Sustainability Index for Integrated Urban Water Management (IUWM) in southern African Cities

Case study applications:
Greater Hermanus Region and Maputo City

Prepared for:
Neil Armitage
Associate Professor

Prepared by:
Sheilla De Carvalho
MSc Student

Department of Civil Engineering
University of Cape Town, August 2007

DECLARATION

I, Sheilla Cristina Pinto De Carvalho, know the meaning of plagiarism and declare that all the work in the document, save for that which is properly acknowledged, is my own.

Signed: Signed by candidate   Date: 15/08/07

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It is my sincere hope that this research and the investigations conducted in the field of Integrated Water Resource Management and Integrated Urban Water Management contribute to change and improvements both at policy and implementation level. It is my belief that this research must go beyond the academic realm to encompass the relevant fields of study and ultimately work towards informing and benefiting society.

Abstract

Service provision in low and middle-income countries, defined so by the World Bank, is presenting a challenge to the growth of economies and development of cities in the less developed regions of the globe (World Bank and Oxford Press, 2004). Of particular concern are those services which are water related. It is estimated that currently 300 million people in Africa do not have access to safe drinking water and 313 million have inadequate access to sanitation (CONAGUA & WWC, 2006).

The critical situation in the water sector continues to jeopardize developmental principles and undermine strategies for poverty eradication. On the assumption that the failure in service provision can be largely attributed to an inability to holistically address all aspects of urban water management, a systems approach was used to develop a relevant and robust sustainability index which assesses the capacity of a city or a portion thereof to be sustainable.

This thesis details the process of developing the Sustainability Index (SI) for a multi-dimensional assessment of urban water systems. In this research, an analysis of the current problems facing developing cities, particularly in Sub-Saharan countries, was undertaken. This was done so as to provide some insight into the current developmental issues hindering sustainable development. An examination of the urban water cycle was also carried out to illustrate the links within the cycle and between the various water uses and services.

A process model was developed which addresses the multi-dimensionality of sustainability and the dynamism of urban water systems. This model combines aspects of the iterative procedure for assessing environmental sustainability introduced by Lundin *et al.* (2002) with the step-wise process proposed by Nardo *et al.* (2005). The process model then enabled the development of the sustainability index. The SI was compared to other sets of indicators, both local and international, to assess its relevance and comparability to similar initiatives. Furthermore it was screened through a set of criteria for compliance with research objectives. The end result was a composite SI structure which incorporates several variables, indicators and components. The Sustainability Index is composed of 5 components, which disaggregate into 20 indicators and ultimately into 64 variables.

Two southern African cities, Hermanus and Maputo, were then selected as case studies to test the applicability and validity of the index. A descriptive summary on each case study was provided to establish the status quo regarding urban water management issues.

The validity of composite indicators such as the SI is often questioned as a result of the biases introduced by weight allocation. In order to address this issue several weighting sets were developed so as to determine the influence of differentiated weighting on the final index scores. In addition to the balanced and unbalanced equal weight sets, five biased sets were developed. These five weight sets cater for the five dimensions of sustainability explored in this research.

The index results conformed to pre-established assessments of each case study. Hermanus obtained a high overall SI score of 74%, while Maputo's performance was less then adequate with an index score of 42%.

SI scores, as well as component and indicator-level analysis demonstrated that the index can in fact highlight areas for improvement. Furthermore it can guide more appropriate action and policy-making for better service delivery and improved resource management. Differentiated weight allocation produced variations in the SI scores; however these were not significant at this level. Component, indicator and variable scores on the other hand varied considerably as a result of variations in weighting. This supports the need for appropriate weight allocation which is locally relevant. Recommendations were made on the basis of the index analysis: firstly, towards the improved management of urban waters and better service delivery in the two case studies; and secondly, towards indicator refinements and improved data acquisition.

Acronyms

AdeM: Private Water Utility, Mozambique
AfDB: African Development Bank
AMCOW: African Ministers Council On Water
ARA-SUL: Regional Water Board for the South
ASSCODECHA: Local Community Based Organisation
AU: African Union
AWF: Africa Water Forum
AWV: Africa Water Vision
CEH: Centre for Ecology and Hydrology
CENOE: Disaster Management Unit, Mozambique
CEPR: Centre for Economic and Policy Research
CMM: Maputo Municipal Council
CMCM: Matola Municipal Council
CRA: Water Regulatory Council
DANIDA: Danish International Development Agency
DFID: Department for International Development
DINAGECA: General Topography Directorate
DNA: National Water Directorate
DNG: National Directorate of Geology
DPSIR: Driving Force- Pressure-State- Impact- Response
DS: Directorate of Health
ELCA: Environmental Life Cycle Assessment
EMS: Ecological Management Systems
EP: Ecological Footprint
EPI: Environmental Performance Index
ESI: Environmental Sustainability Index
ETAR: Wastewater Treatment Plant
EU: European Union
EVI: Environmental Vulnerability Index
FBW: Free Basic Water
FIPAG: Water Supply Assets and Investment Fund
FUNAB: Fund for the Environment
GDP: Growth Domestic Product
GHWCP: Greater Hermanus Water Conservation Programme
GWP: Global Water Partnership
HIV/AIDS: Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome
HDI: Human Development Index
HDR: Human Development Report
HPI: Human Poverty Index
INAM: National Weather Institute

INGC: National Institute for the Management of Natural Disasters
IUWM: Integrated Urban Water Management
IWMI: International Water Management Institute
IWRM: Integrated Water Resource Management
LCA: Life Cycle Assessment
MCMC: Markov Chain Monte Carlo
MDGs: Millennium Development Goals
MICOA: Ministry of Environmental Affairs for Mozambique
MISAU: Ministry of Health for Mozambique
MOPH: Ministry of Public Works for Mozambique
NEPAD: New Partnership for Africa's Development
NGOs: Non-Governmental Organisations
NRF: National Research Fund of South Africa
NRW: Non-Revenue Water
OECD: Organisation for Economic Cooperation and Development
PPP: Purchasing Power Parity
PRB: Population Reference Bureau
REDE: Department of Compilation of Statistical Data for Mozambique
SADC: Southern African Development Community
SAICE: South African Institute of Civil Engineering
SI: Sustainability Index
SIDS: Small Developing States Institutions
SOPAC: South Pacific Applied Geosciences Commission
TMF: Total Material Flow
UD: Urban District
UFW: Unaccounted For Water
UN: United Nations
UNEP: United Nations Environment Programme
UNESCO-IHE: United Nations Educational, Scientific and Cultural Organisation; Institute for Water Education
UN-HABITAT: United Nations Human Settlements Programme
UNICEF: United Nations Children's Emergency Fund
UWM: Urban Water Management
WB: World Bank
WBI: World Bank Institute
WBO: Water Basin Organisation
WES: Water, Environments and Sanitation
WHO: World Health Organisation
WMO: World Meteorological Organisation
WRVI: Water Resources Vulnerability Index
WWAP: World Water Assessment Programme

Glossary of terms

Free Basic Water: This refers to the first 6000 litres of water provided per household per month at no supply cost, in accordance with South African national legislation.

Greywater: Greywater also known as sullage refers to wastewater generated from domestic activities (washing clothes and utensils, bathing, washing hands and cleaning the household) and excludes wastewater derived from toilets.

Household: Refers to the total number of people living in one residential unit and sharing the same source of water.

Peri-urban: Refers to areas of human settlement within or close to cities characterized by levels of service between those commonly associated with urban and rural areas. Frequently peri-urban settlements are informal with inadequate planning and no legal land tenure (Armitage, 2005).

Researcher/developer: In the context of this thesis, the term researcher(s) and/or developer(s) refers to the principal person(s) involved in the development of the indicator and its application to Hermanus and Maputo.

Sanitation: Refers to the removal and management of wastewater and excreta from the source (point of generation) to a final specified destination (terrestrial or aquatic receiving environment).

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1. Introduction

1.1 Background

"Sustainability is a simple idea. It is based on the recognition that when resources are consumed faster than they are produced or renewed, the resource is depleted and eventually used up. In a sustainable world, society's demand on nature is in balance with nature's capacity to meet that demand. When humanity's ecological resource demands exceed what nature can continually supply, we move into what is termed ecological overshoot" (Ecological footprint network, 2006).

The past two decades have introduced significant and unprecedented changes in developing cities worldwide, both in scale and magnitude. Population growth, urbanisation, globalisation, decentralisation and climate changes have been important contributors to this global transformation which has in many respects reshaped societies. The total world population has risen astoundingly, reaching 1.7 billion by the beginning of the twentieth century and 4 billion by the 1970s (PRB, 1999). Currently this number exceeds the 6 billion mark. Furthermore population projections estimate that such growth will continue well into the future reaching 8 billion people by the 2020s and 9 billion by 2050 (PRB, 1999).

Alongside this boom in population, there has been a parallel transformation within economic, social, political and environmental spheres. Globalisation has opened up the invisible doors of virtually every country and city in the world. With economic growth and the prosperity of some cities, there has been a general move to urbanisation. Decentralisation and democratisation have been additional factors for change, shaping the face of politics as well as the state of many an economy. Amidst all this change, significant benefits have been accrued to both economies and societies in general. Nevertheless there has been a continual widening of economic gaps between social classes and the majority of the world's population continues to live under extreme poverty (CONAGUA & WWC, 2006). The consensus amongst economists such as Weisbrot (2002) and De Long (2001) is that whilst significant growth has been observed in most parts of the world, the unprecedented gap in per capita incomes has resulted in unsatisfactory progress in developing countries, with the possible exception of India and China. This has particularly been the case for many developing cities in Africa, Latin America and Asia. These are cities characterised by low levels of education and employment; and which experience high poverty rates and display increasing social and economic inequalities, as well as mediocre public services and high vulnerability levels. Yet it is in these very same cities that the majority of the world's population dwells. Not only this, but predicted population growth is expected to occur in small cities and towns of developing countries (NRC, 2003).

Aside from the global forces that have helped to reshape cities, there have also been significant changes at the local level. A brief look at historical events illustrates that most African countries have been in a perpetual state of transition; from colonialisation to freedom wars, to independence, to civil war, to political, social and economic instability.

To an extent the above discussed factors substantiate the lack of visible and underlying social and economic growth of many cities of the South. This, coupled with the inability or reluctance for progressive changes, has resulted in slow advances towards sustainable development and the goals of sustainability. Inadequate service provision in developing countries is one of the factors which has contributed to this slow development. It is however vital in efforts to eradicate poverty and promote economic growth as well as social development. Utilities are the backbone of development, without which true and sustainable development is not possible. Of particular concern are those services and utilities which are water related. It goes without saying that mankind is dependent on water for survival. More than this, in this age of industrialisation and mass production, cities are strongly dependant on a good and reliable supply of fresh water, a resource which can prove limited given availability and accessibility factors. On the other hand, the growth rates and prosperity levels of some cities in developed countries have proven highly unsustainable, reinforcing the need for appropriate planning and managed growth. Developing societies demand greater resources. More so, the demand on the environment for the extraction of resources and disposal of unwanted wastes increases with this growth. Wackernagel *et al.* (2002) indicate that the biosphere's coping capacity has been exceeded since the 1980s and humanity has reached what has been termed 'ecological overshoot'. In other words, resources have and are being consumed and disposed of at a much faster pace than the environment can replace or absorb them.

Other than the supply and utilisation of freshwater, there are other services which merit attention. The provision of adequate sanitation – collection, treatment and disposal of certain human wastes – as well as stormwater drainage complement water supply towards the fulfilment of basic service provision. These are the three services which are categorised as water services, services for which supply in the greater part of the developing world has fallen far short of the demand. The overall benefits that these provide to society, the economy and the environment emphasize their importance to the development of cities.

Integrated Water Resource Management (IWRM) is a planning, preparation, precaution and risk-avoidance tool which incorporates all aspects of water management at a regional scale. In the context of cities, urban water management is applicable. Urban water management can incorporate the management and provision of the three water services. It proposes to address some of the water related developmental issues such as inadequate service delivery, poor resource management, demand management and financial constraints. Furthermore it can also address cross-cutting issues which include: gender inequality in the water sector, physical and social wellbeing, wealth redistribution, education, and ecosystem preservation. Where such aspects of urban water management converge and are viewed and addressed holistically, the term becomes Integrated Urban Water Management (IUWM).

To address the slow delivery of services and the significant backlogs as a result, the Millennium Development Goals (MDGs) were developed and endorsed by world leaders during the UN Millennium Summit of 2000. This set of eight target driven goals provides developing nations with concrete objectives for driving progress towards sustainable development. In order to effectively adopt and monitor the achievement of MDGs, it is necessary to develop assessment tools which can gauge the progress towards each target.

Integrated Urban Water Management can contribute significantly towards the achievement of MDGs. It is therefore necessary to measure progress in this field, in an effort to assess and promote sustainability in water management.

1.2 Aim of research

The aim of this research was to develop a composite index that can assess the capacity or potential of urban water systems to be sustainable with regard to the management of resources and provision of services in southern African cities. This involved the construction of an index which is scale, time and spatially relevant. Furthermore an index which enables a good understanding of the pressing issues in the context of each city so as to guide policy makers and decision-takers towards improvements in policy and management. Towards validating the index, case study applications were necessary, the results and assessment of which provide support for the research. The underlying objective was to study, review, redevelop and rethink on sustainability in the water sector in order to provide valuable conclusions with regards to the case studies explored, and ultimately test such assumptions and conclusions through the developed Sustainability Index (SI). The development of a SI aims to improve the quality and scope of projects in the water sector and seeks to benefit all echelons of society. More specifically it is designed to inform policy and decision-makers at all tiers of government. This is largely due to the role that legislation and policy has had, and continues to have on the development of cities.

"If assessment tools and their indicators are meant to act as warning/alarm bells, then they had better ring loudly enough and be near the right people who can act on them" (De Villiers Leach, 2006).

1.3 Thesis Layout

This thesis consists of seven chapters. Chapter 1 provided historical background leading up to some of the issues currently facing developing countries in Africa. The chapter continues with a brief introduction of the aims of the research, both as an individual piece of work as well as in view of the broader research initiative taken at the University of Cape Town. Chapter 2 explores the literature on assessment methodologies and tools building towards the process of developing the Sustainability Index.

Chapter 3 explores the development of the sustainability index, starting with the refinement of the urban water cycle representation. It follows on to provide an account of the process of building the underlying indicator framework. Chapter 4 describes the methodology adopted for developing the index and the methods explored for indicator aggregation. A brief description of the programmes used and/or developed to run the indicator is also included. This is followed by Chapter 5, which begins by providing a brief logic behind case study selection. The chapter then introduces the reader to the two case studies, Hermanus and Maputo, presenting a broad view of the status quo in each city. Chapter 6 presents a discussion of the results obtained from the indicator applications and highlights the limitations and problems encountered during the research process. In conclusion, Chapter 7 recapitulates the ideas and concepts introduced; it reiterates the findings and makes recommendations on the basis of these.

2. Literature review

The literature reviewed in the subsequent sections provides an overview of the major themes, concepts and tools explored in this research. It follows the development of assessment tools in the past three decades or so, and explores these in more detail. A critical review and analysis of these tools was undertaken to ascertain their relevance to the development of the sustainability index for Integrated Urban Water Management.

2.1 Sustainability in context

A brief clarification on crucial terms such as sustainability and sustainable development is required.

The concept of *Sustainability* can be applied to a number of categories, of which social, economic and ecological sustainability are often the principal components. The term literally refers to the maintenance or sustenance of something. More broadly, and in the context of developing cities, sustainability is considered to be keeping in mind the goal of attaining or maintaining the quality of life. To this end, Sutton (2000) presents three levels of sustainability, of which two are relevant to this thesis; survival sustainability and maintenance sustainability. Survival sustainability refers to the achievement of basic sustainability, and maintenance sustainability refers to the preservation of the generally expected quality of life. The third level illustrated in Table 2.1, improving the quality of life, goes beyond notions of maintenance and expected/normal quality of life to propose a higher standard of living than is addressed in this research.

"The environment is defined as the aggregate of surrounding things, conditions, or influences i.e. the surroundings, the air, water, minerals, organisms and all other external factors surrounding and affecting a given organism at any time; as well as the social and cultural forces that shape the life of a person or population" (Random House Webster's College Dictionary, 1995).

Environmental Sustainability refers to that balance which achieves the unimpaired maintenance of environmental sources and sinks (end state/goal). Gasson (2000) offers the following definition of a sustainable city (system): *"an environmentally sustainable city is one which meets its present and future human development objectives without growth in throughput of matters and energy beyond the regenerative and absorptive capacities of its local, national or international hinterland"*. This can be expanded to include the following: a sustainable city is also one which optimises opportunities for minimising inputs and outputs into the system by adopting practices, processes and technologies which emulate nature and its functions.

Table 2.1: Dimensions and levels of sustainability (Sutton, 2000)

ECOLOGICAL	SOCIAL	ECONOMIC	
Level 1: Survival Sustainability			
Protection of life support systems Prevention of species extinction	Capacity to solve serious problems	Subsistence	**Global** ↓ **Local**
Level 2: Managing quality of life			
Maintenance of decent environmental quality	Maintenance of decent social quality i.e. vibrant community life	Maintenance of decent standard of living	**Global** ↓ **Local**
Level 3: Improving quality of life			
Improving environmental quality	Improving social quality	Improving standard of living	**Global** ↓ **Local**

This notion of reducing inputs and outputs is also addressed by Robèrt *et al.* (2002), where the authors establish four system conditions which broadly define the goal of sustainability, through sustainable development targets. Robèrt *et al*. place great emphasis on dematerialization, which they explain to be the reduction of material flows, and the substitution or exchange of type and/or quality of flows, goods and services. This is aimed at ensuring reduced environmental burdens and contributing to more socially balanced societies. While one has to accede to the logic of this view, from a general sustainability perspective it is important to maintain a balance between socio-economic and environmental sustainability.

In the words of De Villiers Leach (2006): *"There is an assertion (on the part of Robèrt et al.) that dematerialization has to happen first so that the burden on the ecosystem can be reduced, and then equity in the distribution of benefits can happen (not parallel, one before the other)."* This underlying assumption that benefits derived in one area can trickle down or extend to other areas has been ruthlessly criticised by authors such as Pieterse (2002).

In the water sector there is scope for both the trickle down and extension of sustainable development benefits; however, this is only possible when there is a complete awareness and consideration for all aspects of sustainable development, social above all. In this regard, Robèrt *et al.* (2002) have failed to address the complex and multi-dimensional concept of sustainability, maintaining a bias towards environmental sustainability.

Sustainability represents an optimal end state; however this is neither fixed nor constant but is rather time and space relevant. Sustainable development therefore offers the direction needed to deliver on many of the sustainability goals. It is the process through which specific targets are set, actions are planned and strategies implemented in order to deliver on current needs in a manner which is responsive to the earth's capacity to replace 'used' resources and absorb 'generated' wastes, while being conscious of the needs of future generations (Goodland & Daly, 1996).

The above definitions have introduced the ensuing discussion; however they fail to spatially contextualise this study. The emphasis of this research is on cities and urbanised settings. In other words the emphasis is on those areas exhibiting development of a sufficient scale to raise sustainability concerns. This is not to be strictly defined but rather encompasses a number of criteria which attribute an area its 'cityness'; population sizes, population densities, degree and expansion of infrastructure and works, access to services and commodities, and the level of economic trade, to name a few. Within that context, a *system* is the functional whole of a set of parts or interacting elements (De Rosnay, 1979). In this case the broader system is the city but the city in itself is represented by multiple and diverse sub-systems. The interconnectedness of such systems within the broader ecosystem is highlighted in both Figure 2.1 and Figure 2.2.

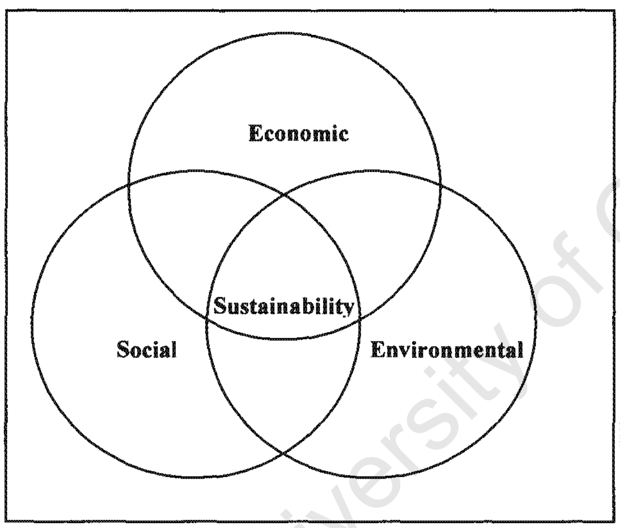


Figure 2.1: The triple bottom line concept

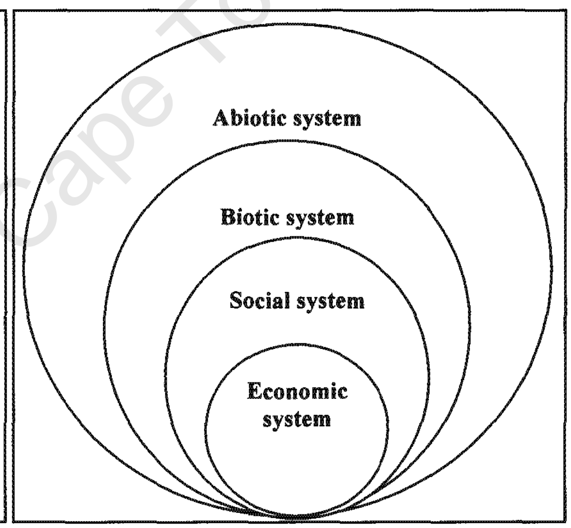


Figure 2.2: Interconnected systems (Mebratu, 1998)

The common perception that sustainability is the meeting ground of social, economic and environmental principles is not incorrect. What is incorrect is the interpretation of the interrelations between these spheres as exemplified by the triple bottom line approach (Figure 2.1). This idea of an isolated social sphere or an isolated economic sphere is not appropriate, rather human interactions and society should be seen to find expression within the broader ecological sphere. Similarly, economic activities generally occur within a social realm. This readjustment illustrated in Figure 2.2 creates greater room for sustainability in all spheres and does not depend entirely on the 'chance' or 'imposed' meeting of social, economic and environmental spheres.

Ultimately sustainable development is dependant on the balance of all three aspects; social development, economic growth and environmental protection. Of all three, environmental protection is often the least acknowledged and at times the most limiting factor to the growth of cities.

2.2 The water cycle

Exploring the notion of sustainability in the water sector demands an understanding of the water cycle, starting with the progress through and impact of water on the environment. Towards this, the urban water cycle will be discussed in more detail, so as to explore the relevant impacts of man on nature, and relate them to the natural cycle of water through the earth.

Figure 2.3 illustrates the water cycle as it applies to an urban setting, deviating slightly from the more simplistic natural water cycle.

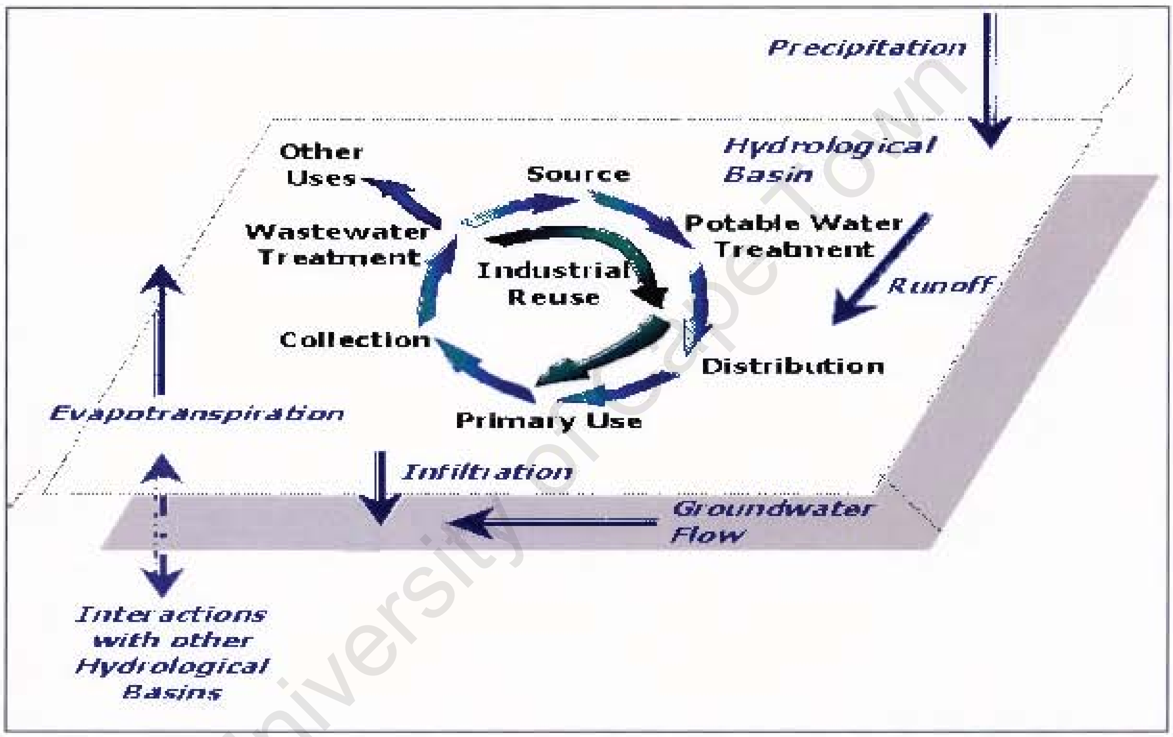


Figure 2.3: Urban water cycle (UNU-INWEH, 2006)

Water is introduced into the system through precipitation (input), it is conveyed as runoff or flow, and deposited or stored in one of three forms: in a surface water body, underground collection, and within man-made structures such as dams and reservoirs. These then become the principal sources for urban centres from which water is drawn and distributed to the various users, and these in turn return a percentage of this water to original sources as wastewater. Wastewater can be collected and treated for further use or disposal, or alternatively it is directly disposed of without any treatment. Throughout this cycle, from system inputs, through the various phases within the system (throughput), and finally to disposal (output), evapotranspiration plays a significant role.

The above representation is nonetheless oversimplified for the purposes of this thesis, lacking the level of detail required to explore the progress of water and the key components of water services in the system. The Urban Water Cycle will be revised in Chapter 3. It is however important to note at this early stage that the input, throughput and output sequences of water are significantly and constantly altered as a result of human activities.

2.3 Integrated Water Resource Management (IWRM)

Integrated Water Resource Management is a tool, a management ideology and methodology, which facilitates addressing the challenges of managing water; enabling and enabled by a supporting policy and legislative environment such that resource management is socially fair, economically feasible and environmentally sensitive. In other words, it calls for more than just the triple-bottom line approach to planning and implementation. It does this precisely because it insists on taking both a broad and comprehensive view on water management, looking at integrations between and within the human and natural systems. Furthermore it acknowledges that integration must be viewed *"as a process of change in political, social, economic and administrative systems"* (Lenton, 2004).

The integrated management of water resources requires a multidisciplinary, multi-dimensional and multi-faceted approach to decision making and action taking, which takes into consideration a wide spectrum of stakeholders. It raises awareness for both international and local water issues, however it is mostly applicable at regional scale. The broad spectrum of activities include: resource management; service provision coupled with infrastructure development and investment; legislative and policy activities; measures to ensure appropriate regulation of both use, and distribution of resources in order to balance the multiple and often contradictory water requirements, as well as the socio-economic and environmental aspects (Water Encyclopaedia, 2007).

The importance of water as a basic human need and right, as well as the vital role this resource plays in societies, has been highlighted in the introductory chapter. This is not only reflected by global developmental agendas but more importantly it has trickled down to local level planning, programmes and research agendas. In tandem with this, this thesis has explored some of the current and potential future problems in water management, drawing attention to the need for greater consideration and investment in the water sector. Guided by the 1992 Dublin principles, Integrated Water Resource Management provides a response to these issues (WMO, 1992). It creates awareness of the need for appropriate management of water resources, and appropriate action in the provision of services. IWRM recognises the importance of water and water supply to all and with this it acknowledges the social priorities, ecological impacts, and economic value that should be attached to the management and provision of this resource.

There is often conflict across the 'competing' dimensions of sustainability, and this has resulted in conflicting debates on the acceptance of water as an economic good. The perception is that by 'monetising' water supply, access to a fundamental right has been denied to millions throughout the developing world, and so the social component is jeopardised at the expense of sound economics. On the other hand, in aiming to comply with social fairness and equity, the environment has often been compromised. However, there are ways of offsetting or minimising these contradictions. For example, many governments have introduced significant subsidy schemes to ensure that the poor have access to water while maintaining favourable economic returns on services provided. The Free Basic Water (FBW) policy of South Africa stands as a clear example. Larger consumers of water pay higher tariffs for increasing consumption levels and the poor who cannot afford their basic requirements, are subsidised. In this way, not only is a degree of fairness and equality ensured but water efficiency is encouraged as well.

Whereas in theory this concept is sound, in practice it can and often does fail to deliver on the expected benefits to the majority. This is mainly because there lacks a concerted movement forward which would enable the full benefits from such policies as the Free Basic Water policy to be received by all. Free access does not signify equal access. In this case it is necessary to address not only the economic dimension of poverty but also to be inclusive of the underlying social inequities. This, amongst other issues, can be addressed through Integrated Water Resource Management. In addition to policies, the MDGs provide concrete targets for the provision of water and sanitation services and the appropriate management of water resources to ensure that development goals are aligned with sustainability concerns. Summing up, the IWRM approach provides the opportunity to translate verbalised goals to real and relevant action which can ensure that MDG targets are achieved and sustainability is continuously imbedded in development paradigms.

The reluctant adoption of IWRM in African countries can be attributed to a number of factors. For one, like many other ideologies and methodologies, IWRM finds its roots in the literature of developed countries, resulting from a progressive paradigm shift towards a holistic and comprehensive approach to water management. This brings to question the appropriateness of this approach given different social, economic and natural settings. While the potential benefits of adopting IWRM in developing countries are undeniable; better health, increased productivity, food security, economic growth and consequently poverty alleviation; the resource demands are also great. It is therefore not so much the usefulness of IWRM that is a deterrent but rather, in view of the financial and human resource limitations of many African nations, a poor capacity for implementation. A second point of relevance pertains to the general approach to IWRM. Acknowledging that implementation of IWRM plans must and does originate at political and institutional levels, through government institutions such as South Africa's DWAF (Department of Water Affairs) and DNA (National Water Directorate) in Mozambique, the lack of wider inclusion of the public and private sector alike has possibly also contributed to a restrained acceptance.

2.4 Integrated Urban Water Management (IUWM)

Cities have long since been recognised as major environmental stressors. The ever-increasing demand for sources and sinks to cater for the needs of civilisation is evidence of this. It is therefore important to study, monitor and manage the impacts of urban environments on the broader environment.

Integrated Urban Water Management is a component of Integrated Water Resource Management. It addresses the imposition of society on the natural water cycle and explores, through appropriate management and concerted action, avenues for improved service delivery. Fundamentally IUWM is based on efficient management of water resources including surface water, ground water, rainwater as well as methods of desalination and recycling regarding the collection, treatment, disposal and conservation of water. It also incorporates social and economic considerations geared at improving living conditions and empowering communities to create and manage sustainable livelihoods.

There are three main components of IUWM, namely: the physical component, the institutional and management aspects, and the policy background which supports development. The physical component relates to the development and expansion of infrastructure for service provision. This component is largely dependant on financial resources. The management aspects, including monitoring and maintenance of existing works ensures the optimal use and long-term sustainability of resources (life cycle analysis thinking). This requires a high degree of both inter and intra-sectoral coordination and a high capacity for implementation, demanding large investments in social capital and human development, in addition to the financial requirements. Finally, the third component addresses the need to develop and apply appropriate legislative and institutional frameworks which support the provision of services and the sustainable use of resources.

Integrated Urban Water Management extends further than the supply of services and the impact of such on the water cycle. IUWM is a tool that integrates water management in the broader context of society. It is therefore reasonable to extend the impacts of the water cycle from the broader natural environment to the social and economic spheres. The result is that IUWM integrates the need to provide for societies' needs while catering for both sustainability and development concerns.

As will be illustrated in Chapter 3, IUWM also explores the contributions of Non Revenue Water (NRW) within the water cycle. NRW refers to that percentage of water which goes unbilled and/or unaccounted for. This can be broken down into two sub-categories: Unaccounted For Water (UFW), which refers to the percentage of abstracted water which is lost through the various processes up to distribution to users. Some of the main causes are high rates of evaporation; leakages due to old and faulty equipment; inadequate operation and maintenance practices; vandalism and illegality (illegal and inadequate connections). The other component, Free Basic Water (FBW), refers to water which the public is entitled to as a result of legal stipulations (ordinances and laws), as is the case in South Africa, where 6kl of water per household are provided monthly at no charge (Armitage, 2006).

Non-revenue water has significant implications for the efficient management of water resources. While on the one hand water must be made accessible to all, it is important to keep in mind the economic value of water and the costs of providing water related services to consumers. This demands that there be some form of cost-recovery to ensure that services operate sustainably and that efficient management is assured. High water losses and high rates of UFW place great stresses on the environment for the continual or increasing supply of water. In water scarce environments, such as is the case of the Western Cape, and other areas of South Africa, such losses undermine the sustainability of supply. Whilst the reality is that water losses are unavoidable, these can however be significantly reduced through appropriate operation and maintenance of infrastructure and greater capital investments. In addressing sustainability of water supply it is vital to explore UFW in more detail, especially because this component can account for more than half of the bulk water intake of a city, as is the case in Maputo, Mozambique. Official records for the city indicate that more than 58% of the bulk water is unaccounted for (AdeM, 2006).

Free basic water presents a more complex problem, a problem which is much less researched and documented. The dilemma is in the duality and contradiction of free basic water provision. Water is subsidised as a social/public good and therefore the benefits and repercussive gains are significant, however so are the implications and repercussive effects. The main benefits to health are indisputable and so are other social gains. There are also economic and environmental benefits and one can again say that the gains are irrefutable. So what then are the problems? The lack of direct or significant returns on the service provided can, and in some cases does, jeopardise the overall sustainability of a system, in spite of cross-subsidisation. This is because cross-subsidisation is dependant on a significant proportion of wealthy and large water consumers, which is not the case in many cities of southern Africa. The reality is that the majority of the population in these cities, particularly those in denser urban settings, are poor. The result is that the demands on municipalities, many of which already run at a loss, are great. When balanced against the health benefits and expected long-term socio-economic gains, the short-term costs are somewhat immaterial.

On the consumer's side, the provision of services for which they cannot afford, not only regarding payment but more importantly regarding maintenance, has contributed to the failure of many schemes. A considerable portion of the population of cities live in peripheral or urban informal settlements and have little in the way of infrastructural support (top structures/houses), a fact which also complicates the provision of services. To overcome some of these difficulties the suggestion is that services be upgraded with improvements in living conditions, provided that a basic minimum is delivered.

A different perspective can be introduced; one can argue that cross-subsidisation and free provision of goods is encouraging a culture of non-payment, one which can and often does contribute to excesses and wastages. Furthermore, the lack of economic accountability can encourage a negative outlook on services. A poor sense of ownership and individual responsibility for the maintenance of infrastructure is therefore absent, mainly because the costs are not incurred by the users.

From an environmental viewpoint, it is reasonable to assume that greater demands will be placed on the environment as a result of FBW, granted that most of it is necessary, because excesses and wastage will undoubtedly add to the already stressed water resources. There are many questions to be answered, both for water supply alone but also with regards to its compatibility with other water related services. The tradeoffs are difficult to achieve and the issue is debatable. This discussion has simply raised awareness of potential problems in the provision of FBW and the dissipative nature of NRW, both of which can render a system unsustainable. It is not within the scope of this research to make recommendations on the approach to service provision; nonetheless the writer is of the opinion that in the context of developing cities worldwide, it is crucial to prioritise the social objectives and ensure access to basic services for all.

2.5 Monitoring sustainable development for the achievement of sustainability

Sustainability and risk management are closely related. Risk reduction and risk-avoidance are good approaches towards sustainability and conversely, high risk levels threaten the sustainability of a system. These are intrinsically linked and the result of one affects the other. Such correlation will be drawn upon in considering the sustainability of urban systems. Integrated Water Resource Management demands the continual appraisal of risks which can fall into one of the following five categories, (CONAGUA & WWC, 2006):

1. Divergent supply and demand levels
2. Water quality concerns
3. Competing water uses
4. Infrastructure failure
5. Effects of climate change and resulting hydro-meteorological disasters

In the interest of succinctness, the above categories will not be detailed. Mention is made of these in order to draw attention to possible sources of risk, which can increase the vulnerability of human and natural systems and hence threaten the overall sustainability of cities. The final index will take into account measures of all five categories of risk.

2.5.1 Evolution of the concept of sustainability

As early as the 1800s, the concept of limits to growth became evident in the writings of economists such as Robert Malthus, through his renowned theories predicting that the world population would outrun its food supply half way through the 19th century (Bungo, 2003). His claim was that unchecked population growth increases geometrically while food supplies follow an arithmetic growth pattern (Dhamee, 1996). This and similar theories contributed to a strong movement towards environmental mindedness, prominent in the 1960s and 1970s (Bartelmus, 1994). During this and following decades literature highlighting the impacts of development and growth on the environment emerged, gaining considerable recognition in academic debates and international development agendas but failing to translate to concrete actions.

The 1990s re-introduced the environmental conservation debate and promoted the inclusion of environmental objectives within broader concerns for socio-economic development. Strongly championed by the World Commission on Environment and Development (WCED), the introduction of the notion of sustainable development, *development which meets the needs of the present without compromising those of future generations,* provided the necessary entry point for environmental sustainability concerns within policy debates (WCED, 1987).

The undertaking of international treaties such as The Rio Declaration and Agenda 21 began to demonstrate the level of commitment at the global scale and served to create awareness for sustainable development world-wide. At the local level however, attempts at implementation continue to fall short of the goals. Institutional weakness, poor policy backing and a general disregard for sound environmental management practices are only some of the more commonly mentioned problems.

The proposal or support of a theory of sustainability will draw on the understanding of basic and fundamental principles. This involves understanding both the opportunities and limitations for development and growth, exploring the work of Bartelmus (1994), "Environment, growth and development: The concepts and strategies of sustainability"; amongst others.

2.5.1.1 Limits to growth

All societies, peoples and nations require certain basics for survival and this has been so throughout the ages. The very definition of sustainability in the introductory section, states that the goal of sustainability is to maintain or sustain the quality of life and this primarily entails survival. Modern and industrialized societies have however extended far beyond this need for survival into more complex and structured systems. Human beings have become more materialistic, in an increasing reliance on materials and goods. This has led to an increasing dependence, and consequently greater interaction with the environment for the supply and absorption of the very same material resources acquired or disposed of. Such interactions with the environment however are guided by certain laws. These laws govern system interactions and energy and material flows and therefore influence the behaviour of all biological systems and species. In earlier decades, growth was largely limited by human resources and capacity. Today the limits to growth centre largely on the earth's capacity to cope with the increasing population numbers, the pressures of development and impacts of urbanisation and globalisation. In other words, the environment currently acts as the limiting factor. Goodland & Dally (1996) have gone so far as to suggest that humanity has already reached the limits to growth era.

The limits to growth theory, coupled with the claims made by Malthus in his first essay on the theory of unchecked population growth and later revised in his essay on "the principle of population growth", touch on a very important point (Malthus, 1803). The current rate at which resources are consumed and wastes are discharged is far surpassing the rate at which the environment can safely replace and absorb them, and this extends to the water sector.

An assessment of sustainability of urban water systems explores this notion quite closely. Current practices in the water sector, particularly with regard to resource exploitation and distribution, have to a large extent contributed to a state of water insecurity affecting millions of Africans. Current population growth trends in the continent and elsewhere in developing countries substantiate the once seemingly absurd Malthusian theory. Furthermore many of the 'global' ecosystems are fast reaching their sustainability limits whilst the limit of some has far been surpassed, resulting in what has been termed 'ecological overshoot' (von Blottnitz, 2006; Wackernagel *et al.*, 2002).

Awareness and consideration for these issues demands a degree of caution when addressing the provision of services and utilisation of finite resources such as freshwater. Far from addressing the problems, the debate on the state of the 'global' environment has too often focused on the allocation of blame, with a refusal from developing nations to accept a 'share of the blame' for much of the pollution and resource depletion. Low levels of development in poor countries, particularly in Africa, exclude these as large contributors to the global pollution phenomenon. The fact is that richer, more industrialized countries have certainly offered far more to the global resource depletion phenomenon; however the consequences affect all, rich or poor. Furthermore, both population growth and expected economic development in developing parts of the world will to an extent invalidate this argument in future.

The Water Poverty Index (WPI) produced by Sullivan *et al.* (2002), emphasises this last point by predicting an increase of more than a factor of seven for both domestic and agricultural water requirements from the year 2000 to roughly 2030, due to population growth, a phenomenon which will take place largely in Asia and Africa. This will render many of the worlds regions either 'water stressed' or 'absolutely water scarce'. However the solution certainly does not lie with the meting out of blame, contrarily, the magnitude of the challenge demands that there be a pooling of capacities and efforts. It requires an integrated and comprehensive approach to problem solving from all involved.

2.5.1.2 Systems thinking and theory

If the aim is to work cooperatively, then it is necessary to create the conceptual framework which will enable the integration of different disciplines and backgrounds. The concept of systems thinking was firstly introduced into the development debate to enable this integration. Systems thinking, if anything, mirrors the complexity of reality for which a multitude of complex, interconnected paths and links must be considered. It provides the framework from which one can then understand and model reality.

Richmond's (1991) view on systems thinking reveals that perspective which one can gain if one is able to observe the myriad of underlying relationships and interactions between the parts which make a system. He defines it as "*a continuum of activities which range from the conceptual to the technical*". It is a simple and yet appropriate description of a concept resulting from the understanding and exploration of countless avenues opened up by interdisciplinary work. It provides the necessary conceptual framework to deal with complexity in a more orderly manner. A systems approach takes this theory further to provide a methodology which enables the collection and organisation of knowledge in order to improve the efficiency and efficacy of actions taken (De Rosnay, 1979).

As has been pointed out, systems thinking has great potential for stimulating change in both theory and practice, highlighting the need for interdisciplinarity, integration, coordination, efficiency and relevance of thought and action. However it is for these same reasons that its success at implementation level has been somewhat restrained. Human beings; scholars and practitioners in particular, create 'situational' barriers which hinder practical applications of systems theories. The very need for interdependence and trust is seemingly threatening to an independence of thought and action; sharing is associated with a surrender of power and 'give and take' resonates more with a takeover. Many are also 'conditioned' to see things in a particular way, whether by convention or through the education processes undertaken. Consequently there is a failure to 'stand back and see the bigger picture or the whole and its interrelating parts' (Richmond, 1991).

A change of perceptions and adoption of new views and visions has become necessary. Meadows emphasises the importance of leverage points towards overcoming obstacles and the challenges to development through the '12 places to intervene in a system'. The 12 points provide relevant entry-points for action, it is however at level one and two that the most effective change can be prompted; firstly through "the power to transcend paradigms"; and secondly by adopting "the mindset or paradigm out of which the system – its goals, power structures, rules, its culture – arises" (Meadows, 1999).

Integrated Urban Water Management coupled with the underpinning systems approach, challenges those very mindsets and demands a paradigm shift towards a more integrated and interrelated way of thinking and working. Changing thought patterns and perceptions becomes imperative to the approaches taken to achieve goals, down to the methods and tools employed. Ultimately, the goal is to be able to be flexible enough to adapt to the circumstances, both in time and space and therefore to be able to 'transcend paradigms' and adopt new ways of thinking and acting.

In tackling sustainability, the researcher endeavoured to take on a systems approach in order to be able to comprehensively analyse and evaluate the nature and complexity of interactions in the Urban Water Cycle. Furthermore, keeping to the same concept, the Sustainability Index – the final product – will itself embody the very same integrative, comprehensive and flexible precepts.

2.6 Investigation of metrics and tools for assessment

The previous sections provided the necessary background and established the need to monitor development; firstly to determine current performances; secondly, to guide progress; and thirdly, to monitor that progress according to sustainability principles. This section is mainly concerned with exposing, discussing and evaluating (where possible) some of the tools available for assessing sustainability in a variety of systems and for a variety of end objectives.

There are three approaches or types of tools which can be employed for such assessments. In order of more to least complex these are: models, indicators and criteria. A detailed discussion of the first two will follow, however assessment criteria will not be detailed but will rather be employed in the process of selecting indicators. Ultimately the aim of all three tools is to assess and monitor however different they might be. It is also in the interest of this sustainability Index that all three tools be used, complementarily.

2.6.1 Models and simulations

Models and simulation exercises enable the understanding of complex systems which are governed by numerous links and interrelations. The idea is that models can provide information about actual systems without the need for extensive field measurements, if any, and hence are a less costly approach. They produce various possibilities of 'reality' based on the guiding inputs, and provide a different perspective on the problems under analysis (Alberti, 1999).

The urban growth phenomenon coupled with the increasing need to improve urban water management, has prompted the development of numerous models in the last three decades or so to promote understanding and facilitate assessment of either the human or environmental dimension to urban growth. Whilst the assumption that models can approximate reality, and do so by demanding less capital expenditures, is theoretically sound, it has often failed in practice. The analysis of complex scenarios or systems has often required the use of several descriptive parameters in order to calibrate such models. This in turn demands large amounts of data, data which if properly compiled could provide for a decision-making tool in itself.

