.31 /kl**
		2005 single block Tariff (P_U)	**R 6.54 /kl**

As can be seen from this example illustrated in Table 35 and Figure 39, the single block unit tariff required to cover the free basic supply of 6 kl per household (to all households) and the water losses is 52% more than the actual unit cost to supply the water. This is due mainly to the actual billable volume of water being 61% of that which is supplied. Also, the external unconditional grant effectively reduces the tariff required to cover the supply costs by 7.4%. It should be noted that in the case of Bredasdorp, the external subsidy (provided through the Equitable Share), does not completely cover the free basic water provided to indigent households. This grant is unconditional and therefore its allocation to the various services is not consistently applied by all municipalities. In Bredasdorp, the grant is used to subsidise the monthly basic fee that is charged to each household as shown in Table 34. This subsidy is only applied to the indigent households. The balance of the cost to provide free basic water and to cover the water losses is effectively cross-subsidised through charging a unit tariff (P_U) of R6.54/kl, resulting in an increase of approximately 50% on the unit cost (C_U) of supplying the consumptive demand.

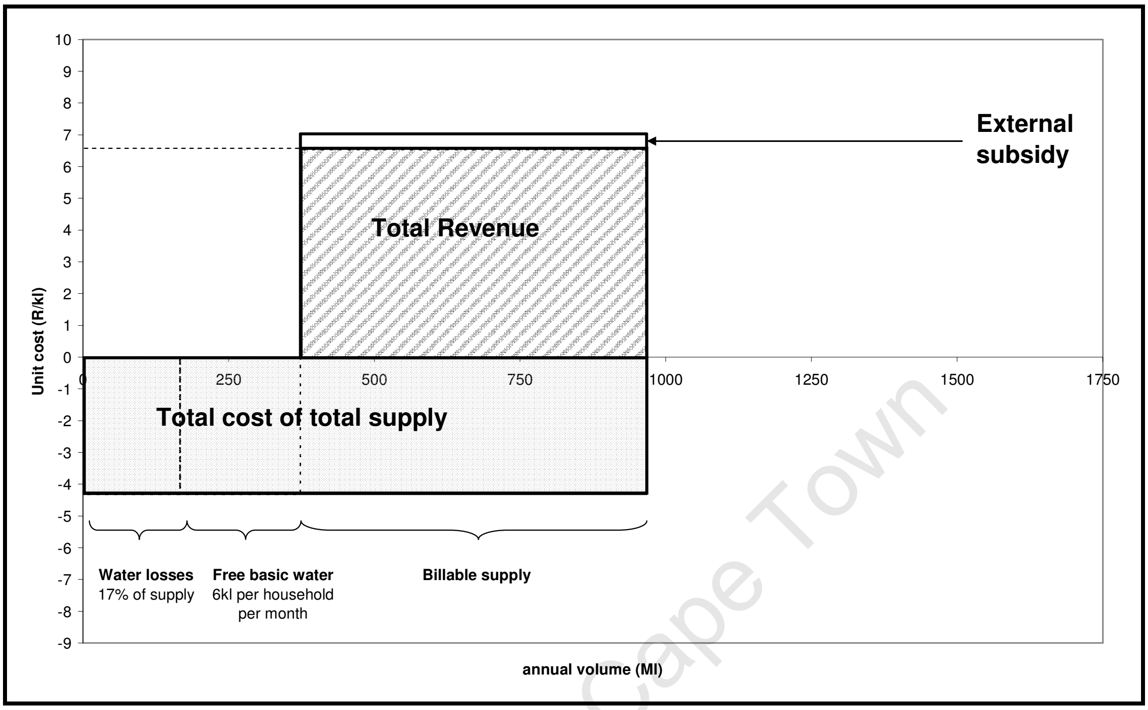

Figure 39: Cost and revenue balance for Bredasdorp for 2005 under normal climate conditions

7.7.2 Analysis of future tariffs

In order to compare the base year (2005) tariffs with those of the future, the average volumes and costs for the period 2006-2035 were calculated. For this analysis, the levelised cost equation has been used to calculate the average unit cost (C_U) for the period 2006-2035. In this case the consumption demand has been consumed and not the installed capacity. The relevant consumption volumes and related financial information are provided in Table 36. The demand was estimated to grow at 2.3% per annum over this period.

Table 36: Average annual volumes and 2005 present value costs for NC (2006-2035)

Average annual volumes		Average present value finances	
Water losses at 17%	244,738 kl	Supply cost	R 6,210,466
Free basic water	299,059 kl	Unconditional external subsidy	-R 418,532
Billable supply volume	895,840 kl		
Total volume	1,439,637 kl	Total recovered Revenue	R 5,791,934
		Average unit cost (C_U)	**R 4.31 /kl**
		Average Tariff (P_U)	**R 6.47 /kl**

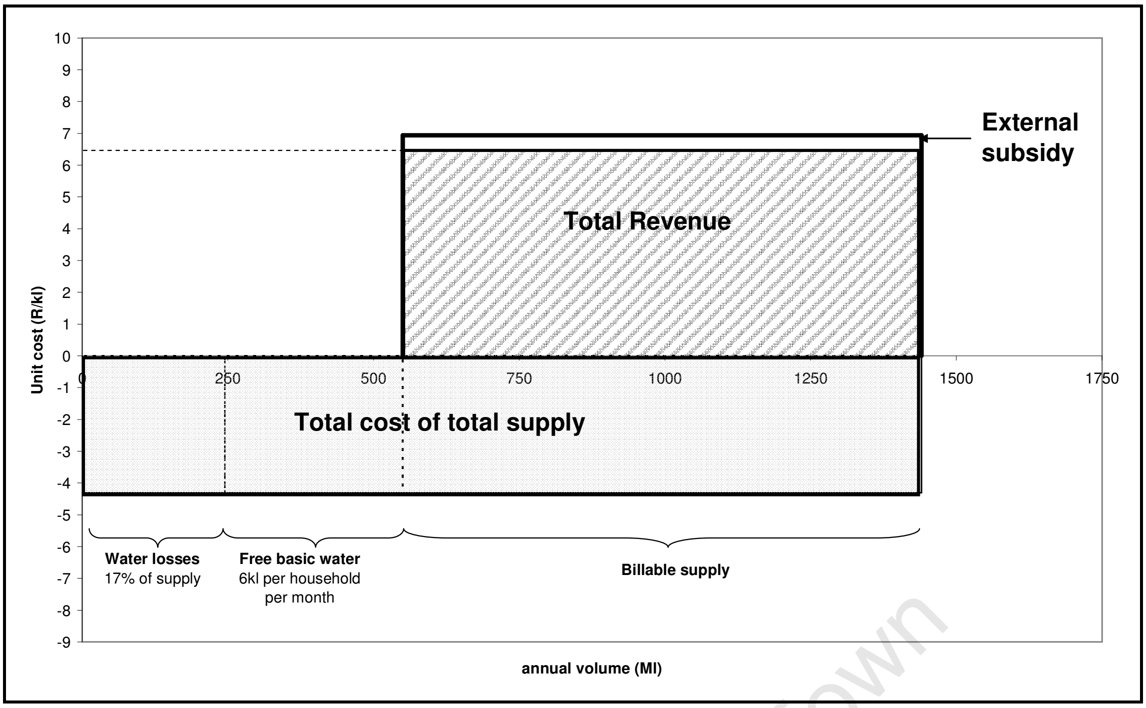

Figure 40: Average cost and revenue balance for Bredasdorp under normal climate conditions (Period 2006 – 2035)

When considering the impact of climate change on the system for the same period, it can be seen from Table 37 that the water demand has remained the same. Only the cost of supply has increased due to the increase in the cost of securing further water sources which are further away from the town. This has the effect of increasing the average unit cost of supply (C_U) from R 4.31/kl to R5.34/kl – an increase of 24%. This in turn results in an increase of the tariff (P_U) by 25%.