Another problem is that many models have until now been 'sectoral or mono-disciplinary' (Bertrand-Krajewski *et al.*, 2000). In many cases there has been a lack of integration of all dimensions of sustainability within one single model. Human development and urban growth models mostly overlook ecological processes and the same is true of environmental models which have largely failed to incorporate the human dimension.

In response to this lack of integration within modelling, Alberti (1999) proposed the Urban Ecological Model (UEM) with the objective of quantifying major sources of human-induced environmental stresses. The model framework developed represents the urban ecosystem broken down into a number of subsystems, and further represented by human and biophysical variables. For example, the model will analyse and propose the changes in land uses and physical development as a result of predictions in locational behaviours of households, businesses and developers. The result is a first attempt at assessing ecological and human-induced impacts 'simultaneously'. The overall Urban Ecological Model is based on various sub-models which simulates three types of human induced environmental stressors; land conversion, resource utilisation (water, energy and materials), and emissions. This model proposes an assessment of the broader urban ecosystem, which surpasses the urban water aspect considered here, however it does provide an interesting perspective on multi-dimensional modelling accounting for spatial and temporal dynamics.

An additional limitation of some models is that they are driven by short-term outcomes. Cities are dynamic, constantly transforming systems, but at the same time impacts can reverberate for decades into the future. Modelling of the urban environment must therefore capture this dynamism while taking due cognisance of long lasting effects of human activities, instead of being based on the "stationary hypothesis and on short-term processes" (Alberti, 1999).

Alberti also tries to address this in the UEM, which accounts for spatial differentiation by proposing different spatial resolutions in assessments, as well as accounting for the temporal aspects by proposing the definition of different time steps (monitoring stages) for the different urban activities.

In the context of the tool being developed, two particular models were of interest. The first is represented by the grouping of Pressure-State-Response type models which have been widely used in the interpretation and development of environmental indicators.

The second model, System Model, was developed by Robèrt *et al.* (2002) and correlates strongly with the step-wise approach envisaged for the development of the SI.

2.6.1.1 Pressure-State-Response (PSR) Framework

The PSR model builds on an earlier and more simplistic stress-response model in that it does not attempt to specify the nature of interactions between the social and ecological spheres (human activities and environmental impacts). The PSR model specifies that humans can and do exert pressures on the environment, which in turn can change in response to those pressures. As a result of these changes, society responds accordingly in order to prevent, mitigate, and/or reduce detrimental impacts. This framework of action-impact-response is illustrated below (Figure 2.4).

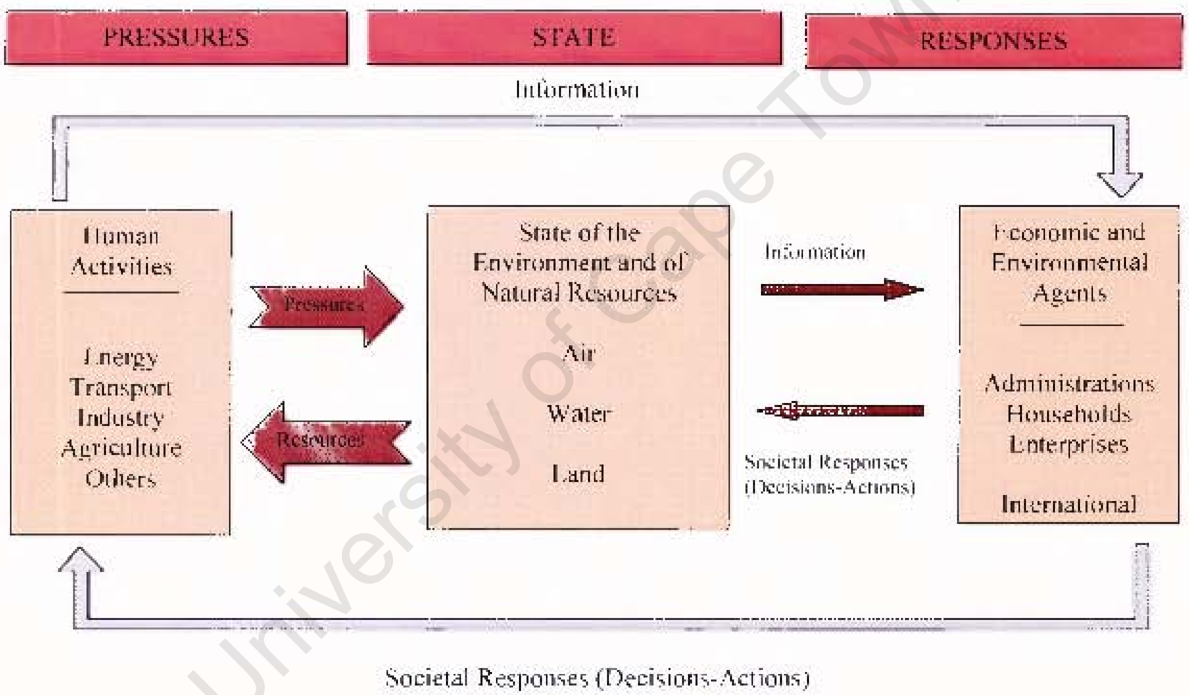


Figure 2.4: Pressure-state-response framework (OECD, 1993)

This particular model has been extensively used as the basis for developing environmental indicators; however it proposes somewhat linear relationships between the human-environment interaction continuum, and fails to address the multi-faceted and multiple relationships between the two spheres.

a. Driving Force-State-Response Framework (DSR)

The DSR proposes much the same theory as previous versions; humans induce certain forces on the environment which can and do alter its state and as a result of such alterations, society responds accordingly. In this model however, the word 'pressure' has been replaced with 'driving force'. The reasons for this are: firstly, this enables the consideration of both positive and negative impacts for which the word pressure was somewhat contradictory; and secondly, the use of the term 'driving force' accommodates the inclusion of a wider range of activities within the social, economic and institutional realm and henceforth allows for the wider development and adoption of indicators. The framework is adapted to address sustainable development concerns in particular. It employs a matrix approach which incorporates three types of indicator categories (horizontally) and the spheres of interaction and action which can be labelled the 'dimensions of sustainable development' (vertically) (Toolbox, 2007).

Table 2.2 illustrates the basic concept of the DSR. The multi-dimensional approach undertaken in the DSR, as opposed to earlier developments of the model, is more aligned to the objectives of this research. The model nonetheless fails to address the temporal and spatial dynamics of urban systems.

Table 2.2: DSR Framework: Sustainable development matrix (Toolbox, 2007)

	Driving force	State	Response
Social			x
Economic	x		
Environmental		x	
Institutional			

b. Driving Force-Pressure-State-Impact- Response (DPSIR)

A sequential upgrade of earlier pressure-response models is the DPSIR. This model does not remain fixed but rather responds to changes in environments, such as process and technological upgrades, information and data acquirements. In other words, it is responsive to progress.

The DPSIR (Figure 2.5) takes the initial PSR model a step further and it provides the framework for assessing environmental problems resulting from both driving forces such as industry and the pressures they place on the environment (gas emissions, waste) (Toolbox, 2007).

In isolation, the individual models are limited. The need for completeness demands that characteristics of all versions of the PSR model be incorporated into a single conceptual framework, taking into account three main aspects; the driving force-state-response principle, multi-dimensionality, and relevance to temporal and spatial dimensions.

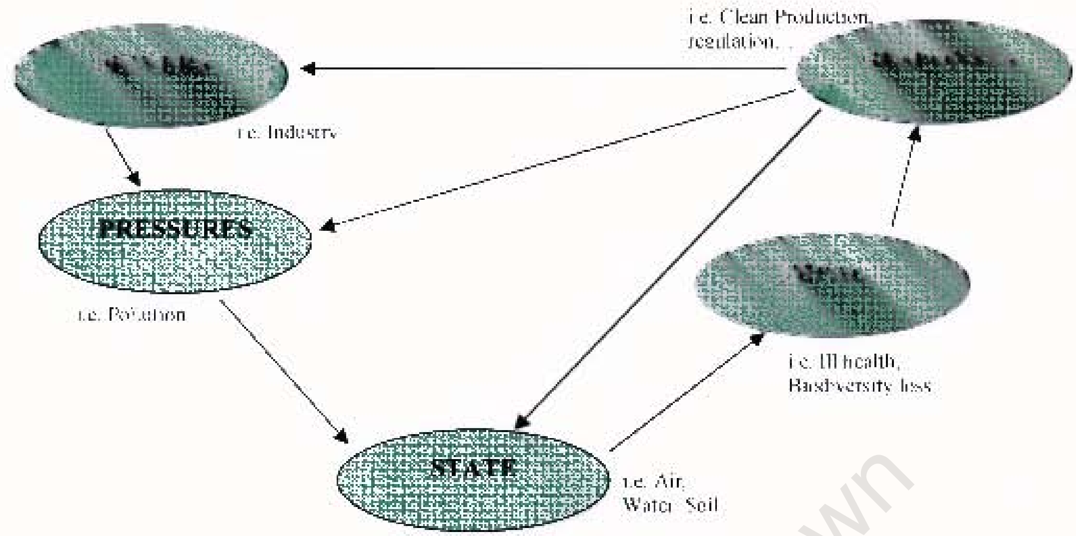


Figure 2.5: DPSIR Framework (EC, 1999 & Toolbox, 2007)

2.6.1.2 Systems model

Robèrt *et al.* (2002) present a selection of tools for the management of sustainable development. They begin by proposing a five level model to be used in the assessment and planning of complex systems, as seen in Figure 2.6.

1	**System constitution**
2	**Goals and outcomes:** Principles for sustainability (end state)
3	**Process:** Principles for sustainable development (goal)
4	**Actions**
5	**Tools:** Monitoring and Auditing

Figure 2.6: Systems model (Robèrt *et al.*, 2002)

Level 1 defines the overarching system, the ecosphere, by establishing its constituents and guiding ecological, economic and social principles. At level 2, principles for sustainability are proposed in line with the definition of sustainability adopted. Stating the desired goals leads to identification of the process to be taken towards the achievement of such and ultimately a plan of action geared towards it (levels 3 and 4). Establishing a system of monitoring and auditing is essential in assessing the soundness of the actions taken and the progress towards the goals stated. It is at level 5 that tools such as the one currently in development become crucial, in providing not only quantifiable and concrete measurements but also in displaying often very technical and complex information for the wider public. The structure provided by this model provides a concise and clear way of going about the assessment of urban systems, it provides direction. Furthermore it identifies the level at which tools can more effectively be introduced. To support the general applicability of the model, Robèrt *et al.* also discuss various tools in the context of this framework, and emphasise that most tools are complementary to each other, provided they uphold the principles of sustainability. The authors encourage the application of this systems model in developing and applying tools, in order to improve the synergy within and between assessment tools at large.

There is an important distinction between the principles of sustainability, which inform the objectives and outcomes that are to be derived from any actions taken, and the principles of sustainable development which will inform the process to be taken to achieve sustainability. One highlights the desired end goals and the other defines the process and informs concrete actions towards the achievement of such goals. Clarification is needed to ensure that sustainability is not perceived as an end state but rather as the succession of continually changing objectives leading to a hypothetical 'ideal' state. This pursuit of sustainability through the achievement of sustainable development does nonetheless highlight that Robèrt *et al.*, have taken into consideration both the short-term achievement of concrete objectives, as well as a longer-term strategic perspective on achieving sustainability.

As is commonly the case, the more comprehensive version of the above model fails to address the multi-dimensional nature of cities. It is somewhat biased towards the fields of expertise of the various contributing authors. It strongly emphasises the environmental dimension of sustainability, and is somewhat neglectful of the social, economic, political and institutional aspects. In a sense, it almost gives the impression that the authors have placed environmental preservation, for which they have proposed dematerialisation and substitution as key actions, over social concerns for survival and development. Nonetheless there is scope for addressing this shortcoming. Levels 2 and 3 in the model structure enable the reshaping and introduction of underlying principles of sustainability and sustainable development.

As with the majority of literature on this subject, this model represents many of the issues experienced by developed countries, and this is evident from the emphasis on environmental concerns, at the expense of social priorities, a bias which is unacceptable in the context of poorer nations. Moreover, given the background of the authors, the systems model takes on a very academic and technically driven approach; lacking the social aspect of participation and consultation which is essential for broader relevance and application. This is partially understandable as resource and time constraints are often limiting factors in this regard, however questions remain as to the applicability of the tools in real scenarios, which Robèrt *et al.*, have failed to address.

Overall there is great scope in this research for incorporating both the pressure-state-response type models as well as the framework provided by Robèrt *et al.* One enables the consideration of real world behaviour and the other provides the structured framework to go about assessing this.

2.6.2 Indices of sustainability

2.6.2.1 Ecological Management Systems (EMS)

These are mainly management and administrative tools which guide businesses and institutions in controlling and altering their impact on the environment. The use of metrics such as the ISO 14001 and the EMSA fall within the broader category of ecological management systems and help businesses maintain a level of ecological preservation which will prevent the need for more extreme remedial measures in future (Robèrt *et al.*, 2002).

2.6.2.2 Environmental Life Cycle Assessment (ELCA)

Environmental Life Cycle Assessment provides the necessary instrument to assess and quantify the environmental burden of a specific material or service taking into account its entire life cycle, from "cradle-to-grave" (see Figure 2.7).

Figure 2.7: Complete life cycle of a single product (Scienceinthebox, 2006)

This tool enables both qualitative and quantitative assessments, impact analysis as well as the identification of opportunities for improving or eliminating these environmental burdens. This process encompasses the entire life cycle of a material or service, it is therefore both time and cost consuming, and consequently it has not been widely accepted and used. Von Blottnitz (2006) describes the main components and sequence of a life cycle assessment from a goal definition phase through to scoping and analysis. Goal definition provides a qualitative view on what the situation is and what it should be, therefore defining the objectives and functions of such an assessment.

The subsequent step is an inventory analysis, which can be broken down into the following stages:

Inputs into a system → **interactions** and processes within the system → **outputs** from the system to the broader environment.

Based on this analysis, an impact assessment can be carried out to identify both the sources of stress and their respective contributions. A further step is proposed; an interpretation phase for the analysis of results. This is important in establishing potential improvement areas within the life cycle of a material or service and to highlight possible points for intervention. In answer to criticisms that ELCA is not practical, some researchers have proposed to streamline this tool, with modifications introduced primarily in the initial goal definition stage. Objectives are then adjusted to comply with the needs identified by the end-users and the level of accuracy desired. In this way, ELCA can become more practical for use in a variety of settings and for a variety of end-users (Robèrt *et al.*, 2002).

ELCA is a detailed analysis of individual materials or services. If a broader assessment of material flows within a system is required, Total Material Flow (TMF) analysis is more appropriate, detailing the same information at a macroeconomic level.

Both EMS and the ELCA approach are heavily biased towards smaller, less complex systems analysis which may be undertaken at a company level or sector-level for governments. The comprehensive approach to resource accounting is both time consuming and capital intensive. It often requires high data inputs and the technical skills necessary to interpret results and propose alternative sustainable applications. Institutions in developing countries have nowhere near the capital and human resource capacity needed for such assessments, much less governments and public organisations. For this reason this tool becomes impractical.

2.6.2.3 Natural Capitalism

Common criticisms of purely economic assessments of urban growth (urbanisation), as provided by the Economic Analysis (EA) approach, are related to its failure to account for both social and environmental aspects. Natural Capitalism (NC) is more inclusive of the environmental aspects but in its neglect of social concerns, it again fails to be sufficiently comprehensive.

A common response to demands for assessing environmental sustainability is that nature is too difficult to measure and that abstract concepts such as sustainability are not only difficult to define but even harder to quantify. This may be true, but it has not impeded sociologists and economists from attempting to define or measure equally abstract notions such as choice and rights, freedom and democracy; nor has it impeded the quantification of notions of poverty, health and wellbeing. This argument is therefore invalidated by the measures available to overcome such constraints.

The Natural Capitalism approach recognises that in order to integrate the ecological dimension within economic considerations, it is important to take into account all the relevant aspects of society and the environment (Robèrt *et al.*, 2002). The theory behind Natural Capitalism looks at the shift from human capital constraints to natural capital constraints. Whereas in the past natural resources were abundant and the limiting factor to development was a lack of skilled labour, today, natural resources and supporting ecosystems represent the critical components to development. This marks a return to the fundamental 'limits to growth' theory. As a result businesses and institutions must adjust and conform to the Natural Capitalism 'accounting system', for which there are four underpinning and guiding principles (Hawken *et al.*, 1999):

1. A radical increase in resource productivity. This looks to minimise both inputs and outputs and maximise on throughputs.
2. Rethinking and redesigning with the notion of complex closed loops in mind rather than the single, linear approach, and therefore develop methodologies and technologies which acquiesce to this.
3. Adoption of the 'service provision' rather than the 'goods distribution' approach in business to emphasise the actual services provided and move away from over-consumptive and wasteful practices.
4. Investments in natural capital, the support systems for human existence and societal functioning.

The above points reinforce the following conclusion; the economy or economic system must be viewed within its true context, to be existing, and hence dependant on, the broader social and ecological spheres. This dependency provides the real and relevant constraints to economic growth, which will be limited by natural capital and not man-made capital as was previously perceived. These points are certainly pertinent to the water sector, and should be seen as guiding principles for the period of change ahead. There are however valid criticisms to a full scale Natural Capitalism approach. Firstly, man-made capital has become indispensable in the development of societies and the path of development currently undertaken will reinforce this. Secondly, any single-sided or one-dimensional approach to strategic thinking is bound to lose relevance. Finally, sustainable development must ensure the integration of all pillars of sustainability; social, institutional and political, as well as environmental and economic.

2.6.2.4 Ecological Footprint (EF)

The concept of an ecological footprint was initially introduced in the early 1990s by Canadian ecologist, William Rees, and Mathis Wackernagel. It allegorically describes the amount of land and water required by a population or species to survive, for the attainment of sufficient resources as well as absorption of wastes, given contemporary technologies (Ecological footprint network, 2006; Wikipedia, 2006). In simpler terms, the Ecological Footprint is used as a measurement and management tool to assess and indicate the environmental sustainability of systems and networks. Through this assessment of relative consumption, the tool serves to educate on the issue of consumption patterns and create awareness for the overall impacts on the environment. Ultimately the EF attempts to change behaviours through better information and knowledge dissemination, and as such it is a strong social tool.

Some valid criticisms of this method have been raised and are relevant here. For one, the EF was developed and initially adopted by developed countries, consequently criteria and indicators might have little relevance to the needs and priorities of poorer nations. Although resource consumption can be and is significant in both settings, the reasons for this differ considerably; the per capita (over)-consumption in developed areas being counter-balanced by (under)-consumption by significantly greater numbers in poorer countries. Secondly, this indicator makes rather simplistic assumptions and rough estimations. For example, the indicator does not consider multiple land uses or multiple links between resources, users and their environments.

The Ecological Footprint has nonetheless effectively fulfilled its goal. It has, and continues to create significant understanding of consumption and disposal patterns and it has reached not only the more schooled individuals but it has truly endeavoured to enlighten the common man. The concept employed is simple and expressive, going to the core of the matter and shocking the user into awareness.

"Today, humanity's Ecological Footprint is over 23% larger than what the planet can regenerate. In other words, it now takes more than one year and two months for the Earth to regenerate what we use in a single year. We maintain this overshoot by liquidating the planet's ecological resources. This is a vastly underestimated threat and one that is not adequately addressed" (Ecological footprint network, 2006).

The EF remains very general and while it does create a sort of shocked awareness, it does not indicate key stakeholders in the force for change and certainly does not provide concrete direction for this change, aside from pointing that change is indeed needed. This, as well as the actual aspects under assessment, marks a significant difference between the EF and the SI. The concept is nonetheless ingenious, because it forces the ordinary citizen to realise that if consumptive patterns of humanity currently demand more than the one planet available, there is indeed a problem. It also points to the inequalities in cities and across the globe and stresses the contribution that each individual is making towards such.

2.6.2.5 Environmental Sustainability Index (ESI)

The Environmental Sustainability Index provides a yardstick for the environmental performance of nations through assessments of the degree to which these undertake environmental protection and preservation, as well as the level of commitment to subsequent issues at the global, national and local scales. This is achieved through the integration of 76 variables which aggregate into 21 indicators and further into 5 components, which ultimately inform the final index. The information represented highlights both the natural endowments of an area as well as the commitment to environmental preservation. It achieves this through assessments of pollution (past, present and potential future sources), environmental management and capacity to undertake environmental management (YCELP, 2005).

The diagrammatic representation provided below describes the overall structure of the ESI.

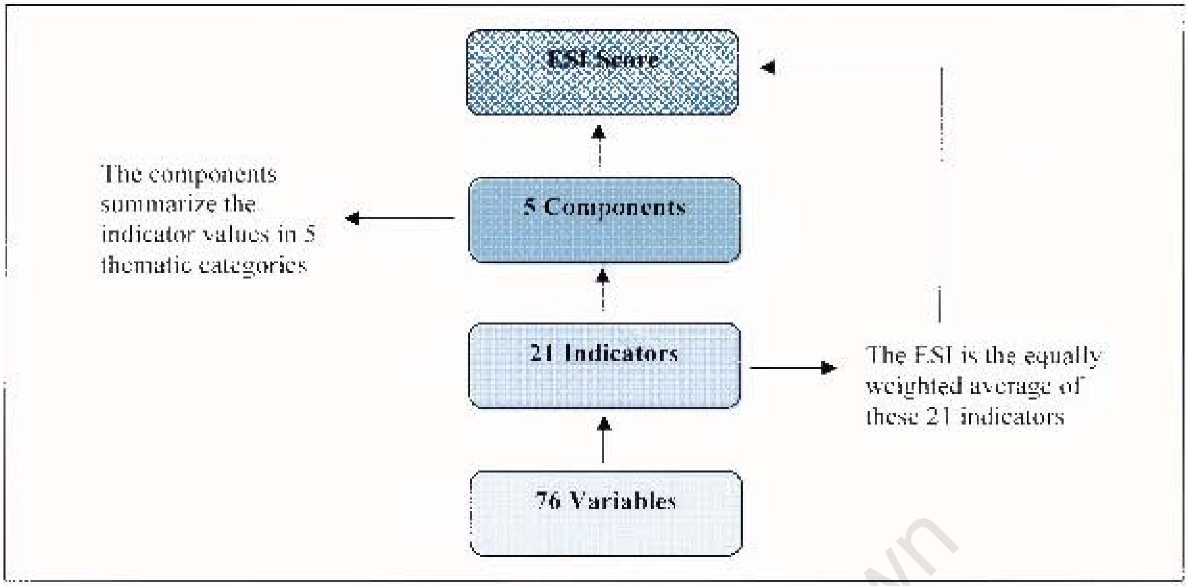


Figure 2.8: Component breakdown of the ESI (YCELP, 2005)

The sub-indicators and variables fall within the following five component categories:

- Environmental systems
- Reducing environmental stresses
- Reducing human vulnerability to environmental stresses
- Societal and institutional capacity to respond to environmental challenges
- Global stewardship

Standardisation of variables was performed to maintain comparability and commensurability. For this, common denominators were developed and used i.e. GDP, total population, city population, the average price of gasoline, total land area, to name a few. Data was then transformed to allow for imputation and aggregation, according to the pre-selected model for the ESI. Where data was missing, estimates were made based on a common imputation assumption, that the data was MAR (missing at random). Three different imputation methods were used: The Markov Chain Monte Carlo (MCMC), which was eventually chosen; a regression-based modelling approach and an expectation-maximisation algorithm. Following from which, data was winzorized, which entails the shifting of observed values so that they fall within stipulated percentiles.

Variables were then aggregated into the 21 sub-indicators, according to established weightings. Given that countries place varying importance on different variables, an equal weighting system was adopted. This seemed to provide for a relatively neutral starting point. An analysis of the quality and coverage of data was also produced. Significant data gaps presented certain difficulties, and ultimately 60% data coverage was stipulated for the inclusion of a country into the ranking system. The ESI has strongly influenced the development of the sustainability index, providing a list of indicators and variables which are relevant to current environmental concerns.

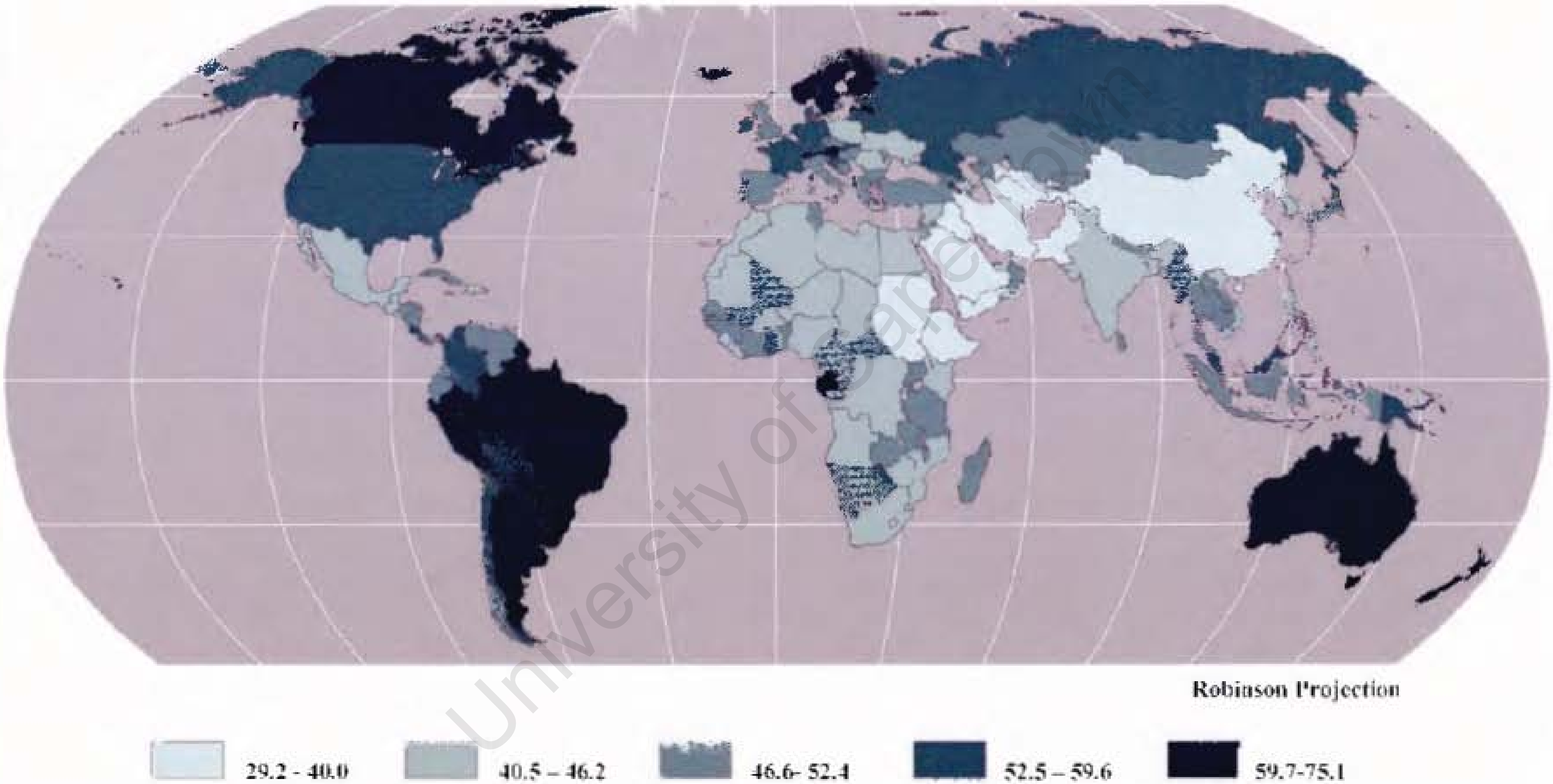
For a detailed description of the Environmental Sustainability Indicator and its sub-components refer to YCELP (2005).

The ESI provides a powerful tool for analytically assessing environmental sustainability; as a result it is a strong policy-guiding instrument. It also allows for benchmarking of the various countries included through comparative analysis of the indicator results, stimulating both positive competition in general and within cluster areas, e.g. EU countries, SADC countries, developed or developing countries, countries within the same climatic regions or countries with similar population dynamics. Furthermore, it offers the opportunity to showcase and encourage appropriate policy responses to environmental issues, as well as highlight good practices across institutional structures and relevant technologies.

To a large extent the 2005 national ESI scores conformed to expected results, differentiating between those countries with greater or less resources: economic, human, natural and social. In some cases development and industrialization and consequently natural resource depletion, particularly non-renewable resources, were identified as major environmental stressors. In other cases, underdevelopment, poverty-induced and poverty-responsive initiatives coupled with poor capacity and low investments in pollution control and environmental preservation led to resource depletion, particularly in terms of renewable resources. To this effect, clusters were used to highlight similarities amongst countries with common characteristics.

Both the overall ranking and the cluster ranking exercises illustrate the benchmarking potential of this tool, highlighting the 'leaders and laggards' in the progress towards environmental sustainability. For example, the ESI scores indicate that Finland, Norway, Uruguay, Sweden and Iceland are currently the top ranking countries, while North Korea, Iraq, Taiwan, Turkmenistan and Uzbekistan displayed the lowest scores. Within cluster categories Austria and Belgium had the highest scores and Taiwan and the UK featured at the bottom of the group for cluster 1 (defined for those countries with low stresses and vulnerabilities and moderate stewardship capacity). The same was true of comparisons made across the different indicators. Country performances varied for different indicators and none displayed very high scores across all indicators, stressing that all countries can gain from benchmarking environmental performance, and hence can benefit from the ESI. The mapping exercise in Figure 2.9, illustrates the benchmarking capabilities of the ESI. This spatial identification of environmental sustainability can help to identify which areas require greater attention and why. The ESI provides a wide-ranging assessment of environmental sustainability for the majority of the world nations, consequently ESI indicator scores can enable comparisons with similar indices.

Figure 2.9: Environmental Sustainability Index 2005
Country ESI Scores (YCELP, 2005)



As one of the first tools explored the ESI introduced the methodological approach of disaggregating components into indicators and finally into variables, as well as the concept of benchmarking and spatial mapping. As with the ESI, an objective of a sustainability index is to assess the relative rather than absolute performances, in order to draw conclusions from the experiences of others, and encourage constructive competition.

The need to test the robustness of any such tool and apply it to real case scenarios was put forth by the ESI developers, and this enabled the identification of preliminary statistical techniques in the validation of indicators.

It was established that reliable and sufficient data is essential to ensure that indicators perform their intended function and that the results they display are reliable. This was illustrated by the exclusion of certain countries from the ESI assessment for lack of compliance with data requirements. It is therefore vital that every country, whether included or not in the ESI, prioritise data collection and monitoring initiatives. This would considerably enhance the applicability of this and similar indicator initiatives.

The ESI, and sustainability indicators in general, is concerned with informing on progress toward sustainability and assessing sustainable development. The ESI however provides a much broader assessment of the environment at the national level, whereas this research addresses the urban dimension specifically but more explicitly focuses on the water sector. It is as a result that the ESI is more ecologically-driven, and in part diverges from the research objectives of thesis.

The scale of implementation of the two indicators also differs considerably. The ESI was developed and applied with the purpose of national benchmarking; this research on the other hand, is geared towards local-level (city or system) applications. The indicator development and selection process will therefore differ.

2.6.2.6 Environmental Performance Index (pilot EPI)

The pilot EPI, introduced by the developers of the ESI, exhibits many similarities with the latter. It was developed with the aim of fulfilling a substantial gap in assessing the performance of nations in relation to targets such as the MDGs. Many nations currently lag far behind their MDG targets. Some critics propose that the abstract nature of these goals provides little in the way of implementation-level strategies, and where progress has been made, the lack of monitoring and assessment tools renders this progress barely discernible.

Through its performance-to-target approach, the EPI proposes to address such criticism, as well as set up a system for continual revision and implementation of goals and targets. It centres around two important environmental protection imperatives: firstly, the reduction of environmental stresses on human health; and secondly, the promotion of ecosystem vitality and sound natural resource management. Both of these reflect priorities inherent in the MDGs as well as concerns expressed by decision-makers and implementation-level institutions (YCELP, 2006).

The EPI provides a sound basis for comparing and linking economic performance with environmental protection of each country. This initiative tracks down proximity to target over time, based on a set of environmentally desirable outcomes. Performance is measured through 16 quantitative metrics which fall under the two broad categories mentioned above.

For each of the 16 indicators, relevant goals/targets were identified which comply not only with international standards but are also inclusive of expert opinion. Under the two objective categories, sub-components were explored, namely: environmental health, air quality, water resources, biodiversity and habitat, productive natural resources and sustainable energy. These were further disaggregated into groups of two to five indicators, resulting in the final 16 indicators. Aggregation enabled country comparisons for the sixteen indicators, the six policy groups, and for the two main component categories.

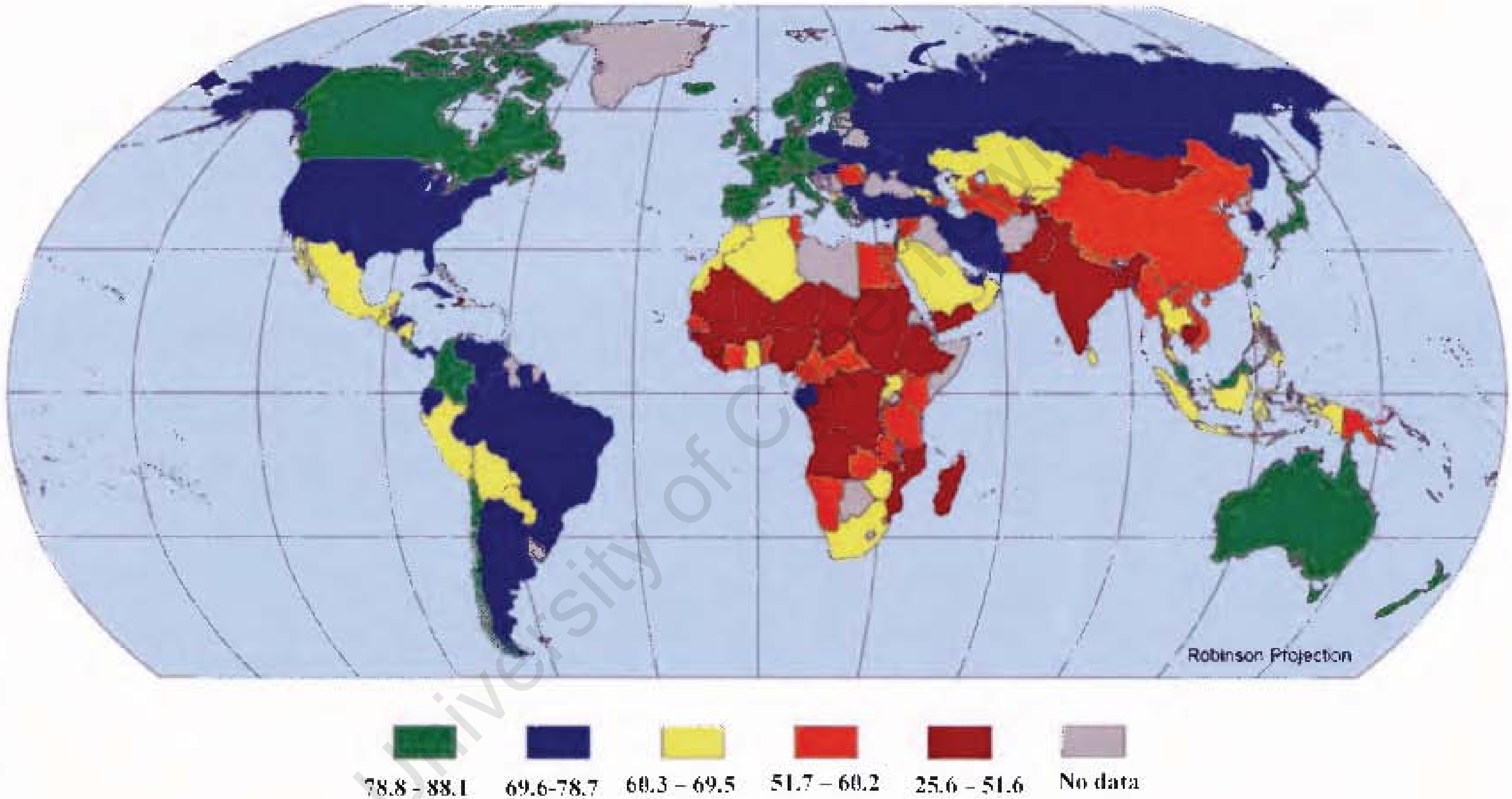
For comparison purposes, all indicator values were converted to a proximity-to-target measure, scored from 0 – 100 (100 being the highest possible score and 0 the worst). Indicator weighting varied. The EPI employed a combination of equal weighting, and where literature lacked clarity on appropriate weights allocation, statistically derived weights following on the PCA method (Principal Component Analysis) were used. PCA is a complex statistical method which determines how important the indicator is for its aggregate group (component); the higher its factor loading the better it can inform the component.

2006 EPI rankings showed that New Zealand, Sweden, Finland, the Czech Republic and the United Kingdom are current leaders amongst the group of countries assessed, and that Ethiopia, Mali, Mauritania, Chad and Niger are current laggards (Figure 2.10). The top ranking countries could be characterised as developed and economically competitive countries of the North with the opposite being true for lower ranking countries. This indicates a strong correlation between economic performance and environmental sustainability, with more affluent countries having far greater resources and capacity to introduce sustainable protection measures. High overall scores however did not signify high scoring across all the policy categories discussed.

To reiterate, the EPI shares many similarities with the ESI. The same clustering approaches are used to enable comparisons between nations with similar characteristics and features. The EPI follows on the methodological footsteps of the ESI, however it provides a valuable addition; the use of targets to assess progress towards concrete goals. This is crucial because benchmarking in isolation is not sufficient to determine whether there is indeed progress towards sustainable development. What it does is inform that some countries are performing better than others. The introduction of targets sets base levels for the achievement of sustainability and it ensures that this is a continual process.

The two tools are complementary, but the EPI makes for a more practical and target-driven tool. As with the ESI, the EPI has a strong ecological bias hence the irrelevance of some parameters to this thesis. Furthermore, the tools used to present results again bring to attention the need to visually engage and captivate the reader, whilst transmitting the necessary information.

Figure 2.10: 2006 Pilot Environmental Performance Index Country EPI Scores (YCELP, 2006)



2.6.3 Risk indicators

2.6.3.1 Defining risk and vulnerability

The United Nations defines risk as occurring when hazard, vulnerability and exposure co-exist. It is the potential for harm or loss as a result of human or natural induced impacts on vulnerable environments (WMO & UN-ISDR, 2006).

Vulnerability refers to the susceptibility of a system and/or its components to hazards due to exposure, whereas hazard refers to a potentially damaging event. The opposite measure of vulnerability would be a measure of resilience. It therefore follows that a high measure of one will reduce the measure of the other.

There are two main categories of risk; natural risks as a result of natural hazards; and human-induced risks which occur due to anthropogenic causes (WMO *et al.*, 2003; Snoek, 2006). Both are of great concern in urban planning and urban water management. In reality however, these become closely interlinked, where the expression of one may be due to the impacts of another. For example: fire is generally a man-created risk but it can be compounded by strong winds (exposure) and poor access to water (vulnerability) leading to an even greater hazard. The effects of climate changes also provide a good illustration. Consensus amongst scientists and experts is that anthropogenic contributions to climate change will find expression in more frequent and destructive natural disasters, such as increased frequency of droughts and floods, cyclones and tornadoes (WMO & UN-ISDR, 2006). High risk levels compromise the stability and sustainability of urban systems. It is therefore possible to correlate vulnerability, risk and sustainability, hence the measure of one will undoubtedly look at all the others.

The clear water linkages and ultimate impacts on society at large – harm to life and damage to property – reinforce the inclusion of risk and disaster management in IUWM. The following sections provide a discussion on some of the risk monitoring and management tools explored.

2.6.3.2 Environmental Vulnerability Index (EVI)

The Environmental Vulnerability Index (EVI) was developed by the South Pacific Applied Geoscience Commission (SOPAC) in partnership with UNEP, and other collaborators (SOPAC & UNEP, 2005).

An indicator-based methodology similar to that of the ESI and EPI is adopted for the EVI. The index measures the vulnerability of the natural environment of a nation or region in an attempt to improve the measurability of existing vulnerability indices such as the economic vulnerability index and a prospective social vulnerability index. The group of vulnerability indices is ultimately aimed at guiding national-scale development to ensure that growth and development remains within the economically affordable and environmentally sustainable levels prescribed. The objective is therefore to identify current natural hazards and man-made practices which function to the detriment of the environment, and which consequently inhibit human development.

By quantifying ecological impacts and benchmarking the current standings of nations it alerts decision-makers, practitioners, officials and the public in general to potential problems. In doing so it encourages a change of attitude and the adoption of new approaches and methodologies (SOPAC & UNEP, 2005).

Vulnerability in the context of the EVI refers to the ability of humans or natural systems to respond to adverse events. Risk assessment is therefore integral to the sustainability index, seeing as high vulnerability is indicative of high risk or high exposure to risk and vice-versa. While the EVI focuses on the environmental aspects of risk and vulnerability, and neglects the social, economic and cultural components, it is nonetheless meant to be used in conjunction with other indicators which assess the other aspects of vulnerability.

The EVI incorporates 50 sub-indicators. Selection of sub-indicators took into consideration three distinct aspects of vulnerability; risks associated with hazards, resistance to shocks and stresses, and acquired vulnerability or damage. The hazard indicators assess the frequency and intensity of hazardous events and 32 sub-indicators were assigned to this category. A country's or region's ability to cope with natural and anthropogenic hazards was assessed through the resistance indicators, of which there are 8. With regard to acquired vulnerability and damage, the aim was to assess the vulnerability due to significant loss of support systems or structures. Examples of this are growing degradation of ecosystems or loss of biodiversity. For this last category 10 indicators were assigned. Selection went a step further to provide an assessment on key issues prevalent through all three categories such as: weather and climate, geology, geography, ecosystem resources and services, and human populations. These were termed the 'type' categories.

The sub-indicators adopted either a 'smart' or end-point approach. This was done in order to allow for a wide range of situations and processes which operate well if the sub-indictor values are favourable. In this way the data requirements were reduced but the reliability of the indictor was not significantly diminished. The idea was that if an end-point was satisfactorily produced or functioning well, then the conditions necessary to achieve that end-point were present and operation was as desired. These sub-indicators were averaged and combined to give the final index score for each nation.

To enable aggregation, all indicators were converted to a single 1 to 7 scale, independent of their original unit of measurement; 1 represents high resilience and low vulnerability and 7 indicates low resilience and high vulnerability. Although there is a general scale from 1 to 7, the defining endpoints vary on an indicator to indicator basis so as to be policy-relevant and data-reliable. For example: whereas for the indicator for high winds the end-points were 148 and 601 (Figure 2.11); for sea temperatures these were 3.7 and 16.4 (Figure 2.12).

Figure 2.11: Scale for high winds indicator (SOPAC & UNEP, 2005)

Figure 2.12: Scale for sea temperatures indicator (SOPAC & UNEP, 2005)

An equal and balanced weighting scheme was used, this mainly as a result of the divergence, both in theory and amongst experts, regarding what should be prioritised and hence rated higher.

The final country or area profile illustrations provided in the EVI report display the sub-indicator scores as well as the final index score, and exemplify the visual tools that can be employed to simplify and hence attract attention to the results presented (SOPAC & UNEP, 2005).

Similar to both the ESI and EPI, profiling of individual indicators, as well as grouping of indices into thematic categories was performed. In this case, a final ranking system was adopted according to the five categories displayed on Table 2.3.

Table 2.3: Assessment of EVI scores (SOPAC & UNEP, 2005)

EXTREMELY VULNERABLE	365 +
HIGHLY VULNERABLE	315 +
VULNERABLE	265 +
AT RISK	215 +
RESILIENT	< 215

Some of the limitations of the EVI involved limited data collection for indicators; in most cases, this was restricted to the past 5 years, on the assumption that the immediate past had a much stronger influence on the short-term environmental vulnerability and ecosystem functioning and/or responses. Lack of data was overcome by making the index as flexible as possible. Where data on a particular sub-index was missing or the particular sub-indicator was not applicable, calculations were done on the basis of data that was available and relevant.

In contrast to both the ESI and EPI, the EVI is significantly less complex, not only in its demand for data but also with regard to the methodology used for compiling the data, and calculating the index. However criticism of the same applies: the approach is rather simplistic and may very well hide significant data gaps and distortions. Nonetheless the aim was to produce a practical tool subject to continuous upgrades.

With regard to its relevance to this research, the EVI presents an opportunity for identifying crucial environmental hazards which might compromise the sustainability of urban water environments, particularly those hazards which pose significant risks to the area of interest, i.e. southern Africa.

2.6.3.3 Disaster Risk Index (DRI)

The Disaster Risk Indicator (DRI) provides a measure of the national mortality risk due to exposure to certain disasters such as earthquakes, tropical cyclones, floods and droughts. It also considers social and economic aspects which either contribute or can be linked to the risk of death. This indicator however fails to address other facets of risk which do not directly threaten life i.e. loss of livelihood, economic costs to individuals and society at large (UNDP, 2004).

The indicator encapsulates the definition of risk provided earlier which states that risk arises as a result of exposure to a hazard which is compounded by a specific group's vulnerability to it. The risk indicator therefore adopts the following conceptual framework (WMO & UN-IDSR, 2006; UNDP, 2004).

$$Risk = Hazard \times Exposure$$

Risk is dependant on the probability of the occurrence of a hazard and the exposure of a given group to that hazard. This however does not explain the different impacts similar hazards have on areas experiencing similar levels of exposure. The missing variable is vulnerability, which assesses both the adaptive and coping capacity of groups to deal with hazards. The emphasis is therefore on vulnerabilities to the hazard and not the hazard *per se*, which is often uncontrollable in any case. Calculation of the DRI follows the following steps (UNDP, 2004):

1. Calculation of physical exposure. The areas exposed to the four types of hazard selected are identified and this aspect is expressed, in both absolute and relative terms, as the average number of people exposed to a given hazard in a given year, given the frequency of the hazard.
2. Calculation of relative vulnerability. Given that vulnerability is dependant on countless socio-economic, cultural, political, institutional and physical aspects, the DRI adopted a proxy for vulnerability. The number of people actually killed per year has been used as an indication of the actual risk. Vulnerability was then calculated as the ratio of the number of deaths resulting from hazards and the number of people exposed.

3. Calculation of vulnerability indicators. As a final step, the indicator compares the measure of vulnerability provided above with values for 26 selected social, economic and environmental indicators using a multiple logarithmic regression model.

As with any other tool, the DRI has made tradeoffs and consequently both reliability and representability of results has been affected. Firstly, the indicator restrictively assesses risk of death and fails to include very significant losses to livelihood, economic costs, environmental damage and other social disruptions. Secondly, the indicator monitors both medium and large scale disasters but neglects the impact of small-scale hazards, which can have extreme cumulative effects. Thirdly, in terms of the data used (1980-2000) countries which experienced disasters prior to the assessment time frame were significantly 'underscored'. Finally, with regard to the variables used; these were selected on the basis of existing global datasets, consequently other variables which might have been useful were not included (UNDP, 2004).

A clear outcome of this exercise was the identification of the links between development and the risk of disaster. In response to this, the indicator illustrated that in certain countries with similar exposure, the associated death rates varied, often pointing to 'development paths' which were either disaster or risk sensitive or alternatively compounded disaster and risk levels. This thesis explores sustainability of urban water systems and therefore will focus on disaster management in the water sector, an area with great potential for mitigating both risk and exposure to risk. For example, adequate water supply to an area, while not eliminating the risk of fire, can help mitigate the more serious impacts of a fire. Therefore access to water supply is linked to disaster management.

Safety networks and adequate institutional management can contribute to reducing the impacts of hazards by responding quickly and efficiently to a crisis (good disaster management). This was illustrated, albeit to the contrary, during the major floods of 2000 in Mozambique, after which thousands were left homeless and exposed to poor hygiene conditions.

Figure 2.13: Man collecting water and food supplies in Chibuto, Mozambique (UNEP, 2007)

Figure 2.14: Thousands in need of flood relief, Mozambique (Bible Society, 2007)

In these cases the social, institutional and governmental responses can and do work to reduce the primary threats to life by improving access to potable water and adequate sanitation, and by supplying food and basic shelter, hence the necessary accounting of disasters in sustainability considerations.

2.6.4 Socio-economic indicators

Achievement of goals and targets such as those set by the MDGs requires the necessary tools to monitor progress and assess results. Towards this objective, the UN has provided information on the rankings of countries in relation to MDG targets. Assessment of the progress in under-developed countries has been difficult due to lack of data and, where this exists, due to poor dissemination of information. A track record has nonetheless been maintained. This track record reports on the progress and achievements of all 53 African countries towards the attainment of the millennium goals. It serves as a good indication of socio-economic progress in the continent and can be used in conjunction with indices such as the Human Development Index and the Human Poverty Index in order to identify priority areas for intervention, both spatially and sectorally.

2.6.4.1 Human Development Index

Initially developed in 1990 by Pakistani economist, Mahbub ul Haq, the Human Development Index (HDI) has become an integral part of the work done by the UNDP on human development. It has since 1993 featured prominently in the annual Human Development Report. In essence, this composite index traces the level of development of nations across the globe and provides comparative measures through the analysis of four components which fall under one of the following three categories (Wikipedia, 2007a):

- **Health and well being**, assessed on the basis of life expectancy from birth (i).
- **Literacy and education**, measured through school enrolment rates (ii) and adult literacy levels (iii).
- **Standard of living,** which makes use of the log of per capita GDP (Gross Domestic Product) at PPP (Purchasing Power Parity), expressed in US Dollars (iv).

The aim is to assess a country's performance along the development continuum, determining whether it is developed, developing or underdeveloped. Furthermore it employs a ranking system for the 175 UN member countries included. Monitoring of a number of socio-economic, political, cultural and environmental issues is undertaken and compared to the progress achieved under each of the basic categories of the index. The Human Development Report provides a comprehensive list of these, recording their achievements.

The 2006 report, introduced in Cape Town in November 2006, focuses on power, poverty and the links to the global water crisis (Wikipedia, 2007a). The findings illustrate that the gains achieved by some developing or developed countries have been strongly offset by the deteriorating performances in Sub-Saharan Africa and South Asia.

The report emphasises the importance of meeting the Millennium Development Goals towards a more equitable and sustainable future. It also addresses the failure of most Sub-Saharan countries in setting and/or meeting target dates, resulting in an overall poor global performance towards MDGs. Given that the MDGs provide an initial entry-point, albeit a challenging one, for the elimination of water and sanitation backlogs, the prospects for "water and sanitation for all", the motto of the 1970s and 1980s, are not positive.

2.6.4.2 Human Poverty Index (HPI)

Assessments of poverty and vulnerability have made use of a number of tools, both quantitative and qualitative. The measure of this has been somewhat problematic because poverty or the expression of it cannot be simply put down to a number. The social and environmental implications cannot be neatly enumerated and calculated, the human aspect attributes it an almost abstract dimension. Nonetheless efforts have been made, and these have provided a strong indication of the level of vulnerability, exposure and destitution that millions experience worldwide and particularly in Africa. The Human Poverty Index developed by the UN provides a measure of these. It makes improvements on the HDI by incorporating additional variables (UNPD, 2006a).

Assessments are made based on the same three categories employed in the HDI, however the variables adopted differ as follows: (i) probability at birth of not surviving to the age of 60 (%), (ii) people lacking functional literacy (%), (iii) long-term unemployment (%), and (iv) population below 50% of median income (%).

In the case of both indicators, endpoints are set for individual variables and a score is obtained on the basis of these. Variables are equally weighted to arrive at the final indicator value. Both the Human Development and Human Poverty Index explore the socio-economic dimension lacking in previously discussed indicators such as the ESI and EPI.

The indicators display a socio-economic bias and therefore in the context of this research will serve as complementary tools to the more ecologically-focused indices discussed, which in isolation also fail to provide a multi-dimensional view of sustainability. Both the HDI as well as the HPI served to guide the researcher in the direction of useful indicators for which considerable data has already been gathered and synthesised. In the absence of similar indicators to the one under development, the HDI and HPI, amongst others, serve as useful comparative tools.

2.6.4.3 Falkenmark Index, water scarcity and water stress indicators

Falkenmark, Lundqvist and Widstrand (1989) introduced the Falkenmark water stress indicator, largely in response to growing debates around the issues of water stress and water scarcity. Presently, the debate revolves around the water crisis and its impacts on development, or rather lack of, in countries of Asia, Latin America and Africa, and how to gauge the true extent of the problem (Rijsberman, 1994).

Falkenmark *et al.*, proposed a simple measure of water stress/scarcity. They proposed a threshold water availability value based on which area-to-area comparisons could be made. Their research led to the identification and proposal of a $1700m^3$ per capita per year renewable water resource estimate. This value is based on informed approximations of water requirements for a variety of activities under domestic use; agriculture and industrial developments; applications in the energy-sector; as well as the need for maintenance of ecological systems. This culminated in the assessment of national performances based on such thresholds and the following stipulations were provided: a country which cannot provide the basic $1700m^3$ per capita water requirement is considered water stressed; and those for which levels fall below $1000m^3$ and $500m^3$, are ones of water scarcity and absolute scarcity, respectively (Rijsberman, 1994).

The simplicity of this tool has had and continues to have great appeal, particularly in addressing water management and governance issues in policy discussions. In his assessment of the water crisis phenomenon, Rijsberman provides a perceptive examination of the strengths and weaknesses of the Falkenmark indicator, identifying the following advantages: 1. the data requirements are minimal and often readily available; and 2. the underlying foundation of the index is based on intuitive assessments and hence with regard to both meaning and applicability the tool is easy to understand and apply. For this reason alone, Rijsberman maintains that the Falkenmark index will not soon be replaced in policy debates, in spite of more in-depth and comprehensive tools which can provide a more accurate assessment of the situation.

Rijsberman also highlights some of the limitations of the index. Firstly, the use of annual, national averages can hide significant temporal and spatial variations. This is however acceptable as the definition of both temporal and spatial scales is necessary to ensure continuous and systematic appraisals. These might however be more pertinent if they address on the one hand seasonal variations in the availability of water (possible seasonal time intervals), but also more local-level variations (city-wide or regional).

Secondly, the indicator fails to account for the role of infrastructure in considerations of water availability. A country or region might be limited in terms of natural endowments; however technology has provided the means to overcome this to an extent. Cape Town, for example, is a water stressed region and in response the city has undertaken to build dams, the Berg River Dam being perhaps the last to be built for decades to come, in order to secure sufficient volumes for the following years.

Thirdly, the simplicity of this threshold-based analysis does not recognize that water demands differ from country to country depending on factors such as climate and lifestyle, level of development and technological advances (Rijsberman, 1994). It is also worth noting that a society's or nation's ability and willingness to cope with limited water resources varies.

Literature provides various other examples of such water indicators, many of which have built on the concepts introduced by the simple Falkenmark index. The Water Resources Vulnerability Index and the Criticality Ration are such examples, however these will not be discussed here (Rijsberman, 1994).

Ultimately tradeoffs are necessary to ensure that while a tool is sufficiently inclusive and complete, it does not loose its practicality and applicability. Put simply, more emotive and intuitive tools have proved to have greater appeal and to cater for a wider base of potential users.

2.6.4.4 Water Poverty Index (WPI)

The concept of a Water Poverty Index (WPI) is firmly rooted in the need to establish the influence or impact of water (or lack of) and related services on poverty. It was first introduced by Dr Caroline Sullivan at CEH Wallingford, and later upgraded by her in collaboration with stakeholders in at least four countries; Tanzania, Sri Lanka, South Africa and the United Kingdom. The WPI both recognises the linkages between water and poverty and proposes to measure these through the use of indicators. Furthermore, the recognition of the role of water in poverty eradication has emphasised the need to incorporate ecological, and particularly water, considerations in development planning approaches. Whilst extensive research has explored the socio-economic aspects of poverty, and has culminated in the development of management tools which link the environment and poverty, the water perspective on poverty alleviation has been significantly neglected (Sullivan & Meigh, 2006). The WPI was developed in recognition of this fundamental vacuum in literature.

Conceptually, the WPI combines five main components which help to determine a population's or region's susceptibility to poverty as a result of lack or poor access to water. The aim is to take a holistic approach to water poverty by combining an assessment of the availability of the resource with the degree of accessibility, given the environmental conditions of that region. It is then evident that this tool strongly favours spatial identification of poverty. In other words, it is possible to identify those areas which are relatively water poor given their scores, and based on the sub-indicator assessments, it is possible to prioritise not only the geographically water-poor but also improve on specific areas of the water sector which have been identified as problematic, be these resource or capacity-related (Sullivan & Meigh, 2006).

The WPI adopts an approach which is similar to the one used for the development of the Human Development Index (HDI). A composite index is used which aggregates both variables and indices according to their obtained values and attributed weights. While variable selection can vary depending on area-based priorities and availability of data, the component categories are fixed. Components were selected to represent the following major concerns which the index tries to address (Sullivan & Meigh, 2006):

- Resources: this is a basic indicator of the availability of water in the specific area of study.
- Access: this is an indication of the degree of water provision to an area, given requirements for agriculture (even if only subsistence farming), as well as domestic use.
- Capacity: looks to the ability of people in the region of concern to access water, and is based on income considerations as well as education levels and health status.

- Use: provides an assessment of the various uses for water in a given area and the contributions these make to the local and greater socio-economic environment.
- Environment: this criterion recognises the importance of maintaining a certain level of ecological integrity and therefore assesses the impact of water management on the environment.

Alternative approaches for calculating the WPI such as the gap method and the time-analysis approach were explored. The gap method enables a ranking approach where the WPI scores obtained for each region are compared with a baseline value; country rankings are generally done using this method. Target values, which are indicative of a sustainable situation, can be assigned to each component, based on both quantitative and qualitative assessments. The component values obtained from data are then compared with the target values to provide a gap-determined WPI (Sullivan, 2002). The time-analysis approach works on the basis of the time taken to obtain water or the work time required to be able to afford certain volumes of water. Both methods were deemed useful but the preliminary work on the WPI has kept to the composite index approach.

The development of the WPI highlights an important conclusion; indicators and/or variables adopted must be site specific to retain relevance to local issues. This is not to say that in the case of the initial WPI developed, the indicators and variables developed are not adequate, but simply that they should only be used if deemed pertinent for the temporal and spatial scales selected. Availability and access to data is also a strong determinant of the variables to be used. Identified needs and wants as well as established priorities, whether these are social, economic, ecological or policy-related, are additional factors in guiding variable selection. Reaffirming what has been stated above, scale is an important factor; but this will be largely dictated by existing data or the methods available for making data correlations and/or assumptions. To illustrate this last point, studies carried out by both Cullis (2002) and Sullivan *et al.* (2003 & 2006) adopted various scales – national, catchment, sub-catchment and enumerator – for implementation of the WPI, and consequently the data requirements varied. For the different scenarios, there will be more appropriate and 'accurate' datasets. For example, whereas the national population census may be appropriate for a national WPI such a broad assessment may be too coarse for a community-level application of the WPI, in which case alternative data sources and variables would be adopted.

One also comes to the realisation that more refined scales or localised areas of study result in more accurate or perhaps more representative results obtained from the application of such an index. Scale therefore plays an important role in the application and relevance of indicators. Sullivan *et al.* (2003 & 2006), report on the community level and national level studies undertaken to demonstrate the possible indicator and variable variations depending on the scale adopted.

The findings of the WPI applications at both national and local scales led to the following conclusions: firstly, it demonstrated that this tool does in fact highlight those areas which experience greater water poverty. It also stressed those aspects of water poverty such as resources, use, and capacity, which require greater consideration and investment.

The mapping approach was illustrative of the results obtained at local levels. Secondly, it was possible to establish that the WPI can indeed be used at different scales but in order for this to be applicable, data and hence underlying variables and indices must vary according to the areas' specific needs and priorities. Thirdly, it was possible to validate that variable selection, data collection and WPI formation is better served through a consultative and participatory engagement of all stakeholders.

The inherent flexibility in the indicator structure as a result of 'open' adoption of variables is representative of the dynamism of systems, their transformation with time and variation with space. It is a key component of the research currently undertaken and was pursued in this thesis.

The developers of the WPI were also able to draw clear links between water and poverty, proposing to explore an area of research which has been lacking, despite the contributions that water can make to poverty alleviation. While the links between water and poverty in the sustainability index might be implicit, the inherent benefits of improving water management will certainly highlight this point.

The problem of inadequate data for differing scales led to the conclusion that there is a need to correlate data collection exercises in order to obtain information which can enable scaled applications of the WPI. For example, data gathered at national level (national population censuses) may preclude the use of such for WPI development simply because the 'right' questions were not asked. The recommendation is that national surveys/questionnaires include WPI related questions, to the extent that is economically and practically feasible.

The WPI focuses on water supply particularly, to the neglect of other water services which can contribute to increased social decline, leading to economic decline and hence increased poverty. This is particularly the case with sanitation, which has significant impacts on health and social well-being. An objective of this thesis is to explore all water related services. In this regard the WPI fails to provide a complete view of the system and identify other water related poverty contributors. There is also a strong bias in the WPI towards the social and ecological aspects of poverty, with limited emphasis on the political, economic and institutional dimensions.

Apart from the obvious conclusions drawn with regard to the significance and utility of the indicators here explored, the overall analysis of water scarcity and water poverty has also yielded significant results. In answer to the question posed by Rijsberman's (1994) "Water Scarcity: Fact or Fiction"? on whether there is indeed global water scarcity, some findings will be discussed. Literature is somewhat contradictory in this regard; there are those that support the Malthusian view on the depletion of water resources, which can be inconsistent with the facts and figures. The human development report is but one source that proposes a different viewpoint on the water situation. The view expressed is that indeed there is fresh water scarcity but that this is a spatially localised phenomenon, with strong cross-continent, and cross-country variability, and at times with significant local differences.

The issue is not one of 'running-out' of fresh water in the true sense as proposed by some, but rather it is with regards to the contradictory approaches to socio-economic growth and ecological preservation. Furthermore, one can find some direction by differentiating between water insecurity for human consumption – resulting from poor policy orientation and even poorer institutional management – and water insecurity for agriculture and livelihoods development – a clearer expression of water stress/scarcity. Therefore in the context of achieving the MDGs, the aim is to tackle water insecurity resulting from the lack of a concerted movement towards better policy, management and implementation of water resources and water related services.

Overall, the above discussed indicators made a significant contribution to this thesis in that they served to highlight the links between water, water services, and poverty reduction.

2.6.5 Sustainability and risk in integrated urban water management

The sustainability and risk indicators developed by Stoeckigt (2006) and Snoek (2006) respectively have to an extent provided the entry-point to this research. The following sections summarise their work.

2.6.5.1 Sustainability Index for Integrated Urban Water Management (2006)

The aim of the research conducted by Stoeckigt (2006) was to explore the literature on sustainability and relevant indices with the ultimate aim of developing a composite measure of sustainability for the assessment of urban water systems.

Through the development of a sustainability index Stoeckigt (2006) undertook a re-evaluation of the urban water cycle providing the necessary adjustments to incorporate and detail the major aspects of integrated urban water management. An index was developed adopting a similar approach to that used in the development of the 2005 ESI. The final index disaggregates into three major components – socio-political, economic and environmental. Informing these three components, 16 variables were created, which were further disaggregated into 44 variables.

Weightings were assigned to each variable, indicator and component, based on an analysis of the literature available and expert opinion, as well as individual input. Appendix A provides a detailed account of the final sustainability index structure. Following on the ESI approach a scale of 0% to 100% was selected, for which 0% represents the lowest possible score or no sustainability achieved, increasing up to a 100% representing a fully sustainable system. This was followed by the development of a spreadsheet which enabled the user to attribute values and 'fill in' the necessary information, for which the programme then calculated scores for each individual variable, sub-indicator and component according to the method of aggregation adopted.

In order to test the model, the indicator was applied to five distinct, theoretical scenarios:

- An informal settlement, based on Khayelitsha and Doornbach in Cape Town.

- A city in a country with a corrupt government, based on Bulawayo in Zimbabwe.
- A tourist town, based on the holiday town of Hermanus, South Africa.
- A poor African city, based on the capital city of Sierra Leone, Freetown.
- A new residential development, based on the Pearl Valley Golf Estate development in Paarl, South Africa.

Table 2.4 provides a summary of the results obtained for the five cases explored, as well as a breakdown of components for a detailed appraisal of the underlying causes of the individual index scores.

Table 2.4: Results of sustainability index applications (Stoeckigt, 2006)

Situation/ component	Socio/ political	Environmental	Economical	Total sustainability
1.Poor African city	19%	38%	46%	**34%**
2.Informal settlement	30%	46%	36%	**37%**
3.Corrupt government	37%	59%	48%	**48%**
4.Tourist town	45%	53%	64%	**54%**
5.New Development	51%	85%	83%	**73%**

Given the characteristics of each case study and an understanding of the aspects driving such environments, the results obtained from the index applications were not entirely unexpected. The conjectural nature of the cases will have been a big contributor to the deviation of results from reality. Where information was obtained based on similar existing situations, data was most likely imprecise, outdated or unreliable. The weighting system utilised might have also created certain biases towards aspects being assessed, which in practice were irrelevant. Fine-tuning of the index will have highlighted these limitations which given the time constraints went overlooked. Apart from the data limitations, the composition and underpinning conceptual framework of the sustainability index was based on some critical assumptions, some of which have not been tested and others which might be relevant in theory but are not applicable in practice. For these reasons, albeit being extremely useful in concept, the indicator requires further work.

The underlying indicator structure, methodology, and variable selection has proven very valuable for the work to be undertaken in the progression of this research. Building on the work done by Stoeckigt enables to an extent, the inclusion of an interdisciplinary and multi-stakeholder ideology and provides greater input from additional sources.

2.6.5.2 Risk assessment in Integrated Urban Water Management

The risk indicator (Snoek, 2006) directly complements the sustainability index discussed above. An extensive literature review was carried out and it allowed for appreciation of concepts such as risk, vulnerability and hazard. An assessment of current tools and approaches contributed significantly to the development of this risk indicator.

A review of the water cycle similar to that undertaken for the sustainability index, was conducted, the product of which was slightly modified to suit the intentions of the particular research.

This index was largely informed by the 2006 pilot Environmental Protection Index, also developed by the Yale Centre for Environmental Law and Policy. A breakdown of three components – social/political, environmental and economical – into sixteen indicators, as shown in Appendix A, was employed. The sixteen indicators were then disaggregated into 44 variables. For compatibility purposes, the variables, indicators and components used for the sustainability index were used here, although the methods employed for calculation differed. Conceptually the development of the risk index is underpinned by the following formula:

$$Risk = Vulnerability \times Severity \times Probability$$

Risk is therefore a function of the vulnerability of a community or area, the severity of the event, the shock or stress affecting it and the probability of occurrence. Vulnerability, as defined for this risk indicator, refers to the susceptibility to exposure. It implies a lack of resilience to a determined impact. Severity reveals the degree or extent of damage that can occur due to a hazardous event. Probability identifies the probable occurrence of an event and how often this might take place (frequency).

The selected variables were assigned values, which in practice would be represented by true measures and statistics. The variables were also assigned weights to indicate their 'importance' within the indicator. The product of the value and weight of each variable was then summed up to give the indicator values. To comply with the above assumption, that risk is the product of the three factors (vulnerability, severity and probability); while in practice only making use of the product of two factors (value and weighting) it was assumed that two of the three components of risk were combined. In this case, vulnerability and probability were combined as one category of the index and severity represented another category. The link between vulnerability and severity is nonetheless also valid and should be explored in further research, or alternatively a model should be devised which can incorporate all three components of risk individually, rather than combining two. This would certainly enable better understanding of each component.

Due to time and data constraints, the risk index relied substantially on qualitative assessments. Values for indicators were provided on a scale from 0 – 5, 0 indicating low/no threat of hazards as well as low vulnerability and 5 indicating a high frequency of hazards as well as high vulnerability. The values obtained for indicators were then multiplied by given individual weightings and this produced the values for the three components of the final index. The three main components – social, economical and environmental – were then equally weighted, and multiplied by the calculated value, resulting in the final indicator. Given the subjective nature of weights adopted for variables, indicators and components, these can be adjusted to represent the intent and the priorities of the end-user.

As with the sustainability index developed by Stoeckigt (2006), the risk index was tested by way of five theoretical case studies. The same diverse scenarios were explored and the following table provides the summary of those results:

Table 2.5: Results of risk index applications (Snoek, 2006)

		Case study				
		Informal settlement	Politically unstable city	Seasonal tourist town	Worst case scenario	Best case scenario
Risk (%)	Social	31%	33%	13%	54%	5%
	Environmental	50%	43%	57%	56%	20%
	Economic	67%	56%	44%	57%	24%
	Total	**50%**	**44%**	**38%**	**56%**	**16%**

2.7 Constructing a composite index

The ultimate aim of this research is to develop a composite sustainability index which can summarize the range of issues which contribute to the sustainability of urban water systems. It therefore follows that this will draw considerably from existing methodologies and approaches. Nardo *et al.* (2005), provide developers with the following step-wise methodology to develop composite indicators:

1. Building a **theoretical framework** which will provide the underlying basis for indicator selection and support the overall indicator structure.
2. **Indicator selection**, termed by Nardo *et al.*, 'data selection', involves the selection of appropriate indicators for the field of research, given their relevance to current issues, their appropriateness to the area in question, their scientific and analytical basis and ability to effectively represent the issues they are designed for (measurability).
3. **Multivariate analysis** requires an investigation to assess the overall indicator structure, given the various assumptions made in the development process.
4. **Imputation of missing data** involves looking at the steps followed, in order to arrive at acceptable datasets, and where data is missing, determining how to address the issue.
5. **Normalisation** involves the conversion of indicators and/or variables to a comparable form, ensuring commensurability of data.
6. **Weighting** entails the determination of a weighting system in order to aggregate sub-indicators and/or variables, according to prioritised issues or statistically determined loads.
7. **Aggregation** refers to the grouping of indicators according to the underlying conceptual framework.

8. **Robustness and sensitivity analysis** is conducted to assess the robustness of the composite index with regard to the underlying assumptions made in the construction of the index, as well as the 'sensitivity' to changes in such assumptions.
9. **Establish links to other variables** providing an opportunity to make comparisons to other indicators and, where possible, verify and validate certain assumptions and choices made during indicator development.
10. Develop visually appealing and user-friendly tools towards enhancing **visualisation.** This step is also key in ensuring that indicators are well received by their target audience. Findings should therefore be presented in a simple and transparent manner, and results should be displayed so as to elicit the desired responses.

The above steps are comprehensive in their coverage of indicator development and application; however they also involve an extensive exploration of statistical analysis and models. While there is a need to address the statistical soundness of any index, there are limitations to this initial exploration of indicators. Given the time and resource limitations, it will not be possible to undertake such a comprehensive exercise as proposed by Nardo *et al.*, however all steps will be addressed, albeit in the order and to the degree that is suitable to this research as will be seen in the subsequent chapters.

2.7.1 Deriving indicator weights

The preceding discussion details the process necessary to arrive at a final robust indicator, and weight allocation is highlighted as a key step (6); however this is almost always a conflicting exercise, and as a result it calls for particular attention. There are three main approaches to indicator weight determination, for which a number of methods will then be explored. The first is an application of equal weights, the second enables weight allocations based on statistical methods, and the third option allows for stakeholder participation and consultation in determining appropriate weights (JRC, 2007). The simplest and most commonly used is the neutral approach, where all sub-indicators and components are equally weighted. This can be done so as to represent the equal importance of all components within the overall index or it can illustrate the lack of consensus regarding indicator prioritisation. This first approach is simple and easily understood and therefore will not be discussed. Through relevant examples and methods the other two approaches will be briefly examined, as discussed by Nardo *et al.* (2005).

2.7.1.1 Statistical models

Principal Components Analysis (PCA) and Factor Component Analysis (FA*)* determine the maximum variation possible by way of the least number of factors. Indicators and variables are grouped in such a way as to form composites which can capture the most commonalities (information) amongst them. Firstly, correlation in the data structure must be checked to identify whether indicators share the same factors; the lower the correlation, the least likely that there is commonality of factors. This is followed by the determination of factors loadings, towards the eventual construction of weights. Ultimately, indicators displaying a high correlation with one another will be assigned lower weightings, because they assess similar, or the same, issues.

Data Envelopment Analysis works on the basis of establishing an efficiency frontier or reference line. Case studies displaying the best performance are used to represent the frontier line and the remaining cases are assessed in relation to that frontier.

The Unobserved Components Model makes an assumption that indicators are dependant on an unobserved variable and an error term i.e., improvements in health are dependant or influenced by improvements in water supply and sanitation, accounting for an additional error term. The rationale is that one gains an understanding for the indicator in question by estimating the unknown component. The weight is then assigned in such a way as to reduce the error in the composite index.

2.7.1.2 Opinion-based methods

The Budget Allocation method brings together various experts and practitioners in the fields concerned, and based on their knowledge, experience and judgement, enables the determination of a weighting system. Much in the same way as budgets are allocated for projects or activities, experts are required to assign proportions of a set budget to individual variables. This approach has the benefit of being representative of the established priorities and needs in the specific context, however if composed of many variables (usually more than 10), it complicates the allocation of budgets to the various issues of concern.

Public Opinion; this method proposes that an extensive consultation process, generally through polls, surveys, interviews, questionnaires or workshops, be undertaken to establish the degree of concern expressed by the general public for particular issues. On the one hand, a wide consultative approach has the benefit of being inclusive and representative of public concerns; however it is both time and resource intensive and is often rejected for more 'efficient' alternatives.

Analytic Hierarchy Process; this method involves a pair-wise comparison of indicators or variables to determine, based on a defined scale, the importance of one in relation to the other. This approach enables the breakdown of a complex problem or concept such as sustainability by establishing a hierarchy of priorities. In line with this, indicators and/or variables are ranked on the basis of both quantitative and qualitative assessments, ultimately resulting in trade-offs characterized by the assigned weights.

Conjoint Analysis takes a step forward from the conventional public or expert opinion-based approach, to effectively determine a 'willingness to pay' for the services offered. Whereas the other approaches combine the assigned values of indicators, their importance or worth, Conjoint Analysis disaggregates preferences by establishing multiple scenarios for which respondents must indicate a preference.

Ultimately, all methods involve some form of statistical validation, albeit to different degrees. The selection of a particular approach should be based on the level of expertise of the developer and the preference and resources available; which often prevent the use of more time-intensive approaches.

2.8 Conclusions

In general, this thesis aims to address all three components of IUWM, which will be represented in the indicator. More specifically, the sustainability index is concerned with time and spatial monitoring of the performance of cities, with the ultimate aim of improving policy and decision-making. It therefore proposes to highlight issues in management, which will have an impact on policy making. This then translates to changes in infrastructure provision and service delivery.

In developing the sustainability index, due consideration was given to various interactions within the urban water cycle as well as to the possibility of introducing 'closed' loops where linear, mono-functional and singular approaches to service provision are evident. Chapter 3 highlights some of the links. Use of clean water for non-consumptive uses of water such as flushing toilets is a clear example of such mono-functionality, where otherwise grey water might have been used. The under-exploration of rainwater as a source of domestic water is another example. Currently this resource enters drainage systems and is conducted towards treatment facilities or disposed of at significant economic and/or environmental costs.

2.8.1 Applicability of tools

Having described some of the more common tools for assessing sustainability currently discussed in literature and applied in practice, it is important to make clear the differences between these. Some tools adopt a more analytical approach for which the assessment and understanding of system performances is the main target. Other tools are geared towards practical uses and are guided towards informing implementation-level activities. These are used to guide policy-making and action-taking in a direction which takes into account the development needs of a system, while at the same time acknowledging that the very same system is governed and limited by certain factors, both at present and in future. A third set of tools are used to create awareness, encourage dissemination of information and promote education. A revision of some of the tools explored in this chapter can provide a good example of the aforementioned differences.

The Ecological Footprint has become a powerful analytical and environmental awareness tool. It demands measurements of the natural capital available in order to promote improved management thereof. This tool is based on much of the same concepts demonstrated in sound financial management practices. The EF can be applied to any desired scale, from the simplest system to complex accounting of cities or regions and as far as global accounting of resource use. In an urban context, the EF can calculate the equivalent amount of land to sustain a city's activities in terms of the resources needed to sustain it and the wastes generated by it, given the technologies available (Wackernagel & Rees, 1996; Wackernagel & Sommer, 2006; Wackernagel *et al.*, 2006). This tool however does not provide the level of analysis required to guide decision-makers towards a targeted course of action. On the other hand, tools such as the ESI have the necessary qualitative and quantitative background to be more relevant in policy debates.

Tools such as the ESI and EPI also highlight areas for improvement and guide by example, encouraging countries to take action through a comparative and benchmarking approach. Nonetheless both the ESI and EPI are scale-restricted, providing national accounts of sustainability where local assessments might be more relevant. In contrast, the Water Poverty Index has proposed to undertake assessments at different scales. The same can be said of the Environmental Life Cycle Assessment, a tool which can be applied to a good or service, the performance of a company or a country.

2.8.2 Comparative analysis of indicator results

A review of the indicators highlighted the following findings. On the one hand, the indicators explored have set the foundation for the development of the SI. Moreover they have provided insights into the performance of countries, including the two countries under review. Table 2.6 illustrates the performance of specifically selected developing nations, and one can note that performances are generally consistent across all indicators. This is certainly the case for the first five indicators. Furthermore, the scores largely conform to the pre-established expectations of the performance of each country.

Conclusions were also drawn from indicators other than those displayed in Table 2.6. It was possible to extract valuable information in the form of variables and indicators which were useful towards the development of the SI.

Regarding sustainability and issues relating to the environment, it is common to adopt a less technical attitude and discussions are often limited to the study of what is 'ecologically good or bad', and to qualitative assessments of the impact of human development. It has been argued, and validly so, that sustainability is a far too abstract and complex (multi-faceted) issue to be quantified. In answer the following arguments are proposed: (i) Willingness and capability to quantify such abstract aspects as health, poverty, democracy and human rights, can and should be extended to issues of sustainability; (ii) Sustainability covers a multitude of issues, many of which share causality links which are simply too diverse and intricate to discern in a single exercise, however it is precisely due to the complex nature of the subject that an assessment tool is required. This only strengthens the case for such indices which can provide a more accurate and comprehensive picture of the 'environment'. Furthermore, given that decisions are strongly reliant on hard facts, data and numbers, appropriate indicators can guide appropriate action.

The aim is not to find the easiest approach for gauging sustainable development in IUWM, in which case assessments of sustainability might not be applicable. The objective is to explore the possibility of a sustainability index which can gauge the capacity of a system to be sustainable; given its current conditions, observing past practices, and accounting for future needs; in an effort to modify current behaviours.

Table 2.6: National indicator rankings

Country	ESI Rank [1]	EPI Rank [2]	EVI Value[3]	WPI[4]	HDI[5]	Falkenmark[6] 1000m³/capita/year	Ecological Footprint[7] ha/capita	DRI[8] (No. of deaths/year)
Southern Africa (SADC member countries)								
Botswana	34	-	181 (resilient)	56.6	0.58	5.4	1.30	2
Lesotho	-	-	280 (vulnerable)	43.2	0.54	2.4	0.60	2
Mozambique	107	121	227 (at risk)	44.9	0.32	8.0	0.70	4828
Malawi	74	91	249 (at risk)	38.0	0.40	1.7	0.70	28
Namibia	32	92	200 (resilient)	60.0	0.60	15.0	1.60	0
South Africa	93	76	324 (highly vulnerable)	52.2	0.70	1.2	2.80	62
Swaziland	-	101	243 (at risk)	53.3	0.58	3.6	1.10	26
Tanzania	63	83	257 (at risk)	48.3	0.44	2.5	0.90	22
Zimbabwe	128	74	200 (resilient)	53.4	0.55	1.5	1.00	5
Zambia	60	98	210 (resilient)	50.4	0.43	10.7	0.80	0
Others								
Ghana	49	72	279 (vulnerable)	45.3	0.54	2.1	1.10	10
Uganda	57	78	283 (Vulnerable)	44.0	0.44	2.4	1.50	13
Brazil	11	34	281 (vulnerable)	61.2	0.75	36.4	2.20	106
India	101	118	381 (extremely vulnerable)	53.2	0.57	1.9	0.80	2932

1. Yale and Columbia University. 2005. Environmental Sustainability Index: Benchmarking National Environmental Stewardship.
2. Yale and Columbia University. 2006. Pilot Environmental Performance Index.
3. SOPAC & UNEP. Building Resistance in SIDS: The Environmental Vulnerability Index
4. Paper by Lawrence, Meigh and Sullivan, 2002
5. Paper by Lawrence, Meigh and Sullivan, 2002; & Human Development Report, 2006
6. Paper by Lawrence, Meigh and Sullivan, 2002
7. Roughly 1.89 ha are available/person (http://globalis.gvu.unu.edu/)
8. The Disaster Risk Index is represented either as the absolute or relative number of disaster related deaths per year (UNDP, 2004)

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Namibia	32	92	200 (resilient)	60.0	0.60	15.0	1.60	0
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3. Development of the index

3.1 Integrated Urban Water Management

The literature review in chapter 2 has introduced and clarified the meaning of Integrated Urban Water Management (IUWM), and how this fits in with the broader concerns for Integrated Water Resource Management (IWRM). It has also emphasized the need for inter and multi-disciplinarity in the area of water management. The following sections will therefore not focus on the theoretical principles of IUWM but rather address more practical concerns, starting with a depiction and detailing of the urban water cycle, followed by a short discussion on the components of urban water management and the types of services addressed. The process of indicator development will then be discussed and the chapter concludes with the presentation of the Sustainability Index (SI).

3.1.1 The urban water cycle

Figure 3.1 shows the urban water cycle. The diagram is illustrative of the three major services concerned, namely; water supply, sanitation and sewerage, and stormwater. It is also inclusive of the losses of water in the system through natural processes (evapotranspiration) or human actions and interactions with the system. It takes into account the critical issue of Non-Revenue Water (NRW) and disaggregates it into components; Free Basic Water (FBW) and Unaccounted For Water (UFW). In addition, sources of water other than those formally established by service providers are also detailed in order to draw attention to potential supplementary water sources.

From Figure 3.1, it is possible to view the interconnectedness of the urban and natural water cycles; the urban water cycle representing a subset of the natural water cycle. This illustration also indicates the sources and sinks of water in the urban cycle (1). From that point onwards, water is collected and treated for consumption (2). The majority of this goes to the water network for distribution (3), however a percentage is lost due to evaporation (4A.1). Of the water directed to consumers, a great part of it is accounted for throughout the distribution network and reaches the various consumers via the same.

In less developed countries, however, there is a considerable amount of water that is not billed, which is termed Non-Revenue Water. NRW (4), has two major components; Unaccounted For Water (4A), which includes all the water that leaves treatment facilities but does not officially reach consumers. In other words it leaves the treatment facilities accounted for but does not get registered or metered at the consumer end. This may be due to leakages in the network, illegal connections, vandalism and theft of components of the system. The second component is Free Basic Water (4B), the provision of which is not common in many countries. This is nonetheless a significant component of NRW, not only because it applies to one of the case studies – Hermanus, South Africa – but also due to the precedent it sets in terms of free provision of an essential and often unaffordable service in an environment of extreme poverty and inequality.

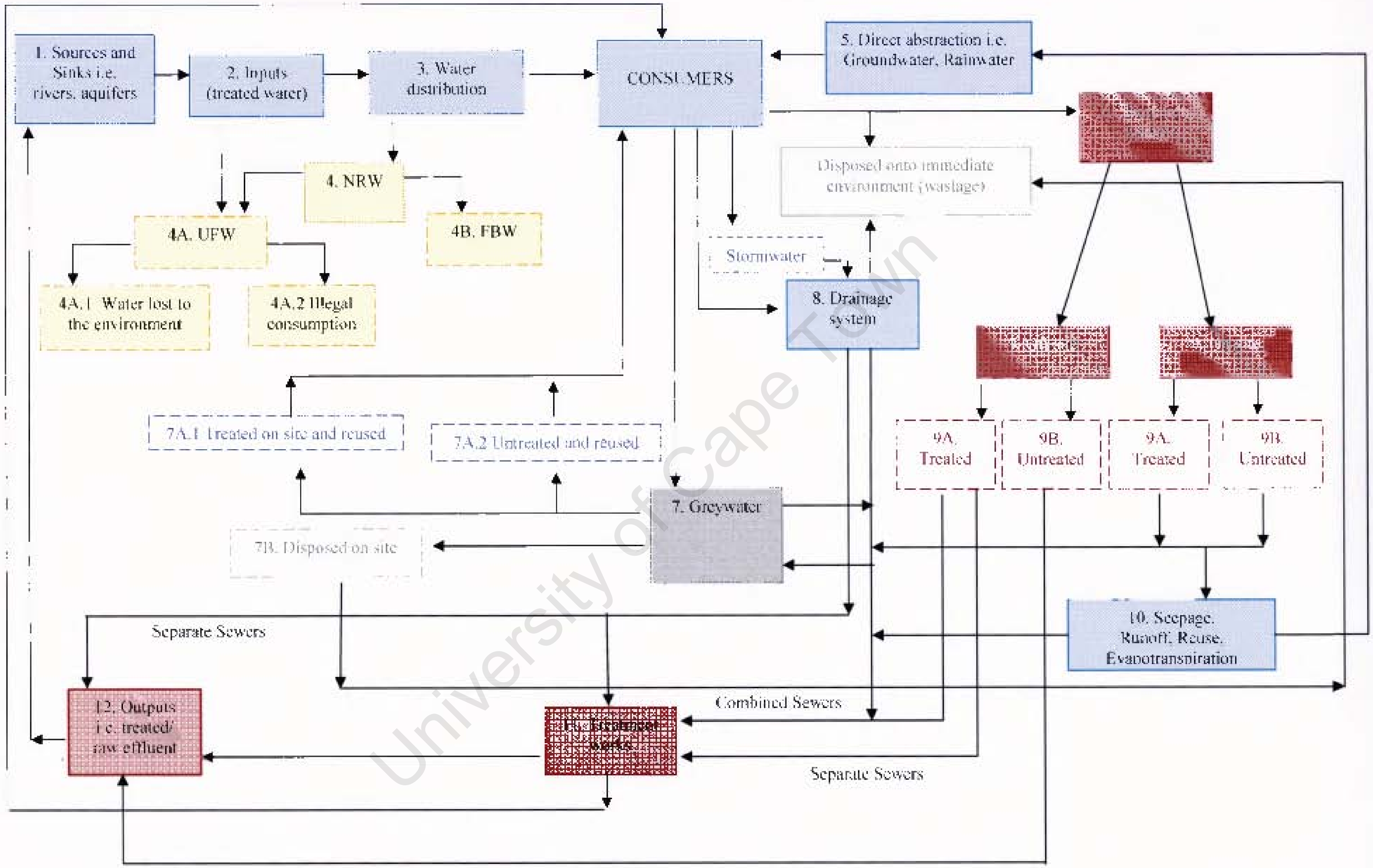


Figure 3.1: Urban Water Cycle

Aside from water supply via the formal network (4), consumers may have other sources at their disposal. There can be abstraction from boreholes, wells, springs, lakes and rivers, and use of rainwater; what has been termed 'direct abstraction' (5). Alternative sources of water include; reuse of untreated or treated greywater for purposes other than drinking (7A.1, 7A.2), reuse of onsite treated or untreated wastewater (10) as well as reuse of off-site treated wastewater (11). A percentage of onsite treated or untreated wastewater may seep into the soil and can be stored as groundwater, part of it evapotranspirates and the remainder is either utilised or conveyed to formal drainage systems as runoff (10).

Water sourced or supplied to consumers proceeds to a number of destinations; it can be used in maintaining sanitary systems (6), discharged as used greywater (7), discharged into stormwater networks (8), or simply discharged onto the environment as a result of losses or neglect. The type of sanitation – on-site (9A) or offsite (9B) – and the combination of wastewater and stormwater systems employed, will determine the volume of bulk water abstracted which has moved through the system. This will either undergo treatment (11) before it is returned to the environment as an output (12) or will be discharged directly onto receiving environments as an output (12). This then leads back to the various sources and sinks (1), hence completing a full cycle (cradle to grave).

The purpose of this representation of the urban water cycle is two fold; firstly, it provides a review of the alterations to the natural environment due to societal activities and human-induced impacts. Secondly, and as a consequence of the first objective, it responds to these alterations so as to derive the most benefits for society with the least impacts on the environment. In other words, by highlighting the interconnectedness of urban water systems, with particular emphasis on the three water services, it is possible to identify linear functions and inefficient practices with the ultimate aim of closing the loops and maximising functionality and use of resources.

Integrated Urban Water Management questions the traditional, inflexible and somewhat persistent approach of separate provision of water services. Given that the availability and reliability of water supply is becoming less certain, and in view of growing populations, expanding societies, competing uses and more recently; climatic changes; the need for alternative solutions to fresh water supply has become apparent. This brings the notion of a balanced urban water system strongly into focus. It encourages trade-offs, substitutions, and where possible elimination of current unsustainable practices, through a holistic approach to planning, implementing and maintaining water services. Furthermore, it underscores the importance of demand and supply management; education, awareness creation and stakeholder consultation; all this within an environment supported by appropriate regulation and policy (Mitchell, 2006).

3.1.2 Levels of service (LOS)

The following section will clarify on what is meant by levels of service, which services are included, and what are some of the current benefits and limitations of service provision. The term 'levels of service' as employed here implicitly refers to the degree to which the combination of services satisfies social, cultural and economic preferences taking into consideration acceptability, accessibility and convenience.

Firstly, the services accounted for include the three major water-related services, namely; water supply, sanitation (including the disposal of wastewater) and drainage. In the case of wastewater, the level and type of service often dictates under which category this will be addressed; whether it is a sanitation issue or a drainage problem.

Although not directly related, a fourth service merits inclusion; solid waste management. The issue of urban litter is one that is experienced in every city worldwide. In developing countries, where urbanisation is leading to a growing consumerist movement and the capacity for solid waste management continues to fall behind the growth level of cities, evidence has been given to the term 'pollution of poverty'. In response, practical solutions have been put forth for the efficient management of urban litter. The ultimate aim is the preservation of the environment, of which aquatic systems are of most concern to this discussion. IUWM is a vehicle through which the problem of urban litter can be directly linked to the pollution of aquatic systems, so as to elicit parallel and efficient responses towards the preservation of such environments.

The following Table (3.1) presents the five categories of service adopted in this thesis, including the degree of accessibility and commodity offered.