Table 37: Average annual volumes and 2005 present value costs for CC (2006-2035)

Average annual volumes		**Average present value finances**	
Water losses at 17%	244,738 kl	Supply cost	R 7,684,097
Free basic water	299,059 kl	Unconditional external subsidy	-R 418,559
Billable supply volume	895,840 kl		
Total volume	1,439,637 kl	Total recovered Revenue	R 7,265,538
		Average unit cost (C_U)	**R 5.34 /kl**
		Average Tariff (P_U)	**R 8.11 /kl**

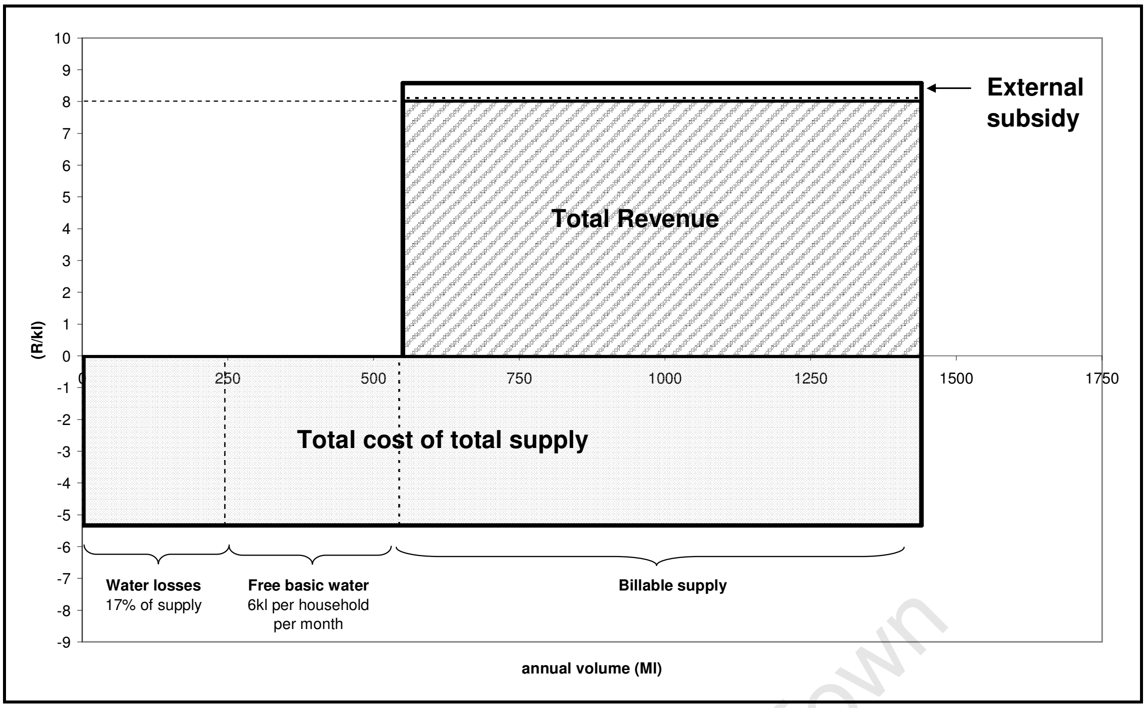

Figure 41: Average cost and revenue balance for Bredasdorp under climate change conditions (Period 2006 – 2035)

Therefore the unit selling price will need to increase by an average of 25% over the period 2006 to 2035 in order to accommodate the climate induced water scarcity by 2035. If this price increase was implemented in a linear fashion over the period, it would equate to a price increase on the NC scenario of 50% in 2035, as illustrated in Figure 42. Another option would be to apply a sudden initial increase and then stabilise the percentage increase for the rest of the period. This would have the same impact as reducing consumption through tariff mechanisms and may result in reduced demand, thereby effectively delaying the capital investment and reducing the tariff. A delayed price increase could also be an option if the impact of climate change is uncertain, and political buy-in is not possible. However, the steep tariff increases towards the end of the period would make the financial sustainability of the system unworkable with an 100% increase in the tariff by 2035 relative to the present/normal climate case.

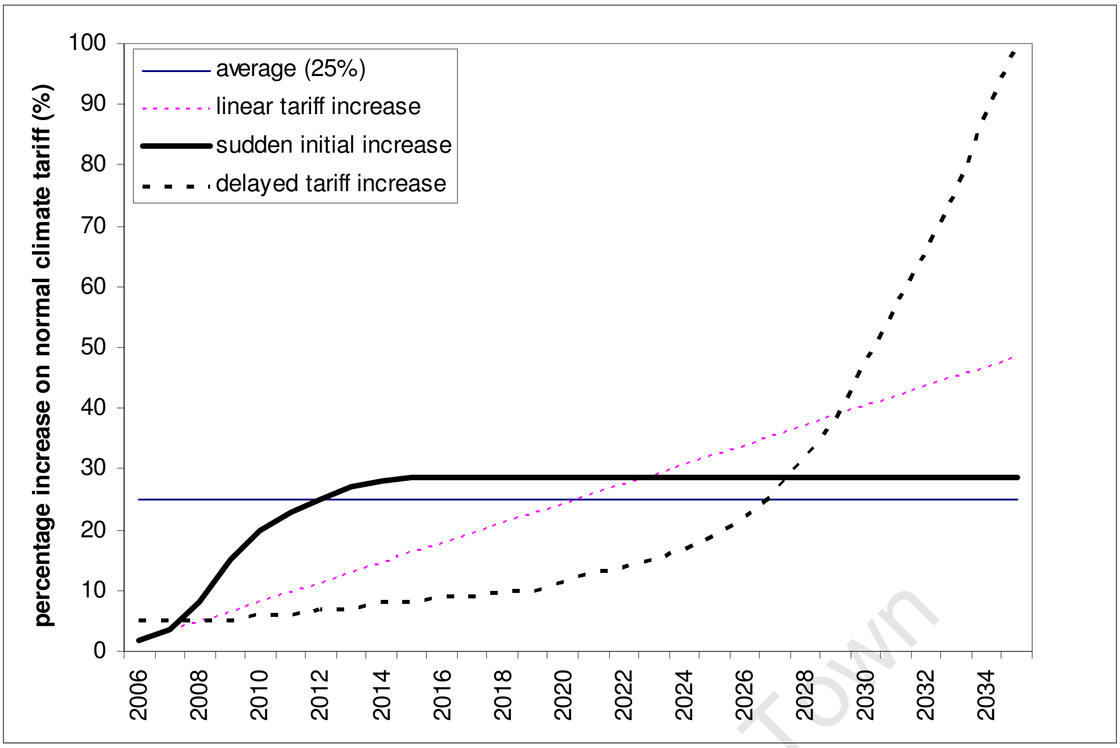

Figure 42: Possible climate induced tariff increases against normal climate tariff