Table 3.1: Levels of service

LOS	Water Supply	Sanitation	Drainage	Waste collection
LOS 1	- Full supply (in-house connection)	- Conventional sewerage - Simplified sewerage - Alternate sewerage i.e. vacuum sewerage	- Conventional - SUDS	- Frequent & reliable (weekly)
LOS 2	- Roof tanks - Yard tanks - Yard taps	- Septic tanks - On-plot sanitation (improved)	- Conventional - SUDS	Regular (once every 2 weeks)
LOS 3	- SSIPs - Public tanker - Public standpipes	- On-site communal facilities (improved latrines)	- Greywater management	Infrequent (once monthly)
LOS 4	- Communal standpipes - Vendors - Kiosks	- Bucket toilets	- Informal drainage	Informal collection (> 4 weeks)
LOS 5	None	None	None	None

3.1.3 Benefits and limitations of service provision

The achievement of sustainability in the context of developing countries demands that social upliftment principles be prioritised. Towards this end, IUWM advocates far more than integration, it proposes that the collective work for the individual and that the individual gains work to benefit society as a whole. For example; water supply and the provision of related services have direct and evident benefits for individuals, however on a large scale, improved individual health contributes to the preservation of society as this decreases the probability of the outbreak of diseases such as cholera.

Economic benefits and environmental gains are less evident but no less important. Improved health can translate to improved productivity, and this in turn can lead to increased incomes and economic growth. Efficient provision of water can contribute to the preservation of water resources and ecosystems, particularly in areas experiencing scarcity or water stress. The adequate management and disposal of wastes, through the use of appropriate sanitation and drainage methods, also contributes to the preservation of these systems and the reduction of pollution.

It is however widely accepted, both in literature and amongst governments, institutions and society that service provision in the developing world has continued to fall short of current demands, not to mention the demands that are estimated for future generations. This has compromised the well-being and development of millions worldwide. Reemphasising the important role that water-related service provision plays in the functioning of cities and recalling the potential benefits such challenges cannot go unaddressed. First and foremost, this entails the consideration of social aspects of water provision, which demand that there be fairness and equality in resource distribution. From a less altruistic point of view, if one acknowledges the invaluable role that water plays in the sustainability of societies, then failure in service provision becomes a problem and challenge for all; rich or poor.

Returning to the context of developing countries, water related morbidity and mortality rates continue to be unacceptably high, presenting challenges for socio-economic development and contributing to the widening gap between the poor and the rich. The problem evolves from one of social inequality to highlight limitations in political leadership, economic growth and stability, infrastructure investments and inadequacies in management.

Without denying the role of water as a public good, it is equally important to acknowledge the costs imbedded in the delivery of water-related services, often requiring large investments in infrastructure and management. Economic considerations are key determinants of the levels of service to be provided, based on the ability of consumers to pay for these services, and the need for cost recovery. This again raises significant challenges, in particular for less developed countries where the majority of the population subsists on very low incomes, if any, and cannot afford the tariffs imposed. In response governments can, and have, addressed this challenge. An example of this would be the adoption of basic and/or block tariffs which can ensure that those who cannot afford are supplied with a minimum and those that consume far more than the stipulated minimum, are duly charged. Such, and similar, strategies have been implemented in South Africa, and the success of these initiatives in certain settings merits broader consideration.

The social and economic aspects are strongly interlinked, but do not work in isolation. Achieving the necessary balance between ensuring the general well-being of society whilst maintaining a level of economic stability, has not proven an easy task, as evidenced by the failure to achieve cost-effective and extensive service provision in many African cities. This weighting of priorities demands a high level of capacity from governments to develop appropriate policies and guide development; and of institutions to put this into practice in an efficient and resource-wise manner. However it is often the case that institutions are too small or too big, under-capacitated or under-resourced, too urban or too rural to "effectively address sustainability and poverty concerns" (DPU, 2006).

The over-use of water resources is a consequence in itself. As populations and societies grow, so does the demand for water, and this coupled with the polluting practices of cities places a burden on existing freshwater resources. Both wastage and pollution of resources bear significant costs: environmental costs due to the damage to ecosystems and dependant species; social costs due to the degradation and loss of such environments; and economic costs due to escalating investments for the mitigation and restoration of aquatic systems.

The discussion has thus far highlighted that water services are essential for the preservation of life and the maintenance of societies, but that in spite of this there is an economic cost to provision which must be duly reflected. It has also pointed to the inadequacies of governing and administrative institutions in ensuring that services are delivered efficiently, highlighting the lack of resources as the main challenge; human, financial and otherwise.

The question remains of how to prompt change and encourage improvements, and in doing so, how to assess the state of service delivery? In part, this research proposes to respond to this question by monitoring the performance and capacity of cities to be sustainable. Progress however demands more than monitoring, it demands that targets and goals be set against which improvements are measured. Due to their wider recognition and acceptance, the Millennium Development Goals were explored and the table in Appendix B illustrates the links between poverty eradication, water services and the MDGs (WHO & UNICEF, 2004). The table highlights potential benefits to health, productivity and wealth as a result of improved water and sanitation provision. Issues such as gender equity and vulnerability are also addressed, as are concerns for the environment and the preservation of ecosystems. These will be reflected in the indicator developed, with the aim of representing developmental agendas as well as pursuing local priorities.

In conclusion, it is important to stress that although efficient water supply and service provision is essential for growth and progress in African countries, it is not sufficient to ensure development in this area. This must be complemented by work in other sectors and at different levels of society. It demands certain complementary inputs such as active community participation, appropriate technologies and design, improved capacities and most importantly, an overall willingness for change.

3.2 Theoretical framework and index model

Multidisciplinarity and integrated approaches have thus far been emphasised as the vehicles which can enable coordination and action at the appropriate level to guide sustainable development. This paradigm shift from the conventional and dogmatic single discipline approach was not only central to this research, but its benefits have also been evidenced both in literature and practice. An acceptance of this ideology demands the establishment of priorities, goals and targets which can drive the developmental movement. Towards this, the need for performance assessment and monitoring is evident, therefore tools which promote an understanding of sustainability and inform on the progress towards sustainable development are required.

A study of urban water management issues exposed a number of links and loops between the different parts of an urban water system. This complexity can at times render such assessments impractical or unfeasible, particularly where cooperation across the disciplines is lacking. To address this potential shortcoming, this research explored the theme of multidisciplinarity embodied in the principles of systems theories, advocating integration and cooperation across disciplines for better exposure of some of the links within and between urban systems, its beneficiaries and supporting ecosystems. Integrated Urban Water Management was interpreted as the tool which enables cross-linkages and the application of this concept of multidisciplinarity, further enabling the integration of the various physical, social, economic and environmental elements within the water sector and across related sectors.

A requisite of any assessment is the identification of suitable tools for reporting on the issue at hand, and the identification of methodologies for assessment. These can be simple assessment criteria, performance indicators and/or conceptual models. Conceptual models can often be complex and tend to involve a number of parameters for which measurement is resource intensive. On the other hand, assessment criteria are largely subject to qualitative assessments and fail to provide the numerical dimension needed and desired. Indicators provide a compromise between these two approaches; on the one hand they allow for both qualitative and quantitative assessments, and on the other hand – depending on the number and incorporation of indicators – they can address the complexities of reality which are sought by model representations. In short, well defined indicators can facilitate the communication of sustainable development.

The literature review has highlighted what has and is being done with regard to improving the understanding of complex and often abstract concepts of sustainability. Furthermore it has demonstrated that not only the interest but also the work for sustainability exists and has exemplified this through the discussion on some of the tools developed for monitoring sustainability. Incorporating elements from theory and the practical examples discussed, the following steps were used in the development of the SI (Figure 3.2).

The methodology adopted was based on the five-level model by Lundin *et al.* (2002), coupled with the step-wise methodology proposed by Nardo *et al.* (2005). The first step was to build a solid backdrop to the indicator by exploring the theory on sustainability and clearly defining goals and expectations. From this, it was then possible to substantiate the index by identifying the underlying issues which had to be represented and measured. Indicator selection is by nature a subjective exercise, influenced by the views of the developers or other influential sources. It was therefore necessary to ensure that the process of development was, above all, consistent, clear and logical. Secondly, in order to maintain a measure of relevance it was necessary to recognise the views of others who have either undertaken to do similar work or have experience in the fields of study, and practice concerned.

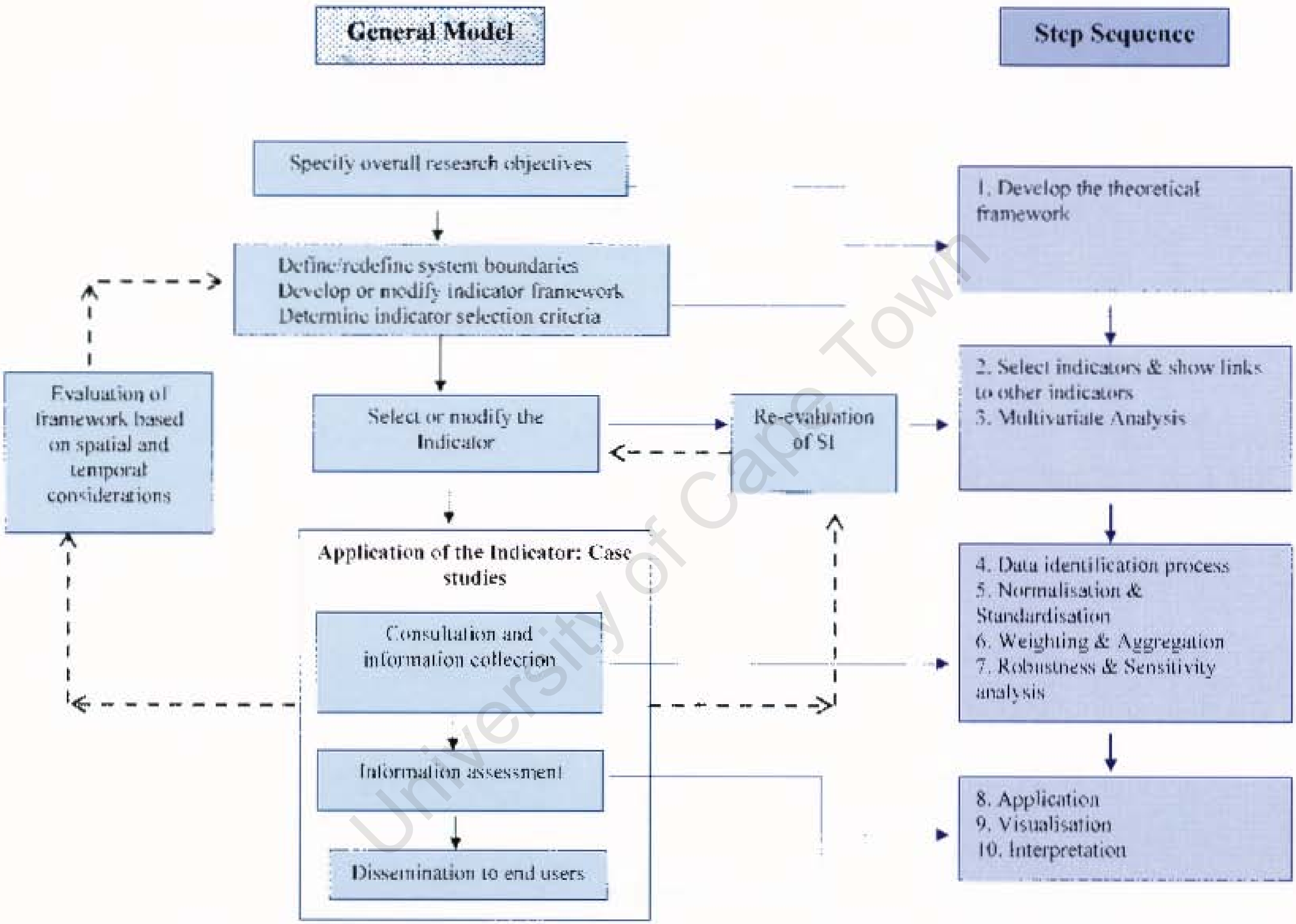


Figure 3.2: Step-wise approach to SI development (adapted from: Lundin *et al.*, 2002; Nardo *et al.*, 2005; and Robèrt *et al.*, 2002)

Having established the index structure, the index was then applied to two case studies. This was done to help determine the methodical soundness of the index and establish the usefulness of the tool, much in the same way as pilot projects introduce changes at a manageable scale, without exhaustive resource outflows. It was also necessary to test whether indicators selected were time and space-relevant and whether there was sufficient quality data to inform these, as this is perhaps the biggest constraint to the use of indicators.

As a check, the researcher established a pre-condition that applications of the index should yield expected results. In other words, the results should not deviate considerably from the observable facts for both case studies. Aside from this, it was necessary to test whether the indicator could provide significant information on the capacity of a city to be sustainable based on robust measures, both qualitative and quantitative, which can then inform appropriate policy and provide direction for activities in the water sector. To this end it was stipulated that results must be well represented so as to be easily interpreted and support pertinent conclusions.

The final step was to communicate the findings to the target audiences, taking into consideration two factors: firstly; audiences might not be familiar with the theoretical and technical aspects of the process and therefore presentation of the tool must always be simple and illustrative of the results it wishes to portray. The second point is that if the indicator is to be applied (not simply interpreted) elsewhere, then mechanisms to facilitate the use by others should be put in place. The complexity, time consuming and resource-intensive nature of some indicator tools have certainly contributed to some misgivings and a general disinterest for such assessment tools. To avoid this, the developer undertook additional steps to improve the user interface feature of the index, by exploring an alternative packaging tool to the basic Microsoft Excel Spreadsheet. Furthermore, it will be stressed that although the SI is data-intensive, much of this information already exists and was obtained for the two case studies in question.

The above steps are iterative, to be employed until plausible results and a satisfactory product are obtained, but at the same time recognising the time and resource constraints. These will be explored individually in the sections that follow.

3.2.1 Building the foundation for sustainability

In this section the conceptual underpinnings of the sustainability indicator will be addressed, however before any such attempt to define the structure, it is necessary to address two very important aspects of the process. Firstly, a clear understanding of sustainability is required; an exploration of its dimensions as they relate to the topic at hand; this will be termed the conceptual model. Secondly, a clear characterization of the indicator must be provided, expressing the purpose and objectives of its development and composition.

In answer to the first concern; there is no clear and unique definition of sustainability in literature; there are however a number of definitions which articulate the message that the term sustainability conveys or should convey, and these have already been discussed.

For the purpose of this research, sustainability was extrapolated from the triple bottom line perspective; highlighting the social, environmental and economic dimensions; and yet shortcomings of this model have demanded revision. For one, this definition fails to account for the institutional dimension, which explores human interactions in an environment governed by rules and regulations, cultural beliefs and societal values, and which also provides the legal interpretation of 'integrated management' necessary for the regulation of (inter)actions and the minimization of impacts. In favour of revising the triple bottom line approach, Valentin & Spangenberg (2000) present a 'Prism of Sustainability' composed of the four dimensions of sustainability, namely: social, economic, environmental and institutional. These are partially correlated with the four categories of capital; man-made, social, natural and human capital.

The institutional dimension in this case represents both political and administrative aspects, however the political and administrative aspects contribute significantly to the success or failure of integrated management, independently of one another, and as such merit a categorical separation. This is strengthened by the context in which the indicator will be applied. Corruption, poor representation and low levels of democracy are commonly cited problems in almost any public (and private) sector in the cities of Africa. On the whole, legislative and political support for development has been heavily criticized. At the same time, understaffing, under-resourcing, the brain drain phenomenon and the loss of institutional memory continue to be strong contributors to poor water management in the public sector. While intrinsically linked, the two aspects present unique sets of problems which must be tackled accordingly, hence the call for a separate and fifth dimension of sustainability; the political dimension.

To address the second concern, the ensuing discussion will detail the characterization of the indicator. As Bertrand-Krajewski *et al.* (2000) appropriately point out, a common misconception in assessment and measurement exercises lies in the emphasis on "what is to be measured?" rather than answering the fundamental question; "what do we want to know?". The means of measurement will undoubtedly follow from the problem identification. It was thus vital that the objectives and desired goals of this research be clearly stated at the onset, in order to avoid the common pitfall of attempting to assess too much and engage in lengthy and costly data collection and interpretation exercises, which can ultimately lose relevance to complexity.

3.3 Indicator characterization

3.3.1 Redirecting the aim of research

In practical terms, the aim of this research was to assess whether urban water systems have been able to consider and integrate the five dimensions of sustainability at both management and strategy levels. This then required the integration of both spatial and temporal considerations in the development and application of the indicator, and somewhat strict boundary definitions. Following the line of reasoning presented by Bertrand-Krajewski *et al.* (2000), there are common methodological problems which unless addressed and surmounted will render any realistic attempts at assessing and monitoring sustainable urban water management irrelevant. These are:

- Clear definition of research and operational objectives.
- Concerted multidisciplinary measurements.
- Quality of metrology

These are valid points which must be, and were, addressed in the process of defining and developing indicators. Firstly to define the objectives of the research the following questions were answered:

1. Problem identification: What must be answered or what is the problem?
   Based on the realisation that service provision in many African cities has fallen considerably behind the demand, and in recognition of the significant social, environmental and economic impacts, the researcher identified that the problem is one of inappropriate management of resources. Furthermore it was established that this failure in water management may very well be the result of poor integration and the adoption of silo-type approaches in addressing what is otherwise a multi-disciplinary and complex sector. The problem posed by this research is how to assess and quantify the extent of such unsustainable practices in urban water management.

2. Stakeholder assessment: Who are the interested parties and who will benefit from the indicator?
   The tool was developed with the aim of informing political, social and legislative entities, towards reinforcing social awareness and through such encourage political and legislative change. The relevant parties identified are; government institutions, management authorities and the public.

3. Problem definition: What must be measured in order to solve the problem?
   The broader issue is a city's or region's incapacity to perform sustainably. In the context of this research, problem definition demanded the assessment of the capacity (or lack thereof) for sustainability, hence the need for a measurement tool which assesses the capacity of a city to undertake sustainable management of urban waters.

4. Identifying constraints: What are the constraints or limitations to answering these questions and solving the problem?
   This entailed the identification and description of all possible limitations to the research and how to overcome these given the resources available. Research constraints and limitations were identified and are detailed in Chapter 6.

5. Boundary definition: How were the boundaries of the research defined? What were the appropriate space and time scales and are these realistic?
   Having understood the nature of the research and its limitations, it was then possible to set reasonable temporal and spatial scales. The indicator structure will retain flexibility to enable, when and where necessary, adjustments to the spatial and temporal boundary definitions. Spatially, the indicator was limited to city-level application. Application was undertaken for different case studies (Hermanus and Maputo), to test applicability at different scales of development and growth. The time dimension presented a greater challenge. Given the four months in which data was collected, analysed and interpreted, it was not possible to track temporal progress. This might in fact have been a futile exercise had it been attempted, because the

action-response time periods tend to extend beyond a couple of months or even a year. Consequently these time considerations must be accounted for when employing the index for monitoring purposes. In this way the progress tracking characteristic of the index can be tested.

To complement the principal aim of this research proposed in the introductory chapter and partially answered by the above questions, categorical objectives were set out and will be discussed. This approach of defining the underlying precepts of research and the desired outcomes ties in closely with the Bellaglio Principles for development and assessment of sustainability indicators (Walmsley *et al.*, 2004). The 29 Bellaglio Principles provide a set of criteria for the selection of indicators, in order to ensure that these are not only relevant to the issues at hand but also relevant to the system for which they will be used. The first principle underlines the need for a clear guiding vision, informed by the desired outcomes and goals towards the achievement of sustainable development.

Selection of indicators through the 29 Bellaglio assessment principles is a comprehensive exercise which is resource intensive; requiring both significantly greater time and capital resources than is available at the level of this thesis. A less exhaustive approach was employed here. Goals were established in line with the pillars of sustainability established, and these are presented as follows:

Research objective: To undertake a well defined, methodical and multidisciplinary approach to urban water systems assessment based on rational metrology and the identification of 'lacking' areas of research.

Scientific/technical objectives:

- Link the concept of sustainability and integrated water management, as well as apply the dimensions of sustainability to urban water management.
- Introduce a quantitative measure of performance for IUWM.
- Apply the sustainability indicator to real case scenarios to validate model assumptions.
- Improve the knowledge of IUWM in case study areas, identifying areas for improvement, and where possible, make suggestions for improvement.
- Establish an initial database of the two case studies for future users.
- Introduce the notion of spatial benchmarking through indicator results; starting with the two case study areas.
- Emphasise the need for temporal progress-tracking and improved monitoring, linking this with the indicator.

Social objectives:

- Expose the issues in service provision and link these to urban water management, especially drawing on the trade-offs between social and economic development.
- Create the awareness for sustainability concerns in urban water management.

- Highlight society's contribution to both the problems associated with water management as well as the poor responses to solving these problems.
- Promote a social consciousness to encourage change at this level but also to capacitate society to drive change at the political and institutional level.
- Demonstrate the social impacts, mainly health and wealth related, associated with water services, particularly for the poor.

Economic objectives:

- Emphasise the role of water and its services in poverty alleviation.
- Highlight the links between improved management and the possible economic gains/savings.
- Emphasise the role of investments in infrastructure development and service provision, in order to access the poorer income groups and hence contribute towards poverty alleviation; reemphasising the current under-exploitation in this sector.

Environmental objectives:

- Introduce, in practice, the environmental sustainability dimension to urban water management.
- Track performance with regard to environmental impacts.
- Underscore the current water scarcity and insecurity situation in much of developing Africa.

Institutional and Political objectives:

- Emphasise the role of government and institutions in urban water management.
- Highlight laggards and leaders, both sectorally and across the different study areas through indicator results.
- Correlate this work with similar initiatives undertaken by institutions involved in the study or management of urban waters to enhance complementary use.

3.3.2 Multidisciplinarity and the systems approach to assessments

The concept of multidisciplinarity has been extensively discussed. Suffice to say that the sustainable management of urban systems demands that different disciplines be brought together and dealt with in an integrated manner. However this has often been difficult, not only owing to the reluctance of the different discipline groups, but more importantly, as a consequence of this lack of communication and coordination, data measurements often follow different methodologies, have adopted different time and space scales, and are represented in different units of measurement; consequently these cannot be compared and merged. While these difficulties have been recognized and some attempts have been made to establish commonality of assessment, this still means that any attempts at integration require a beginners' approach whereby data needs to be collected or at least converted to suit the particular tool.

In developing the sustainability index, components were used to represent the different dimensions of sustainability. These five dimensions form the support structure of the index and were termed indicator components. This in itself addresses the multi-dimensional nature of urban systems but it still hides the various disciplines involved such as; hydrology, sociology, ecology, geology, meteorology, anthropology, economics and applied engineering. These were represented by the different indicators and variables employed. The holistic approach taken here proposes to address the dimensions of sustainability as they apply to the 'business' of managing all urban water aspects rather than the single service performance assessment, as suggested by some.

3.3.2.1 Linking the components of sustainability

It is not sufficient to identify the dimensions of sustainability and set indicators for these five dimensions; these alone "*are only expressing some of the necessary preconditions to maintain the self-reproduction cycles of the (five) interlinked subsystems, without giving any information on the character and effect of the linkages*" (Valentin & Spangenberg, 2000). In order to render the sustainability index commensurate and operable it was necessary to go a step further and through indicator selection interpret the interlinkages between the five dimensions of sustainability. The following examples illustrate where these linkages can be drawn:

- The indicator "water use", alternatively "users of water", gives an indication of the distribution of the resource for the various competing needs, which is ultimately limited by the capacity of supporting environmental systems. Yet at the same time it provides an idea of the equity of distribution to the various users. This links the social and environmental dimensions.
- The indicator "levels of service (LOS)" shows links with the ability of users to pay for those services, however it addresses far more than the economic dimension, going to the core of the Dublin principles to address the human and social rights of individuals to have access to basic services. Furthermore, the indicator illustrates the link with the environmental dimension as a result of the impacts related to poor service delivery on resources such as groundwater, soil and surface water systems. It also links in with the institutional and political spheres through the capacity needed to provide adequate and differentiated levels of service as well as the policy environment necessary to support such activities.

The list of examples is as diverse as the number of links between the dimensions of sustainability. The discussion on the urban water cycle serves to illustrate some of the overarching links, and this idea of interlinkages has been embedded in the selection of indicators.

3.3.3 Addressing the metrological dimension of assessments

Metrology is the science of measurement, and it involves the characterization, understanding and communication of units of measurement (Wikipedia, 2007b). The need to address metrology is strengthened by two main concerns; firstly, the combined use of data presented in different units; and secondly, the issue of accuracy and reliability of data, what is termed traceability. Traceability refers to the ability to relate measurements or values to referred sources, and for which uncertainties are stated. An integral part of traceability is therefore the determination of uncertainty (Wikipedia, 2007b). Both issues are of concern here due to the limited, and at times questionable, data used.

Commensurability of data will be significantly relevant in both selecting variables and calculating the final index, and this will be addressed in more detail in Chapter 4. In order for the indicator to be relevant it must reflect real conditions, and for this to be true, data must be both reliable – obtained from dependable sources – and uphold a certain standard of accuracy, given an internationally accepted margin of error. These conditions will be pursued when acquiring and selecting information for use.

With regard to uncertainty, this research has endeavoured to use sources which are both reputable and frequently referenced. However, data was limited in the case study areas and as a result qualitative assessments as well as less 'accurate/reliable' data were used. Although an important aspect of assessment, the execution of field studies and direct data collection were not direct goals of this research. This was nonetheless undertaken where necessary towards building a more reliable database. A major limitation was that some data simply does not exist, and alternate methods of attributing variable values were required. Mention is made where this is the case.

3.4 Indicator selection

This indicator development initiative is part of a broader research thrust and an appreciable amount of work had already been done by Stoeckigt (2006) and Snoek (2006). Taking that into consideration the indicator selection process was guided by the following steps:

1. Review of existing indices to identify suitable indicators and variables. Where applicable indicators were introduced or removed, resulting in a revised indicator structure.
2. Development of selection criteria to compare the research objectives to the revised indicator structure. Checks were performed for each indicator as will be discussed in Section 3.4.1. A precondition was established to ensure that indicators were compliant with a minimum set of criteria.
3. Comparison of indicators selected thus far with those provided by the World Water Assessment Programme (WWAP) for South Africa. WWAP is the vehicle through which feedback on the progress of sustainable water development goals and targets can be achieved. Such targets are discussed and set by World Water Forum (WWF) member countries and this initiative is supported by the UN. This was aimed at linking this work and the SI with internationally recognised initiatives.

4. Comparative analysis with relevant local (for South Africa and Mozambique) monitoring initiatives, emphasising the need for local relevance and support for indicators.
5. Preliminary consultative approach during data collection, which enabled not only acquirement of data but also an exchange of views regarding the indicator framework, furthermore it enabled discussions on the issues relevant to both case settings.

This phase of indicator validation and alteration was essential. While time constraints limited the degree of consultation undertaken, it was necessary and possible to engage with stakeholders, albeit to a small extent. Further consultative and participatory work is required to make relevant and more widely acceptable decisions regarding the index.

3.4.1 Indicator selection criteria

Donnelly *et al.* (2007), provide a comparison of different sets of criteria used for indicator selection, with the aim of developing a set of criteria for selecting environmental indicators for use in strategic environmental assessment. A similar approach was used here, taking the summary of criteria presented by Donnelly *et al.* (2007), and selecting criteria most relevant to the needs of this research. Table 3.2 summarises the set of criteria adopted in the development of the sustainability indicator. This was coupled with input from various professionals in the institutions involved in water management both in Mozambique and in South Africa, as well as academics and experts in the field of urban water management.

The selection criteria were then compared to the revised indicator structure in a matrix presented in Appendix C. Indicators were assigned a score of 1 if in compliance with the criteria and 0 if not. The scores were summed up horizontally and the total used to determine whether the index merited an inclusion or not. A minimum compliance of 8 out of the 12 criteria was demanded, unless the indicator was extremely relevant to the overall structure of the index. If possible indicators and variables were altered and as a proviso were again compared with the selection criteria.

Ultimately, all indicators satisfied the 8 out of 12 compliance stipulation, granted that some were adjusted to ensure this. This then enabled the formulation of the index and its sub-components. Subsequent to this comparisons were carried out with the WWAP indicator set and the key focus areas for development in the water sector in South Africa.

Table 3.2: Criteria for guiding indicator selection (Donnelly *et al.*, 2007)

Criteria	Description and justification
1. Policy relevant and meaningful	This signifies an alignment with existing legislation, policy imperatives and in support of the sustainable development vision.
2. Scientifically (methodology and metrology)	The indicator should support the underpinning principles of sustainability (rational thought process) and must in itself be supported by a technically sound approach to data collection as well as logical methodological assessments.
3. Goal Oriented: Representative of real conditions and desired outcomes (Multidisciplinarity)	The index must assess progress towards the ultimate goal of sustainable development by establishing progress towards targets and the achievement of objectives. The indicator must be both spatially and temporally relevant, addressing the concerns of the area in question. Furthermore it must relate to real and relevant goals.
4. Understandable, easily represented and interpreted	Given the complexity and multidisciplinary of the subject at hand and the systems approach taken, it is important to maintain clarity not only for parties linked with the process of developing and using the indicator, but more importantly for those using this tool in decision-making. The indicator must be able to communicate the necessary information to all relevant stakeholders in a transparent and concise manner.
5. Show trends over time and responsive to change	The acceptance that sustainability is not a fixed goal but that rather it is strongly linked to the dynamism and transformations in society leads to the need to be reactive to those changes. For such, the indicator must be responsive to changes but still maintain the aspect of measurability towards the targets set.
6. Based on reliable and available or easily obtainable data (both quantitative and qualitative)	Information gaps, data availability and reliability are often limiting factors in any assessment, this is more so in African countries, and specifically with regards to some of the dimensions here addressed i.e. ecological data. The level of data gathering, processing and storing required for in-depth assessments is often incompatible with the realities of many institutions, where resources are scarce. It is necessary therefore to base indicator selection on those aspects for which data has been collected or can be easily done, not withstanding the need for reliable data.
7. Enables benchmarking or cross-comparisons	A key outcome of this research is to create awareness for sustainability concerns and the need for measurement and monitoring. Benchmarking can be a strong tool in this regard, particularly when it shows the laggards and leaders in a particular sector. Indicators selected must enable cross-comparisons, in other words these must be relevant to the different contexts in which they might be employed.
8. Cover (where possible) a range of issues (Interlinkages)	There are countless indicators which can be used for measuring sustainability and sustainable development but ultimately a selection must be made. This trade off between simplicity and relevance can be

	largely overcome through the selection of indicators which inform on a number of issues, extending beyond what is directly being measured.
9. Adaptable/flexible (substitutable and upgradable)	Given that priorities and issues vary both temporally and spatially, it is vital to maintain flexibility, not only regarding the indicators selected but the overall framework of the SI. Indicators must therefore be flexible to revisions and alterations.
10. Complement existing monitoring and management initiatives	Given that many institutions and organisations (in Africa) are understaffed and overloaded with work, any attempt at avoiding duplication of work is crucial. Indicator selection and SI development must therefore align with existing work.
11. Literature review and group effort	Indicator selection was also informed by an extensive literature review process which highlighted common indicators for assessment of sustainable development. A second significant source was the work done by Stoeckigt (2006) who initiated the work into the development of the SI.
12. Stakeholder input	Although the consultation process was limited, it enabled short discussions with a variety of stakeholders into the validity of certain pre-selected indicators. In some instances this served to reinforce the case for already selected indicators, or introduce new ones.

3.4.2 Indicator correlation with WWAP indicator issues

Following on the criteria-based screening process, a comparison with the 164 indicators, grouped under 11 challenge areas, proposed by WWAP was conducted. From this it was possible to establish any correlation between the SI and the WWAP, and where useful import, remove or revise indicators (Walmsley *et al.*, 2004).

The table in Appendix D illustrates the comparison between both sets of indicators, providing an assessment of the association between both, based on the judgement of whether there is: high, medium, poor or no correlation. It shows the indicator number in the SI structure which is closely linked to the WWAP set, therefore this table must be used in conjunction with the final revised indicator table presented at the end of this chapter.

Considering that the WWAP indicator issues are grouped under 11 challenge areas (see Table 3.3), a short discussion on the relevance of these challenge areas to the Urban Water Management sector will follow. It is important to note that while this exercise motivates the inclusion and exclusion of certain indicators, it is nonetheless subjective to the opinions of the researcher. A wide and inclusive consultative approach would enable more reliable and relevant comparisons.

The comparison carried out highlighted three important findings. The first and most immediate observation was that there is a high correlation between the indicators prioritised in this research and those introduced by the WWAP. The second observation supports the first, where it is observed that not all WWAP indicator issues find resonance in the SI. Going down the list of WWAP indicator issues it was possible to establish that several indicators monitor the same or similar aspects of water management. In the development of the sustainability index, this was avoided and in fact a further step was taken to select variables which could be representative of multiple issues and hence avoided repetition (selection criteria 8). Thirdly, this exercise permitted the detection of key/challenge areas for this project based on the WWAP challenge areas. It was immediately apparent that WWAP challenge areas 1, 5, 6, 7 and 11 are highly relevant to the sustainability index, as indicated in the following table. This was to be expected given that the challenge areas fall in line with 4 out of the 5 dimensions of sustainability explored in this thesis. The following table provides a summary of the WWAP challenge areas and it illustrates the correlation of these to the pillars of sustainability.

Table 3.3: Linking sustainability to the WWAP challenge areas (Walmsley *et al.*, 2004)

WWAP Challenge areas	Correlation with the dimensions of sustainability
1. Meeting basic needs	Social
2. Securing food supply	Social
3. Protecting ecosystems	Environmental
4. Sharing water resource	Social
5. Managing risks	Social and Institutional
6. Valuing water	Economic
7. Governing water wisely	Political
8. Water for industry	Social and Environmental
9. Water for energy	-
10. Ensuring the knowledge base	Social and Institutional
11. Water and cities	Social

Challenge area 11 addresses the urban dimension, which is central to this project and as such the underlying indicator issues feature prominently in the SI. The environmental dimension is addressed both in the sustainability index and in the WWAP challenge areas; however the correlation between both sets of indicators is low due to use of different monitoring variables. This does not reduce the significance of this facet of sustainability; it simply illustrates subjectivity of analysis and a preference for different indicators. Ultimately there are countless indicators which can be used.

The challenge areas showing least correlation are; securing food supply (WWAP Challenge area 2) and water for energy (WWAP Challenge area 9). Again this observation is not unexpected. In the urban context for which the SI was developed, both agriculture and energy generation are not prioritised, except where they impact on the socio-economic performance of cities. This is not to say that these are not significant, but that they do not take precedence over issues such as service provision, and are not as consequential as other uses, in the urban context. The WWAP indicator list is not sufficiently descriptive of the meaning and purpose of the indicators. This lack of clarity contributes to the subjectivity of this evaluation.

3.4.3 Evaluation of local level monitoring initiatives: South Africa's Key Focus Areas (KFAs)

The following 15 key focus areas (KFA) identified by the National Water Resources Strategy focus on addressing the principles embodied in two important pieces of legislation; namely, the National Water Act (No. 36 of 1998) and the Water Services Act (No. 108 of 1997) (Walmsley *et al.*, 2004). Through DWAF (Department of Water Affairs and Forestry) programmes and projects, this strategy provides the vehicle for implementation of national objectives towards developments in the water sector (Walmsley *et al.*, 2004).

- KFA 1: Ensure the sustainable development and management of plantation forestry to optimize equitable economic benefit, particularly in rural areas.
- KFA 2: Ensure the sustainable development and management of indigenous forests to optimize their social, economic and environmental benefits.
- KFA 3: Ensure Sustainable Forest Management (SFM) in South Africa by developing effective oversight of the sector and facilitating cooperative government.
- KFA 4: Promote sustainable forest management in Africa and internationally.
- KFA 5: Ensure that communities and disadvantaged groups are empowered to make use of trees and forest resources to support sustainable livelihoods.
- KFA 6: Ensure reliable and equitable supply of water for sustainable economic and social development including the eradication of poverty.
- KFA 7: Ensure the protection of water resources.
- KFA 8: Develop effective water management institutions.
- KFA 9: Align staff, stakeholders and the general public to a common vision for Integrated Water Resources Management (IWRM) and develop, capacitate and empower them in related best practices.
- KFA 10: Ensure provision of basic Water Supply and Sanitation for improved quality of life and poverty alleviation.
- KFA 11: Ensure effective and sustainable delivery of water services to underpin economic and social development.
- KFA 12: Ensure effective Water Services Institutions.
- KFA 13: Ensure effective local-level operations and management of DWAF water services schemes.
- KFA 14: Promote and support sound policy and practice of Water Services to achieve millennium targets in Africa.
- KFA 15: Promote IWRM in Africa in support of NEPAD.

In the context of urban environments and addressing the concept of sustainability from the five-dimensional point view, it was possible to establish the relevant KFAs for this project.

Focus areas 6 to 15 resonated strongly with the assessment priorities of this study. The remainder 1-5 KFAs promote improvements in the management of forests, a topic significantly removed from the current discussions. This nonetheless indicated that the SI does have good correlation with local priorities, and as such is representative of relevant and current issues.

3.4.4 Risk awareness

For the sake of completeness and in the interest of relating the work being done on sustainability indices to the work on complementary risk indicators undertaken by Snoek (2006), a brief comparison with risk and vulnerability priority areas was also conducted.

The literature review introduced the concept of risk and its relationship to vulnerability and sustainability. Five categories of risk were presented and those will be used here to establish a concrete link between vulnerability and sustainability (see Table 3.4). Table 3.4 highlights the correlation between potential risk factors and measures of sustainability in urban water systems. It also establishes the relevance of such measures to the development of a sustainability index. Most noteworthy are water quality concerns such as the management of wastewaters and the preservation of ecosystems through appropriate design and management. This is due to the current water polluting practices in developing countries, as well as the incapacity to introduce management, monitoring and mitigation initiatives which can reduce the levels of 'pollution of poverty'.

3.4.5 Addressing the need for stakeholder participation

Indicator development is inherently a subjective exercise; consequently it may only be representative of the opinions of a few. However it is important that the indicator is widely applicable and broadly acceptable. There is inevitably disagreement as to what assumptions, ideology and methodology should be employed. The continual progress in the field of indicator development does not permit a static approach but rather encourages a constant debate on the subject. While there are many scientific approaches to aid in decision-making, these do not lose much of the subjectivity but rather serve to test some of the assumptions made. One in fact questions whether subjectivity is a problem, seeing as solutions need to be place and time relevant and must cater to the needs of those employing them. The issue lies in poor decision-making, when it is limited to the opinions and decisions of few but which will impact the lives of many. It is for this reason, amongst others, that stakeholder input, public consultation and involvement is strongly advised. In the process of developing the SI, several institutions were consulted, both in South Africa and in Mozambique. However given the time limitations it was not possible to undertake the level of team work and stakeholder participation often recommended for the development of indicators.

Table 3.4: Identification of risk and vulnerability for sustainability assessments

Categories of risk	Useful measures of sustainability	Relevance to sustainability index
1. Divergent supply and demand levels	- Access to water supply - Level Of Service - Capacity to pay for services	This addresses the issue of inequitable resource distribution which is particular to urban areas. And it also addressed the socio-economic aspects of service delivery.
2. Water quality concerns	- Access to water supply -Wastewater management (quantity and quality) - Stormwater management (quantity and quality) - Compatibility of water systems with the surrounding environment - Compatibility of sanitation systems with the surrounding environment - Environmental stresses	In view of 'dwindling' quality resources, it is important to mitigate some of the impacts of the 'pollution of poverty' phenomenon characteristic of underdeveloped countries. Adequate management of urban waters; quality and quantity can address this.
3. Competing water uses	Use (categorical users of resources)	There must be a balance between all the users of water, inline with the development priorities in context.
4. Infrastructure failure	Investment levels Institutional and technical capacity	This involves not only the physical aspects of ensuring continuity and function but also the necessary financial and human resources to manage and maintain infrastructure.
5. Effects of climate change and resulting hydro-meteorological disasters	Susceptibility to disasters	The devastating impacts of recent natural disasters have threatened the sustainability of cities worldwide. Due consideration of these must be given in strategic planning.

3.5 Sustainability Index framework

The reviewed and revised indicator is detailed in Table 3.5. Given that much has already been said on this and that the table is sufficiently descriptive, it will stand as the final presentation and summary of the index. The multivariate analysis, step 3 of the process model adopted and illustrated in Figure 3.2, was then conducted.

3.5.1 Multivariate analysis

This chapter concludes with the verification of some of the assumptions made regarding the process and achievement of the index. There has been an increasing dedication to indicator development in recent times, but whilst the numbers have been significant, the validity and quality of some indicators remains questionable. For lack of concrete guidance as to indicator development, some indices have been based on randomly selected criteria and indicators, extremely subjective assumptions and at times illogical foundations. It is not surprising then, that both the concept and the tools themselves have received unrelenting criticism. For this reason Nardo *et al.* (2005) provide indicator developers with a detailed sequence of steps designed to improve not only the underlying indicator structure (inputs), but also the data on which the indicator is based and the outputs (results) which propose to inform and guide decision-makers.

Step 3 of the SI development process entails indicator verification thorough the assessment of the indicator structure and the arguments for indicator selection. Moreover this step involves the verification of the appropriateness of data along various levels of measurement such as at sub-indicator and/or variable level. This is addressed through multivariate analysis.

As discussed in the literature review, there are a number of statistical analysis methods which can be employed to perform multivariate analysis of composite indicators; however these were not pursued here for various reasons. The biggest restriction was due to the limited number of indicator applications undertaken. A single application to each of the two case studies was performed, with upgrades done with improvements in data availability. From the brief and somewhat superficial research into the topic of statistical analysis – relevant models and methodologies – it was possible to discern that most approaches require multiple cases with significantly more data, in order to perform such an analysis. Some of the methods go so far as to stipulate a minimum number of cases i.e. both PCA and FA adhere to rules of thumb such as the rule of 10 (a minimum of 10 cases are required for each variable) or the rule of 100, and so on. Another example is that of cluster analysis, which proposes the grouping of objects such as study areas, species or individuals which share similarities (Nardo *et al.*, 2005). It was not however possible to perform cluster analysis and draw significant conclusions for only two case studies, and very different ones at that.

The second deterrent related to the time and resource limitations, which prohibited an in-depth exploration and application of such methodologies as PCA (Principal Component Analysis) and FA (Factor Analysis). Statistical analysis is an important aspect of validating the indicators developed; however in the context of this research it represented a small component of the overall research objectives. For the purposes of this research, the concept of multivariate analysis served as a check for certain conditions through the following steps:

- Revision of theoretical framework and verification of conceptual indicator structure; checking for indicator relevance to the two case studies as well as to the broader environment for which the indicator is being developed, i.e. southern African cities.
- Determining the soundness of sub-indicator and variable selection processes i.e. indicator selection criteria and comparative analysis.
- Identification of 'groups' of variables sharing similarities and estimation of the degree of relevance given the possibility of duplication.

The above checks were completed prior to finalising the indicator structure provided in Table 3.5, and where necessary variables and sub-indicators were eliminated, added or restructured. Future research and refinement of the index will undoubtedly demand more extensive application of the index, and this will enable the use of multivariate analysis methods such as PCA, FA and Cluster Analysis. This is strongly recommended in order to verify the analytical integrity of the indicator and where weaknesses are detected, undertake or recommend further improvements.

As indicated in Table 3.5, the final indicator structure is composed of: 64 variables, where necessary these are broken down into smaller units of measurement; 20 sub-indicators; and 5 component categories. This illustrates to a large extent the complexity of composite indices which explore various fields of study in order to be representative of reality. Complexity is therefore required, however complications are not, and the inclusion of so many variables and sub-indicators begs the question of how practical the indicator is.

It has been acknowledged thus far that lack of resources and poor capacity are some of the limiting factors of development in the South, and yet this research proposes the use of a complex and somewhat lengthy indicator, demanding the collection of information on 64 variables. The developer recognises that this is a possible drawback, and once again makes clear that by no means is this a final product, rather it is an entry-point exploration of what can and might be included in the assessment of sustainability. As such, the indicator will be refined in future, and in all probability, downsized. That said, despite the constraints, it was nonetheless possible to collect data for most of the variables in the four months of data acquisition. It should therefore be possible for the targeted decisions-makers (at policy level) and action-takers (at implementation level), most of whom have this data and/or the contacts through which they can access it, to make valuable use of the index.

Table 3.5: Final Sustainability Index (SI) structure

Component (5)	Indicator (20)	Variable (64)
1. Social security and cultural acceptability (Social fairness and equitable resource distribution)	1. Access to water supply	1.1 Total collection time
		1.2 Gender bias
		1.3 Conflict over water sources
		1.4 % with access to protected water
	2. Access and use of sanitation facilities	2.1 No. people per sanitation facility
		2.2 Safety of use and safety to access facilities
		2.3 Cultural and social acceptability (type, odour issues, visual and physical contact with excreta)
	3. Levels of Service (LOS)	3.1 Water supply
		3.2 Sanitation
		3.3 Drainage
		3.4 Waste collection
	4. Vulnerability to disasters	4.1 Susceptibility to natural disasters
		4.1.1 Dolines and sinkholes
		4.1.2 Earthquakes
		4.1.3 Droughts
		4.1.4 Tornados
		4.1.5 Cyclones & floods
		4.1.6 Tsunamis or shock waves
		4.1.7 Fires (impact of fires due to inadequate water supply)
		4.2 Risk Management and disaster mitigation
	5. Health (morbidity and mortality)	5.1 Under 5 mortality rate
		5.2 Malaria-related mortality rate
		5.3 Reported cases intestinal and infectious diseases per 1000
		5.4 HIV/AIDS prevalence
	6. Education and awareness	6.1 Level of dissemination (various forms of advertising accessible to all income groups)
		6.2 Level of stakeholders consultation and public participation
2. Economic (Economically sound: economic growth and cost-returns)	7. Capacity (to pay or access services)	7.1 % people with secondary education
		7.2 Unemployment rate
		7.3 Income levels
		7.4 No. of days per year taken off work due to water related diseases (Loss of income due to sickness)
		7.5 Min/Basic water tariff

	8. Cost Recovery	8.1 % users paying for water
		8.2 % of unaccounted for water (UFW)
		8.3 % of free basic water (FBW)
	9. Investment levels	9.1 % budget increase for water supply
		9.2 % budget increase for sanitation
		9.3 % of budget increase for O&M
		9.4 Sources of investment
3. Environmental performance (Environmental protection and preservation of ecological systems)	10. Fresh water Resources	10.1 Per capita water availability (l/capita/day)
		10.2 Reliability or variability
		10.3 Water quality at source
	11. Sustainability/ Feasibility of water sources	11.1 Sustainability of source
		11.1.1 Local Groundwater
		11.1.2 Rainwater
		11.1.3 Local surface water
		11.1.4 Imported groundwater
		11.1.5 Stormwater
		11.1.6 Greywater
		11.1.7 Imported surface water
		11.1.8 Brackish water
		11.1.9 Treated effluent (wastewater)
		11.1.10 Salt water
	12. Use (resource distribution per sector)	12.1 Domestic
		12.2 Industrial
		12.3 Agricultural and livestock
		12.4 Maintenance of ecosystems
	13. Wastewater management	13.1 Effluent quantity
		13.2 Effluent quality
	14. Stormwater management	14.1 Effluent quantity
		14.2 Effluent quality
	15. Compatibility of water system with the surrounding environment	15.1 Close to solid waste dump or landfill site
	16. Compatibility of sanitation systems with	16.1 Located on flood prone area
		16.2 Steepness

		16.3 Depth to groundwater table
		16.4 Soil permeability
		16.5 Ground stability
	17. Environmental stresses	17.1 % of polluted water sources
		17.2 % of total area identified as severely water stressed
4. Political support and international stewardship	18. Governance	18.1 Democracy and representation
		18.2 Measure of corruption
		18.3 Defined roles and responsibilities
	19. Compliance with policy	19.1 Government policies
		19.2 MDGs
5. Institutional capacity and technological progress	20. Institutional and technical capacity	20.1 Adoption of IWRM approach
		20.2 No. of water management institutions
		20.3 Adoption of alternative water supply technologies
		20.4 Adoption of 'sustainable' sanitation
		20.5 Corresponding education levels for O&M
		20.6 Monitoring capability (including issues of data quality)
		20.7 Reliability of service provision
		20.8 Failure in service delivery due to dependence on other sectors (electricity, transport etc)

4. Building the index

4.1 Data selection: sources, reliability and dealing with missing data

The issue of data availability and quality is often a big deterrent to the use of indicators. It is thus important to approach data collection with caution. Ideally, the user should have easy access to reliable, quality data which is not only complete but frequently and consistently updated and made available. However too often this is not the case, especially when one requires extensive information covering a range of topics, which is the case of this composite indicator. In the context of the two case studies, obtaining any data, much less accurate and reliable data was a difficult undertaking. In the South African context, this was facilitated to a large extent by the size of the case study, Hermanus being relatively small, and the efficiency of management. There were however issues of poor cooperation and communication with municipality officials which led to delays in the refinement of the index results.

In Maputo, the process was more time-consuming, and lengthy waits did not always culminate with the acquirement of data or any indication as to where or if it exists. Poor cooperation, poor knowledge and awareness of data, complex and at times unnecessary bureaucratic processes, a high level of 'data confidentiality', outdated or incomplete reports, and at times dubious sources of data were the main contributors to the incompleteness and incoherence of the data-set for Maputo. Consequently, it became apparent that a process of data procurement and selection was required. The following 5-step approach was developed to guide the researcher and future users of the sustainability indicator through the process of establishing and employing appropriate data for the underlying variables. The following addresses the raw data requirements prior to normalisation and standardisation.

Step-wise data acquisition process:

1. Establish credentials (reliability and credibility of source) of potential data sources and/or producers of data.
2. Obtain and screen data sources for reliable, quality data.
3. Where insufficient original data exists, employ data imputation techniques to 'fill in the blanks'.
4. Where imputation is not possible, make informed guess estimates based on expert input and personal experience.
5. If steps 2-4 fail, then attribute a 0 score for the particular case or eliminate the variable from the index.

A more in-depth exploration of the above steps reveals the results of this process:

Step 1: Establish credentials

Given that urban water management and urban service provision is often the responsibility of municipalities and government institutions, establishing credentials on potential data sources or producers of data involved first establishing contact with these authorities. These were then able to indicate additional reliable sources in the various fields concerned.

The Overstrand Municipality, previously the Hermanus municipality, is currently the main service provider and water management institution for Hermanus; however various engineering consulting firms undertake exploration and investigation studies on its behalf. A first consultation with officials at the Overstrand municipality was sufficient to secure support for this initiative and the list of consultants was readily provided. A comprehensive list of data sources and the documentation obtained for both case studies is given in Appendices E and F.

In the Maputo context, time was of the essence as the researcher had less than three weeks to establish contact and obtain data, therefore contacts were made simultaneously with the following institutions: Municipality of Maputo (CMM), National Water Directorate, AdeM (the water service provider), and FIPAG. This was also due to the fact that the municipality is only partially responsible for the provision of services and management of resources; water management is shared by a number of institutions, of which the above constitute the key role-players. From these sources, secondary and tertiary parties were indicated and contacted. In addition to the list of contacts and summarised documentation provided in Appendices E and F, Appendix G presents summarised notes of the discussions with various stakeholders, where these were deemed relevant.

Step 2: Data acquisition and screening process

The second step involved consultation with the above organisations to facilitate the information sharing process. Given the time limitations, data gathering was conducted speedily, often neglecting any detailed scrutiny of the actual data. This proved both beneficial and prejudicial; beneficial because as much data as possible was gathered, often more detailed than required; and prejudicial because considerable time was spent locating and duplicating data sources which were ultimately not used in the indicator application.

For Maputo, the greater part of three weeks was spent locating sources of information, at times to no avail. There were several cases where data was referred to but the relevant organisations lacked the actual reports and documentation, consequently use was made of 'old' and at times outdated information.

In order to determine which data complied with the necessary requirements, a screening process was carried out inline with the following dimensions of quality, discussed by Nardo *et al.* (2005):

a. *Relevance* refers to the degree to which the data fulfils its intended purpose.

b. *Accuracy* reflects the degree to which the data approximates 'real' values.

c. *Reliability/credibility* is based on the source or producer of data and whether this source is either officially accredited or internationally recognised.

d. *Timeliness* addresses the time lapse between the time of measurement or the time between the event and the time the data is made available.

e. *Accessibility* refers to the ease of access and the appropriateness of the form of dissemination, evaluating primarily whether data is easily accessible to the audiences it targets, and secondly whether it is accessible to the general public.

f. *Interpretability* reflects the ease of understanding for users so as to enable them to make appropriate use of the data.

g. *Coherence* and *clarity* reveals the degree of logic and consistency in data products so as to provide clarity of use. Moreover the same information must have the same meaning, independent of where it is displayed, otherwise the differences must be clearly indicated.

The majority of data on Hermanus proved to be reliable on almost all of the above dimensions, with the exception of interpretability and the timeliness factors which were at times lacking. For example; there has been no update of the Water Services Development Plan (WSDP) for Hermanus since the 2003 report; however personal communication with the municipality has indicated that there are plans in motion for a tender proposal in the near future.

In the case of Maputo, the overall credibility of sources was assured, however for different variables the data failed to comply with one or more of the remaining dimensions of quality. The problem with interpretability arose mainly with regard to some internal documents such as AdeM's annual reports which failed to be clear on certain technical and financial aspects. This is understandable, given that the documentation was produced for internal use, but it nonetheless precluded the use of certain data.

Coherence and clarity proved to be one of the biggest challenges because urban water management responsibilities in Maputo fall to various organisations, some of which are neither governmental nor public. Coordination and information exchange has become a strenuous and time-consuming activity, one that is too often disregarded or neglected. Where data was obtained from multiple sources, it was found that results could be incompatible or contradictory. For example; reports by FIPAG, AdeM and the municipality indicated different service coverage levels, granted that the publishing dates varied somewhat. Given the relatively good credibility of all three sources, it was difficult to single out one source and at times it was necessary to use them in combination or make simple judgement calls as to which was more appropriate.

It was also difficult to reconcile aspects such as investment levels, as many organisations are currently investing in this arena and at times with little or no consultation with the remaining stakeholders. Determining institutional capacity levels also proved a challenge, mainly due to the multiplicity of activity and the lack of reporting on the part of some organisations.

Finally, it was observed that there is a big problem with consistency and timeliness of data up-dates. The national survey for Mozambique is conducted on a 10 year cycle, the last having been conducted in 1997 and the next is to be conducted towards the end of 2007, the results of which will be published the following year.

The results of the 1997 survey are undoubtedly outdated. Factors such as population numbers have certainly changed and therefore were deemed unusable. To account for this gap in data, projections were used based on observed growth rates, acknowledging however that these are 'refined guesses' at best. Water resource studies were also significantly outdated; most documentation obtained having been produced in the late 1980s. Some of the reports used referred to complementary or prospective studies which might have provided more up-to-date information, however upon request these were not available, either having been lost or misplaced.

Step 3: Dealing with missing data

Significant data gaps were encountered and it was not possible to obtain sufficient data to inform all variables. Where data was missing or where the available data failed to directly answer the questions posed by the indicator, one of two options were chosen. Firstly, if data was available but did not directly answer the questions posed by the sub-indicators then variables were either re-worded or proxies were used. In cases where data was completely missing, it was necessary to devise a means of 'filling the gap'.

There are numerous methodologies for imputing data, some more complex than others, and although in theory the literature has permitted a brief exploration of some of the techniques, in the interest of simplicity and brevity statistical modelling techniques were not pursued but rather the following simple and logical means of imputation were investigated, (Nardo *et al.*, 2005):

- *Hot deck imputation*: this involves the use of data from similar units or cases to fill in the blanks in the cases where data is missing. For example; if Case A shared significant similarities to Case B, such as similar economic status, then it was possible to use the information on Case B to fill the gap in Case A, i.e. given similar economic conditions the capacity for service payment was also assumed to be similar. This was not directly employed in the two applications of the SI because Hermanus and Maputo do not share sufficient similarities to draw comparisons and import data, however it may very well be used in other more suited applications.
- *Direct substitution* requires a direct replacement of one unit or case with another, where sufficient information for the alternative unit or case exists. Although not in the exact sense as described in literature, this technique was employed when considering multiple sets of data, displaying conflicting results. Decisions were made as to which source would provide the best estimation of reality and in this context substitutions were used to test assumptions. This method was initially considered for index applications at the neighbourhood-level; however this option was disregarded for lack of sufficient and compatible data at this level of assessment.
- *Cold deck imputation* enables the developer to substitute the missing value with that provided by an external source. As a result of the diverse nature of the information required and the limitations to data acquirement, all data obtained was considered 'internal' to the research, therefore cold deck imputation was not directly employed. This approach becomes valid when the study is restricted to specific sources of information such as survey studies, census' and sampling for example. In that case, additional sources would be considered 'external' to the research.

One must exercise caution when using the above methods. Upon concluding imputations, there is a risk of assuming that the dataset was complete and forgetting that certain implicit assumptions were made which if not addressed can undermine the robustness of the indicator. More formal statistical models such as regression imputation, unconditional mean/median/mode imputation and the Markov Chain Monte Carlo (MCMC), can provide greater assurance of imputation effectiveness. However as stated before they require a higher number of case applications to enable data imputation and therefore could not be used here.

On a final note, single imputation approaches are more than adequate for this first phase development and application of the Sustainability Index. The suggestion is that when wider application of the indicator is undertaken, addressing a greater sample size, more complex imputation methods be explored to provide better estimations of data variance.

Step 4: Making informed guesses

Where extensive data gaps occurred, which could neither be substituted nor inferred, the subsequent step was to consult the views of experts in the field. This was done either through an extensive review of the literature or through consultation with officials and experts working in the two case study areas. Equally important at this stage, were the observations and personal judgment of the Urban Water Group working on this project. Despite the possible subjectivity of this option, it was deemed useful given that there is considerable knowledge both within the group as well from the researcher, who has done investigative work in Maputo prior to this, and is also native to the city and as such was able to share some insights.

Step 5: Exclusion of variables or zeroing variable scores

The final step considered either a complete elimination of the variable from the index structure or an attribution of a 0 score to the particular case lacking information on the variable. Given that the indicator was designed to suit the countries in question and address the problems in southern Africa in particular, it is not a question of whether the indicator is appropriate but rather it is dependant on the data available. Whilst it is not desirable to undermine the overall index by eliminating variables, this remained a possibility where data requirements were not met. This would reduce the bias for or against the case study with or without data for that particular indicator.

The option whether to exclude a variable or attribute a zero score should be done on a case study basis and on a variable-to-variable basis, simply because the overall importance of variables varies depending on their relevance to the setting and their importance within the general index structure. Ultimately, it was decided that the indicator structure would remain unaltered as it was shown in Chapter 3, Table 3.5. To address the issue of missing data the researcher reverted to the previous step (step 4). This is in no way a reflection of the inflexibility of the index. Given the limited time, it was viewed as a limitation in the data collection process rather than the product itself, at this preliminary phase of applications.

Contrary to what some developers have proposed, this index is not limited to the assessment of inputs, or throughputs, or outputs singly. Nardo *et al.* for example, have suggested that in the interest of precision and transparency, developers employ either one or another category. Their argument being that these do not measure the same aspects and consequently cannot be grouped. This does not have to be the case because; firstly, any need for clarity can be easily satisfied by a well introduced and justified indicator, where the purpose of development is well stated; aim, objectives, goals and applicability. Secondly, it has been duly stressed throughout this thesis that an assessment of sustainability requires a broad view of the system, encompassing all its parts. Therefore, following this line of reasoning one can conclude that the inclusion or exclusion of categories of indicators is largely dependant on what is to be measured and what this entails in order to answer the questions posed at the start. The researcher has endeavoured to take on a systems approach rather than a sectoral approach, therefore it has been imperative to consider all the system components. For example; the necessary input measures (investments) which can guide and improve the process of growth and development (improved capacity for payment and better accessibility to services) in order to arrive at the desired outcomes/outputs (improved health, poverty reduction and growth) are all key to managing urban water systems sustainably.

In the following section this issue of indicator incommensurability will be addressed to a much greater extent. The incompatibility of variables measured in different units will be dealt with, and indirectly so will this issue of inconsistent indicators.

4.2 Normalisation

The SI undertakes the aggregation of multiple and diverse variables, and it is often the case that variables are measured and represented in irreconcilable units. It therefore follows, that in order to compile such a complex indicator one needs to standardise the data according to a set and comparable frame of reference. There are a number of techniques which achieve this and in the following discussion a select few will be presented as discussed by Nardo *et al.* (2005). These methods highlight the possible routes explored in this research, but ultimately one technique was employed, keeping in line with the need for clarity and simplicity.

- *Ranking:* This method enables a relative measure of the performance of city or study area based on a pre-established best-case. While it is no longer possible to assess performance in absolute terms, the benchmarking exercise enables cross-area comparisons, both provoking responses and stimulating change. This approach becomes extremely relevant when similarly performing countries are grouped around clusters and their similarities and dissimilarities are highlighted, making an evident case for laggards and leaders. The ranking can be done in relation to a case under assessment or to an established or favoured reference area.
- *Distance to reference:* The distance to reference approach establishes the performance of a city or study area in reference to a pre-determined fixed target. It is a measurement in reference to a proposed ideal outcome, and as a result may enable an incremental movement towards that fixed end-point. This concept of setting and

following targets for the achievement of sustainable development goals has in part been the driving influence behind indicator development. As such, performance-to-target assessments should be acknowledged in any process of developing indicators, and have been looked at in this research

- *Categorical scale:* In a categorical scale approach, scores are assigned to individual indicators or the lowest level of measurement, in this case the variables. These categorical scores can be either quantitative, a score from 0-100, or qualitative, assessing on the basis of good, adequate, or poor for example. This gives an idea of absolute performances but depending on the scale chosen, can obscure significant differences across variables and within indicators. Variations might not be significant in terms of the overall score but become problematic if these produce a change in the final rankings.
- *Comparison to mean:* The method involves the determination of the mean value, to which all other values are then compared. The mean value receives a 0 score and indicators above and below the mean receive 1 and -1 accordingly. While favourable for its simplicity, this approach fails to recognise the degree to which areas are under or over-performing, i.e. while Case A might be performing seven times better then Case B, both will be scored equally.

Ultimately there are limitations to the use of any of the above techniques. More specific to this research, there are limitations due to the restricted number of case study applications. It becomes unreasonable to employ either the ranking system or the comparison to mean, simply because the results could be biased towards the dominating case (performing exceptionally well or extremely badly). In the ranking system this can be largely overcome by the selection of an 'external' reference. With the comparison to mean approach, missing data for one of the two case studies ultimately denies the use of this technique.

It was resolved that the indicator conversion should employ a categorical scale normalisation approach, where all indicators were to be scored on a 0 – 5 scale. The scoring from 0-5 is fixed, however the endpoints vary from variable to variable, much in the same manner as with the EVI. One might have adopted a larger scale, say from 0 – 100 for more clarity in the results, however given that the reliability of the data itself can be questioned; this would not have provided any real advantages in this case.

One needs to keep in mind that the single final number is but a 'snapshot' of the 'health and vitality' of a system and not a definite representation, therefore the final assessment demands further exploration of the contributing component and indicator scores, as will be pursued in the discussions.

The majority of categorical scales were selected on the basis of pre-established reference points, standards or rules i.e. wastewater quality criteria, guidelines provided by the World Health Organisation and others. However where literature, expert opinion or personal knowledge were not sufficiently clear, subjective scales were selected, attempting to balance the distribution across endpoints.

Close observation of any of the filled-in spreadsheets (results sheet), will illustrate that the higher the score for a variable, the better it performs towards sustainability; with the exception of vulnerability to disasters, where the higher the susceptibility to disasters and the lower the management and mitigation of risks, the lower the sustainability of urban water systems. The spreadsheet was designed in such a way as to ensure this. Appendix H provides a detailed discussion on the standardisation of each variable as well as a more in-depth description of the SI subcomponents. This coupled with the attached Excel spreadsheets, gives the reader and potential user a better understanding of the structure and functionality of the index (see attached CD for Excel sheets).

4.3 Weighting systems and aggregation

In the context of indicator development, weights often serve to emphasise issues of particular concern. Those issues which need to be highlighted will be given higher weightings and hence greater importance in the final index score. This section explores the process of determining and applying different weightings to verify the modifications in the results.

As a first step, an equal weighting system was applied to all components and variables so as to establish an initial base situation. However it is well understood that perceptions and priorities vary from place to place and from time to time, therefore a further step was taken, where subjective weighting systems were explored. This was done to introduce the necessary or desired biases towards certain issues.

It is important to stress again, that this research does not presume to provide 'the answer' but simply to explore possible solutions; therefore, the weights used here are by no means fixed and final. In fact, if anything, this research encourages greater reflection on and exploration of the topics discussed and endeavours to be flexible enough to enable alterations.

Accepting that assignation of weights is an inherently subjective exercise provides some flexibility in determining the method to be used. The literature review highlighted some of the possible statistical techniques which can address, to an extent, the issue of subjectivity; however the researcher did not pursue these for the same reasons that denied the use of similar statistical techniques in multivariate analysis, the limited number of datasets. Statistical methods should however be explored in future research.

4.3.1 Neutral weighting

Equal and Balanced

The first trial made use of a balanced equal weighting system, where all variables within sub-indicators were equally weighted, and all sub-indicators within component categories as well as components making up the index, were also equally weighted.

Equal and Unbalanced

In the unbalanced approach, to start off all variables were equally weighted. This means that sub-indicators with the highest number of variables received higher overall scores. Two options were then available; on the one hand, one could continue to attribute equal weights to all 20 sub-indicators and 5 components, or alternatively, provide equal weightings to indicators within the same component category and equally weight all components. Both approaches were attempted with little variation in resulting scores, therefore for the sake of brevity only one approach will be reported on in the results.

4.3.2 Subjective weighting

Allocation of weights to indicators is a conflicting issue, which has given rise to many debates around the validity of composite indicators. Inconsistency and lack of definition is such that no set 'global' weighting scheme or methodology for determining weights has been put forth. In some instances, indicator developers have attempted to define a weighting system which can be widely applicable, while others have avoided the issue by adopting the equal weighting approach. Others have opted not to address a widely-applicable weighting set but rather employed specific indicators and weights for a specific context.

Some examples of where lack of consensus has led developers to opt for equal weighting schemes are the ESI and EPI. The Water Poverty Index (WPI), which also makes use of composite aggregation, attempts to somewhat diversify by proposing that both a balanced and unbalanced equal weighting approach be undertaken. The developers of the WPI propose a weight selection table based on specific local descriptors and hence variable weightings (Lawrence *et al.*, 2002 & Sullivan *et al.*, 2003). Many more indicator initiatives propose similar approaches.

In the absence of a defined and recorded methodology for assigning weights, the developer considered two avenues of recourse: the one option was to pursue statistical analysis to arrive at weightings, and the second was to undertake an extensive consultation process which would allow for the input of various stakeholders and experts.

Ultimately, a combination of both approaches was adopted. Firstly, engagement with stakeholders was achieved, albeit briefly, and from these meetings key concerns and priorities which demanded greater weightings were established. Secondly, the developer adopted a ranking approach, in which variables were ranked within their indicator category and then assigned corresponding scores.

Five additional sets of weightings were developed in line with the five dimensions of sustainability represented in the index, and here the consultation process became relevant, helping to highlight key variables. The intention was to propose various weighting schemes which could then highlight progress along the various dimensions of sustainability, rewarding those areas which perform better with regard to one or more of these dimensions.

The results of all different weight applications will be compared to draw conclusions as to the influence of differentiated weighting on the overall performance of the case studies. At this point it suffices to say that the adoption of different weightings did alter the indicator and component scores; however the overall sustainability index value did not vary significantly. A table of the subjective weighting sets developed is provided in Appendix I.

At the start of this thesis, the need for flexibility was emphasised, and mention was made of enabling the user to modify the indicator to suit the users' particular needs. This option is still available to the user, who has the freedom to manipulate the tool in order to restructure the indicator. The weighting options previously discussed also provide some flexibility of choice and highlight possible tradeoffs. Where some might argue that changing both the constituent indicators and their relevant weights might render temporal comparisons meaningless, the argument is made here that sustainability is not constant but rather varies with both time and space. As a result, the priorities for achieving sustainable development must change accordingly.

4.3.3 Composite index aggregation

The sustainability indicator was calculated using the composite index approach. Composite indicators have been used in indicator initiatives such as the Human Development Index (HDI), the Environmental Sustainability Index and the Water Poverty Index (WPI). The decomposition of the SI into components, sub-indicators and variables has already been discussed. This section simply provides the aggregation formula used and it proposes some additional methods for future exploration.

The sustainability index for a particular area/region (SI_i) is the sum of all the weighted components (Equation 4.1). Variables and sub-indicators are aggregated in the same manner as components. The standardised value of the respective component X_i, is multiplied by the attributed weight, w_{xi}, to give a value on a scale of 0 – 5. For the sustainability index in question, the formula will be represented as shown in Equation 4.2, accounting for all 5 dimensions (components) of sustainability:

(4.1)
$$SI_i = \frac{\sum_{i=1}^{N} w_{x,i} X_i}{\sum_{i=1}^{N} w_{x,i}}$$

(4.2) $$SI_i = \frac{w_s S + w_e E + w_{ev} EV + w_p P + w_i I}{w_s, w_e, w_{ev}, w_p, w_i}$$

S- Social; E- Economic; EV- Environmental; P- Political; I- Institutional.

The symbols: w_s, w_e, w_{ev}, w_p, w_i: represent the weights for the 5 components mentioned above.

This method of summing up weighted and normalised sub-components is by far the most commonly used, mainly for its simplicity in aggregation and representation of multiple issues. There are however some shortcomings, for example; the quality and relevance of the composite index depends largely on the quality of the underlying indicator framework, the compound sub-indicators and components, their unit of measurement and the overall interpretation of their importance (weights) within the composite index. Furthermore, indicator incommensurability can render the results obtained unrealistic or irrelevant. Finally, there is also the issue of presupposed compensability, where it is assumed that independent of the variability of the underlying components, if the final scores for two cases are equal, then, their performances are equal. There is an assumed equality derived from very particular inequalities (Nardo *et al.*, 2005). This will be illustrated by the following example, using the same components developed for the SI; social, economic, environmental, political and institutional. If city A and B score as follows for the above components:

City A: 1, 1, 10, 2, 2 = 16
City B: 4, 4, 1, 3, 4 = 16

The composite index values are the same, however the two settings represent different socio-economic, political and environmental scenarios; suggesting that caution be taken when interpreting results.

Efforts have been made to address all of the above shortcomings by testing assumptions, undertaking comparisons with other initiatives, adopting different weighting schemes and finally by evaluating results at the level of the index as well as at the component and indicator level.

In the end, there are two schools of thought regarding the development and application of composite indicators. The one group believes that this summarised presentation of results provided by composite indicators is not only relevant and realistic but also meaningful, (Nardo *et al.*, 2005), and that the very comparative, and at times competitive-driven, nature of indicator application which stresses the 'bottom line', irrefutably attracts the much sought attention of policy makers. The other school of thought believes that, while indicators are undeniably useful, the final aggregation into a composite should be omitted for the very sound criticism that the selection and aggregation (weighting) of indicators is and will continue to be extremely subjective and ultimately dissatisfactory to some.

Accepting both viewpoints, the opinion proposed here is that; because many of the water management issues highlighted thus far have gone either poorly addressed or completely unchallenged, the simplicity and strength of composite indices in conveying a message and motivating for change is crucial. The information these provide must certainly be disseminated with caution, and above all must stress that indices provide but a rough assessment of reality and not the final appraisal.

4.5 Robustness: sensitivity and uncertainty analysis

In the interest of a clear and transparent process and product, it is important to stipulate how certain one is about the assumptions that are made and how these affect the indicator. This has been done at each step of the indicator development process, however this section proposes to summarise these and estimate the overall robustness of the indicator. Two aspects are of concern when addressing indicator robustness, namely; sensitivity and uncertainty. Sensitivity analysis provides an assessment of the variation in results based on the assumptions made, and how these then impact on the composite index. Closely related to this is the analysis of uncertainty of the output due to uncertainties in the input (Nardo *et al.*, 2005).

The determination of both enables the developer to establish whether relative rankings vary, depending on the variations in assumptions made. It would certainly be valuable to be able to validate the assumptions made here, however it has not been possible to employ any statistical techniques, for the following reason: indicator application to two case studies negates the benefits of significant variability in ranking, and secondly, to corroborate this; the performances of the two settings are considerably different, so much so that it is safe to assume that even when accounting for uncertainty and sensitivity in the model the relative positions would remain.

It is however possible to qualitatively assess the robustness of the index. To begin with the indicator selection process has been substantially biased, informed largely by the opinions of the developer and the Urban Water Team. To balance this, a compilation of previously adopted selection criteria were used to screen out indicators and variables; and a comparison with widely recognised indicator sets was undertaken. The next step demanding attention was the use and imputation of data. The limitations here were widely acknowledged, nevertheless, for the sake of transparency, a data sheet for each case study is attached (Appendices J and K). The datasheets describe the data used, the assumptions made, as well as cases where data was imputed or guesses were made.

The final step which demanded attention was the attribution of weights. To address this issue, weighting sets were developed, focusing on the different issues raised by stakeholders in a methodical fashion. The results, which will be discussed in Chapter 6, will show that there can be variability due to differentiated weighting but it will also be shown that, overall, this variation does not have a big impact on the index score. This does not detract from the subjectivity of the exercise but rather provides for some experimentation.

On a closing note, the developer has endeavoured to be as thorough as possible; applying the theoretical concepts of sustainability, systems thinking and multidisciplinarity, as well as addressing the statistical dimension of indicator development.

4.6 Developing the tools to run the indicator

Having developed the indicator, highlighted some of its limitations and contextualised the two case studies, the next step was to actually apply the index to two case studies. Prior to indicator applications two programs were used and/or developed and will be considered here as two separate tools, although for the same input in information both tools should arrive at the same results. The first tool used was a simple Microsoft Excel spreadsheet and the second tool – SI 2007 – was developed using Visual Basic 2005 Express Edition, a programming package. The following sections will review these tools in more detail.

In keeping with the sequential model in chapter 5, indicator application and visualisation is described here as one of the last steps in the process, however in fact this is an ongoing process and refined through improved indicator definition and information collection. As was demonstrated by the step-wise approach in chapter 5 (methodology of indicator development), this and all steps are under continual revision, until satisfactory to the developer and end-user.

4.6.1 Microsoft Excel

Firstly, an Excel workbook was created, in a similar format as the workbook developed by Stoeckigt (2006) and Snoek (2006). The Excel tool consists of five worksheets. The first and second are fill-in sheets, where the user can attribute values to the various variables provided. In fill-in sheet 1, the user will work mainly with the levels of service for the area in question (Figure 4.1), where issues (variables) are linked to the LOS. The extract from the fill-in sheet shown in Figure 4.1 illustrates this; the empty blue-shaded spaces must be filled in with the relevant information as shown, ensuring that the total adds up to 100%.

%		% located	% located on slopes of steepness				
	LOS	**on flood prone area**	**0-1%**	**2-3%**	**4-10%**	**>10%**	**TOTAL**
	LOS1						
	LOS2						
	LOS3						
	LOS4						
	LOS5						

Figure 4.1: Extract from fill-in sheet 1 (part sustainability index tool)

Fill-in sheet 2, on the other hand presents a multiple choice type scenario; tick boxes are provided adjacent to the options to be selected. The scores attributed for the tick boxes descend from the highest score, 5 to 0. There are some cases, as shown in Figure 4.2, where two ranges are provided, but only one option can be selected.

	OR	
☐ 50%		☐ 50%
☐ 49%-40%		☐ 51%-60%
☐ 39%-20%		☐ 61%-80%
☐ 19%-10%		☐ 81%-90%
☐ 9%-5%		☐ 91%-95%
☐ <5%		☐ >95%

Figure 4.2: Extract from fill-in sheet 2

The third spreadsheet, the calculations sheet, provides a breakdown of the scores and how these were assigned to each variable (Figure 4.3).

%	Level of service	Water supply	Sanitation	Drainage	Waste collection
	LOS1	5	5	5	5
	LOS2	4	4	4	4
	LOS3	3	2	2	2
	LOS4	1	1	1	1
	LOS5	0	0	0	0
Rate					

Figure 4.3: Scores attribution to variables for the indicator; levels of service

This is followed by the fourth sheet, in which the final results are calculated and presented. In the results sheet, variable scores are provided from the previous calculations sheet (both sheets are linked), as well as the corresponding weights. This then gives way to the calculation of sub-indicator, component and finally the sustainability index scores (Figure 4.4 and 4.5).

The final sheet works as a check for possible errors made by the user; similar error checks are also provided in the other sheets to ensure that values are filled in correctly. For a detailed view of the spreadsheet refer to the full case application provided in the complementary CD (Tool 1, CD).

4.6.2 Programming with Visual Basic 2005

Visual Basic (VB) 2005 is a simple and easy programming language which enables first time programmers to create solutions and develop programmes that run on Microsoft Windows systems. VB 2005 allows the programmer to design and draw their user interface (UI), without going to the extra trouble of writing code for the UI, and hence allowing more time for problem solving and event coding (Willis & Newsome, 2005).

The main purpose of developing a specific programme to run the indicator originated from an understanding of the limitations of Microsoft Excel as an indicator tool, in terms of presentation and ease of navigation.

Component	Weight	Rate	Indicator	Weight	Rate	Variables	'eight	Rate
Social security and cultural acceptability	0.20	3.39	1. Access to water supply	0.17	4.91	1.1 Total collection time	0.25	4.64
						1.2 Gender bias	0.25	5.00
						1.3 Conflict over water sources	0.25	5.00
						1.4 % with access to protected water sources	0.25	5.00
							1.0	
			2. Access and use of sanitation facilities	0.17	4.77	2.1 No. people per sanitation facility	0.33	4.74
						2.2 Safety of use and safety to access facilities	0.33	4.78
						2.3 Cultural and social acceptability	0.33	4.78
							1.0	

Figure 4.4: Sub-component scores; extract from results sheet

Sustainability Index (SI)	74%
Social	68%
Economic	74%
Environmental	87%
Political	89%
Institutional	53%

Figure 4.5: Final component scores; extract from results sheet

It is not necessary to detail the actual format of the programme, as it was designed based on the spreadsheet and therefore is similar in appearance. It has, however, been significantly compressed; where the Excel spreadsheet indicated and calculated scores, with SI 2007, this was done in the background through the code.

Instructions are given to guide the user regarding the procedure to be followed. Furthermore, certain checks were provided to ensure that errors are avoided. The different weighting schemes created were also provided and the user simply selects which set he/she wishes to employ. It is recommended that the user spend some time exploring the tool, in order to fully understand what has been proposed here (Tool 2, CD).

All of the above features of the tool simplify its use and avoid confusing the users with the underlying computations and somewhat lengthy formulas. Adopting a relatively more complex computation tool than the basic Excel sheet can also deter users from altering any fundamental components of the indicator, as they would have to be well versed in the VB2005 language to do so. All in all, because the programme was specifically designed for the application of this index, it provides a more formalised and personalised tool with an improved user interface which is appealing to a wider audience.

Given more time the tool could have been significantly refined, however at this preliminary stage, where the developer was simply getting acquainted with programming and this particular programme, the product fulfils its intended purpose. The Excel workbook can be modified so as to fall inline with the assessment requirements of the user. It provides a degree of flexibility which is not available in the SI 2007, therefore the two tools complement eachother.

5. Background to case studies

In order to test the indicator, two case studies were selected. Hermanus and Maputo were chosen for a number of reasons, and these will be explored in more detail in the following section, however, ultimately the deciding factors were those of time and resource availability. This chapter starts by exploring the selection of the two case studies. It continues to provide a short descriptive summary on the status quo of these two distinct cities, much of it helping to build a portrait of each city which will then enable verification of indicator results.

5.1 Selecting the case studies

Case study selection was relatively simple, largely due to the constraints already mentioned. Chapter 4 has highlighted the difficulties in obtaining data for such a wide range and number of variables, and to avoid compounding the issue, case selection was restricted by distance and probability of acquiring information in the limited time available for the completion of this thesis.

Other factors also influenced the selection of the two final cases. There was an interest in exploring different scenarios, with the aim of testing the wider applicability of the index. At the same time it was important to retain certain similarities, which could help draw a common link across most developing African cities, particularly southern African cities.

In the interest of diversity, different economic, socio-cultural, political and historical backgrounds were used as criteria, in order to contrast the study areas. The issue of water management in an urban context was also a big determinant. Maputo has evidenced significant challenges in the provision of services to the majority of the population, maintenance of service quality for all, and capacity for monitoring and managing resources. In contrast, Hermanus has consistently displayed a commendable performance in water management in the past, including its ability to cope with extreme variations in water demands through the very effective Greater Hermanus Water Conservation Programme. It offers a useful contrast to the situation in Maputo; however this must be understood in the context of much lower population numbers and densities, as well as significantly higher income and education levels.

The familiarity of the researcher with both cities was also important; being a native to Maputo City and a resident in the Western Cape for the past six years, as well as being fluent in both Portuguese and English, was advantageous. Furthermore, the researcher has some research background in both areas, having concluded both secondary and tertiary education in South Africa, and conducted research in Maputo at undergraduate level.

5.2 Greater Hermanus Area

5.2.1 Geographical profile

South Africa is without a doubt the most developed country in the SADC region, and possibly one of the more stable economies in the continent. Its borders with Namibia and Botswana to the North West and North; and Zimbabwe and Mozambique to the South East are well established (Figure 5.1). Situated along two oceans, The Atlantic Ocean and The Indian Ocean, the country occupies the entire south-most portion of the continent.

After more than a decade of democratisation, the country's socio-economic profile is extremely positive. The government, through policy and practice, has taken significant strides towards eradicating the dominant racial and income barriers of the past. Progressive policies such as the Free Basic Water Policy, have ensured achievements such as 74% national coverage in terms of water supply, the majority of it benefiting low income groups (67%) (DWAF, 2007).

In view of growing population numbers, the reduction in the sanitation backlog has also been significant, albeit lower than the expectations for achieving the relevant MDG. According to the joint WHO and UNICEF report (2004) on the progress towards MGDs, in 2002 improved water supply and sanitation coverage for South Africa had risen to 87% and 67% respectively, from 83% and 63% at the beginning of the previous decade.

The Greater Hermanus Area forms part of the wider Overstrand Municipality. The Overstrand Municipality is turn part of the regional Overberg District Municipality, which is situated in the Western Cape Province (see Figure 5.1).

Hermanus is a coastal town, lying on a raised coastal plain along the Indian Ocean, and sloping up towards low-lying mountains to the north. The Greater Hermanus Area aggregates the suburbs of Fisherhaven, Hawston, Vermont, Onrus, Sandbaai, Hermanus, Berghof, Onrus Manor, Chantelair, Kidbrook, Hemel and Arde, Mount Pleasant, Zwelihle, Hermanus Heights, and Voelklip. For the purposes of this research only the following neighbourhoods were included: Fisherhaven, Hawston, Vermont, Onrusrivier, Sandbaai, Hermanus, Mount Pleasant, and Zwelihle (Figure 5.2). This is because these constituted the more urbanised areas of Greater Hermanus.

The climate is typically Mediterranean, characterised by hot, dry windy summers during the months of October to March, and cold wet winters from April to August. Temperatures range from 18°C to 30°C during summer and 8°C to 25°C in winter, and on average an annual rainfall of 650 mm is expected (Umvoto, 2004).

Figure 5.1: Provincial boundaries of South Africa

The rock strata in the area correspond to units from the Malmesbury Group, Cape Granite suite, TMG (Table Mountain Group), Bokkeveld Group, and Bredasdorp Group. In terms of groundwater resources, two main aquifers show promise for future exploitation, although there are others, and these are: the strongly fractured quartzite and sandstone zones of the TMG; and the neogene calcareous sandstone and limestone near the basal unconformity of Table Mountain and the Bokkeveld Group (Umvoto, undated). At present, of particular significance to the town is the peninsula aquifer, extending over large areas of the Western and Eastern Cape, which is partially recharged by rainfall from the mountains surrounding Hermanus.

In terms of surface water resources, the area is supplied by the De Bos Dam situated in the Onrus River. Abstraction from this supplies the majority of Greater Hermanus, with the exception of certain users which utilise groundwater extensively i.e., agriculture and recreation (golf course and sports ground).

With regard to species diversity and ecological preservation, Hermanus is well known for its winter aquatic habitants, whales and dolphins, and Walker Bay has been named a marine protected environment which boasts a wealth of marine life. Fynbos is the predominant vegetation in the area; however extensive alien species invasion has occurred in the past years, particularly in the coastal areas (Umvoto, 2004).

5.2.2 Policy environment and institutional structures

Since the 1994 democratic elections, policy making and implementation in South Africa has been focused on redressing past undemocratic policies and practices. In the water sector, the National Water Policy (NWP), and the National Water Act are the governing pieces of legislation, which are working to ensure a more democratic, as well as socially, economically and environmentally sustainable South Africa. These, coupled with supporting legislation such as the Water Services Act (Act 108 of 1997) and the Strategic Framework for Water Services of 2003, guide progress at all levels of government, particularly at the implementation level of municipalities.

Overstrand Municipality was formed in December 2000, in compliance with the Local Government Municipal Demarcation Act (Act 27 of 1998) and the Local Government Municipal Structures Act (Act 117 of 1998). It is an amalgamation of previously individual municipalities, including the Greater Hermanus, Hangklip/Kleinmond, Gansbaai and Stanford municipalities (DWAF, 2001). The management structure has three distinct components; political, administrative and public participation structures. These in turn are tiered to ensure logistical and practical functioning of the municipality (Overstrand Municipality, 2007).

Figure 5.2: Greater Hermanus and surrounding areas (Google Earth, 2007)

In terms of management, monitoring and compliance with regulations, Hermanus has served as a good example for water management, locally and internationally. It has succeeded in balancing the local socio-economic priorities with those at national level as well as with international development standards. This can be said of the provision and quality of services, resource management and water quality monitoring, treatment of wastewaters, implementation of progressive tariffs and good cost recovery, as well as good environmental management and the preservation of valuable ecosystems. One must not forget however, that there are specific conditions which favour such accomplishments; such as the relative small size of the town, the low densities and high incomes.

There are nonetheless concerns for poor integration and cooperative management within the broader Overstrand Municipality, as there is still an element of differentiated governance and non-uniformity across all four municipalities. Furthermore, because the municipality acts as the sole service provider for the respective towns and surrounding areas, this places an enormous strain on an already overstretched management structure, with limited staff capacity (Overstrand Municipality, 2006c).

5.2.3 Demographics and service provision

The current socio-economic profile indicates that Greater Hermanus is home to over 35000 permanent inhabitants, a number which rises to more than 70000 during peak season (November – February) (Muller, 2007). The main land users and water consumers are; residential, small scale industrial and local businesses, as well as public facilities such as health care centres, schools, and government institutions. Agriculture is practiced in the surrounding areas, which form part of the Overstrand Municipality but are well out of the context of urban Hermanus.

As indicated by the seasonal boom in population, Hermanus is a tourist town, sustained mainly by tourism and affluent holiday visitors. During peak season, the population in Overstrand more than doubles, increasing the number of affluent residents. In contrast, a large portion of the permanent residents of the town experience high levels of poverty. This is the case for the majority of black and coloured residents living in the medium to high density areas of Hawston and Zwelihle (see Figures 5.3 and 5.4). Currently, 31% of the total households in the Overstrand Municipality earn below R1000/month, Zwelihle being amongst the poorest and densest of suburbs (DWAF, 2006). Results from the 2001 National Census confirm these findings (STATS SA, 2001).

Despite these issues, both population and development rates for Overstrand have increased significantly in the past decade. Between 1996 and 2001, an 8.3% population growth rate was observed, and there was a marked increase in the number of approved building plans, indicating a boom in the building industry and ultimately in the economy (DWAF, 2006). In terms of service provision, at least 95% of the population of Overstrand have access to basic water supply, and 93% have access to basic sanitation, under RDP (Reconstruction and Development Programme) standards (DWAF, 2006).

Figure 5.3: Hawston, Greater Hermanus

Figure 5.4: Zwelihle, Greater Hermanus

In Hermanus, more than 70% of the population have access to both full uncontrolled water supply in the household and water borne sanitation. The remainder have access to either yard taps and septic tanks, or communal water supply and VIP latrines (Overberg District Municipality, 2004). Service provision and management at the municipal level has been significantly strained by the population growth and corresponding demand for both high and low income housing.

In general, payment for services and cost recovery is high, in spite of the high poverty levels in some areas. This can be largely attributed to a successful water management programme; the Greater Hermanus Water Conservation Programme (GHWCP). The GHWCP was created in November 1996 in partnership with DWAFs Working for Water Programme. In 1994, the local authority began to take serious note of the marked increase in water consumption during the holiday season; a situation which when coupled with the permanent growth of the town placed considerable pressure on already stressed resources. The initial response was to apply for an increase in water abstraction through the upgrade of the De Bos Dam. This request was rejected, which then led to the development of the GHWCP; a comprehensive demand management plan which was centred on the application of a progressive block tariff, a water-wise approach, and an informative billing system (Deedat *et al.*, 2001). The results of this programme were visible a few short months after implementation, and continue to be visible today, despite the lack of continuity, as is exemplified by the high cost recovery and low UFW rates in Hermanus. Reliability of services is guaranteed through an efficient customer service which is responsive to issues such as; low pressure, leaks and blockages. In a review of the successes of the GHWCP, Deedat *et al.* (2001), advise prudence in highlighting the overall success of the programme without an assessment of the drawbacks. The programme was designed to target those higher consumers and 'wasters' of water and as such failed to inform and acknowledge lower income groups. This served to reinforce the income and race inequalities amongst residents of Hermanus at the expense of social concerns such as; service provision, communication and dissemination; as well as failing to recognise the economic benefits to be gained, mostly for disadvantaged individuals but for society also.

From an environmental perspective, there is assurance of good water quality, both at source and at the supply end. In response to increasing water requirements and development concerns, the municipality has undertaken to conduct various studies into the quality and quantity of resources in the area. These sources include; surface and groundwater, as well as sea water and effluent from the treatment plants. There is a need however, for greater emphasis on education and pollution awareness to secure greater 'buy in' from the collective community and ultimately to ensure the preservation of rivers, streams and natural ecosystems.

5.3 Maputo City

5.3.1 Geographic profile

Mozambique is situated on the South East region of the African continent. It is bordered by Tanzania and Malawi to the North; Zambia and Zimbabwe to the West; South Africa and Swaziland to the South; and boasts an extensive coastline along the Indian Ocean to the East (Figure 5.5).

The country obtained independence in 1975, after which it entered into a period of civil war between the ruling party, Frelimo, and the rebel party, Renamo. Much of the damage to infrastructure observed to this day is as a result of this long period of conflict and war (CARE, 1999). The country has finally succeeded in achieving peace and is now a multi-party democratic state displaying one of the highest economic growth rates in Africa, if not world-wide (UNDP, 2006b). And yet, despite this progress, much of the population still lack access to safe water and sanitation, the basics for survival.