Therefore, for comparative purposes, the *average* CIF_{P_u} ratio for the period 2006-2035 is +0.25 and is derived using the following formula:

$$\text{Average}\ CIF_{P_U(2006-2035)} = \frac{CCP_{U(average)}}{NCP_{U(average)}} = +0.25 \qquad \textbf{Equation 21}$$

By using the linear increase approach, where the tariff increase by 2035 would be 50% above the present/normal climate price increase, it could said that the Climate Impact Factor (CIF) for the tariff (P_U) is 0.5. The linear decrease in rainfall for this 30 year period (2006-2035) is -5.33%[40]. Therefore the CIF for this period could be expressed as:

$$CIF_{P_U(2006-2035)} = \frac{CCP_{U(2035)}}{NCP_{U(2035)}} = +0.5 \qquad \textbf{Equation 22}$$

Whereas,

$$CIF_{MAP(2006-2035)} = \frac{MAP_{(2006)}}{MAP_{(2035)}} = -0.05 \qquad \textbf{Equation 23}$$

As can be seen from results of these expressions, the tariff increase over this period is ten times the absolute magnitude of the reduced rainfall over the same period.

[40] The projected decrease in rainfall for 1990 to 2035 was estimated as 8% (see section 7.5.2), therefore for 2006 to 2035 is would be 5.33%, using a linear extrapolation.

7.8 Summary

Based on this illustrative example, it is shown that as the projected climate change impact nears 8% reduction in Mean Annual Precipitation for the period 1990-2035 and the projected volumes of ground and surface water are reduced by the proportionate Climate Impact Factor of 36% and 30% respectively. This results in the investment cost to meet the water demand in 2035 being more than four times that which would have been required under normal climate conditions. This is because it becomes more expensive to secure new water resources since the groundwater resources are deeper and further away. The introduction of DSM options eases the need for supply side resources and in this example provided approximately 8% more available water for distribution.

These results are indicative of the potential impact of climate change on municipal water resources, but since aquifers and runoff regimes differ vastly from place to place, it is advisable that detailed monitoring of the variables be undertaken to establish the relevant Climate Impact Factor for the specific area under study.

This case study reinforces the hypothesis that climate change is also an economic issue and not solely an environmental one. It is clear from the results of this analysis that an average tariff increase of approximately 25% due to an 8% reduction in projected MAP by 2035 is a likely scenario. The introduction of such a tariff increase would not be sustainable over the longer term. Considering that for the past 5 years, the tariff increases have been in the region of 3-8%, such a large average tariff increase over the period would likely be met with political resistance.

The price increase would be additional to any inflationary increases. This would seem an unrealistic burden for consumers in a small town to be able to absorb. As has been illustrated in the available literature (See chapter 3.3), water is generally price inelastic, but the number of high end users in small towns are not as prevalent as in larger urban centres. Therefore an average increase such as 25% over the period would need to be borne by the middle and low end users, since they make up the majority of the users (66%). This would burden them unduly. Since water is basic need, other sacrifices would need to be made in the household budget (Cairncross & Kinnear 1992).

A policy intervention is required if these small water systems are to remain financially viable and at the same time meet their social obligation of providing a basic water service for free. Two potential financial sources exist, viz. through national fiscal arrangements or international financing mechanisms. At the national level, a further allocation through the external subsidy, the Equitable Share in the case of South Africa, could be motivated for on the basis that basic service delivery is costly under projected climate impacts. Alternatively, a specific national adaptation fund could be set up to deal with potential climate induced impacts.

International adaptation funding is not yet sophisticated enough to accommodate numerous requests from small towns around the world, but at a national level programmatic adaptation funding could be leveraged internationally for this purpose. This could be done either through existing development funding and overseas development aid (ODA) or through an adaptation fund set up under the UNFCCC administered by the Global Environment Facility (IISD 2007). However, the mechanisms and governance of this fund are still far from functional, and policy makers will need to establish an interim measure, since some adaptation interventions need to be implemented sooner than later.

It is true that large uncertainties still plague quantitative assessments of climate change impacts and water resource management, yet what is known for certain is that the climate is changing, that this will have an effect on water resources. Therefore increased efforts will be needed to plan and manage water supplies in future, through increased monitoring and understanding of the interrelationships between climate change, water availability and water demand. The methodology outlined in this chapter will also assist municipal planners to evaluate these financial impacts due to climate change and develop appropriate strategies that ensure long-term water supplies.

This case study has successfully demonstrated how a baseline for small municipal water systems can be established and how the incremental cost due to projected climate change can be calculated. The case study clearly indicates that the incremental cost due climate change impacts on water supplies has the potential to undermine the development goals of developing countries and more importantly, small towns. A fundamental shift at a national and international policy level is therefore required that takes cognisance of climate change projections in order to guarantee the equitable access to affordable water.

A cautionary note however, the simple scaling up of the impact on this small town by the number of similar sized small towns to establish a national picture would be ill-advised. No two towns are the same, nor are the climatic conditions, sources of water, poverty profiles or the demand patterns. This case study should not be viewed as representative of all small towns in arid and semi-arid areas. It merely provides an indicative picture of the possible outcome of climate induced impacts under specific conditions and assumptions.

PART FIVE

SUSTAINABLE SMALL SCALE URBAN WATER SUPPLIES AND CLIMATE CHANGE

The stone in the water knows nothing of the hill which lies parched in the sun - African proverb

CHAPTER 8

8. Towards sustainable access to urban water under climate change

Small towns are confronted by both human and financial capacity limitations and have in general limited their planning horizons to the very near future, where they deal with the impacts of climate variability. Therefore it has been suggested in this thesis that by coping with climate variability, resilience to future climate change impacts can be improved. In the absence of an integrated framework for incorporating climate change impacts in water resource management and municipal development planning, a framework is provided in this thesis. In addition, a methodology for identifying viable strategies at the small town level was introduced, which takes into account the need to assess the barriers that prevent implementing these strategies in the longer term.

The third aim of this thesis was to illustrate that with respect to water resource management, climate change is a socio-economic issue and not largely an environmental one. Access to water in developing countries such as South Africa, is interlinked with the complex ongoing process of providing capacity at local government level. It is therefore an institutional challenge to avoid the debilitating effects of "*water poverty*" at a this level.

The following sections provide a summary of the findings and conclusions documented in the previous chapters. Firstly the impact of climate change on the water supplies to a small town such as Bredasdorp is described, specifically as it pertains to financial cost and the assurance of a basic free supply to all consumers. The notion of access was discussed in the second chapter and considers the responses to this development objective by various sectors, viz. sustainable development, water resources management, urban planning and climate change. A number of gaps were identified and attention was drawn to the lack of an integrated approach to addressing the impact of projected climate change on the delivery of basic services.

In response, the third section outlines the framework introduced in the thesis to assist with integrating climate change into water resource management and development planning. This is a tool that is applicable at both large and small urban levels and can be used for the analysis of other sectors as well. The fourth section of this chapter summarises the methodological approach proposed for small towns to assess their current climate variability strategies, both qualitatively and quantitatively, in order to identify viable long-term strategies to ensure adequate water supplies under projected climate change conditions.

8.1 The impact of climate change on urban water services

The case study of a small town in South Africa such as Bredasdorp, reinforces the hypothesis that the projected climate change impacts on water resources is an economic issue and not primarily an environmental one. This is especially true for small rural towns in arid and semi-arid regions around the world which are in general characterised by low levels of human and financial capital. Whilst the case study reflects a specific impact due to climate change in a specific location, the direction of the trend and the magnitude of the financial impact are of interest globally.

It was found that a projected decrease in rainfall for this catchment of 8% for the period 1990-2035 would amount to a reduction of 30% and 36% for surface runoff and groundwater recharge respectively. This has a significant impact on the water available for meeting the projected future demand both for installed infrastructure and future planned installations. These calculations were based on assumptions of runoff and recharge for this catchment. Accurate monitoring of the available water in relation to historic rainfall is needed to develop an accurate relationship between declining average rainfall and the available water resources via runoff and groundwater recharge.

The example of Bredasdorp illustrates that in order to meet the projected urban water demands in future under a climate change scenario, capital investments would need to be four times that which would be required under a normal (historic) climate scenario. This climate impact factor for capital investment is based on present values and not the discounted additional volumes over the 30 year period. When this was factored into the tariff, together with the operating costs required to ensure a sustainable water service, the increase in tariff indicates that this would be financially unsustainable. An average annual increase of 25% over 30 years (excluding an inflationary increases) would make the unit selling price of water prohibitive for most consumers living in small towns. This is especially relevant when considering that a linear extrapolation of the percentage increase would amount to a 50% increase under climate change by 2035 on top of normal inflationary price increases.

It must be borne in mind that this outcome is based on a number of assumptions and data that are specific to this case study. It is in no way representative of all small towns in arid and semi-arid regions. Further research work should be conducted using the methodology outlined in this thesis for a range of small towns under differing climatic conditions, sources of water, poverty profiles and the demand patterns. A comparative analysis of small towns in both developed and developing countries would provide for some interesting analysis.

Increasing unit costs of water with time tends to be the rule where future drying is projected. As sources close to urban areas become fully utilized, due to increased demand and the impact of drying under climate change, the sources will be needed sooner than originally planned. This will have the effect of increasing the unit selling price to paying customers. The available literature indicates that water is generally price inelasticity and therefore poor households faced with high prices for water will have to make sacrifices in other household needs in order to access sufficient water.

Cross-subsidisation for the poor has been introduced in many municipalities around the world to ensure a low (and sometimes free) tariff for low consumption volumes. This is either cross-subsidised through an external national grant or within the water accounting system using a rising block tariff, where the higher end users pay a higher unit price in order to offset the "lost" revenue. In general, it was found that small towns do not have a large proportion of high end users to fully subsidise the provision of a free basic supply to indigent households and hence the low to middle volume consumers have to carry the cross-subsidy burden. The financial sustainability of a water adaptation strategy will be dependent on an increase in the internal subsidy being acceptable and affordable to the paying customers and whether the external subsidy from central government will be sufficient under climate change to keep the unit price at an affordable level for the paying customers.

Therefore the question that is posed is "How can equitable water access be assured, especially in small scale water systems, in a future world constrained by climate change?" The successful attainment of the Millennium Development Goals is dependent on future climate change impacts being adequately considered when planning service delivery to the poor, especially in terms of affordability.

8.2 The failings of current responses

The answer to this question lies in the combination of sectoral approaches and responses. Primarily the issue of access to basic services such as water is located in the sustainable development discourse. The accepted definition for sustainable development requires that social, environmental and economic considerations be addressed. For a water supply system the delicate balance between the consumption of resources to meet basic needs, the preservation of the natural resources and the equitable access to resources through good social governance is key to achieving a sustainable service.

The attainment of development goals such as those set out in the Millennium Development Goals (MDGs), is seen as the key driver for basic human health and wellbeing. The focus has been predominantly short to medium term and the service is delivered at the grassroots level through local projects and programmes. In the second and fourth chapters, the approach to water access is discussed in the context of sustainable development, integrated water resource management (IWRM) and climate change. Table 38 has been developed to summarise the key features of the three discourses. It is evident from the literature that sustainable development is a conceptual objective while climate change is a reactive response to a changing global environment. IWRM falls somewhere in the middle of the continuum. IWRM is a planning and management tool and approach, while climate change is a response to projected impacts that needs to be incorporated into planning. Whilst it would intuitively seem that there should be some overlap in the policy responses, they are pursued by predominantly separate communities and the integration of the ideas and approaches does not happen easily. This is due mainly to the fact that all three operate at different temporal, spatial and institutional scales. They also have dissimilar foci and approaches and are often informed by unrelated academic and policy environments.

Table 38. Differences between Sustainable Development, Integrated Water Resources Management and Climate Change approaches

	Sustainable Development	**Integrated Water Resources Management**	**Climate Change**
Basis	Social and economic	Engineering and natural science	Scientific and political
Perspectives	Social & economic	Environmental	Environmental & economic
Predominant approaches	Bottom up – community based	Top down	Top down
Focus	Programmes & projects	Policy & infrastructure	Policy and sporadic projects & programmes
Temporal scale	Short/medium term	Medium term	Long-term
Spatial scale	Local scale	Regional scale / catchments	Global scale
Political & institutional scale	Micro & Macro	Meso & Macro	Macro
Access	✓✓	X	X
Scarcity	-	✓✓	✓✓
Climate impacts	-	✓	✓✓

In the third chapter the urban sector approach to basic service provision is introduced, with a specific focus on small urban centres and the provision of water through small water systems. From the available literature, it is evident that there is a large divide between the climate change impacts research and the urban environmental planning. The key focus of urban environmental change has been on mitigation of greenhouse gas emissions and not enough, if any, attention has been paid to impacts of climate change on basic service delivery. It can be demonstrated therefore that the delivery of equitable water services with the aim of reaching sustainable development objectives is through the interlinkage of the urban environment, water resources and climate change drivers, as illustrated in Figure 43.