The capital, Maputo, is situated on the south tip of Mozambique and is the largest urban centre in the country. It boasts one of the most significant ports along the coast of the Indian Ocean. The city is connected to the interior of the continent through the railway network which connects the country to South Africa, Zimbabwe and Swaziland (Figure 5.5).

In some respects, Maputo is very similar to Hermanus; both are coastal urban centres along the Indian Ocean, and like other urban centres throughout Africa, both have experienced astounding population growth and impressive development rates. Both cities are popular tourist destinations, as shown by the fact that Maputo also displays a considerable increase in population during the holiday months of December to January.

The climate is tropical and characterized by months of intense, short duration rains with the highest intensity in January and February, which coincide with the hottest months of the year with average temperatures of 29.7° C. The average annual rainfall in Maputo is approximately 800 mm (Alves, 2004). According to FAO and based on the Weather Bureau's 30 year records, the monthly precipitation varies considerably from 18 mm in July to 137 mm in February. The mean annual evaporation rate, of approximately 1200 mm, exceeds the above reported mean annual precipitation, with implications for water resources and reserves.

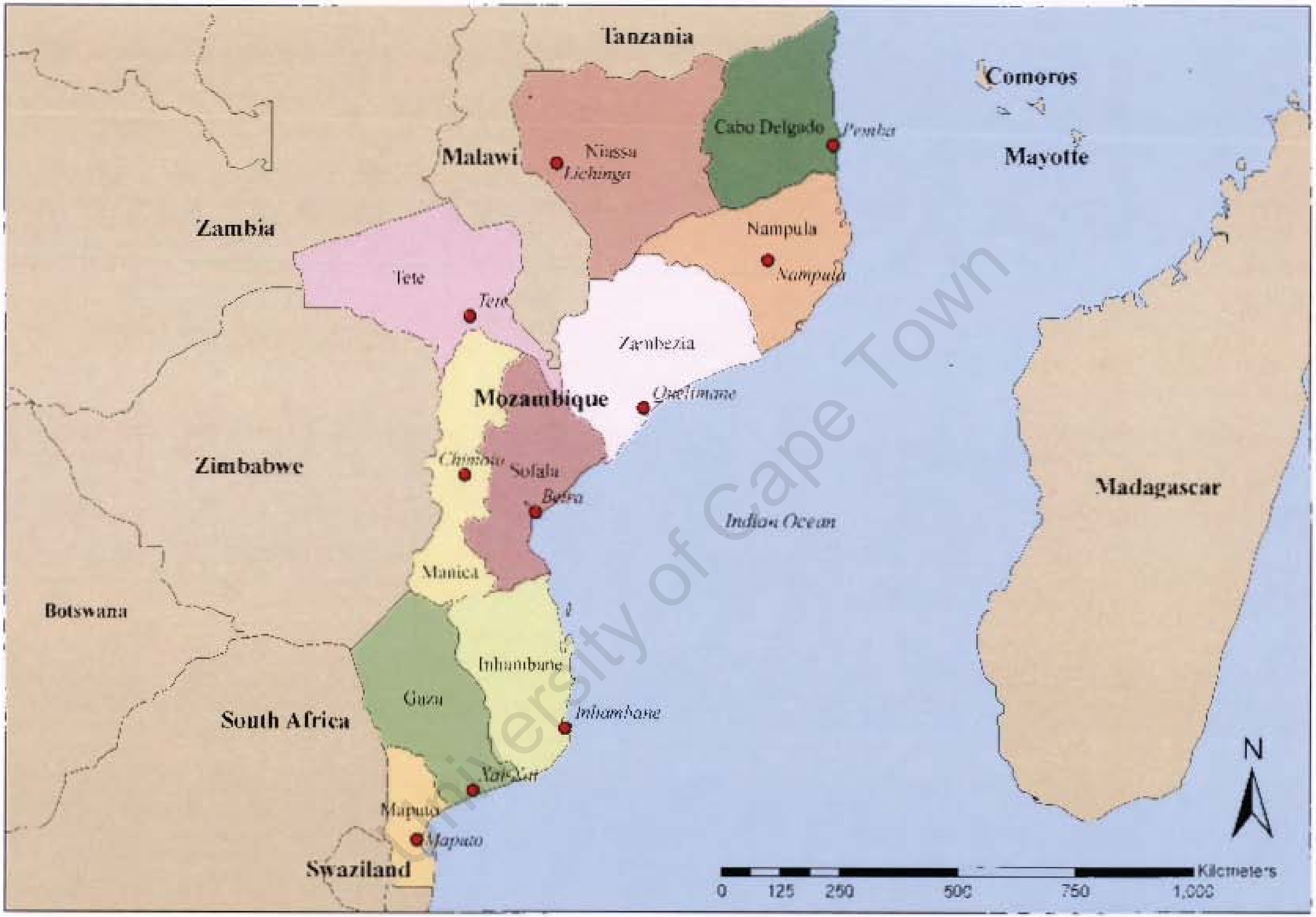


Figure 5.5: Provincial map of Mozambique

Maputo is within the southern portion of the Indian Ocean cyclone belt and while not as strongly affected as the central parts of the country, it has in recent years experienced significant cyclone activity.

In terms of its geology, the Greater Maputo area belongs to the southern Meso-Cenozoic sedimentary basin extending from Port Dunford in Natal (South Africa) eastwards to the Libombo Mountains and northwards to Quelimane in the centre of Mozambique (FIPAG, 2005). During the periods of marine transgressions and regressions, more than 100 million years ago, layered deposits of cretaceous to tertiary age rocks formed an over-layer which was in turn covered in certain parts by sand dunes or quaternary sand deposits e.g. eastern area of Greater Maputo. The groundwater system is determined largely by these features. It is divided into two major units; the sandy/phreatic aquifer (quaternary age) and the promising deep aquifer (tertiary age), which is foreseen to supplement future water demands in the area (FIPAG, 2005).

The area known as the Greater Maputo covers the municipalities of Maputo and Matola. There are nine administrative districts in total, Maputo consisting of six and Matola of three. These districts in turn subdivide into 108 bairros (neighbourhoods), which represent the lowest administrative level (FIPAG, 2005). These can be categorized as the central colonial urban neighbourhoods, the high density peri-urban neighbourhoods situated on the peripheries and the low density rural settlements located at considerable distances from the city centre (FIPAG, 2005). For the purposes of this research, only districts 1-5 within Maputo city and its periphery were considered, these constituting the core of Maputo City as shown in Figure 5.6.

5.3.2 Policy environment and institutional structures

The 1995 National Water Policy (Resolution No. 7/95, 8th August 1995) approved after the promulgation of the Water Law (3rd August 1991) recognizes a number of issues in the management of water, which are epitomized in the following key principles (FIPAG, 2005):

- The fulfilment of basic water supply and sanitation requirements for low income communities.
- Engagement in public consultation and participation throughout the stages of service provision; planning, implementation and maintenance.
- Acknowledgement of both the social and economic value of water; redirecting efforts towards the improvement of service provision and efficient management to ensure this.
- Clear and defined roles and responsibilities of all stakeholders to improve capacity for management.
- The acknowledgement and support of private suppliers of services.
- The implementation of Integrated Resource Management practices.
- The gradual transfer of service provision responsibilities to the private sector, in an environment of strong public-private partnerships.

Figure 5.6: Aerial photograph of Maputo City (Google Earth, 2007)

The guiding policy and regulatory institution at national level is DNA, the National water directorate, however this institution works in partnership with many others. Service provision and water management in Mozambique, but particularly in Maputo, is governed by a multiplicity of role players. This is a working environment which significantly complicates the coordination and integration of management. Some of these key players are:

- The National Water Directorate (DNA – Direcção Nacional de Águas).
- FIPAG, a consortium of Portuguese (Águas de Portugal) and Mozambican companies, which act as the chief investment and financial management body for the five major cities of Mozambique: Maputo, Beira, Quelimane, Nampula and Pemba.
- The Council for the Regulation of Water (CRA), who is responsible for the regulation of water supply and for providing instructions regarding quality of service, tariffs and expansion operations to both FIPAG and the PO (Private Operator), which in this case is AdeM (Águas de Moçambique).
- AdeM, the Water Utility Company for Mozambique, is the Private Operator responsible for all activities relating to the operation and maintenance of the potable water supply system.
- The Municipality of Maputo (CMM), who is responsible for the provision of most services with the exception of water supply (AdeM), electricity (EM) and waste collection.
- ARA-SUL, the Regional Water Board is charged with the management of water resources at a regional scale (South).
- MOPH, the Ministry of Public Works and Housing is not directly involved with service provision however is responsible for the provision and maintenance of public works and infrastructure.

There are several more institutions involved, not only in the provision of services but more broadly with the management of urban waters, such as: Water Aid, UNICEF, Care International, ADASBU, DANIDA, INGC and others.

5.3.3 Demographics and service provision

According to the 1997 National Census the population had reached the 1 million mark. Projections based on a 3.5% annual population growth put this figure today at just under 1.4 million people in Maputo City (INE, 2007). For lack of more recent census data, estimates obtained from FIPAG were used to project the current population for the five districts in question. These indicate a current population of 1 219 938 inhabitants in the urban core of Maputo City (FIPAG, 2005).

The official language in the country is Portuguese, however Makua, Malawi, Shona and Tsonga are common languages among the local residents (UNICEF, 2004). The country displays a variety of cultures, religions and ethnic groups, most of which can be found in the capital city. Shangaan, Manyika, Sena, Makua, among other native ethnic groups, account for 99.6% of the total population. The remaining 0.4% is made up of Europeans, Euro-Africans and Indians.

The main source of water to Maputo City is the Umbelzi River, at which an intake point was established. The Pequenos Libombos Dam, situated roughly 30 km south of Maputo City, yields an annual 56 million m^3 of water, distributed mainly in the formalised parts of town (District 1). The remaining population, in Districts 2 to 5, are either served by small scale systems established by AdeM, private providers or access groundwater resources through private boreholes and wells (FIPAG, 2005).

According to the classification provided by FIPAG, the areas covered by districts 2 – 3 constitute inner, intermediate or outer peri-urban neighbourhoods. It is in these areas, where the majority of the population resides (70%) and population densities are high, that service provision is worst. Actual levels of service, taking into account the three major services, are summarised as follows: District 1 is fully serviced; in terms of full water supply within the household, water borne sewerage and drainage, covered by primary, and in places, secondary drainage systems. This accounts for roughly 16% of the population. A rough indication of service distribution to the remaining population (Districts 2 – 5) demonstrates that 30%, 39%, 15% and 2% have access to levels of service 2, 3, 4, and 5 respectively, as were defined in Chapter 3.

A significant disadvantage of this backlog in service delivery, is the impact that this has on health, particularly in the age groups of 0 – 1 year and 1 – 5 years. This problem is more severe in the peripheral areas of the city where inadequate services and unhygienic living conditions are coupled with poor medical services. Despite the slow progress in service provision, the overall water-related health situation in Maputo City has improved. The trend in the four years of health data obtained by the Ministry of Health (MISAU) from 2000 – 2003 highlights these significant improvements, with decreases in the incidence and mortality rates of cholera, malaria, dysentery and diarrhoea. This can be largely accredited to the emergence and extension of Small Scale Service Providers (SSIPs) in peri-urban areas, projects for water supply and sanitation provision undertaken by donor agencies in specific peri-urban neighbourhoods, and improvements in the quality of service by the water utility, as well as efforts to extend the formal water supply network. The HIV/AIDS prevalence rates on the other hand, have increased, and according to MISAU, Maputo Province and City display the second highest rates in the country, with 20.7% of the adult population infected (ages 15 – 49) (MISAU, 2004).

The aspect of cost recovery for services provided is subject to the capacity of citizens to pay, and this in turn is largely dependant on employment and income levels. Analysis conducted by FIPAG indicated that 73% of the water consumption billed in 2003, was in fact collected. This does not however account for the high UFW rates, which place a considerable burden on the service provider (FIPAG, 2005). FIPAG data indicates that currently 57% of the water intake from Pequenos Libombos is unaccounted for through its stages of transmission up to distribution to consumers. This can be largely accredited to the age of the supply network, poor maintenance and a high number of illegal and poor quality connections (Figure 5.7 and 5.8).

Figure 5.7: Leakages and faulty meters at consumer's side, Maputo (FIPAG, 2007)

Figure 5.8: Leakages in the water supply system, Maputo (FIPAG, 2007)

The Health Census carried out by INE in 2003 indicated that more than 92.5% of the households interviewed in Maputo City fall under the highest wealth quintile, in comparison to 53% in the Province and 15.6% in the country (INE, 2003). In terms of the actual willingness to pay for services, the second beneficiary assessment conducted by CRA, currently at draft stage, indicates that a good portion of the population is not only willing but able to pay for full household water supply: 40% to 76% depending on the mode of payment.

Overall, despite being one of the poorest countries in the world, Mozambique has in the last decade or so shown consistently high growth rates towards slow but progressive socio-economic recovery. From 1996-1997 to 2002-2003, there was a marked decrease in the number of people living below the poverty line, of roughly 15%.

The above points provide a basic view of the current situations in both Hermanus and Maputo. Data sheets developed during the screening of data, and application of the indicator to the two case studies will provide a more detailed appraisal of the status quo of both cities in the context of the indicator and the required data (see Appendices J and K).

6. Results and Discussion

A comparative basis of assessment is necessary to ensure that performances are determined in relation to set standards. This is however complicated by the lack of indicator development and an even greater deficiency in case applications at the city-level scale, hence limiting comparisons with the work done here. This chapter will firstly present the results obtained for the two case studies, providing an assessment of both the individual performances of each city, as well as a comparative study of the two urban centres. It will also serve to highlight some of the factors which influenced indicator scores and discuss how the index can work towards benchmarking laggards and leaders. Secondly, a simple traffic-light diagram based on pre-determined index score ranges will be employed. This will help determine the overall capacity or performance of cities towards sustainable development, as a general benchmark of sustainability. A third approach will be used to establish whether the results obtained from this indicator are comparable to those obtained for similar indices. For lack of scale-relevant indicator scores, this will involve comparisons between the SI scores for Hermanus and Maputo, and those of other indicators such as the national ESI and EPI scores for South Africa and Mozambique.

This section concludes by offering a summary of the problems and limitations encountered and how this might have affected the process and the products (indicator and application results).

6.1 Greater Hermanus Area

6.1.1 Multi-dimensional sustainability performance

All factors considered, Hermanus' standing in the sustainability continuum is exceptionally positive, meriting the status of a highly sustainable city. The overall performance varies from a lowest score of 72% when adopting an economically biased weighting scheme, to 76% when an institutional weighting bias is introduced. Despite the observed maximum variation of 4% as illustrated in Table 6.1, performance levels remain above the 70% mark, independent of the weighting set used. From Table 6.1 and Figures 6.1 and 6.2 it can be seen that there are however inherent strengths and weaknesses in the general management of urban waters, and consequently in the performance across each dimension of sustainability. Single component analysis for Hermanus indicates that three dimensions of sustainability are well established, namely; political, environmental and economic; and in particular performances in the environmental and political spheres remain consistently high across all weighting applications. Social and institutional concerns, while not as well addressed as the above three, receive satisfactory to moderate scores respectively.

The subsequent discussion will follow in the order of higher to lower ranking components, taking a closer examination at causal factors and how sub-indicator scores influenced the overall index score.

Table 6.1: Performance assessment according to categorical weighting schemes: Hermanus

Components/ Weight sets	Equal balanced	Equal unbalanced	Social bias	Economic bias	Environmental bias	Political bias	Institutional bias	Maximum variation
Social	68%	81%	68%	68%	69%	69%	70%	13%
Economic	74%	72%	73%	75%	73%	75%	75%	3%
Environmental	87%	81%	86%	86%	90%	87%	88%	9%
Political	89%	87%	87%	88%	92%	88%	90%	5%
Institutional	53%	52%	59%	43%	52%	60%	59%	17%
SI	**74%**	**75%**	**75%**	**72%**	**75%**	**76%**	**76%**	**4%**

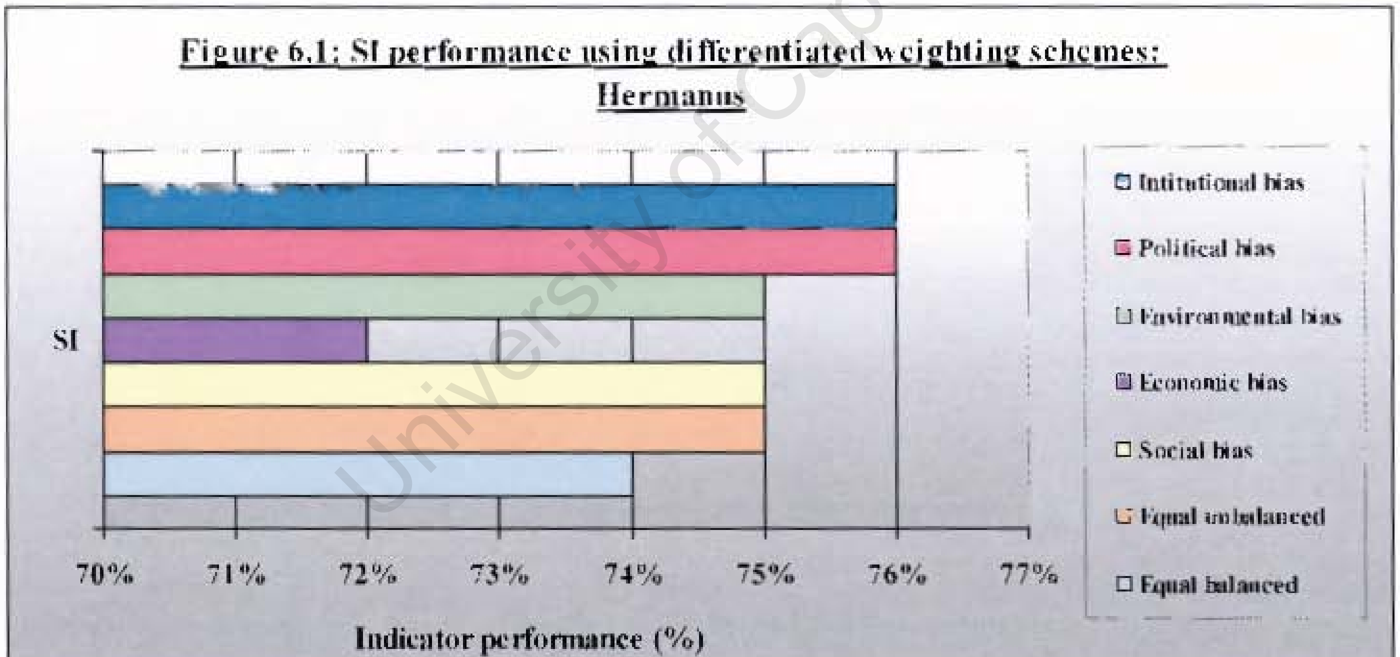
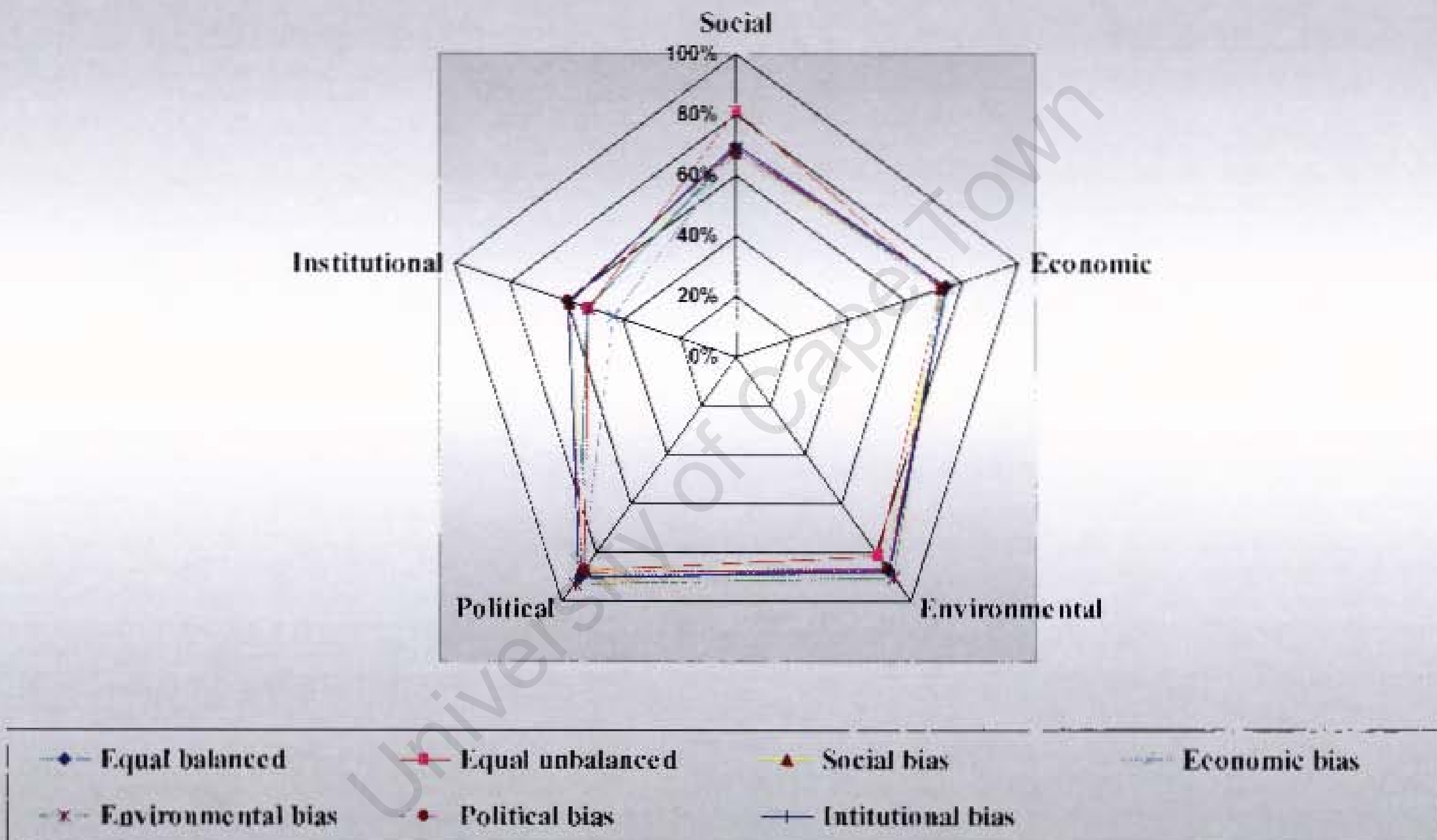


Figure 6.2: Indicator performance assessment using differentiated weighting schemes: Hermanus



6.1.1.1 Political dimension

The good political standing observed is largely derived from a favourable national legislative and policy water environment, which strongly advocates social justice through resource distribution, and environmental preservation, while maintaining national and international development agendas and goals. This component scores highest in all instances of indicator application and this is certainly indicative of a solid policy and legislative background, both nationally and locally.

In the case of Hermanus, national policy has to an extent contextualised both the governance and political settings. In retrospect, there have certainly been visible benefits associated with this restructuring, albeit not as progressive as expected, which are in turn reflected through the high sub-indicator scores for governance and compliance with policy. Whilst this decentralisation of functions to the municipal level has contributed to the wider inclusion of citizens and a more democratic municipality, the amalgamation of smaller management units into the Overstrand municipality has introduced significant management and institutional problems. These will be more clearly reflected in the institutional performance of Hermanus.

6.1.1.2 Environmental dimension

On the environmental front, the scores provide a constant indication of high resource availability and good water-related management to the benefit of the environment. The lowest score obtained was 81% for an unbalanced distribution of weights, and this increased to 90%, when an environmental bias was introduced.

Recent studies have indicated an abundance of underground water resources which elevate the area from a position of scarcity. The detection of significant underground water reserves in Hermanus has undoubtedly contributed to the achievements in environmental sustainability; however other aspects such as management have also had significant impacts on this dimension. The past rates of population growth and development, coupled with the issue of insufficient water resources to match this growth, introduced a state of water scarcity in Hermanus. This issue of scarcity was largely managed through the efforts of particular individuals at the municipality and can be mainly attributed to the successful Greater Hermanus Water Conservation Programme (GHWCP). With the departure of Mr van der Linde (previous town engineer for Hermanus) from the municipality and the abandonment of the water conservation programme, the management and maintenance efforts introduced by the GHWCP collapsed, however this initiative was sufficient to introduce a resource-wise mentality which motivated not only the present use of progressive block water tariffs but also stimulated much debate on water conservation approaches locally and internationally.

Also of concern is the issue of balanced resource use and distribution. The main category of users in Hermanus is domestic, with a small component of commercial. Agriculture and industry are under-explored, and consequently the city is dependant on external sources for the supply of certain goods and services. Furthermore, within consumer categories, domestic in particular, distribution of resources is extremely inequitable, with high income residents utilising significantly greater volumes of water.

Both these aspects mark an un-balanced and unsustainable use of resources, whereas a more balanced water distribution would be indicative of equitable distribution, as well as point towards a possible self-sufficiency in all sectors of society.

6.1.1.3 Economic dimension

Economically, it is possible to observe a consistent performance across all indicators, mainly in recognition of increasing investments in the area of water supply and sanitation as well as significant cost recovery figures for most suburbs in Hermanus. Again, giving credit to van der Linde's initiative, Hermanus was able to significantly reduce its water consumption rates by up to 25%, inclusive of both UFW as well as acknowledged wastages (van der Linde, 1997). This conservative approach has been sustained, and currently UFW levels remain within the 10%-15% range, this in spite of indications that per capita consumption rates have increased (Muller, 2007). Exploring these results further highlights the following findings:

- The capacity to pay for services was deduced on the basis of whether the population was economically secure to access basic services, given their earnings and the required service expenditure. Data from the 2001 Census indicated that a large proportion of the population in Hermanus at the time earned below R1500 per month, and a significant 11% were classified as unemployed. When drawing conclusions from the data available, one needs to bear in mind that the data is 6 years old. The considerable emphasis in job creation since then has contributed to both an increase in the employment figures and improved economic (income) standings of the same population.
- With regard to cost recovery, the indicators show that Hermanus continues to succeed on two fronts; firstly, as a result of good management and maintenance of infrastructure, as well as in the achievement of relatively low levels of UFW. The second achievement refers to the high payment rates, an achievement largely attributed to a successfully implemented block tariff approach as well as the efficient and effective collection rates, although these have at times resulted in public discontentment (Deedat *et al.*, 2001).
- At the level of investments, an increase in annual investments was observed in all three areas considered; water supply, sanitation, and operation and maintenance budgets have mostly increased consistently for the past six years. This was inevitable given the growth in population as well as the targets set for full service coverage stipulated in the Overstrand water services development plan (WSDP) of 2003. Service coverage projections predicted increased development in the area, which coupled with increased maintenance costs for aging infrastructure contributed to the increased expenditure. To support this trend, roll-out of services and considerable infrastructure upgrades have been proposed, and these are highlighted in the 2006 Overstrand Master Plans (Overstrand Municipality, 2006a).

6.1.1.4 Social Dimension

The perspective on sustainable development taken in this research is strongly influenced by social principles. It is geared towards the upliftment of society and 'community enrichment' through the assessment of concrete actions taken to not only improve the quality of life of individuals but also build overall resilience in urban societies. Improvements in accessibility to basic services, progress in efficiency of delivery, and strengthened resilience to natural phenomenon are some of the aspects which in turn contribute to improved health, productivity, and ultimately towards social and economic upliftment. From this perspective, Hermanus has managed to consistently deliver on all major fronts; accessibility to services, quality and standards of service, and improved resilience to disasters.

The majority of citizens benefit from remarkably high levels of service, such as access to full water supply inside the house and waterborne sanitation. According to the 2003 WSDP, only a small percentage of the population (14.7%) had at the time either level two (3.8%) or level three (10.9%) services (see Chapter 3). The WSDP also highlights a proposed medium-term plan (five years) to eliminate the 'backlog' in service provision by 2008-2009 (Overberg District Municipality, 2004). In terms of drainage, the central parts of the town are well covered by a formal system; however some areas are prone to flooding, mostly due to poor housing design and planning (van Vuuren, 2007). This is a problem that the municipality is aware of but is not currently able to tackle at large scale due to budgetary constraints. Waste collection in all areas of the town is undertaken regularly and efficiently.

In terms of vulnerability to disasters, Hermanus is not highly susceptible to any of the major disasters under consideration; with the exception of veld and bush fires, as well as the potential for flooding in some areas, which is recognized mostly as a planning issue rather than any natural propensity to major disasters. Given the high levels of development and efficient management at municipal level, it is safe to assume that the area is adequately prepared for the eventuality of one or more of the accounted-for disasters. Furthermore, engineering design in the form of formal services strongly corroborates these indicator findings.

With regard to health, low incidence of water-related diseases is observed, and this is in line with accessibility to high levels of service, such as convenient and quality water supply and readily accessible sanitation. Moreover, the high education levels and awareness campaigns introduced at school level support this situation. Higher education levels can and have been taken to imply better understanding and greater awareness of basic hygiene principles, as well as customary application of the same.

The observed HIV/AIDS prevalence rates reduce the overall health scores. While HIV/AIDS prevalence is not directly related to water provision, a sufficient and accessible supply of water as well as adequate provision of sanitary services, amongst other things, can contribute significantly to building immunity and hence help mitigate the more immediate and devastating effects of HIV/AIDS. HIV/AIDS data at local level is inconsistent at best; therefore the figure used here refers to the situation in the Western Cape and not Hermanus in particular, which might have altered the score somewhat.

Secondly, HIV/AIDS data is usually obtained at pre-natal clinics which account for mother and child infections, this is then extrapolated for the entire population. The broad data categories covered by the 0 – 5 rank system do account for some inconsistencies, however for the above reasons, caution is advised when interpreting the results.

There are other aspects of the index which show weak performances, such as broad public dissemination and education on matters pertaining to the management of water. Moreover, public consultation and stakeholder involvement, both precepts of the new public management and participatory development approaches to governance currently evident in policy thinking, are largely absent. These are areas requiring greater consideration to ensure wider integration of the different community groups as well as to instil in the public a sense of ownership which is essential to secure sustainability of services at the local level.

The historical context of Hermanus, being a rich and white dominated town, has certainly contributed to an almost selective management approach, however, Hermanus is a town in change and progress, and one almost expects that these issues will become less prominent in future. To its credit, the town has been continually praised for a successful application of block tariffs and a remarkable water conservation programme, which caters for the lowest income groups (indigent and sub-economic groups). Upon the departure of key drivers of the GHWCP, certain aspects of management have been neglected; this lack of continuity has been reflected in the indicator scoring.

6.1.1.5 Institutional dimension

Variables at the institutional dimension illustrate that there is an issue of under-performance at the management level, however this is not directly reflective of the capacity of current staff (education and skill) but rather highlights the under-capacity of the entire unit (understaffed). The amalgamation of smaller municipalities such as the previous Hermanus municipality into the Overstrand municipality has extended the service base without a matched increase in resources and staff. Furthermore, limitations regarding monitoring and data collection as well as in the exploration of alternative technologies on the consumer end (water saving appliances, recycling etc) are emphasized. These stand out as clear areas for improvement, both from discussions with some of the consultants working with and in the municipality, as well as from the gaps observed in reports and current practices.

The implementation of Integrated Water Resource Management (IWRM) principles is evidenced by efficient management of resources, and the exploration of complementary resources such as sea water, additional groundwater, and treated effluent. Reliability and constancy of services is also high, with infrequent disruptions, and when necessary quick and effective responses.

6.2 Maputo City

6.2.1 Multi-dimensional sustainability performance

The circumstances in Maputo are somewhat different to those observed in Hermanus. The index scores indicate a less than adequate performance, with a current standing in the range of 37% to 46% depending on the weighting scheme adopted (Table 6.2). A broad analysis of the results shows that the major strengths lie in the environmental and political dimensions, which achieve scores in the ranges of 42% to 58% and 48% to 52% respectively (Table 6.2). The institutional, economic and social dimensions on the other hand contribute the least to the overall sustainability of the city, attaining scores as low as 18%, 34% and 35% in the above order.

6.2.1.1 Environmental dimension

From the table and charts that follow it is apparent that the environmental dimension offers the highest scores to an overall poor performance. The lowest environmental component score observed when a social bias is introduced is 37% and maximum of 46% is achievable if focus is placed on environmental issues, illustrating the trade-offs between socio-economic development and environmental preservation so commonly emphasised.

Higher component ratings may be largely attributed to lower levels of development and incomparable resource depletion and pollution rates as compared to those experienced in more developed parts of the world. However one must be cautious not to ignore the impacts of poverty and underdevelopment on the environment, which is clearly the case in Maputo. Following on the literature by Bartelmus (1994), one is reminded of the problems arising from lack of development itself. The term 'pollution of poverty', initially introduced in the Brundtland Commission Report of 1987 (WCED, 1987) and discussed by Bartelmus, refers to pollution levels resulting from the lack of development as opposed to pollution due to the actual process of development. The lack of adequate services such as water and sanitation, inadequate housing and shelter, poor health care and malnutrition are described as some of the contributors to the degradation of the environment, which again are evident in Maputo.

Other impacts are: lack of knowledge regarding environmental matters, a general disregard in the face of more pressing developmental problems, incapacity to undertake environmental management even when desired, inadequate or biased policy which places emphasis on socio-economic development with little regard for environmental concerns, and a general shift or misappropriation of 'blame' in the face of more visible and condemnable 'pollutive' practices in developed countries.

This concept of "pollution of poverty" largely explains the moderate to low scores obtained for Maputo, stressing the very inadequacies pointed to in the above discussion. The main areas highlighted by the index being; an unbalanced use of resources which fails to appropriate the necessary agriculture water requirements; resource scarcity given climatic conditions in the region as well as inadequate inter-basin water transfers to Mozambique from neighbouring countries.

Table 6.2: Performance assessment according to categorical weighting schemes: Maputo

Components/ Weight sets	Equal balanced	Equal unbalanced	Social bias	Economic bias	Environmental bias	Political bias	Institutional bias	Maximum variation
Social	36%	66%	37%	35%	39%	36%	37%	31%
Economic	38%	38%	34%	38%	40%	36%	40%	6%
Environmental	56%	51%	42%	55%	58%	55%	57%	16%
Political	50%	48%	49%	49%	52%	50%	51%	4%
Institutional	28%	22%	25%	18%	41%	34%	41%	23%
SI	42%	45%	37%	39%	46%	42%	45%	9%

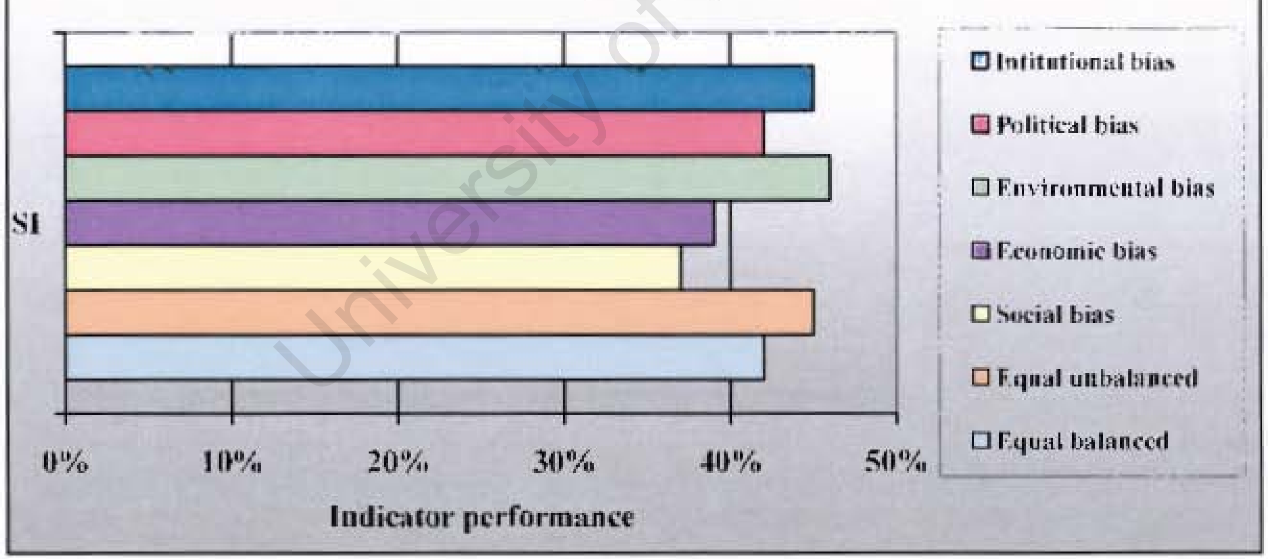
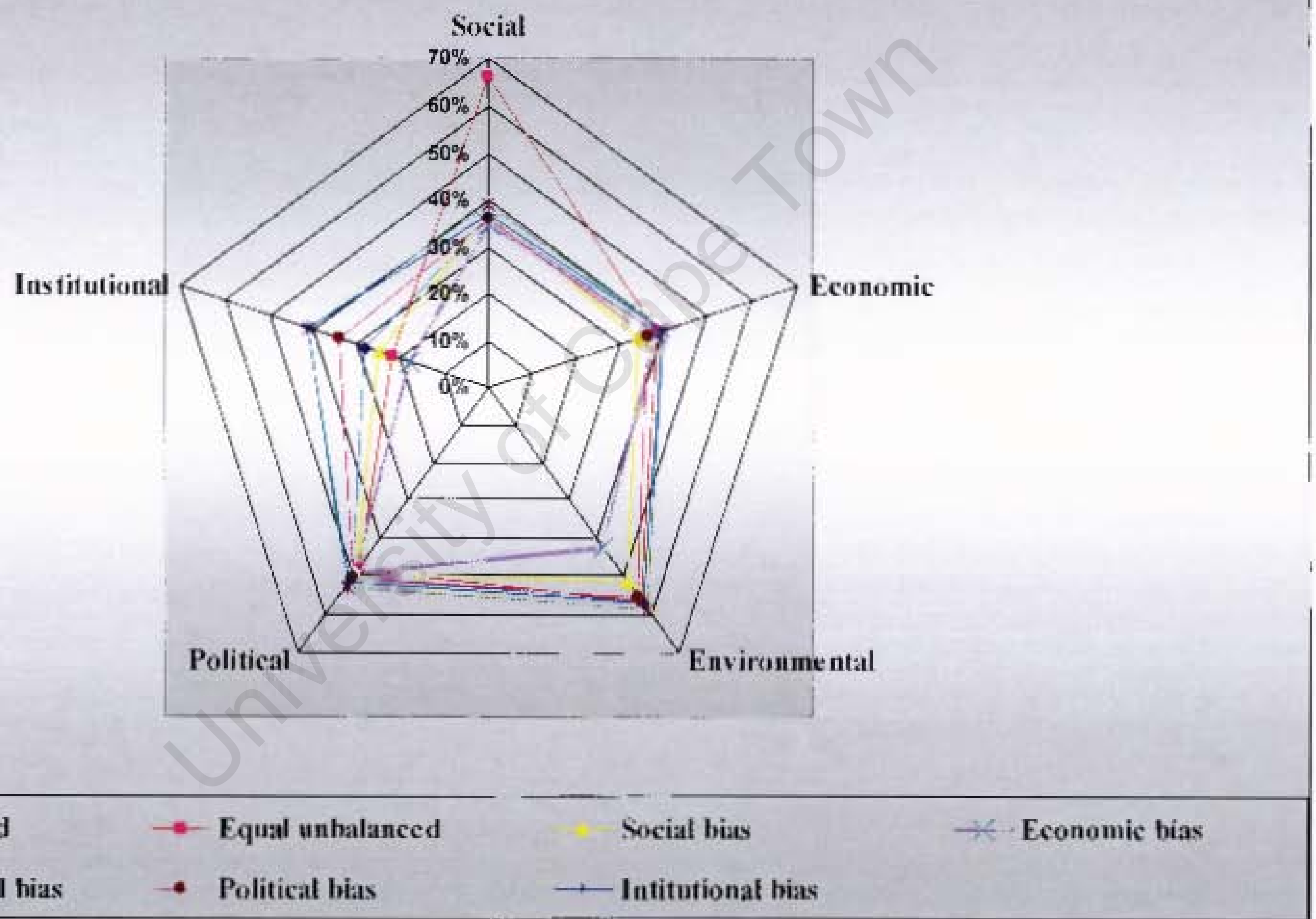


Figure 6.3: SI performance using differentiated weighting schemes: Maputo

Figure 6.4: Indicator performance assessment using differentiated weighting schemes: Maputo



Coinciding with these concerns, there has been a recent emphasis on large scale agriculture at national government level, in recognition of the extent and exposure to famine in parts of the country.

Other areas demanding improvement include: the management of effluent waters such as wastewater and stormwater, which are currently mostly untreated and discharged into receiving marine and riverine environments; the financial and human resource capacity to provide managed and well monitored water services, amongst others, to areas beyond the "cement city" (District 1) so as to enable compatibility with the surrounding environments; and the necessary awareness creation and education to prompt environmental management at the level of decision-making and action-taking, but also by instilling a principled social consciousness for such issues.

6.2.1.2 Political dimension

The higher political ranking in relation to the other three components is somewhat unanticipated as there is a common perception that poor governance and weak and inadequate policies constitute the main inhibitors of growth in the water sector, as well as elsewhere. While such assumptions are not entirely invalid, in order to reach pertinent conclusions one must contextualise the findings in view of the historical, political and natural backgrounds. Historically, there have been long periods of war, after which the country entered a mixed state of euphoria and disarray. In the current context, notwithstanding the quality of legislation and policy, these represent remnant policies of colonial and post-colonial times which have been rendered inadequate, inapplicable or simply unapplied.

The other facet of the country, and certainly of Maputo, is one of constant struggle with nature; cyclones and floods as well as extended periods of drought have become common denominators. From a policy and management point of view, the responses have always been passive or latent rather than pre-emptive or proactive, consequently stalling or retarding development.

Assessment at the sub-indicator level shows that high corruption, low accountability and a lack of transparency are by far the greatest threats to sustainable and democratic governance. According to studies done by Austral and USAID, Mozambique currently ranks amongst the most corrupt countries in Africa, preceded only by Angola and Zimbabwe (Austral, undated; & USAID, 2005). The findings indicate that corruption has become such a pervasive phenomenon, active in all tiers of government, as well as in the business and social environs. It has permeated the societal mantle of morals and values to such an extent that it has become for many 'the way of life'. It is to this 'culture of impunity', and lack of transparency and accountability that the indicator alludes (USAID, 2005). Nonetheless, progress has been observed since the first democratic elections in 1994. Mozambique has taken great strides towards democracy and growth, largely to the credit of good leadership. Furthermore, while the attitude of elitism and superiority at the higher echelons of society is still very evident, there have been changes, provenient of the more resolute anti-corruption leadership of the current government.

"The country (Mozambique) is in many ways a development success story, and the government and its donor partners have stimulated impressive economic growth- albeit from a very low starting point – that seems to have had a positive impact on reducing overall poverty in this poorest of countries" (USAID, 2005).

6.2.1.3 Social dimension

Social sustainability is concerned with far more than the issue of poverty and inequality, although these are often at the root of slow progress towards sustainability in underdeveloped countries. The indicators selected examine issues such as vulnerability, poor health and education, all of which are either causal or consequential to the poverty endemic in Africa. Maputo, and possibly Mozambique, is an environment largely dominated by elitism, an environment dictated by the politically influential and the affluent. It is not therefore surprising that resource distribution in the water sector follows in a similar pattern, and this is evidenced by the limited distribution of services which benefits a minority of the population in the urbanised and wealthier parts of the city.

The indicators emphasize high exposure to disasters, which is indicative of a general state of vulnerability due to poor social safety nets to alleviate the hardest impacts of such disasters.

On average, low scores across all measurements of social sustainability, with the exception of the scores obtained from the equal unbalanced distribution of weights (see Table 7.2), signify not only poor achievements but more importantly allude to a very slow progression towards sustainability goals. The following factors work coactively to stall social development: low service provision; high vulnerability to natural disasters; poor health, particularly in relation to HIV/AIDS prevalence rates; and an absence of awareness creation and dissemination initiatives. At current rates of development, it is difficult to envisage the attainment of targets such as those set-out by the Millennium Development Goals, much less conceive of progressing towards sustainability at the level of developed countries.

6.2.1.4 Economic dimension

The tables and charts demonstrate that firstly; the economic scores are very low, which is indicative of major financial constraints to the process of development. Secondly, it is also possible to observe that there is very little variation (maximum variation is 6%) in the component results which leads one to conclude that irrespective of the emphasis placed on economic aspects of the index through differentiated weighting, the actual performance scores are too low to educe much of an improvement.

On the management side, economic under-performance can be largely accredited to investment limitations and budgetary constraints for the maintenance and expansions of infrastructure. Furthermore, an over-dependence on donor funds obscures the fact that the current economic growth in Mozambique is not self-sufficient, and as such there is a tendency to overlook the issue of long-term sustainability, which is crucial if consistent and enduring improvements are to be obtained.

Cost recovery is another area that demands greater attention. On the one hand, high percentages of UFW have been registered and reported in recent years, and at the same time the volumes of water actually billed and paid for do not represent sufficiently profitable rates. Furthermore the issue of illegal connections and the significant resale of water within peri-urban neighbourhoods have all contributed to the current state of economic insecurity, hindering any possibilities of expansion, as well as maintenance of existing systems, and disadvantaging both providers and their consumer base. From a consumer's point of view, low education and income levels coupled with high water tariffs represent the more pressing issues in terms of accessing reliable and quality services.