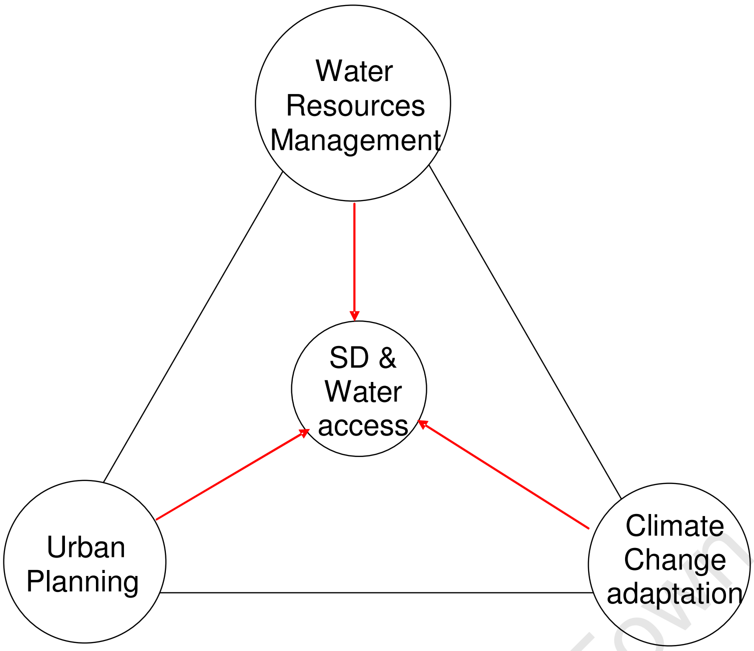

Figure 43: Sustainable development and water access nexus

By introducing the notion of equitable access to water, it has been conceptually demonstrated that the integration and co-ordination of these three sectoral approaches is key to sustainable equitable water provision and hence sustainable development. Therefore, in this thesis, the socio-economic agenda has been strategically located at the hub of the intersection of water resources management, urban planning and climate (or global) change adaptation. It can be seen that the three sectors interface around the issue of equitable access to water. These sectors are focused predominantly on resource planning, with varying degrees of focus on equity. While they are generally pursued by different academic and policy communities and operate at different temporal and spatial scales, there is a need to bring integration into the planning for equitable access, especially when faced with the prospects of projected climate impacts.

IWRM is an approach which focuses much of its attention on the issue of water as a resource and the scarcity thereof. It is usually undertaken at a regional or catchment level where medium term resource decisions are made to meet growing water demands. IWRM at an urban level has been proposed as a tool to ensure sustainable water services, but it needs to take on two missing elements, namely the impacts of climate change and the issue of equitable access. The approach incorporates environmental issues and equity in the user allocation sense, but it does not, however, usually concern itself with issues of affordability and hence access at the household level. The key focus of IWRM is the sustainable management of resources and therefore the inclusion of climate change impacts would seem like a natural fit. However, the issues around climate change impacts on water resources are only more recently being considered by regional water managers, hence the inclusion of these issues is still in its infancy and need to be fully integrated into water planning methods. It has been argued by some, such as Kabat et al. (2002), that IWRM should be the approach for coping with natural climate variability and the precondition for adapting to the highly uncertain consequences of global warming and associated climate change.

To ensure equitable access to water for all under projected climate change impacts, adaptive capacity should be developed that addresses the political, institutional and economic power imbalances. Political expediency and short-term planning horizons, together with poor institutional capacity at the small town level, have in the past resulted in the entrenchment of the vulnerable poor. The impacts of climate change are likely to put undue pressure on the attainment of the MDGs and further exacerbate the low levels of resilience and lack of water access amongst the poor.

In large cities where there is technical capacity to respond to political demands, urban planners are forced to consider development issues. This has resulted in urban water delivery services ensuring a higher water access rate than the rural areas and small towns. Given that there is a general migratory trend from the poorer regions to the wealthier ones, but also that both large and small urban centres are attracting migrants, it is important that planners and policy makers factor this into their development plans. The real challenge, however, lies in ensuring that appropriate technology responses and capacity are instituted in all settlements. Small town local government not only represents a clustering of the poor, but often also a small elite commercial agricultural sector that competes for water supplies, which can often lead to inequitable water access in small towns.

The adoption of the Millennium Development Goals (MDGs) has highlighted the need for equitable water access and has directed much needed funding to meeting this goal. In order to address the issues of affordability, subsidised tariffs and free basic volumes have been provided in most countries. However, this is not always well implemented, and it is not unusual to find poor consumers in developing countries paying more per unit of water than wealthier consumers. Also the unit price of water tends to be lower in large urban centres than in small towns for low volume consumers.

The notion of scarcity is adopted by all three sectors as a volumetric measure of reduced water availability which requires a quantitative supply side solution. This is considered in conjunction with a water deficit, which is a qualitative concept, and requires demand side social responses. Historically the supply side options have been the first to be considered, but more recently there has been a move towards demand side reduction measures. The ability of a society to adjust to variable change in water supply has been termed their adaptive capacity. The higher the adaptive capacity, the lower the vulnerability to variable climate impacts and hence the increased resilience to projected climate change impacts. The converse is therefore also true.

A number of cities, mainly those from developed countries, have begun to consider climate change in their urban planning and have developed adaptation plans. However, this still remains the exception. Most decision makers do not look much further than their political time frames and hence are reluctant to commit funding to a potential future impacts. This is true too of small towns and municipalities, where other pressing development priorities also hinder the long-term planning required for adaptation.

A glaring gap in the literature is evident in relation to small towns and their obligations to meet basic service delivery, specifically basic water supplies. The analysis of small scale water systems and the economic viability of these institutional structures to meet the social obligations is neglected in favour of academic and policy analysis associated with large urban centres. The issues of human and financial capacity, poor data sets, low economic bases and marginalisation by national government and regional institutions appear to be absent from the debates around access to water and affordability at this level. This thesis highlighted these issues and introduced an approach that is intended to bring them into the policy debates, as discussed in the next section.

Access to water in South Africa, as in most developing countries, is interlinked with the complex ongoing process of improving technical and financial capacity at the level of local government. The introduction of rising block tariffs and free basic water has placed small municipal institutions in between the proverbial rock and a hard place. On the one hand they are obligated by national policy to ensure that all citizens receive a basic volume (6 kl per household per month) for free, and on the other hand they have to find the financial resources to achieve this from within their own fiscal budgets. The introduction of an external subsidy in South Africa (the Equitable Share) has provided some respite in this regard, but as demonstrated in the Bredasdorp case study, this will be insufficient under future projected climate change conditions.

Both the climate change research and urban environmental planning approaches neglect the impact of global change on small urban centres, specifically as they relate to the impacts of reduced rainfall, increased frequency of flooding, sea level rise and increased temperature. The analysis of climate change impacts on sustainable development, specifically in urban centres, have been mostly limited to those induced by climate variability such as flooding and periodic drought which have resulted in water shortages and have been responded to through disaster management interventions. Adaptation activities in response to these types of events have been termed adaptive resilience and are aimed at reducing system sensitivity. Longer term impacts due to projected climate change such as the gradual change in rainfall patterns do not generally fit into planning and political time horizons. The response to this gradual impact has been termed acclimation adaptation, where the system sensitivity is made resilient to gradual change in the average climate.

The underlying cause for the lack of focus on climate change as it relates to sustainable water access in urban centres, specifically small towns, is a lack of integration of projected climate change impacts into planning processes. As the case study clearly illustrated, adaptation has direct economic and social implications for access to urban water, specifically in small towns, yet few municipalities are aware of this. This is not surprising, however, given the lack of understanding of climate change issues as well as the absence of a framework within which to introduce these concepts in an integrated manner. The following section summarises the planning tool introduced in this thesis.

8.3 An integrated response

In order to bring these differing, yet overlapping approaches together, a planning framework has been presented to ensure that robust strategies are developed in response to climate impacts in the water sector. Whilst a number of international frameworks have been introduced, such as the National Adaptation Plans of Action and the Adaptation Planning Framework, the focus has in general been on identifying potential climate impacts and then seeing whether they present any chance of disrupting current development activities. The development of adaptation policies and strategies are more limited. In general integrated development planning at national and local level focus on the delivery of social services and in some cases may also address resource conservation. Little evidence exists of projected climate change being integrated into these plans. Without a legislative framework, comprehensive and consistent adaptation planning will not be done by the various spheres of government.

Centralisation of climate change adaptation planning at a national level is not helpful, except at a policy level, since the impacts are felt at a local level. Drawing on earlier work, the thesis reinforced the need for a municipal adaptation planning framework. A two way analysis was proposed where the planned delivery of services in pursuance of the developmental goals is checked against projected climate change impacts to determine the potential for disruption in the future. The application of such a municipal adaptation planning process is also applicable at the small urban centre scale, since it is at this level that people are more likely to be vulnerable. The problems of political, social, institutional and financial capacity are even more apparent in the small urban context and forward planning and insurance are difficult to achieve and hence exacerbate their low levels of resilience to climate impacts.

Drawing on this approach, this thesis introduced a framework for integrating water resources management and climate change issues into these municipal plans. This has been termed a Water Resource Adaptation Plan (WRAP) in this thesis. The WRAP addresses two gaps currently apparent in the municipal water planning and management approaches. Firstly, the consideration of projected climate change is introduced at the water resource assessment stage of the development of a water resources development plan. Secondly, the assessment of water adaptation strategies achieved through a screening process which ensures that the strategies meet both development goals as well as ensuring resilience to projected climate change impacts. This is discussed further in the next section.

The first stage of the planning process is characterised by a holistic analysis of vulnerability. By overlapping the vulnerable water resource areas with the areas of social and physical vulnerability, a clearer picture of the potential hot spots can be achieved. The purpose of this approach is that the planning for water resilience can be proactive rather than reactive. A low level of human capacity exists at this stage of the analysis, and this is even greater at the small town and small water system level. Interactions with local municipalities revealed that there is a limited knowledge and understanding of climate issues at local and municipal level.

The approach to be followed includes the determination of the future projected water use and demand, the projected climate change impact on rainfall and temperature and the resultant impact on available water resources. To date water resource planners have largely resisted accounting for climate change in their planning until the uncertainties are better understood and reduced. A shift away from relying on historical data is required. This is required for both demand and supply projections. It is, however, acknowledged that the projection of population growth and future water demand is difficult to estimate. This is due mainly to the unknown impact of HIV/AIDS on the population growth and also the extent of poverty reduction and its impact on water demand.

The impact of climate change on water resources has been projected using global circulation models (GCMs). Despite steady improvements in the various GCMs, the results from the different models gives varying results, based on the parameters and architecture for each model. However, these models do display a high degree of consensus in the direction of change, but the magnitude of change is still difficult to confirm. Therefore for planning purposes it is best to consider the median of the bounds of an envelope of possibilities. In this way a projected percentage change in the precipitation and temperature for a specific location can be established.

By considering the percentage change in precipitation, a change in the available runoff and groundwater recharge can be calculated for the same period. It has been illustrated that, for example, a 10% reduction in precipitation in a semi-arid region would result in a 30-50% reduction in available runoff or groundwater recharge.

For comparison purposes the impacts of climate change on recharge and runoff can be expressed as a proportion of the available water under current climate conditions. In this thesis this ratio is introduced and is termed the *Climate Impact Factor* (CIF), simply expressed as:

$$\mathrm{CIF} = \left(\frac{S_{\mathrm{Future}} - S_{\mathrm{Current}}}{S_{\mathrm{Current}}} \right)$$

where: CIF = Climate Impact Factor for the study period

S_{Future} = Future supply (either runoff or recharge)

$S_{Current}$ = Current supply in the base year (either runoff or recharge)

Having identified the potential climate change impacts, it is important to apply a rigorous strategy selection process to ensure that climate resilience is achieved as well as the delivery of basic services in line with sustainable development objectives. However, competing priorities often result in medium to long-term planning being sidelined and short-term projects which meet the short political life of decision makers being implemented instead. Further, it is difficult to convince decision makers to consider the need for a climate change strategy, when the climate projections cover a longer time horizon than the political and development frameworks and are also associated with high uncertainty.

It is acknowledged that adaptation is complicated by uncertainties in the probabilities and consequences of climate change and in the adaptive responses of affected systems. In the same manner that water planners have had to accommodate the uncertainties associated with population growth, climate variability, consumption patterns and cost recovery, so too should climate change be included into planning in this systematic manner. It is recommended therefore that the development planning process be iterative to ensure that the plans are regularly modified to include improvements in climate change projections as well as changes in other key drivers.

8.4 Towards resilience to climate change

In developing adaptation strategies for small water supply systems, where human and financial resources are low, it is appropriate to rather build on what is currently working than to introduce costly interventions which require additional technical skills transfer. It is therefore the hypothesis of this thesis that by coping with present-day climate variability in water resources management, which is already a formidable challenge, the resilience to any further impacts of climate change will be largely improved.

As discussed in Chapter 2, adaptive water management can be viewed as a timely extension of integrated water resource management, since it can cope with the challenges of climate induced vulnerability and equitable water access. It can therefore be the encompassing paradigm for adapting to contemporary variability as well as being the prerequisite for coping with the relatively uncertain impacts of climate change on the water system. Adaptive water management strategies that are employed against climate variability, if properly screened, could be used to address future climate impacts due to climate change. The screening of these strategies should consider the second order scarcity in the society in terms of their adaptive capacity and resilience.

As is illustrated in Figure 44, with the reduction of second order scarcity comes improved resilience to climate variability. As the adaptive capacity is developed and strengthened and more of the climate variability is accommodated in water management and planning, so too are the negative impacts due to climate change minimised. By coping with present-day climate variability in water resources management, which is already a formidable challenge, resilience to any further impacts of climate change will be improved. Referring to the schematic diagram it can be seen that with increased resilience the line shifts from A to B resulting in most of the climate variability impacts (the shaded area) being absorbed or reduced, and also consequently more of the climate change impacts (the white area) being addressed. In other words, as the coping capacity to deal with climate variability impacts is increased, so too is the climate change adaptive capacity enhanced. This approach for coping with natural climate variability and the precondition for adapting to the highly uncertain consequences of global warming and associated climate change could be termed *adaptive water resource management*.