6.2.1.5 Institutional dimension

From a management and institutional point of view, Maputo's performance is extremely low. With the exception of progressive moves towards IWRM with neighbouring countries, South Africa and Swaziland, the indicators show the very opposite of what is required for integrated and coordinated management. This is an environment dominated by several organisations, tasked with different functions but often duplicating the work, for lack of communication and coordination. The element of integration which is central to the work undertaken here is largely missing. Central to the institutional under-achievement problem is the lack of technical, monitoring, and managerial skills as well as the financial capacity for change.

The dependence of water related services on other services such as electricity and transportation, which are irregular at best, destabilises water management functions. The data indicates that there are significant planned and unplanned energy cuts on a monthly basis which lead to disruptions in water supply. Failure or breakage of machinery and equipment for the emptying and transportation of sewerage from septic tanks and pit latrines, as well as for the collection of solid waste, is also frequent. Taking all these factors into consideration, it is not difficult to understand the low performance in this category.

For the sake of clarity, it is important to reiterate that much of the information used in the indicator application and discussed in this assessment was obtained from interviews and discussions with officials and practitioners in the cities in question. This was particularly useful in interpreting data provided in official reports and documentation and enabled a qualitative appraisal of the current situation.

6.3 Comparative case study assessment

The following are similarities between Hermanus and Maputo which to an extent enable comparisons between both cities: both are located near the coast; both are urban centres dominated by urban activities and accommodate high densities, particularly in informal areas; both have experienced significant population growth and socio-economic development in the past decade; and to different degrees both are tourist destinations. The differences far outweigh the common factors, hence making it difficult to draw significant comparative conclusions. However as has been mentioned, testing the applicability and relevance of the indicator at different scales was as much an objective of the research as maintaining comparability, hence trade-offs were required. Due to time constraints it was not possible to undertake a third city assessment, however further assessments should be conducted.

Whilst accounting for the subjectivity of an exercise of this nature, and the need for imputing and/or inferring data, nevertheless the results obtained do not deviate significantly from initial performance assumptions. In the absence of similar assessments in the field of IUWM for the cases in question, the descriptive portrayal of the two cities in Chapter 5 will serve as reference points. It was therefore expected that results conform to the pre-assumed performances; moreover, this was needed in order to confirm the validity of the indicator developed.

In the interest of simplicity only one set of weights is displaced in Table 6.3 and the following charts, however comparisons between both case studies will be drawn taking into account the different weights adopted.

Table 6.3: Comparative SI scores for Hermanus and Maputo using balanced and equal weights

Components	Hermanus	Maputo
Social	68%	36%
Economic	74%	38%
Environmental	87%	56%
Political	89%	50%
Institutional	55%	28%
SI	**74%**	**42%**

The use of different weighting sets does result in slight variances in the scores at both index and sub-aggregate levels, with little variance in the overall scores At the aggregate index level, for both case studies, the maximum variation does not exceed 10%; 4% for Hermanus and 9% for Maputo. The variation at sub-indicator and component levels is however much greater, reaching 17% for Hermanus at the institutional level, and 31% for Maputo with regards to social aspects. These results demand some rationalization as to the causes of such discrepancies.

Figure 6.5: Comparative case study analysis employing balanced and equal weights

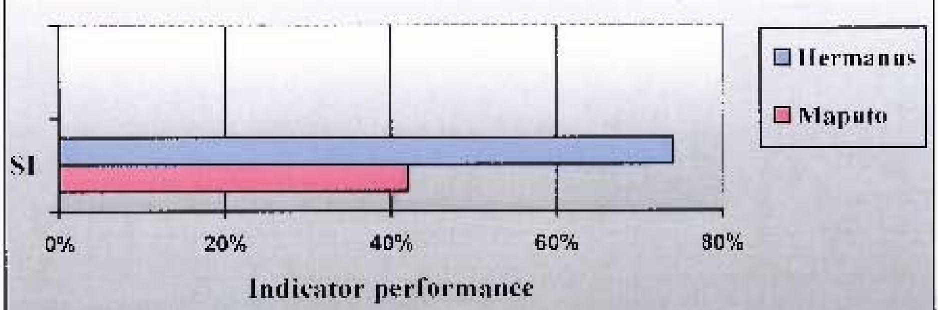
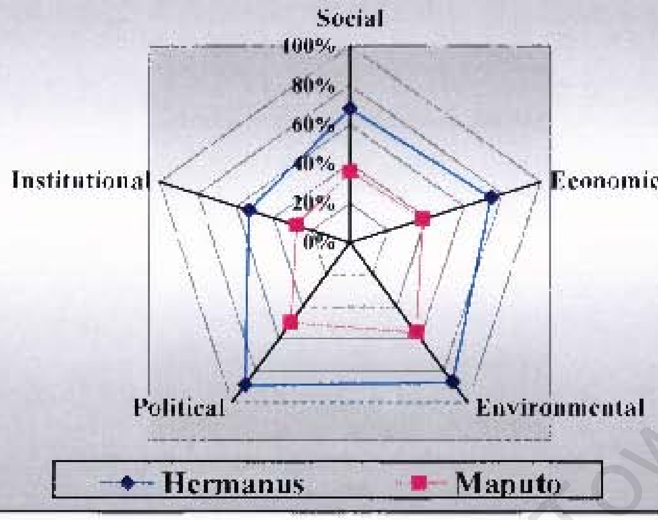


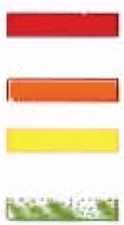
Figure 6.6: Comparative sustainability assessment bewteen Hermanus and Maputo



Comparisons between the two case studies and across all 5 dimensions of sustainability indicate a large difference in scores for Hermanus and Maputo (Table 6.3). This enables an extraction of positives which can guide development in Maputo. There are observable differences in service provision, for which Maputo requires a much more progressive roll-out of services and upgrades in infrastructure. The economic standings also differ as does the level of commitment and capacity to engage in environmental preservation; a sound political environment to enable implementation of practical protection and mitigation measures; transparency and accountability of management and leadership; and the institutional capacity, management expertise and technological progress to deliver on the above.

In conclusion, the following observations are of note; firstly, that all biased weighting sets create a positive focus on the dimension of concern, partially explaining the variations in scores. This is after all the intended purpose of differentiating weights in such a manner, to reinforce the performance of an area in terms of social, economic, environmental, political or institutional aspects of water management. Secondly, the highest score discrepancies are introduced by the equal and unbalanced weighting set. The component results in this weight category do not conform to the general patterns, particularly for the social dimension of sustainability. This can be explained by the significant number of high scoring variables in this category, which given the equal variable weightings, result in higher component scores. Thirdly, the general scores tend to conform to the expected performance levels, attesting to the robustness of the indicator in measuring real situations, however this is also largely dependant on the data. Good quality data will provide relatively good results. Additionally, the indicator development and application process is inherently biased and despite the adherence to objectivity where possible, the need for qualitative or judgment-based decisions make it inevitable that the indicator reflects the views of those involved in its development. The aim is to keep this subjectivity to a minimum and clearly state where the case arises. This is to say that comparisons with expected/assumed realities are not sufficient and should be validated by other work. The developer intended to apply the indicator at a lower scale: at the district, and perhaps neighbourhood-level in Maputo, and at the enumerator level in Hermanus. This would have enabled a more refined analysis of sustainability, delving deeper into community level issues and enabling mapping of the results. This was not possible for two main reasons. The first impediment was the incomparability of certain data. For example: water supply boundaries conform to the formal district boundaries established, however health data is devised on the basis of health care facilities available and therefore different boundaries are used. In other cases, the boundaries are simply not so distinct: which is the case where service facilities service across boundaries or significantly vary within the same areas. The second reason is two-pronged; the actual scarcity of data, as well as the limited time available for seeking and collecting information.

The traffic light diagram illustrated in Figure 6.7 recapitulates all the findings in one simple appraisal, and case studies will be accordingly characterised in the table that follows (Table 6.4).



Categories	Index scores	Measure of sustainability
	0-30%	little/no progress towards sustainability
	30%-50%	very low progress towards sustainability
	50%-70%	satisfactory progress towards sustainability
	70%-100%	highly sustainable

Figure 6.7: Traffic light diagram of sustainability

6.4 Validating the results: exploring other indicators

Table 6.4 provides a comparison of the results obtained for the two case studies, Hermanus and Maputo, with those obtained from other indicators. As a result of the dearth of indicators in this field of urban water management, particularly at city scale, national indicator scores were used. Comparisons were done across the dimensions of sustainability, and therefore the comparative indicators selected were largely relevant to one of the five dimensions of sustainability. For the social dimension, the Human Development Index (HDI) was selected; for economic considerations the Gross Domestic Product (GDP) Index was used; and for environmental concerns, both the Environmental Sustainability Index (ESI) and the Environmental Performance Index (EPI). In the absence of global indicators which are indicative of political and institutional well-being, sub-sets of the ESI which represent the following aspects were used: global stewardship, linked to political leadership; and social and institutional capacity, indicative of institutional and technological capacity.

Table 6.4: Comparative assessment between the SI and similar indices

HERMANUS					
SI Profile	**SI Performance (%)**	**Traffic light assessment**	**Other indicators (%)**		**Notes**
Social	68%		0.653 (65%)	HDI (2004)	(UNDP, 2005)
Economic	74%		0.77 (77%)	GDP index (per capita)	
Environmental	87%		46.2% 62%	ESI EPI	
Political	89%		38.2%	Global stewardship (ESI)	-Participation in international collaborative efforts -Greenhouse gas emissions -Reducing transboundary environmental pressures
Institutional	53%		53.7%	Social and institutional capacity (ESI)	-Environmental governance -Eco efficiency -Private sector responsiveness -Science and technology
SI	**74%**	Highly sustainable			
MAPUTO					
Social	36%		0.390 (39%)	HDI (2004)	(UNDP, 2005)
Economic	38%		0.40 (40%)	GDP index (per capita)	
Environmental	56%		44.8% 45.7%	ESI EPI	
Political	50%		65.7%	Global stewardship (ESI)	-Participation in international collaborative efforts -Greenhouse gas emissions -Reducing transboundary environmental pressures
Institutional	28%		48.9%	Social and institutional capacity (ESI)	- Environmental governance - Eco efficiency - Private sector responsiveness - Science and technology
SI	**42%**	very slow progress towards sustainability			

This assessment indicated that there is a high correlation between the results obtained for the two pilot cities and their relevant country scores for other indicators. There are significant deviations in the environmental dimension scores for the SI and those obtained from the ESI and EPI. This is easily explained, as both the ESI and EPI take into account national assessments of a number of resources and resource management strategies, which are not represented in the SI. Furthermore, national scores can hide significant regional and local variations, which have been picked up at the more refined assessment scale employed in the SI application. In the case of Hermanus, recent studies have indicated an abundance of groundwater resources at the local level, and this has contributed to the overall positive score for environmental management, which is not necessarily the case throughout the country. The political and institutional dimensions also show some discrepancies, and again this could be explained by the differences in indicators selected to assess these components. Where the SI components look to a more local level assessment, the indicators extracted from the ESI follow global and national trends in management and policy.

The aim was to link this initiative with others introduced elsewhere, in order to determine the scope for comparison. This was possible, and overall the scores were within close ranges, leading to the deduction that the results obtained are largely representative of the current situation and so is the sustainability index.

The following section will close by reiterating and summarising some of the difficulties encountered in this research, which will then guide in the proposal of future research imperatives and improvements.

6.5 Constraints and limitations

6.5.1 Pre-planning and data gathering process

- **Poor cooperation and reluctance to share information**
  In some instances, the relevant groups holding information/data were reluctant to share this for a number of reasons, but ultimately it was attributed to the poor understanding of the tool and its purpose. Once discussions ensued, individuals/groups became more interested and willing to collaborate. In South Africa the individuals contacted expressed an initial disinterest in the index as a result of an experience of 'overload' with this type of tool, some of which have been 'impinged' upon municipalities by higher authorities. Suggestions were put forth that the SI should avoid duplicating much of what has already been proposed and undertaken in terms of assessment, and therefore should correlate with local initiatives such as the development of WSDPs.

  In the Mozambican context, poor cooperation was founded on social issues, where people were either not capable or willing to help. The process of moving from government department to government department and back was extremely tedious and often unfruitful. In South Africa, a clear communication of the goals and expected outcomes of the project was in time sufficient to engender cooperation.

- **No information and/or data**
  Some of the information for the selected variables either does not exist or has been misplaced and/or lost, in which case certain steps were taken to substitute or impute data; however this reduced the credibility of the results and the overall confidence in the indicator.

- **Unreliable or inaccurate data**
  The index is strongly reliant on the accuracy and quality of the data used, so even where data was available, the source or producers were not always to the desired standard, but in the absence of better information, such data was used. In future necessary efforts must be made to ensure good and reliable data from reputable sources to improve indicator credibility.

- **Homogenisation of data**
  It was the intention of the researcher to explore the aspect of scale, and how suited the indicator was to different scales. This was possible, to an extent, through the use of different case study sizes; however it was not possible to explore finer scales such as district or enumerator levels, for lack of corresponding service boundaries.

6.5.2 Conceptual framework and indicator development

- **Development of the model underpinning the indicator: systems approach**
  The challenge was not so much in identifying the problem, nor was it in developing an approach for calculating the indicator. The need for multidisciplinarity, integration and systems approaches proved to be particularly challenging. The challenge lay in identifying a model which was both integrative of all aspects of sustainability and at the same time provided a guided step sequence to building the index. The approach taken was to use models already developed and tested for the purpose of similar assessments, and adjust these to match the objectives of this research. This was ultimately achieved by combining the model proposed by Lundin *et al.* (2002) and the Nardo *et al.* (2005) development process.

  Addressing the concept of sustainability demands a paradigm shift from conventional single-discipline approaches; it requires a departure from conservative thinking and demands a welcoming of the multiplicity, complexity and even indeterminacy that characterise reality. Systems thinking and systems theories acknowledge these varied and complex relations between humans and the environments, as well as within human spheres. Following on this ideology and methodology, the challenge was to identify and define the following key aspects and boundaries:

  1. Temporal aspects: The *"extended time horizons: linkages within and between generations"* (Ravetz, 2000). While it is important to be thorough in setting the boundaries and in defining the context for sustainability assessments, in this case the time aspect required some broadness of view. Due to the limited time available, the following approach was adopted: a measure of capacity to perform sustainably was developed which assesses the immediate to short term sustainability of an area across

five dimensions. But it is the longer term changes which are of greater interest (within 5 to 10 years and between generations), particularly if one aims to validate the underlying assumption that this tool can guide decision-makers towards better management of water. This was not possible within the time scope of this thesis. This following of trends will ultimately fall to the municipalities or groups tasked with regular application of the indicator. What was possible was to verify the results obtained from the SI with trends exhibited in reality and illustrated by other indicators.

2. Spatial aspects: The *"extended physical horizons (linkages from local to global)"* (Ravetz, 2000). Defining the spatial boundaries is also crucial. Implementation and work at the local level has often shown greater success than at wider scales. In response to this, one of the key outcomes of the research was to develop a tool which is scale-relevant. In other words, the index can be applied both at enumerator, district, and city level, as well as at the national scale. In this research, application was limited to the city level, however it is proposed that in future, this be tested at all scales mentioned above. While the index does not directly represent the local and global links, the literature review as well as the study of global indicators did serve to highlight some linkages.

3. The *"extended causal chains: from upstream pressures to downstream impacts" (*Ravetz, 2000). This idea of identifying the 'offenders' and the 'victims' was explored, albeit indirectly. The indicators explore the overall well-being of the system and its inhabitants, and therefore indirectly illustrate unsustainable practices, and those accountable for such. Identifying the causal chains is also dependant on the scale of application: at national scale, neighbouring countries can have an impact on the country in question, as is the case of South Africa, Swaziland and Mozambique; the same can be said of the city, district and neighbourhood levels. However what is pertinent is the scope and extent of such impacts at different scales and the required capacity to address these.

4. The *"extended sectoral boundaries: linkages from environmental to human activities"* (Ravetz, 2000).

5. *"Extended value systems: a multiplicity of social, economic, political and cultural perspectives"* (Ravetz, 2000).

Both of these concerns are embodied in the indicator through the inclusion of all dimensions of sustainability; however it was not possible to address all the linkages as these are many and varied, as well as being responsive to the dynamism in societies and environments. Understanding this, the developer proposed to include the more pertinent links which have visible or threatening impacts, nonetheless this leaves countless more avenues for exploration.

- **Communication, consultation and participation**

Not only do indicators help guide policy development but they also help to identify management areas of concern, and hence help guide in 'concretising and moulding' appropriate policy (Valentin & Spangenberg, 2000). The result is that indicators cannot be developed singularly, as this not only defeats the purpose of systems thinking but most certainly will fail to assess general priorities and broader requirements to be measured. Undeniably, the approach to indicator development must take due cognisance of the technical methods and scientific aspects, however it must go beyond this to not only consider other less technical sciences but also endeavour to be more open and collaborative. Development of the SI was largely based on a desk study and the exploration of literature. This failing is certainly acknowledged and where possible consultation with other stakeholders was undertaken, however this was limited by both time and resources. The recommendation therefore is that in future, greater participation and consultation be encouraged and actively sought.

- **Qualitative rather than quantitative data**
  Given that the indicator is strongly number-oriented, accuracy favours the use of quantitative data. The lack of data in this regard has deemed the use of qualitative assessments very important and therefore concessions were made for this as well as for the 'less accurate' nature of the results.

- **The use of proxies**
  The use of proxies is yet another concern; direct measurements of systems characteristics were not always available. Some of this information can be difficult and costly to measure, it may be too abstract or simply impossible to measure, it may be subject to qualitative assessments; expert opinion; or simply lost/misplaced. Where this was the case, proxies were used instead.

- **Variable, sub-indicator, component selection**
  Assessments of sustainability often deviate from real-world phenomenon in that these rely on quantifiable and determinate measurements, whereas in actuality sustainability is characterised by indeterminacy, complexity and diversity (Ravetz, 2000).

Issues of indeterminacy and multiplicity are key to considerations of sustainability. The term indeterminacy, with its genesis in the area of quantum physics, has permeated many fields of science and related studies. One can refer to indeterminacy as a result of technical uncertainties and/or irresolvable uncertainties such as cumulative impact assessments and structural indeterminacies. The bottom line is that indeterminacies arise due to the impossibility of accurate measurement, a fact which is common in assessments of sustainability (Ravetz, 2000). Multiplicity on the other hand explores the very nature of sustainability, a concept so deeply entrenched in the every day reality for which it is possible to observe a myriad of inter-linkages and connections, and which accounts for the diversity in human perceptions, and ideals of sustainability (Ravetz, 2000).

With regard to indeterminacy, several statistical techniques which might improve the uncertainty and robustness of the index were explored; however this was only possible in theory. The issue of multiplicity was addressed almost singularly, presenting the views of the developer, and therefore the indicator is but one of the many possibilities, representing the developer's subjective perception of sustainability.

- **Scoring system: incommensurability of data**
  In order to aggregate variables and overcome the issue of incommensurability, all variables were converted to a common 0-5 scale, irrespective of their unit of measurement. However this scale in itself is subjective, a more refined scale could have been chosen, making it possible to identify smaller variations in indicator scores. Furthermore the ascription of scores to variable ranges or categories was also subject to the developer's interpretation of the indicator and a personal value-base. In other words, where specific standards or targets were not available to assign end-points, both the end-points and intermediate ranges for each index were subject to interpretation.

- **Weighting system**
  Variable, indicator and component weighting is always an issue for debate and as such generates significant criticism. This is simply because spatial and temporal priorities will ultimately inform the importance given to one or another aspect of the indicator, but also because ultimately weights are determined by few on matters that affect many. It is therefore not possible to say with certainty that one set is more appropriate than another. To address this issue, the developer proposed several weighting schemes; nonetheless there are many more possibilities which went unexplored. The suggestion is that where possible, both statistical analysis and stakeholder consultation be employed to determine appropriate weights.

- **Robustness of the indicator**
  Testing to see whether an indicator is in fact robust and can provide a good measure of sustainability is an important step of indicator development. Two aspects are of particular concern: the uncertainty due to missing data or degree of error due to missing data; and sensitivity due to model assumptions. Owing to the limited number of case studies it was not possible to employ statistical methods; however qualitative assessments of indicator robustness were carried out.

- **User friendly and user relevant tool**
  The case for a single-number assessment has been strongly made, however, irrespective of this and in spite of the clarity of such an instrument, it is not adequate to inform on sustainability, support policy debates and policy formulation, and detail progress (Ravetz, 2000).

  In this research both the final index, as well as the sub-component performance scores were presented, in order to ensure clarity and transparency in reporting. The tool was developed for wider awareness creation and propagation therefore it was also necessary to create some form of user interface, enabling others to make use of it in future. In light of this a programme was developed, and is currently at beginning stages of design. SI 2007 is a tool to facilitate the application of the index and attract greater attention to this initiative. It will however require upgrades with every modification to the index, as well as refinements to ensure greater ease of operation.

- **Is the index widely applicable or is it too conditioned to the case studies?**
  The question of whether the SI is widely applicable arises because the indicator was developed and tested with two case studies in mind, both a deliberate and consequential outcome.

In developing the index and selecting the indicators, it was important to set selection criteria to ensure that indicators represented the desired conditions and provided the measurement needed for cities in Southern Africa. To enable a broad application of the indicator beyond the scope of the two case studies, selection criteria were broadly inclusive of the problems in developing countries, as were the indicators selected. In the case of alignment with policy and legislation, a broad view was taken rather than an exploration of individual country or even city policies. This was tested for the scenarios in question, by comparison with local initiatives, but given that the indicator provides great flexibility, this is an aspect that can change to suit the country or city in question. A third case study assessment would have helped to resolve some of these issues; however it was not possible to conduct research on a third city. This will be included in the recommendations provided in chapter 7.

7. Conclusions and recommendations

7.1 Summary of findings

This initiative set out to explore the possibilities for improved management and integration of activities in Urban Water Systems, so as to ensure the efficient delivery of services and appropriate accounting of human impacts on the environment. The research endeavour has its genesis in an initiative undertaken at the University of Cape Town. Poor access to water and sanitation, and the socio-economic and environmental effects of this have demanded the attention of policy makers, governments, academics, practitioners, businesses and civil society at large. It has provided the guiding aspect for many research enterprises such as this, of which the Millennium Development Goals are of particular relevance as they have introduced significant targets for the provision of basic services at the scale necessary to stimulate activity and change. The achievement of such goals, however, begs the question of how one is to assess current performances and measure progress. Indices have provided valuable insight into the current performances of cities and nations, tracking their progress with time and enabling spatial benchmarking to highlight the leaders and laggards in this move towards sustainability. The recognition of the potential of indices as assessment and awareness creation tools has in many respects led to the development of this sustainability index.

The assumption made here is that shortcomings in service provision and management of water resources can be largely attributed to a failure in addressing the interrelatedness and the need for integration in the management of the same. The SI assesses the possibility of cities becoming more sustainable by drawing on the various connections which link the different aspects of Urban Water Management. This was done with the aim of shaping more sustainable cities of the future, by highlighting current unsustainable practices and proposing viable avenues for improvement. It is important to state outright that there was an initial bias towards the use of a simple composite index which could aggregate and weigh up the relevant issues highlighted. Alternative options were explored during the course of this research; such as the possibility of providing a group of indices as the final step rather than one final aggregate. The conclusion was that the provision of a final composite would not detract from the component analysis and that the simplicity and desirability for a single number would ultimately generate greater attention for the underlying issues.

Towards the fulfilment of the scientific and research objectives of the research defined in Chapter 3, the researcher adopted a methodology for the development of the index, applying the following steps:

- Exploration of international and local literature to familiarise oneself with the relevant concepts and theories, as well as identify current trends in the development and application of indices.
- Development of a theoretical framework: this enabled the researcher to provide clarity on the objectives of the research, highlight the multidimensionality inherent in assessments of sustainability, and discuss the dimensions of sustainability and their usefulness, as they were applied here.

- Adjustment and validation of the index through the application of selection criteria, as well as through comparisons with existing local indices.
- Addressing the issue of weights and aggregation of components through the application of differentiated weightings, in the absence of more comprehensive and consultative approaches.
- Addressing the issue of space, scale and time to define the boundaries of research. The issue of scale was addressed through the application of two distinctive case studies. Similarly, the notion of spatial differences was addressed through the benchmarking of two cities. Temporal boundaries were restricted by the time limitations of this research as well as the time scale for change to manifest.

Following on the development of the index, two case studies were selected, in order to test its applicability and usefulness in real case scenarios. The two case studies; Hermanus in South Africa, and Maputo in Mozambique; were briefly described to provide the reader with a broad of view of the status quo in each setting. This then helped to confirm some of the results obtained from the trial applications and ultimately validate the indicator developed.

The results indicated that Hermanus performs well across all dimensions of sustainability, being able to maintain a balance between the needs of society and the preservation of the environment. Such a performance has been supported by a good supply and maintenance of resources, both natural and man-made, including also managerial and monitoring capacities. Maputo on the other hand demonstrated a significantly different performance; it received mediocre to low scores on almost all aspects. These results were not entirely unexpected; in fact this approximation to the observed reality corroborates the assumption that the development of a sustainability index can identify those areas in Urban Water Management which are unsustainable and by doing so, guide the relevant decision-makers towards more sustainable practices.

This research is ultimately geared towards guiding better management of resources, more efficient provision of services, and improved management of the environment. As such, the tool was developed for wider use. For this reason, and in addition to the basic Excel sheet used, another tool was developed in order to communicate the issues represented by the index in a clear and concise manner, avoiding the confusion of the underlying technical aspects. The preliminary SI 2007 tool provides such a solution, enabling the general public to make easy use of the index.

In addressing the 'dimensional' objectives of the research; social, economic, environmental, political and institutional; the precepts of sustainability were structured into the indicator framework, enabling a representation of major issues related to urban water management.

The indicator and its constituent parts serve to expose some of the issues prioritised in the objectives, such as; creating awareness, exposing and linking problems and priorities, emphasising the role-players and relevant stakeholders, and highlighting (with the potential of tracking) performance towards what could be sustainable development, according to the goals and targets set.

7.2 Recommendations:

The outcomes of this research were two-fold: firstly, the development of an index was undertaken; and secondly the index was tested through its application to two case studies. Recommendations will be proposed in two parts. To reinforce the usefulness of the tool, recommendations derived from each case study application will be made, and this will be followed by recommendations for the overall improvement of the index.

7.2.1 Recommendations for the improved management of urban water systems in Hermanus and Maputo

The following recommendations pertain to those areas which demand the most immediate responses, from which gains elsewhere can then be derived. These have also arisen as a result of comparative assessments which show where and how improvements can be made by adopting similar approaches and technologies.

7.2.1.1 Social dimension

- There is need for improved service delivery in Maputo; in terms of coverage, quality and reliability of supply. Wider coverage to peri-urban areas needs to be addressed more efficiently; supply hours per day must also be increased; issues of pressure and consistency of supply must be dealt with to ensure the quality of water.
- Greater emphasis must be placed in establishing safety nets and post disaster management measures in Mozambique, to mitigate the impacts of natural disasters by addressing; inadequate supply of water, inappropriate sanitation facilities, lack of shelter and insufficient food.
- Partnerships between civil society – SSIPs (Small Scale Service Providers) – and public utilities can be key in addressing the gaps in service provision and should be established. This should be pursued in the case of Maputo, where the water utility company (AdeM) is planning to increase coverage to peri-urban areas, where small scale providers operate. The social and economic benefits are evident, but in addition this is in the interest of avoiding public conflict.

7.2.1.2 Economic dimension

- An assessment of the impact of water tariffs on the ability to pay for services must be inclusive of the tariffs charged by service providers other then the utility companies, as these are often the sources that charge the most. This becomes particularly relevant where alternate providers are key to the acquisition of water for subsistence. This is the case in Maputo.
- In Hermanus, tariffs need to be widely and effectively disseminated to all consumers, not only to higher income groups. This will ensure that lower income groups are aware and make use of the lower tariffs, designed for their particular needs.

- The issue of cost recovery is one that is pertinent in both scenarios; however unacceptably high rates of UFW as well as low rates of payment in Maputo jeopardise the economic sustainability and self-sufficiency of the system. The same applies to sanitation, drainage, and waste collection. Repairs and replacements of the older parts of the water supply network must be undertaken with more urgency and expediency in Maputo. Wider coverage will also ensure that there are fewer illegal connections, which contribute significantly to both UFW and NRW.

7.2.1.3 Environmental dimension

- In Maputo, environmental preservation measures are at best considered an after-thought, secondary or tertiary to more pertinent social and economic considerations, to the detriment of the environment. It is recommended that two issues be addressed in the near future: firstly, the overall management of wastewaters, particularly treatment and disposal, must be re-introduced/re-enforced to ensure compliance with minimum standards and decrease pollution to receiving systems; and secondly, greater awareness and dissemination must be undertaken to ensure that the burden on managing institutions is reduced.
- For Hermanus, a continuation of good current practices is proposed, however the municipality and public institutions (schools) must pursue education and training initiatives to enable society to become a collaborator in the management of water rather then a contributor to the wasteful and pollutive practices which exhaust fresh water resources.

7.2.1.4 Political dimension

- It is necessary to introduce greater public consultation measures and encourage stakeholder involvement in the planning and provision of services in order to tackle corruption, the lack of transparency and low accountability in Maputo. Although to a much lesser extent, perhaps at pilot scale, a system similar to that adopted in Brazil (participatory budgeting) could be investigated, where the public is, to an extent, involved in decision-making.
- In Hermanus, there is need for wider inclusion of all groups of society, and consideration of the 'greater good' and not only the good of those who can pay. To this effect, community representation and consultation in planning considerations and budget allocation, is proposed.

7.2.1.5 Institutional dimension

- In both cases, the issue is one of under-capacity, although for different reasons. In Maputo, the actual man power, and the skills and expertise are lacking. To address this, more extensive training (compulsory), as well as recruiting, of staff is needed. In Hermanus, the case is one of a shortage of staff in the face of increased responsibilities. This also demands recruitment but there is less emphasis on the 're-education' of entire staff and teams.

Ultimately, all of the above points depend largely on the financial resources available to ensure the two main denominators; greater investments in infrastructure and management capacity.

7.2.2 Recommendations for future research

The following are recommendations for the improvement of the indicator, in order for it to be more relevant and reliable:

- Engagement with relevant stakeholders and experts to identify pertinent issues and formulate appropriate indicators.
- Vary indicator selection and test SI applicability to the selected two and other relevant case studies; maintaining flexibility and adaptability.
- Develop weighting schemes through the adoption of a more robust methodology for selecting weights. It is recommended that, where possible, a combination of stakeholder input and statistical analysis be employed.
- Ensure the quality of data used, and where this is not possible either eliminate the variable/index/component, or provide relevant proxies for which quality data is available.
- Undertake a wider application of the index and broader testing to a variety of settings to determine the applicability and use of index. More detailed sampling will also enable the application of statistical techniques to validate assumptions made in the development and application process.
- Apply statistical analysis methods to gauge the sensitivity and uncertainty in underlying assumptions as well as due to data gaps (imputation).
- Test the issue of scale by applying the index at local (neighbourhood, district) and national level rather then simply at city level. Explore the option of scaling up or down; firstly, as the indicator stands and secondly by readjusting the structure to suit the context. This might result in different indices for different scales.
- Address the temporal dimension by tracking progress over time and maintaining good records. It is proposed that the indicator be applied on a yearly basis. This will enable recording of relevant changes, and can be aligned with specific institutional annual cycles to ensure commonality of interest and increase potential for acceptance and use. Regarding temporal boundaries, it is also important to identify past trends, and determine how these have influenced current behaviours and events as well as what effects these can have in future practices.
- Alternative methods for calculating the index should be pursued to determine whether improved results can be obtained and/or whether less data intensive, hence resource-exhaustive approaches are possible. This also involves the investigation of whether a set of indicators is more appropriate for a particular setting rather than the composite index as used here.

7.2.3 Recommendations for institutions linked or interested in the research

- Greater emphasis must be placed in the collection and storage of data, but more importantly, there is need for continuity in this process. It must not be a once-off endeavour which is driven by particular research objectives or a specific project. Many of the variables considered here require a considerable number of yearly records to provide an actual measure of change. It is therefore proposed that data collection be undertaken by a dedicated team or incorporated into the work performed by organisations involved in similar work.
- Complementarily, there should be wider inclusion of SI-related questions in formal data collection exercises such as:
  1. School level questionnaires.
  2. Community polls.
  3. Water-related questionnaires of surveys at national level i.e. National Census

  This is to avoid duplication of initiatives and where possible make optimal use of existing resources.
- Aside from the actual pursuit of information, organisations directly involved with the collection of data and tasked with monitoring i.e. CRA in Maputo and Umvoto (temporarily) in Hermanus; must ensure that the data is widely accessible to the public. The difficulty in accessing data is perhaps the biggest contributor to an uninformed public.
- It is proposed that other researchers elsewhere undertake further work in the development of indices in this particular field of study, to enable comparisons and allow for the verification of results obtained.
- Develop and disseminate specific targets/target ranges for some of the issues raised. Initiatives such as the MDGs as well as the target dates adopted by African countries for the introduction and implementation of IRWM approaches are good examples of this.
- Improvements in quality data collection and storage are needed: regular updates and more indicators for better information. This must be undertaken by qualified and skilled personnel who will ensure the quality of data and will report on potential sources of error.

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APPENDICES

Appendix A

Breakdown of the sustainability and risk indices (Stoeckigt & Snoek, 2006)

Components	Indicators	Weight	Variables	Weight
Social/political	Compatibility of sanitation system with the surroundings	0.15	Located on floodplain	0.30
			Steepness	0.25
			Depth to groundwater table	0.25
			Soil permeability	0.05
			Ground stability	0.15
	Susceptibility to disasters	0.10	Dolines and sinkholes	0.10
			Earthquakes	0.20
			Floods	0.40
			Tornados	0.15
			Hurricanes	0.15
	Compatibility of water supply with the surroundings	0.15	Close to solid waste dump or landfill	1.00
	Compliance	0.10	Government policies	0.60
			Millennium development goals	0.40
	Level of service (LOS)	0.05	Water supply	0.35
			Sanitation	0.35
			Drainage	0.15
			Solid waste	0.15
	Health	0.20	Children under 5 mortality rate	0.60
			Malaria mortality rate	0.15
			Intestinal infection mortality rate	0.25
	Community participation/education/awareness	0.05	Level of education or posters	1.00
	Public opinion/cultural acceptance	0.05	Odour	0.05
			Insects	0.10
			Excreta is seen/unseen	0.20
			Contact with excreta	0.40
			Waterborne or not	0.25
	Governance	0.15	Corruption measure	0.50
			Political stability	0.50
Environmental	Water supply	0.25	Quantity	1.00
	Wastewater	0.25	Quantity	0.50
			Quality- Ammonia, P, COD, suspended solids	0.50
	Runoff	0.25	Quantity-type of drainage system	0.50
			Quality-treated/untreated, combined/separate sewers, type of drainage system	0.50

	Dependence on external factors	0.15	Energy	0.30
			Education level for operation and maintenance	0.70
	Water reuse	0.10	Rainwater harvesting	0.375
			Greywater	0.375
			Treated effluent	0.25
Economical	Affordability	0.50	Capital cost	0.30
			Cost of operation and maintenance	0.20
			Unemployment rate	0.20
			Water charges as % of household income	0.30
	Cost recovery	0.50	% of users paying for water	0.60
			% of non-revenue water (NRW)	0.40

Appendix B:

Improving water and sanitation towards the fulfilment of MDGs
(WHO & UNICEF, 2004; UN, 2006a; UN, 2006b)

MDGs	Contribution of improved drinking water and sanitation to MDGs (UNICEF & WHO)	Additional comments (De Carvalho, 2007)
Goal 1: Eradicate extreme poverty	- The security of household livelihoods rests on the health of its members; adults who are ill themselves or must care for sick children are less productive. - Illnesses caused by unsafe drinking water and inadequate sanitation generate high health costs relative to income for the poor. - Healthy people are better able to absorb nutrients in food than those suffering from water-related diseases, particularly helminths, which rob their hosts of calories. - The time lost due to long-distance water collection and poor health contributes to poverty and reduced food security.	- % that goes towards informal means of water supply and sanitation is often much greater then that for access via formal means and therefore can account for a good portion of the household income - Water and sanitation programmes often open up economic opportunities , or in the least create the basis for this i.e. irrigation, aquaculture.
Goal 2: Achieve universal primary education	- Improved health and reduced water-carrying burdens improve school attendance, especially amongst girls. - Having separate sanitation facilities for girls and boys in school increases girls attendance, especially after they enter adolescence.	- Water and sanitation programs often have the added benefit of educating the public, particularly children, about the environment, natural resources and sustainability in practice.
Goal 3: Promote gender equality and empower women	- Reduced time, health and care-giving burdens from improved water services give women more time for productive endeavours, adult education and leisure. - Water sources and sanitation facilities closer to home put women and girls at less risk of assault while collecting water or searching for privacy.	The greater the number of productive/working people in the household the higher the household income.
Goal 4: Reduce child mortality	- Improved sanitation and drinking water sources reduce infant and child morbidity and mortality.	
Goal 5: Improve maternal health	- Accessible sources of water reduce labour burdens and health problems resulting from water portage, reducing maternal mortality risks. - Safe drinking water and basic sanitation are needed in health-care facilities to ensure basic hygiene practices following delivery.	
Goal 6: Combat HIV/AIDS, malaria and other	- Safe drinking water and basic sanitation helps prevent water-related diseases, including diarrhoeal diseases, schistosomiasis, filariasis, trachoma and helminths.	- Sufficient supply of water and safe sanitary facilities improve the

diseases	- The reliability of drinking water supplies and improved water management in human settlement areas reduce transmission risks of malaria and dengue fever.	ability to resist HIV/AIDS (less vulnerable immune systems).
Goal 7: Ensure environmental sustainability	- Adequate treatment and disposal of wastewater contributes to better ecosystem conservation and less pressure on scarce freshwater resources. Careful use of water resources prevents contamination of groundwater and helps minimize the cost of water treatment.	
Goal 8: Develop a global partnership for development	- Development agendas and partnerships should recognize the fundamental role that safe drinking water and basic sanitation play in economic and social development	

Appendix C:

Matrix of indicator compliance with selection criteria

Indicator/Criteria	a	b	c	d	e	f	g	h	i	j	k	l	TOTAL
1.	1	1	1	1	1		1	1	1	1	1	1	11
2.	1	1	1	1	1		1	1	1	1	1	1	11
3.	1	1	1	1	1	1	1	1		1	1	1	11
4.		1	1	1		1	1	1		1	1		8
5.	1	1	1	1	1	1	1	1		1	1	1	11
6.	1	1	1	1				1		1	1	1	8
7.	1	1	1	1	1	1	1	1	1	1	1	1	12
8.	1	1	1	1	1	1	1	1		1	1	1	11
9.	1	1	1	1	1	1	1	1	1	1	1	1	12
10.	1	1	1	1	1	1	1	1	1	1	1	1	12
11.	1	1	1	1	1	1	1	1	1	1	1	1	12
12.	1	1	1	1	1	1	1	1	1	1	1	1	12
13.	1	1	1	1	1	1	1	1		1	1	1	11
14.	1	1	1	1	1		1	1		1	1	1	10
15.	1	1	1	1		1	1	1	1		1	1	10
16.	1	1	1	1			1	1	1		1	1	9
17.	1	1	1	1	1		1	1	1		1	1	10
18.	1	1	1			1	1	1	1		1	1	9
19.	1	1	1	1	1	1	1	1	1	1	1	1	12
20.	1	1	1	1	1		1	1	1		1	1	10
TOTAL	-	-	-	-	-	-	-	-	-	-	-	-	-

Sub-indicators

1. Access to water supply
2. Access to sanitation
3. LOS
4. Vulnerability to disasters
5. Health
6. Education and awareness
7. Capacity
8. Cost recovery
9. Investment levels
10. Freshwater resources
11. Sustainability/Feasibility of water sources
12. Use
13. Wastewater management
14. Stormwater management
15. Compatibility of water supply with surroundings
16. Compatibility of sanitation systems with surroundings
17. Environmental stresses
18. Governance
19. Compliance with policy
20. Institutional and technical capacity

Criteria

a. Policy relevant and meaningful
b. Scientifically sound methodology and metrology)
c. Representative of real conditions (multidisciplinarity) and desired outcomes (goal oriented)
d. Understandable, easily presented and interpreted
e. Show trends over time and responsive to change
f. Based on reliable and available or easily obtainable data (both quantitative and qualitative)
g. Enables benchmarking or cross-comparisons
h. (where possible) covers a range of issues (Interlinkages)
i. Adaptable/flexible
j. Complement existing monitoring and management initiatives
k. Literature review and group effort
l. Stakeholder input

Appendix D:

Correlation of Sustainability Index with WWAP indicator issues
(Walmsley *et al.*, 2004; annex 2)

High: The same or similar indicators used
Medium: Comparable indicators used
Low: Indicators differ however can be representative of the same conditions (even if indirectly)
None: No representation of this indicator

WWAP Indicator	Corresponding SI sub-indicator categories	Degree of correlation
WWAP challenge areas: 1 Meeting basic needs		**HIGH**
Access to basic sanitation infrastructure	(2)	High
Affordable access to water	(1)	High
Capital expenditure on water and sanitation	(9)	High
Operating expenditure on water and sanitation	(9)	High
Service providers meeting reliability requirements	-	None
Service providers meeting water-supply quality requirements	-	None
Actual and total sanitation coverage, global, urban and rural breakdown	(2), (3)	High
Actual and total water-supply coverage, global, urban and rural breakdown	(1), (3)	High
Distribution of unserved people: sanitation	(3)	Medium
Distribution of unserved people: water supply		Medium
Incidence of cholera in the world	(5)	Low
Access to improved drinking-water sources and extension of piped water	(1), (10)	High
Burden of water-associated diseases (expressed in DALYs) with comparative risk assessment	(7)	Medium
Fraction of the burden of ill-health resulting from nutritional deficiencies, attributable to water-scarcity impacts on food supply	(10)	Low
Investment in drinking-water supply and sanitation	(9)	High
Percentage of health impact assessments (HIA) of water-resources development and compliance with HIA recommendations	-	None
WWAP challenge areas: 2 Securing food supply		**LOW**
Agricultural water use by country	(6.3), (12)	High
Area equipped for irrigation vs. total arable land by country	-	None
Area of arable land (whole world)	-	None
Average food price (whole world)	-	None
Average grain yields (whole world)	-	None
Average per capita food consumption (whole world and regions)	-	None
Consumption of livestock products (regions)	-	None
Cropping intensity (whole world)	-	None
Fish consumption (marine, inland and aquaculture [whole world])	-	None
Irrigated area (regions)	-	None
Lending for irrigation and drainage (whole world)	-	None
Number of chronically hungry people by country	-	None
Water used for irrigation: net and gross (whole world)	(6.3), (12)	High
Agricultural subsidies	-	None

Breakdown of food consumption into cereals, oil crops, livestock and fish	-	None
Food imports/exports between regions	-	None
Productivity: $ or vol./m³, efficiency, jobs per drop	(6.4)	Medium
Proportion of crops marketed at government-controlled prices	-	None
Total investment (private, state, development agencies) in irrigation and drainage	-	None
Water used for irrigation (net and gross, groundwater and surface water); informal (supplemental, spate, local water harvesting)	-	None
WWAP challenge areas: 3 Protecting ecosystems		**MEDIUM**
Area of wetland drained	-	None
Biological assessment (perturbation from reference condition)	-	None
Biological water quality (based on community response)	(10),(13),(14)	High
Commercial or other fisheries catch	-	None
Compliance with water-quality standards for key pollutants	(13),(14),(15)	Low
Degree of river fragmentation	-	None
Emissions of water pollutants by sector	-	None
Food production trends	-	None
Hydrological indicators (flow, etc.)	(13),(14),(16)	Medium
Land converted to agriculture	-	None
Levels of endemism	-	None
Living Planet Index	-	None
Numbers or presence/absence of non-native (alien) species	-	None
Numbers/proportion of threatened species (critically endangered)	-	None
Rapid Biodiversity Inventory - Conservation International/Field Museum AquaRAP	-	None
Terrestrial Wilderness Index	-	None
Formation and empowerment of regulatory or other institutions	(20)	Medium
Reporting procedures in place at the national level	(20)	Medium
Restoration schemes	-	None
Sites/species afforded protection by legislation	-	None
Uptake of strategies/legislation uptake for environmental protection	(19)	Medium
WWAP challenge areas: 4 Sharing water resource		**MEDIUM**
Annual flows to the world's oceans	-	None
Basins of high/medium water stress (abstraction as proportion of river flow)	-	None
Countries using the largest quantities of desalinated water and treated wastewater	(11)	Low
Country data on water resources	(20.8)	Medium
Dependence of country's water resources on inflow from neighbouring countries (inflow as ratio of total water availability)	(11)	Medium
Global hydrological network	-	None
Groundwater use for agricultural irrigation	(11)	Low
Largest rivers in the world by mean annual discharge with their loads	-	None
Long-term average water resources	(10)	Low
Mean annual precipitation	-	None
Number of international basins	-	None
Number of treaties/cooperative events for international rivers	(20)	Medium