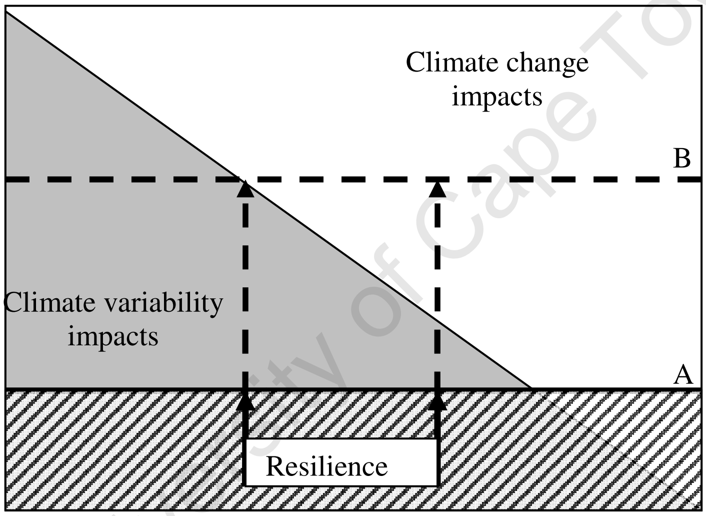

Figure 44: Increased resilience to impacts from climate variability and climate change

The methodology presented in Chapter 6 introduced the concept of using climate variability strategies to address projected climate change impacts. The first step is to establish the level of adaptive capacity in a community or catchment area. This should be an assessment of both the first order (supply side) and second order (demand side) levels. It has been found in South Africa, as in other countries, that technical and planning capacity at the small municipal level is severely lacking. However, Adger and Vincent (2005) warn that there are relevant uncertainties attached to determining *adaptive capacity* such as the reliability of the qualitative data and the clarity of the processes of adaptation and vulnerability. They also warn that adaptive capacity only highlights the resources available for adaptation and not the institutional processes for decision making.

The second step is the identification of strategies that address the development needs of the community as well as prevent negative impacts of current variable climate. In order to do this, a simple multi-criteria analysis tool was introduced. A set of selection criteria, based on sustainable development goals, was proposed and included the important assessment of long-term applicability to climate change. The purpose of the criteria is to initially qualitatively assess the proposed strategies. Once a short list has been developed, a quantitative assessment can be conducted. The table below summarises these criteria.

Table 39: Qualitative and quantitative strategy selection criteria for long-term water planning

Qualitative criteria	Quantitative Criteria
Potential to provide additional yield or saving	Volume of water supplied or saved
Required technology available	No. of households with access to clean water
Local capacity available to implement	No. of households with access to water subsidy
Additional capital expenditure required	Cost of water supplied
Additional running costs required	Employment generated
Local employment increased	
Acceptability to local community	
Impact on local water resources	
Long-term applicability for climate change	

In the assessment of existing strategies, it was found that a number of municipalities have no drought mitigation plans and merely rely on disaster relief from regional and national institutions. By operating in crisis mode and relying on government hand outs and grants, local adaptive capacity that may have been gradually developed through necessity, i.e. acclimation adaptation, has been suppressed through the dependency on external support.

In assessing the implementation potential of the strategies discussed, a number of obstacles and limitations to implementing these strategies have been identified. Specifically the issues of local human capacity and financial resources stood out as the most pressing (Mukheibir & Sparks 2006). This is further exacerbated by a low financial resource base to cover the capital and running costs of most of the strategies. Local government competes for nationally allocated funds for capital expenditure. Running costs are mostly covered from local revenues, which for the smaller and remote local municipalities, are insufficient to ensure water security at this level.

Political buy-in for some of the strategies such as water restrictions and dry sanitation will need to be obtained through education programmes, but these also require human and financial resources. It has been reported that in developing countries additional political and economic barriers result in little or no time and energy to introduce water saving strategies. A shift in behaviour patterns is difficult irrespective of the level of education, wealth or size of the domestic unit.

A number of recommendations for ensuring equitable water access at the small town scale emanate from this study. There is a need for proactive strategies at local and national level to deal with the impacts of drought and climate change on water resources rather than the current reactive strategies, such as providing water by tankers. Specifically, emphasis should be placed on demand side management given the finite amount of water. This is reinforced by the fact that the top three strategies rated by the stakeholders were all on the demand side. However, that is not to downplay the responsibility for better management by the water service providers to reduce wastage and losses in the delivery systems

Strategies that are finally identified not only need to be social, environmentally and economically acceptable, but they need to have long-term applicability if they are to provide adequate resilience to climate change impacts. For example, a strict groundwater management system should be put in place, with early warning mechanisms to report depleted groundwater reserves. Continual monitoring of the aquifer against climate conditions will provide some knowledge of the future potential under projected climate conditions.

In order to successfully implement any of these strategies, the climate induced impacts on water resources should be integrated into local development planning so that adequate strategies are identified to reduce potential risks in future. The lack of personnel and financial capacity at local level must be identified and addressed. A climate change awareness programme should be developed that is targeted at local government officials to equip them with the necessary tools to engage with this issue and implement the strategies that are identified.

Finally, during and after implementation, it is important to conduct monitoring and evaluation of the plan and the specific interventions. Adaptation planning frameworks are not events and should be viewed as ongoing processes. This ongoing process should result in the modification of the plans and strategies at regular annual intervals to take into account changing climate projections, levels of resilience and socio-economic demands.

8.5 Conclusion

This thesis set out to address three hypotheses, viz.:

1. *the incorporation of climate change impacts on water resources into municipal development planning is possible through an integrated planning framework*;
2. *viable water resource management strategies for small towns that address current climate variability can in future also provide resilience to climate change induced impacts, if selected against a set of sustainable development criteria; and*
3. *climate change is also a socio-economic issue and not solely an environmental one*.

Climate change does not presently feature prominently in the mainstream development and water resource management literature, so much so that strategies have not yet been developed to adapt to the projected impacts. Current water management mechanisms and policies have been developed to ensure that the existing supply of water meets the growing demand under current climate variability. However, robust long-term strategies are required to ensure the supply of water matches the projected demand, even in times of reduced availability. In addition to this, it has been demonstrated that climate change impacts will impact directly on the affordability of water services, especially for the poor.

The framework presented in this thesis will enable small town municipalities to identify the additional cost implications and potential barriers for ensuring equitable access to water under projected climate change conditions. This would thereby highlight the additional cost to cope with climate change and the lack of adaptive capacity within the municipality to develop adequate resilience. A claim for external subsidisation would need to be supported by an assessment of the level of poverty within the municipal area. It has been shown that people who are most vulnerable to current climate variability are predominantly the poor. In the context of long-term climate change and possibly enhanced climate variability, it is once again the poor who will suffer most and become more vulnerable. In the more affluent regions of the world, people have a relatively large coping capability, whereas in developing countries a small change in climate variability (i.e. slightly higher frequency of extreme events or a slightly shorter growing period) can have very large effects in terms of food and water security, health, mortality and economic well-being. This was clearly demonstrated by the case study where reduced annual rainfall caused an increase in the average price of water.

In addressing the second hypothesis, a methodology was introduced to assist strategy selection whereby existing water supply strategies adopted during climate variability can be identified and tested for suitability under projected climate change conditions. The intention is to build on existing local knowledge where possible and enhance existing capacity and resilience to climate impacts. Climate variability affects water resources through periodic droughts resulting in short-term water shortages at local municipal level. In order to address these shortages, short-term strategies are currently employed to meet basic domestic requirements. On the other hand, climate change is projected to increase the frequency of droughts, which will in turn have the impact of more frequent water shortages. The implementation of long-term strategies is required to reduce the vulnerability to future frequent droughts. By evaluating and screening the short-term strategies, a suite of long-term strategies can be identified and relevant policies developed to ensure that resilience to current and future climate impacts is ensured.

Large uncertainties still plague quantitative assessments of climate change impacts and water resource management. However, it is known for certain that the climate is changing, and that this will have an effect on water resources. Only the rate and magnitude is uncertain. Therefore increased efforts will be needed to plan and manage water supplies in future, through increased monitoring and understanding of the interrelationships between climate change and water availability. The methodology outlined in this thesis will also assist municipal planners to evaluate these impacts and develop appropriate strategies that ensure long-term water supplies.

The third hypothesis was confirmed through a case study of a small town in a semi-arid region of South Africa. Bredasdorp has limited human and financial resources and as a consequence incomplete data sets which hampers future planning. By applying a simple analytical method to determine the impact of projected climate change on the available water resources, the economic impact of the projected climate change was established. Both the investment capital required and the running costs to ensure uninterrupted supplies increase under the climate change scenario. Under future projected climate change conditions the need for additional funding to cover the incremental unit cost was evident, since the increased burden on the paying customers would not be sustainable in the long-term.

Long-term strategies should be adopted that meet local developmental needs and address the water resource management concerns. This should be done sooner rather than later since resilience will be more costly to develop at a later stage. This will ensure that local governments have in place the necessary adaptive resilience to guarantee that the communities they serve are assured of adequate clean water to meet their developmental needs, despite the uncertainty of future climate projections.

However, as it has been illustrated, the attainment of the Millennium Development Goals in the face of projected climate change comes at a cost. In small urban centres the middle and low income groups will not be able to carry this additional cost. The incremental cost due climate change impacts on water supplies has the potential to undermine the MDGs. To avoid this a fundamental shift in development and planning policies, both at national and international levels, is needed that takes cognisance of climate change projections in order to guarantee the equitable access to affordable water, especially in small towns.

Appendix: Bredasdorp case study – data for the relevant years

Relevant years:	1990	2005	2010	2011	2015	2016	2017	2022	2024	2025	2028	2030	2032	2034	2035
Projected consumption	610,060	967,017	1,112,191	1,137,772	1,246,114	1,274,774	1,304,094	1,461,124	1,529,109	1,564,278	1,674,715	1,752,638	1,834,186	1,919,529	1,963,678
Current situation:															
Groundwater (BH + Springs)	640,000	952,000	952,000	952,000	952,000	952,000	952,000	952,000	952,000	952,000	952,000	952,000	952,000	952,000	952,000
Surface water		305,000	305,000	305,000	305,000	305,000	305,000	305,000	305,000	305,000	305,000	305,000	305,000	305,000	305,000
Total available Supply under NC:	640,000	1,257,000	1,257,000	1,257,000	1,257,000	1,257,000	1,257,000	1,257,000	1,257,000	1,257,000	1,257,000	1,257,000	1,257,000	1,257,000	1,257,000
Reduction due to climate change:															
Groundwater (kl)	640,000	837,760	799,680	792,064	761,600	753,984	746,368	708,288	693,056	685,440	662,592	647,360	632,128	616,896	609,280
% groundwater reduction	0%	12%	16%	17%	20%	21%	22%	26%	27%	28%	30%	32%	34%	35%	36%
Surface water (kl)		274,500	264,333	262,300	254,167	252,133	250,100	239,933	235,867	233,833	227,733	223,667	219,600	215,533	213,500
% surface water reduction	0%	10%	13%	14%	17%	17%	18%	21%	23%	23%	25%	27%	28%	29%	30%
Total Projected supply under CC:	640,000	1,112,260	1,064,013	1,054,364	1,015,767	1,006,117	996,468	948,221	928,923	919,273	890,325	871,027	851,728	832,429	822,780
Nett % loss due to CC	0	12%	15%	16%	19%	20%	21%	25%	26%	27%	29%	31%	32%	34%	35%
Shortfall under Normal Climate	29,940	289,983	144,809	119,228	10,886	-17,774	-47,094	-204,124	-272,109	-307,278	-417,715	-495,638	-577,186	-662,529	-706,678
Shortfall under Climate Change	29,940	145,243	-48,178	-83,408	-230,347	-268,657	-307,626	-512,903	-600,186	-645,005	-784,390	-881,611	-982,458	-1,087,100	-1,140,898
Difference in shortfalls	0	144,740	192,987	202,636	241,233	250,883	260,532	308,779	328,077	337,727	366,675	385,973	405,272	424,571	434,220
% difference															61%
Future Supplies:															
Future groundwater under NC:						260,000	260,000	260,000	260,000	710,000	710,000	710,000	710,000	710,000	710,000
Total Future Supply under NC:	640,000	1,257,000	1,257,000	1,257,000	1,257,000	1,517,000	1,517,000	1,517,000	1,517,000	1,967,000	1,967,000	1,967,000	1,967,000	1,967,000	1,967,000
Future groundwater under CC:	0		260,000	260,000	660,000	660,000	660,000	1,060,000	1,060,000	1,060,000	1,420,000	1,420,000	1,780,000	1,780,000	1,780,000
Future groundwater reduced by CIF			218,400		528,000	522,720		788,640	771,680	763,200	988,320	965,600	1,181,920	1,153,440	1,139,200
Total Future Supply under CC:	640,000	1,112,260	1,282,413	1,270,684	1,543,767	1,528,837	1,513,908	1,736,861	1,700,603	1,682,473	1,878,645	1,836,627	2,033,648	1,985,869	1,961,980
Difference in future groundwater	0	0	218,400	0	528,000	262,720	-260,000	528,640	511,680	53,200	278,320	255,600	471,920	443,440	429,200
% difference															60%
Reduced demand:															
average per cap consumption	204	200	206	206	206	206	206	206	206	206	206	206	206	206	206
1) Outdoor water restrictions			9,731	9,955	10,903	11,154	11,410	12,784	13,379	13,687	14,653	15,335	16,048	16,795	17,181
2) Active leakage control			38,924	39,820	43,611	44,614	45,641	51,136	53,516	54,746	58,612	61,339	64,193	67,180	68,725
Total DSM saving under NC:	0	0	48,655	49,775	54,514	55,768	57,051	63,920	66,895	68,433	73,264	76,673	80,241	83,974	85,906
Future demand under DSM:	610,060	967,017	1,063,536	1,087,997	1,191,599	1,219,006	1,247,043	1,397,204	1,462,214	1,495,845	1,601,450	1,675,964	1,753,945	1,835,555	1,877,772
% reduction due to DSM:			4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Future groundwater under DSM	0			260,000	260,000	260,000	660,000	660,000	1,060,000	1,060,000	1,060,000	1,420,000	1,420,000	1,646,000	1,646,000
Groundwater reduced by CIF				216,320			517,440		771,680	763,200		965,600		1,066,608	1,053,440
Future Supply under CC & DSM:	640,000	1,112,260	1,064,013	1,270,684	1,223,767	1,212,037	1,513,908	1,439,261	1,700,603	1,682,473	1,628,085	1,836,627	1,794,608	1,899,037	1,876,220
Cost of DSM implementation (R.)			70,101	71,713	78,542	80,348	82,196	92,094	96,379	98,596	105,556	110,468	115,608	120,987	123,770

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