Shared aquifers: number/resource volume/conflicts relating to changes that might suggest international basins where there is a shared aquifer	-	None
Water availability versus population	(10)	High
World maximum point rainfalls for different durations	-	None
World's largest groundwater systems	-	None
Biological contaminants (E. coli/thermo-tolerant coliform)	-	None
Demand changes (sectoral) and distribution	(10), (12)	Medium
Existence of law for judicious distribution of water	(19)	Medium
Mechanisms for sharing within country (allocations/priorities) both routinely and at times of resource shortage	(20)	Medium
Naturally occurring inorganic contaminants: fluoride and arsenic	-	None
Organic pollutants load	-	None
PDSI or aridity index (moisture index)	-	None
Proportion of water use by industry, agriculture, and domestic sector	(12)	High
UNESCO/IAEA/IAH/ECE Groundwater Index	-	None
Use/yield {Yield = f (Q, variability in both space and time, storage)}	-	None
Water policy accounts and statements	(19)	Low
Water stress threshold map	(10),(17)	Medium
WWAP challenge areas: 5 Managing risks		**HIGH**
List of severe natural disasters since 1994	(4)	High
Major drought events and their consequences in the last century	(4)	High
Trends in causes of food emergencies, 1981–1999	(4)	High
Trends in great natural catastrophes	(4)	High
Budget allocation for mitigation of water risk (total and % of total budgets/yr.)		
Legal and institutional provisions for risk-based management (established/not established)	(4.8)	High
Losses: country and basin level data, by region and globally, in human life (number/yr.), in real and relative social and economic conditions	(4)	Low
Number of people living with 100-year flood. Vulnerability map based on the proportion of land within 1 km of river with slope	-	None
Other than water-related risks (% of losses from seismic, fire, industrial and civil-stability risk)	(4)	High
Population exposed to water-related risk (number of people/yr., income groups)	-	None
Risk reduction and preparedness action plans formulated (% of total number of countries)	-	None
Risk reduction in flood plains (% of total flood plain populations)	-	None
Risk-based resource allocation (country, international organizations [yes/no])	-	None
WWAP challenge areas: 6 Valuing water		**HIGH**
Water tariffs	(8.4)	High
Annual investment in urban and rural sanitation	(9)	High
Annual investment in water for agriculture, water supply and sanitation, environment and industry	-	None
Comparison of the price of water from the public utilities and informal water vendors	-	None
Level of cost recovery for urban water supplies	(8)	High
Level of cost recovery for water supplies for agriculture	-	None

Price of water from municipal water-supply systems	(8.4)	Medium
Sources of investment funds	(9.4)	High
Average price of water in rural water- supply systems	-	None
Price of water charged to farmers for irrigation	-	None
Sewerage charges	-	None
WWAP challenge areas: 7 Governing water wisely		**HIGH**
Existence of defined water rights	(19)	High
Existence of institutions (water- resources authorities) responsible for management (including issuing abstraction and discharge permits)	(20.2)	High
Existence of water-quality standards, for effluent discharges, minimum river- water-quality targets	(13),(14),(15)	Medium
Asset ownership properly defined	-	None
Defined roles of government (central and local)	(18.3)	High
Existence of legislation advocating Dublin principles	(19)	High
Existence of participatory framework and operational guidelines	(6)	Medium
Financial commitment for IWRM adoption	(20)	Medium
Institutional strengthening and reform (post-1992)	-	None
Numbers of instances when water- service providers experience a raw water shortage	-	None
Private-sector involvement and stakeholders' responsibility established and implemented	-	None
Water quality in rivers, lakes, etc.	(10)	Low
WWAP challenge areas: 8 Water for industry		**LOW**
Competing water uses for main income groups of countries	(3),(7)	Medium
Contribution of main industrial sectors to BOD production in high income OECD countries and in low income countries	-	None
Economic value (in US$) obtained annually by industry per cubic meter of water used	-	None
Industrial water efficiency	-	None
Industrial use of water per capita by total developed water per capita	-	None
Pollution from industry	-	None
Reuse/recycling	(11)	Medium
WWAP challenge areas: 9 Water for energy		**NONE**
Deployment of hydropower	-	None
Distribution of households with access to electricity in 43 developing countries	-	None
Installed hydro capacity	-	None
World's electricity production	-	None
Access to electricity: rural and urban coverage for the whole world	-	None
Efficiency/Productivity (output per m^3)	-	None
Per unit cost of renewable and nonrenewable energy sources	-	None
Use of water in thermal towers and competition with other uses	-	None
WWAP challenge areas: 10 Ensuring the knowledge base		**MEDIUM**
Density hydrological monitoring stations worldwide, by region	-	None
Expenditure on ICT	-	None
Gross enrolment at primary school	(6),(7)	Medium
Illiteracy rate	(7)	Medium

Number of hydrological monitoring stations, by World Meteorological Organization (WMO) regions	-	None
Number of television sets and radio receivers per 1,000 persons	-	None
Research and development expenditure for selected countries	-	None
Newspaper circulation per 1,000 inhabitants	(6)	High
No. of water-resources institutions	(20)	High
No. of water-resources scientists	-	None
Number of websites with available information on water-resources countries xx	(6)	High
Water topics in school curriculum	(6)	High
challenge areas: 11 Water and cities		**HIGH**
Child mortality rates: deaths per 1,000 live births	(5)	High
Children < 5 years: diarrhoeal diseases linked to inadequate water and sanitation	(5)	High
Industry and commercial: m^3 per day	-	None
Mega cities around the world	-	None
Proportion of urban populations with access to "improved" water supply and sanitation	(1)	Medium
Sanitation: access to "improved" sanitation - %, sanitation: sewer connections - %, solid waste collection - %	(3)	Medium
Water consumption levels: Domestic: litres per capita per day (lpcpd), water meter tariff (punitive structure aimed at reducing water thefts)	(12)	Medium
Water-impounding reservoirs (dams): supply volume m_3 per year	-	None
Water source (river) distance from demand centre: % > 8 km, inter-basin transfer: %	(1)	Low
Water supply cost per litre	(8.4)	High

Appendix E
List of Reports

E.1: List of sources and documentation for Hermanus

Sources	Data
Umvoto Africa	- Water source development and management plan for the Greater Hermanus Area, Overstrand Municipality: Inception report (2002), Compendium report (2004), Scoping report (2005), Monitoring Reports (2005-2006)
GLS	- Overstrand Water Services Development plans 2003 - Investigation into the application of desalination for the supply of potable water in the Overstrand . Hermanus area, 2004 - Overstrand municipal spatial development framework; Volume 2: Development strategy, 2006
SRK	- Personal communication
Ninham Shands	- Integrated Water Resource Planning Study, 2001
Africon	- Sanitation backlog study for the Western Cape Province, 2006
DWAF	- Aerial photography - Working for water programme (maps, photography and reports)
Overstrand Municipality	- Integrated Development Plan (IDP) - Strategic Development Framework (SDF) - 2004-2005 and 2005-2006 Overstrand Municipality budgets - Service delivery information - Complementary water studies
Arcu Gibb	Monitoring data on WWTPs (Hermanus and Hawston treatment works)
UCT: EGS, Civil Engineering	Overstrand: background study
UCT Library: Statistics South Africa	2001 Census data

E.2: List of sources and documentation for Maputo

Sources	Data
Ninham Shands	- Joint Maputo River Basin Study, 2005 - Mozambique Water Information- Building Block 3, 2004
Umvoto Africa	- Seismic activity in Mozambique
AdeM (Water Utility)	- City maps illustrating water distribution and sources - Annual Reports (internal progress reports): 2003, 2004, 2005, and 2006 Director plan; diagnostic characterisation of current situation and definition of goals and objectives, 2007
CMM (Maputo Municipal Council)	- Regulation of the public sanitation and drainage systems for the City of Maputo, 2003. - Strategic Sanitation Plan for 7 municipalities: Draft strategic sanitation plan for Maputo, 2007 - Terms of reference: Consulting for the elaboration of a director plan for sanitation in the city of Maputo, 2007
DNA (National Water Directorate)	- Stormwater drainage management for Maputo City, 1984 - Review of water resources of Maputo Province, 1989 - Groundwater exploration in the area of Maputo, Mozambique, 1989
FIPAG	- Indicators and monitoring criteria in the distribution of water for Maputo City - Joint Umbeluzi River Basin Study: First National Water Development Project NWDP I, 2005 - Second National Water Development Project NWDP II: Rehabilitation of the water supply network to wider Maputo, 2005
Water Aid	- The development of Maputo Sanitation services - Water, Sanitation and Hygiene Programme; PPO WASH 2007-2009 (prepared in 2006) - WASAN Maputo; sanitation coverage data for Costa do Sol, Albasine, Mahotas, FPLM, and Hulene B, in Maputo City. - Community profile study regarding hygiene and sanitation practices in the neighbourhoods of Laulane, Mahotas, and Hulene A and B, in the city of Maputo, 2006 - Water and sanitation project: summary report for Costa do Sol and Albasine. - Water supply coverage in Mozambique: Who is covered and at what level of service. Compilation of reports on NED.
CRA	- Beneficiary assessment study 2007
UNDP	- Health census for Mozambique, 2003 - HIV/AIDS prevalence data for 2004 - Review of the Ministry of Health child mortality data: main findings for 1999-2004 - Country Evaluation: Assessment of development results; Mozambique, 2004 - Mozambique country cooperation report, 1998-2001 - Mozambique; United Nations Development Assistance Framework

	(UNDAF), 2002-2006 - Mozambique; 2005 Human Development Report: Achieving the MDGs; development up to 2015
UNICEF	- Facts sheets for Mozambique - High resolution photos and maps
INAM (National Institute of Meteorology)	- Review report of the cyclone situation in Mozambique for the period of 1998 to 2006 - The Mozambican floods of 2000: (Chapter 4 of the review report) - Maps of the distribution of cyclone events in the Indian Ocean
INE (National Institute of Statistics)	- 1997 census data
World Bank	- BPD (Building Partnerships for Development) Sanitation series. Sanitation Partnerships: Maputo case study
MISAU (Ministry of Health)	- Facts sheet on water-related diseases and HIV/AIDS prevalence in Maputo
INGC/CENOE	- Summary report on 2001 floods

Appendix F:

List of individuals contacted, interviewed and potential sources of information for Hermanus and Maputo

Name	Occupation	Contact	Institution	Comments
		HERMANUS		
Elretha Louw	Infrastructure Design and Management solutions	(021) 446 2336 (direct line) (021) 446 2300 082 800 6984 Elretha@africon.co.za	Africon International	MSc: Natural Sciences/ Disaster Management, Cape Town PhD Topic: *The Impact of climate change on human health in the Western Cape; a disaster risk assessment*. Stellenbosch
Brent Wheeler	Water losses specialist	(012) 427 2000	Africon International: Tshwane	Not contacted
Prof. Bruce Hewitson:		(021) 650-2878 fax (021) 650-3791 hewitson@egs.uct.ac.za	Environmental and geographical science, UCT. Shell Environmental & Geographical Science Bldg 4.12	
Prof Chris Hartnady:	Working in the field of siesmotectonics and morphotectonics	(021) 788 8031	Umvoto Africa	Groundwater monitoring
Nabeel Rylands:	Africon International. Infrastructure Design and Management solutions	(021) 446 2354 nabeel.rylands@gmail.com nabeelr@africon.co.za		Compiling information on and developing vulnerability indictors in association with Elretha Louw.
Larry Ferguson		(021) 950 7100 082 808 9889	Department of Water Affairs and Forestry (DWAF)	
Dirk Crafford	Water Engineer	(028) 384 0111	Gansbaai (Overstrand municipality)	
Institute of Water Quality Services (IWQS)	Roodeplaat Dam: DWAF Unit. Resource quality services		DWAF	Not contacted
Hendrik Honey	Civil engineer (civils division) and Director at Africon International, Cape town		Africon International	PrEng. Specialist in the field of water treatment.
Graham English		English@Shands.co.za	Ninham Shand	Provision of Internal Strategic Perspective study done for the Western Cape/ South Africa

Prof. Barry Gasson			UCT	Consulted on the issue of appropriate indicators and index formulation during class lectures.
Ruwani Walawege		(021) 650-2999 (021) 650-3791 fax walawege@egs.uct.ac.za	Environmental and geographical science, UCT (Climate Change). Shell Environmental & Geographical Science Bldg., 4.04	Provided documentation on Hermanus.
Tobie Louw:	Civil engineer (civils division) and Director at Africon International, Cape town	TobieL@africon.co.za	Africon International	PrEng. Expertise in the field of Resource Management Impact. Knowledge and valuable input in the field of water management as well as background in studies and projects in the area.
Stephen Muller	Civil Engineer: Director of infrastructure and planning	(028) 313 8000	Overstrand Municipality (Hermanus)	
Bernard King		bking@overstrand.gov.za	Overstrand Municipality (Hermanus)	Provided financial data
Kevin Winters	Environmental and geographical science, UCT Shell Environmental & Geographical Science Bldg., 4.08	(021) 650-2875 (021) 650-3791 fax kevin.winter@uct.ac.za		
Janet Bodenstein		(021) 650-2869 bodenstein@science.uct.ac.za	UCT. Department of EGS. 2.18	
Leigh Sonn		(021) 650-2945 sonn@enviro.uct.ac.za	EGS 1.04: DIMP (Disaster Mitigation Unit)	
Simphiwe Mashicil	Water services	(021) 950-7127	DWAF	
Andre Roux		(021) 950-7100 ocp@dwaf-wcp.wcape.gov.za	DWAF	
Bea Whittaker	Hermanus: Milkwood communications	(028) 341-0322 milkwood@ilink.nis.za		Unavailable
James Van Der Linde	Civil Engineer: previous town engineer for Hermanus	(028) 3700 300 ivdlinde@iafrica.com	Hermanus municipality	

Rhuvene Miles		(021) 950-7251 milesr@dwaf.gov.za	DWAF	
Tarron Dry		(028) 313-8000 083 366 9490	Overstrand Municipality	
Craig Spencer		082 414 8867	Cape Nature	
John Roberts		(021) 950 7100	DWAF	
Derick Molen		(021) 950 7100	DWAF	
Natash Davies	Water quality	(021) 950 7100 davisn@dwaf.gov.za	DWAF	
Hayley Salomon	Water management	(028) 313 8000	Hermanus Municipality	
Sulet Gildenhuys		(021) 866-8000 gildens@cncink.wcape.gov.za	Cape Nature	Unavailable
Tierck Hoeckstra		082 496 2447	Cape Nature	Uncooperative
Kornelius Rimann			Umvoto Africa	
Dave Crombie		021 469 9101 (t) 021 424 5571 (f) 082 478 6422 (c) DCrombie@gibb.co.za	Arcus Gibb	
Marius Koch		Phone: +27 21 880 0435, Fax: +27 21 880 0389 mariusk@gls.co.za	GLS	
		MAPUTO		
Engo. Delario Sengo	Water Resources Management	+258 825805970	DNA	
Engo. Pedrito			DNA	
Engo Valdemir Matavel	Head of Sanitation Division		DNA	
Frederico Martins	Operations Manager	+258-1-491529 +258-1-498840 258-1-498881 fax +258 823025430 fmartins@fipag.co.mz	FIPAG	

Jaime Matsinhe		+258-1-491529	FIPAG	
Izidine Opressa	Head of Department: Project Planning,	+258-1-498758 +258-1-498758 fax +258 823025419 izdyn@yahoo.com.br funab@tvcabo.co.mz	FUNAB	
Fernando João Nhampossa	Director of water and sanitation management for the Maputo Municipality	+258 821466637 dmas@intra.co.mz Fernando_nhapas@hotmail.com	Maputo Municipality (Water and Sanitation) , CMM	
Gaye Thompson	Social Anthropologist	+258 823287320	SARL	
Manuel De Freitas		+258 -1-491127 +258 -1-491679 fax	UNICEF	
Antero de Pina	Project Officer: Water, Sanitation and Hygiene Promotion	+258 -1-491127 +258 -1-491679 fax +258 823263090 apina@unicef.org	UNICEF	
Jaime Comiche		+258-1-481400	UN-HABITAT	
Stella Pinto	Assistant Resident Representative: Head of poverty eradication and HIV/AIDS unit	+258-1-481400 +258-1-481429 +258-1-491691 fax stella.pinto@undp.org	UNDP	
Steven Greenhalg		+258 822705820	DANIDA/MICOA	
Manuel J. C. Alvarinho	President	+258-1-312825 +258-1-312826 fax cra-presidente@teledata.mz presidente@cra.org.mz	CRA	
Fernando Nhantumbo	Executive Secretary	+258-1-312825 +258-1-312826 fax secretario@cra.org.mz fnhantumbo@cra.org.mz	CRA	
Magalhães M. Mangamela	Service Quality Monitoring Officer	+258-1-312825 +258-1-312826 fax magalhaes@cra.org.mz	CRA	
Pedro Pimentel	Maputo Programme Manager	+258823939960	Water Aid	
Carla Barros Costa	Programme Officer (Civil Engineer)	+258823124420 carlac@tvcabo.co.mz	Swiss Cooperation, Mozambique	

		carla.aguasan@tvcabo.co.mz		
Ana Lúcia Obiols	Water Coordinator	+258-1-492064/6 +258-1-492077 fax ana@care.org.mz	CARE	
Casimiro Sande	Head of department		CENOE-INGC	
Engo. Naiane		+258 823072800	AdeM	
Agostinho Fernando			MICOA	
Dr. Lote			MICOA	
Ana Candido			MISAU	
Enga Natasha			CONSULTEC	
Paula Santos		+258 828782950	IMPACTO	
Clara Panguana			INE	
			INAM	
Additional agencies contacted			DNHA	
			DNG	
			INGC	
			Directorate of Health, Maputo	
			DINAGECA	
			Ara-sul	
			DINAPOTE	

Appendix G:

Issues addressed with individuals consulted

Appendix G.1: Interviews for Hermanus case study

- Mr Stephen Müller
Director of Infrastructure and Planning
Overstrand Municipality
Date: 19/02/07
Time: 9:30 am
Location: Hermanus Municipality Offices

Mr Muller provided an updated (in the last 2 weeks or so) list of the current population numbers in the Overstrand municipality by suburb; as well as a list of consultants currently involved in projects in the Greater Hermanus/Overstrand Municipality area:

Muller: The 12 point programme has more or less collapsed due to discontinued management. Some of the older residents of Hermanus still follow the basic water wise approach, but more out of habit than monitoring from the municipalities side. It has been determined that outsiders who come to Hermanus on holidays, from Cape Town and other parts of the country, are more water conscious than the residents of Hermanus themselves.

Sheilla: This can be testament to the programmes collapse. Hermanus' programme which was once hailed for its success at water management no longer exists and this discontinuity has proven to undo some of the benefits accrued in the past.

Muller: There are no major problems with the growth in the informal settlement at the current time. Yes, the settlement (Zwelihle is the only major informal settlement) is growing but it is densifying rather then sprawling.

Muller: All areas have water borne sewerage, however some still operate on septic tanks and are not yet connected to the formal sewerage system.

- Mr Deon Van Vuuren
Date: 19/02/07
Time: 14:30 am
Location: Hermanus Municipality Offices

Van Vuuren: Most people have access to water, within the 200m and with regards to the basic amount.

There are some problems with areas which are more water scarce. In Gansbaai for example, the purifying process (problems at treatment plant) have put limitations on the capacity of supply and the engineers there find the supply side at a limit.
There are areas in Overstrand which have problems but in general the greater Hermanus area is performing adequately.

There are problems with stormwater, however this is due to poor planning and lack of investment. Financing was given for top structures without catering for the cost of services such as stormwater, sewerage etc.

The problem with stormwater however affects the broader Hermanus, mainly due to lack of financing to upgrade and extend the separate stormwater network.

The major constraint at the moment is financing. The figures indicate that a large capital injection is required to provide the level of services desired however this has not been forthcoming and therefore the municipality has made due with smaller projects and investments to upgrade bit by bit.

Staff capacity can also present a problem. The same people that were there in the 1980s are still there.

Sheilla: With regards to the last comment, I am unsure whether this means they are unable to cope with technological advances and progresses in the field or whether the numbers have remained the same but yet the population has grown, therefore staff cannot cope adequately. It seems that the latter is more likely, since the question asked referred to whether the staff can currently cope with the population it serves.

- Mr Dave Crombie
(Arcus Gibb)
Date: 01/03/07
Time: 16:10 am
Location: UCT Tea Room

Mr Crombie suggested that I look into Budgets to analyse what has and has not been included in budgets for the term in question, in that way it is possible to see which areas the municipality is targeting and those which it is neglecting. In this way it will be possible to identify potential problem areas and to assess the performance. This might merit the inclusion and/or exclusion of variables in the indicator. It might also help in assessing priority areas hence aid in weighting o variables and indicators.

Mr Crombie suggested that an investigation behind the reasons for the change from ground water sourcing to surface supplies (e Bos dam) be carried. There was already indication that there was groundwater so why was this simply abandoned and a new and eventual insufficient source opted for? Suggested I speak to James Van Der Linde or someone at Ninham Shand who was working there at the time the De Bos Dam was commissioned and built.

He displayed some enthusiasm regarding the indicator and its concept and accepted to provide any guidance in respect of fine-tuning the index.

Appendix G.2: Interviews for Maputo case study

- **Izidine Opressa** (Chemical Engineer)
Head of Department
Project Planning, FUNAB (Fund for the Environment)
Time: 26/03/07 11:00
Location: Maputo, FUNAB Offices

Mr. Opressa demonstrated great interest in this initiative, in particular with regards to the links being established between the management of different water services. His area of interest further extended to the area of wastewater management, which is sorely lacking in Maputo. His preoccupation with the discharge of untreated as well as poorly treated effluent into the Infulene Valley was largely in consideration for the environmental and social (health) implications of such a practice. In his brief appraisal of the indicator structure, the environmental dimension met with considerable scrutiny.

- **Engo Delario Sengo (Engineer)**
Water Resources, DNA (National water Directorate)
Time: 28/03/07, 8:30am
Location: Maputo, DNA Main Offices

Mr Sengo expressed concern with the reliability and robustness of this tool. He questioned whether any statistical tools for testing the robustness of the tool were or would be employed. His referral to methods such as the Crystal Ball and the Monte Carlo Simulation which had been lightly explored in the literature, was valid. This to address concerns of variability and uncertainty within the model (testing model assumptions).

Monte Carlo Simulations make use of computer models to make predictions about real life scenarios. Whereas the basic excel spreadsheet programme enables the analysis of deterministic models, for which the answer is the same for the same given parameters, no matter the number of calculations; Monte Carlo Simulations use random number inputs to iteratively evaluate deterministic models. (Google, 2007)

Crystal Ball is the software package which makes use of the Monte Carlo Simulation technique to facilitate scenario analysis (multiple 'what if' scenarios).

In response to questions of whether similar initiatives have been undertaken in Mozambique, he answered that lack of data and monitoring initiatives is common.

- **Engo. Pedrito (Engineer)**
DNA (National water Directorate)
Time: 28/03/07, 9:30am
Location: Maputo, DNA Main Offices
Engo Pedrito suggested that in view of the lack of data or difficulty in accessing it, field work be undertaken. This was discussed further and it was understood that time limitations constrained such an exercise. It was suggested that if possible, one neighbourhood from each of the 5 Urban Districts be selected as representative of the situation in the district at large. The shortcomings of this approach are well understood. He also suggested that for the purposes of this research, where data was missing, this could be overcome by calculations or extrapolations (based on assumptions) of existing data, i.e. 60% of water consumed is released as effluent.

He was able to supply some information:

- Geology: the majority of soils in the city are permeable, clayey sandy soils with high coefficients of permeability.
- UFW: His opinion was that this was above 30%.
- Use of effluent is made for irrigation purposes in the Infulene Valley.
- In terms of rainwater harvesting, all new buildings must be equipped with mechanisms for the collection of rainwater.

- Frederico Martins
Project Coordinator (Gestor de projectos)
FIPAG (Water Investment Fund)
Time: 28/03/07, 10:00 am
Location: Maputo, FIPAG Offices

A short discussion on the structure and purpose of the indicator was followed by an explanation of FIPAGs role within the water supply sector by Mr Martins. The issues addressed were service provision, governing legislation (institutional framework), and the role of the various partners/collaborators. Mr. Martins provided a clear picture of how the water supply business functions. In this way it was possible to correlate this with the objectives of the sustainability index for improved water management in the Mozambican context.

- Fernando João Nhampossa (Civil Engineer)
Director, Maputo Municipality
Municipal Directorate for Water and Sanitation
Time: 29/03/07, 10:30am
Location: Maputo, Municipality Water and Sanitation Offices

Discussions with Mr. Nhampossa focused mainly on the sanitation, wastewater management and drainage issues in the city. Responsibility for water supply, management and regulation fall largely with AdeM, DNA, ARA-SUL, CRA and FIPAG.

In the field of wastewater management, little is being done and his opinion is that top tiers of government do not consider this a priority area when competing with water supply, street illumination and solid waste management, for which great part of the budget is allocated.

Operation at existing primary treatment facilities is poor, largely up to the whims of nature. When and where possible, effluent is discharged into the treatment ponds with no consideration for operational concerns. This process is hampered by availability of equipment (trucks), running capital (for repairs, petrol, staff salaries etc) and consequently the system as a whole fails to perform its designated function.

At management level, the department is understaffed, under-resourced and under-capacitated.

- Gaye Thompson
Sociologist/Social anthropologist, SARL
Time: 30/03/07, 17:30
Location: Maputo, Somerschield (private residence)

The discussion with Ms Thompson was very insightful. She was able to name various studies that have been or are being carried out which will provide the information necessary for the application of the indictor to Maputo. Furthermore, she was constructive in her criticism of the variables chosen, acquiescent with some and providing alternatives for others i.e., she suggested that instead of using income levels as a measure of economic stability, rather employ measures of per consumption or ownership of goods; the reason being that people are generally reluctant to inform on full incomes and also because this does not take into account non-monetary wealth. Her experience in socio-economic studies in the country enabled a better appreciation of some of the issues which can be represented by the indicators for sustainability.

- Steven Greenhalg
DANIDA
Time: 03/04/07, 13:40
Location: MICOA Offices

Mr Greenhalg expressed some concern with the commensurability of variables and the complexity of the indicator. In his opinion, a different view to indicator construction should be taken. Instead of approaching it from the point of view of dimensions or categories of sustainability, rather one could approach it from a business point of view, where performance indicators should be developed and applied to the businesses of water management, hence the three major services (water supply, sanitation and drainage) and then these could be related to resource management, socio-economic, political and environmental criteria. If possible, then the efficiency of all 3 services should be combined to provide a overall measure of sustainability of the urban water system.

- Manuel J. C. Alvarinho
President, CRA (Water Regulatory Council)
Time: 09/04/07, 15:30
Location: CRA Offices

CRA is the water supply regulatory body for Mozambique. Amongst other functions, a key role of CRA is to develop monitoring and evaluation tools so as to determine the performance and progress of this service. Indicator development and application is therefore an area of great interest. This research resonates with some of the monitoring objectives of CRA and as such it presents a great opportunity for working partnerships. This was addressed by Engo. Alvarinho, the president of CRA who displayed interest in forming these partnerships with the University of Cape Town and more specifically in finding possible ways of integrating the Urban Water Project aimed at developing indicators for the assessment of Urban Water Management. The UCT research thrust is currently focused on South African cities, however a possibility for extending it to other Southern African countries such as Mozambique are pleasing and is certainly inline with the research objectives of this thesis.

Appendix H

Understanding and preparing indicators for aggregation

A. Socio-cultural

This component assesses the impacts on society at large due to current water management and service provision practices, as well as resulting from a number of cultural and societal customs.

Six sub-indicators were selected to represent the socio-cultural component, and these in turn are detailed through the use of several variables.

A.1 Access to water supply

This indicator determines accessibility to resources, being flexible to changes in both time and space. It is quite common to speak of water stressed and water scarce areas but the implications of this are less well discussed. Dwindling water resources, in the face of growing economies and issues of increasing populations, has taken great prominence in water management debates. And while not wanting to take away from the issue of absolute water scarcity; the bigger problem is one of poor *exploitation* and *access* rather then a 'running out' of the resource itself. To this end, one must distinguish clearly between water scarcity and water insecurity. The former indicates a lack of the resource to cope with demands of some or all spheres of society (economic, social and environmental). The latter points to poor access to resources, often due to poor infrastructure development, low capital reserves and weak policy and institutional capacity to provide for the needs of millions.

Given that greater part of freshwater resources, both surface and underground, is shared between two or more countries, regions or areas, a key concern is the potential for *conflict* over shared resources as a result of scarcity or perceived scarcity. This indicator therefore looks at issues of water insecurity rather then water scarcity, which will be addressed to an extent by the resource availability and variability indicators.

- Total collection time (minutes/day)
  The variable takes into account the total time spent by households collecting water. In an urban scenario, collection distances may not be an issue, depending on compliance with certain policies which stipulate the distance to water source, however, problems do arise in densely populated peripheral urban areas with poor infrastructure, where queuing can account for a significant part of the day. The total time of collection is represented as a function of the level of service available to each household. Depending on the level of service, a score from 0-5 is attributed to that area.

Table H.1: Collection time

Level of service	Collection time Score
LOS 1	5
LOS 2	4
LOS 3	2
LOS 4	1
LOS 5	0

- Gender bias

  Gender discrimination in water management at the household level is an issue that is directly raised by the MDGs. In most parts of the world, women and children are responsible for collecting water for the household, an activity which significantly robs them of time. This is time which can be invested elsewhere, such as in education, employment or income generating enterprises. These two groups are also often the groups which in the case of insufficiency, go with less. This variable aims to be inclusive of the gender discrepancy in water collection, by taking measure of the number of men per household collecting water per day as well as by assessing the decision-making authority women have in the household. Because the aim is to address a discriminatory practice, and not to shift the gender bias, the indicator aims at a balanced contribution, therefore up to 50% male participation in the activity reflects a positive score.

Table H.2: Gender bias

Categorical scale		Gender Bias Score
Range 1	Range 2	
50%	50%	5
49%-40%	51%-60%	4
39%-20%	61%-80%	3
19%-10%	81%-90%	2
9%-5%	91%-95%	1
<5%	>95%	0

- Conflict over water resources

  This variable will reflect the extent to which water insecurity impacts on maintenance of social systems. It will assess the degree of conflict over accessible water resources and hence provide a measure of the level of access, or lack thereof at the desired scale (within communities, between households or across boundaries). The higher the incidence of conflict, the lower the final score, therefore where conflict arises, quick responses to potential conflicting and disruptive situations are desired.

Table H.3: Conflict over water resources

Categorical Scale	Qualitative assessment	Gender Bias Score
0%	Equitable distribution (not free distribution) and effective IWRM and IUWM.	5
1%-10%	Good problem resolution in the case of conflicting interests. (ACTION)	4
11%-20%	Preliminary engagement in discursive problem resolution. (DIALOGUE)	3
21%-50%	Conciliation of parties but not resolution (PLACATION)	2
51%-90%	Neglect and/or incapacity	1
>90%	Highly conflicting at all scales i.e. blatant disregard for the issue, power struggles and extreme inequality, extremely disruptive to civil society.	0

- % access to protected water
  A measure of access to water must be inclusive of the degree to which the source is safe for human needs (drinking and washing). This variable reflects the percentage of households/communities with access to a safe water source(s).

Table H.4: Access to safe water sources

% with safe access	Access to safe source scores
>90%	5
90%-70%	4
69%-50%	3
49%-30%	2
29%-15%	1
<15%	0

A.2 Access and use of sanitation facilities

This indicator explores the availability and convenience of sanitation facilities as well as cultural acceptability, and vulnerabilities of certain groups.

- No. of people per sanitation facility
  Backlogs in sanitation are even greater then those in water supply. The impact of inadequate sanitation facilities can have wide repercussive effects, on health, human development and growth, and the environment, to name the more obvious ones.

This variable reflects the coverage of sanitation facilities, and will therefore highlight the inadequacies in places where one can often take the existence of some facilities for satisfactory provision.

- Safety of use
  The failure of many sanitation schemes, on the basis of both cultural and practical weaknesses, has been widely documented, so much so that both have become key criterion in the selection of the type of sanitation facilities to be provided, alongside more technical criterion such as ground stability and distances to groundwater. Safety of use and access is a key concern when making use of such facilities, especially for more vulnerable groups such as children, women, disabled people and the elderly. This variable reflects the degree of attention that has been given to such concerns in current sanitation schemes.

- Cultural acceptability, ease of operation and maintenance
  This variable explores the social and cultural norms which govern day-to-day practices. It explores how well current sanitation schemes and types have integrated the cultural and societal customs of the given area. This is to ensure that what is provided is in fact used. Many schemes have failed for lack of recognition of the customs observed by the potential users.

Explicit information on the above variables can be difficult to obtain, and might in fact require the use of extensive surveys and questionnaires. Surveys were initially to be conducted in selected areas of the two case studies, however the time constraints on data collection did not permit this. Assessment of the variables was then reworked to fall inline with the levels of service. This link is reasonable, given that higher levels of service are often associated, and deliver greater safety of use and access, and higher cultural acceptability due to improved formality of the service linked to societal and cultural standards. Furthermore, higher levels of service propose to serve smaller aggregations of people, generally at the household level, at which specifications of type and use can be made.

Table H.5: Access and use of sanitation facilities

Level of Service	No. of people per sanitation facility	Safety of use	Socio-cultural acceptability
LOS1	5	5	5
LOS2	4	5	5
LOS3	3	3	3
LOS4	1	1	1
LOS5	0	0	0

A.3 Levels of service

The first step in moving towards some of the targets stipulated by goals such as the MDGs, is to ensure that at the very least, basic levels of services are provided. The stipulation of such has been established by organisations such as the UNDP, for which the minimum supply of water is 20l/person/day at distances no greater than 1000m; and by the WHO, who has stipulated a basic 50l/person/day at distances no greater than 200m. In the same way as there are social and economic classes in society, Services have conformed to tiers of service provision, for which income levels and ability to pay are the key factors. In accordance to these, and looking back at the four services discussed in chapter 3, service levels are scored as follows:

Table H.6: Service levels

%	LOS	Water Supply	Sanitation	Drainage	Waste collection
	LOS1	5	5	5	5
	LOS2	4	4	4	4
	LOS3	3	2	2	2
	LOS4	1	1	1	1
	LOS5	0	0	0	0

A.4 Vulnerability to disasters

The notion of risk and the relationship to vulnerability and sustainability have already been introduced. The following variables will assess the susceptibility of an area and its inhabitants to one or more of the relevant natural, and at times man-induced, disasters for the areas in question (southern Africa). As the risk increases, so does vulnerability. This coupled with actual exposure contribute to a lower overall sustainability, hence this is the only variable that displays an inverse relationship with sustainability of the system.

- Susceptibility to disasters: includes exposure to dolines and sinkholes; earthquakes; droughts; tornados; cyclones and floods; tsunamis or shockwaves; and fires.

  The table illustrated below, fails to address the susceptibility to disasters occurring simultaneously in the same area (city). This is because an assumption is made that there is a low probability of more then one of the major disasters occurring at the same time within city boundaries. This, of course, is not entirely implausible and the best approach to account for such a possibility is to assign a percentage to each event.

Table H.7: Susceptibility to disasters

%	Disaster	Score (measure of exposure)
	Dolines or sinkholes	5
	Earthquakes	5
	Droughts	5
	Tornados	5
	Cyclones and floods	5
	Tsunamis or Shockwaves	4
	Fires	4
	None	0

- Risk Management and disaster mitigation
  In the event of a disaster or in awareness of susceptibility to it, risk can be mitigated by good management, and appropriate design and awareness creation. In the event of poor preparedness and handling of the situation, there is an option for remediation. There are nations however which are not capacitated to engage in neither preparation and mitigation nor remediation, and are extremely vulnerable to the 'temperament' of nature.

Table H.8: Risk management

Risk management (qualitative assessment)	Score
None	5
Poor disaster management	4
Compensative risk management (remediation)	3
Effective disaster mitigation (good response)	2
Risk awareness and preparedness (prior to disaster)	1
Risk avoidance by desing	0

A.5 Health (morbidity and mortality)

Despite the common perception that water supply can ensure improvements in health, there is no assurance that this will always be the case as there are many other factors, many of which are not related to the water sector, which can have significant detrimental health impacts. However having said this, one acknowledges that the causational link between the two as well as scientific backing as to the diseases which can and do result from poor water supply (quantity and quality) and inadequate sanitation, is sufficient to demand consideration.

To address the water-health relationship, it is common to look at the most vulnerable groups who will be worst affected by poor access to water i.e. children.
The first three variables are directly linked to this sense of vulnerability, and to an extent summarise the health situation in an area in relation to water. The fourth variable,

HIV/AIDS prevalence, is not directly related to water however it can be severely impacted by the availability or lack of this resource and proper provision of its services. Sufficient supply of water and safe sanitary facilities improve immunity to diseases and hence contribute to the ability to resist the more debilitating effects of HIV/AIDS and reduce the risks of spreading the virus.

- under 5 mortality rate
- malaria mortality rate
- reported cases of intestinal and infectious diseases per 1000 people
- HIV/AIDS prevalence

Table H.9: Health status and water related diseases

Under 5 mortality rate	Malaria mortality rate	Reported cases of infectious diseases/1000	HIV/AIDS prevalence	Score
0%	0%	0	0%	5
1%-5%	1%-10%	1-20	1%-5%	4
6%-10%	11%-20%	21-100	6%-10%	3
11%-20%	21%-30%	101-300	11%-20%	2
21%-30%	31%-40%	301-500	21%-30%	1
>30%	>40%	>500	>30	0

A.6 Education and awareness

- Dissemination. This variable reflects the level of education for water related matters. It includes dissemination of information and awareness creation for issues such as basic hygiene, demand water management and water wastage, resource availability and associated costs to the delivery of services (both economic and to the environment). The attribution of scores will reflect the methods for dissemination employed, the target audience and the effectiveness of approach given the socio-cultural, education and income differences amongst the wider population.

- Consultation and participation. This variable assesses the level of engagement between stakeholders in reaching decisions collectively, if not unanimously. In Hermanus, for example, past practices have illustrated a decision-making process that was not only biased but outright undemocratic.

  It has been brought to attention that certain decisions were at times single-handedly made by municipality employees, without the awareness or input from other colleagues, much less the community at large. This lack of transparency can affect the general acceptance of programmes or projects, and cause wide dissatisfaction within and amongst communities. In Mozambique one finds that the majority of the population is generally uninformed about major activities which impact their lives. Moreover the means of communication employed, if any, exclude great part of the population who cannot read or write and do not have access to the 'modes' used for dissemination.

In practice, very little effort has been made to quantify both variables. In many instances, education and awareness features prominently only in programme objectives and strategic outputs, while visibility on the ground is minimal. This strengthens the case for the inclusion of these considerations and it also highlights the problem in obtaining quantitative data on them. Scoring will therefore be done on the basis of qualitative assessments, such as: excellent (5), effective (4), satisfactory (3), poor (2), very poor (1) and nonexistent (0).

B. Economic: stability and growth

This component addresses the economic dimension of water management, exploring the necessary investments for the adequate provision of services, infrastructure development and maintenance of work. At the same time it assures the need for cost recovery. It recognises the Dublin principles which state that access to water should be made available to all, but that parallel to this; it acknowledges that water has an economic value, both as a resource and also regarding the need for collection, treatment, distribution, and discharge. In response, this indicator attempts to balance the social priorities with economic concerns.

B.1 Capacity

Capacity provides a measure of people's ability to access and pay for water services, based on their education levels, income security (employment) and income levels, as well as the financial demands for basic supply of services. Simply, capacity looks at people's ability to pay, given how much they must pay and how much they have, therefore indicating whether economically people have access to this essential resource.

- % people with secondary education: This is the total number of people with secondary education in a given area.
- % unemployed: This gives the percentage of unemployed people within the study area.
- Monthly income from employment (income brackets): This variable assesses the ability of households to access and pay for water services, on the basis of monthly household incomes. For comparison purposes, all units will be converted to South African Rands (ZAR).
- Loss of income due to sickness: There is a correlation between poor health and low productivity. This link is not questionable, however it is difficult to assess is the extent to which one can justify poor productivity due to poor health and well-being. One can argue for the inclusion of the physical, emotional and psychological effects resulting not only from poor accessibility and low benefits from water and its services, but more importantly due to the underlying causes, inequality and poverty.

For this reason a proxy was used, referring to the number of days per year taken off work due to water related diseases.

- Water Tariffs (R/l)
  The aim is to determine the fairness of tariffs, given disparate income brackets. In this way correlating; payment rates, access to and selection of different service providers, on the basis of the rates charged. While in this case, this has been restricted to the tariffs charged by formal institutions, as these are the groups targeted by this research, it is the informal providers that demand more attention. Informal providers often charge much higher fares than utility companies, however due to poor access to formal networks; people are consigned to paying higher rates. However because this initiative proposes improvements in the delivery of formal services, which have been indicated as the preferred sources in Maputo and are the only sources in Hermanus, it is not entirely unreasonable to exclude other providers.

Table H.10: Capacity for accessing and paying for services

% with secondary education	% unemployed	Monthly income brackets (R)	Loss of income due to sickness (days)	Water tariffs	Score
100%	0%	>R3500	0	R0-R0.9	5
99%-70%	1%-20%	R3500-R2500	1-10	R1-R2.5	4
69%-40%	21%-40%	R2499-R1500	11-40	R2.6-R4.5	3
39%-20%	41%-60%	R1499-R1000	41-70	R4.6-R5.5	2
19%-10%	61%-80%	R999-R500	71-110	R5.6-R8	1
<10%	>80%	<R500	>110	>R8	0

B.2 Cost recovery

A significant contributor to poor service provision is the lack of financial resources for expansion and maintenance. In the interest of self-sufficiency and sustainability, providers should aim for high cost recovery, provided it does not jeopardise the social precepts. In developing countries, the problem of cost recovery is one of poor payment levels combined with unacceptable resource wastages.

- % users paying for water: This addresses the payment rates and return on investments aspect.
- Non-revenue water (UFW & FBW): This variable refers to the percentage of water which is not billed (non-revenue water), and this includes both free basic water and unaccounted for water. Although high NRW values are undesirable, it is important to understand the crucial role of free basic water to thousands who cannot afford to pay. However the free basic water policy extends to few and in the context of this research, it applies only to South Africa.

  There is some merit in arguing that high unaccounted for water rates in countries where illegal connections to formal supply systems is common, can to an extent constitute free basic water, however this is neither formalised nor intentionally pursued. For the purposes of the assessments carried out here it does not constitute FBW.

The variable will be calculated in two parts and the two sub-variables will then be averaged (equal weight) to provide the final score for NRW:

- % UFW: the aim being the achievement of the lowest possible 'loss' rates.
- FBW (l/person/day): the notion of free basic water explores the assumption that because water is more then a simple commodity, every human being has the right of access to it and more so, where some cannot pay, it is the responsibility of government to ensure that everyone has a minimum supply.

Table H.11: Cost recovery

% users paying for water	NRW			Score
	UFW	FBW		
100%	0%	50	50	5
99%-70%	1%-10%	49-30	51-70	4
69%-50%	11%-20%	29-20	71-80	3
49%-30%	21%-30%	19-10	81-90	2
29%-10%	31%-50%	9-1	91-100	1
<10%	>50%	0	>100	0

B.3 Investment levels

Inadequate investments in water infrastructure and human capacity have proven to be the biggest constraints in efficient management of water resources and service delivery. Previous discussions on the issue of resource scarcity indicate a problem of both water scarcity and water insecurity affecting great part of Sub-Saharan Africa. This indicator provides a measure of the annual growth in investments in this sector. While this does not provide a measure of the supply versus the need for investment, it will illustrate whether there is continual progress.

Given the state of many national economies in Africa, the investment categories will provide modest appraisals of increasing commitment to infrastructure development. Another aspect for consideration is the source of investments. Africa's over-reliance on international and regional aid continues to frustrate any attempts at self-sufficiency and this is certainly a drawback in the process towards sustainable development. Furthermore, current policy has stipulated that significant decentralisation of power to municipalities be undertaken however, financially, municipalities continue to be largely dependant on both regional and local government, a condition which threatens their long term sustainability.

- % of budget increase for water supply (WS)

- % of budget increase for sanitation provision (SP)
- % of budget increase for operation and maintenance (O&M)
- Sources of investment

Table H.12: Investment levels

% budget increase for WS	% budget increase for SP	% budget increase for O&S	Sources of investment	Score
>40%	>40%	>40%	Local government	5
30%-31%	30%-31%	30%-31%	Local NGOs, donor agencies and businesses	4
30%-21%	30%-21%	30%-21%	Regional government	3
20%-11%	20%-11%	20%-11%	National government	2
10%-1%	10%-1%	10%-1%	International aid	1
0% or decline	0% or decline	0% or decline	None	0

C. Environmental management and ecosystem preservation

This component proposes that the environmental dimension of sustainability be equally addressed alongside socio-economic considerations, in order to ensure that in the very least, a basic preservation of ecological systems is maintained. There are two main reasons for this; firstly the human dependence on the environment demands that ecosystems be preserved for the purpose of sustaining current and future generations. The other, more philosophical and ethical reason, revolves around the need to appropriately share our one planet with the remaining inhabitants of earth. The precautionary principle applies in both instances: 'in the absence of perfect information' or understanding of certain aspects, caution is advised.

C.1 Fresh water resources

This indicator shows the availability of water based on the existing freshwater resources for a certain area. It is assessed on the basis of per capita availability, reliability and variability, as well as the quality of raw water supplied.

- Per capita water availability (l/capita/year)
  In their Falkenmark indictor; Falkenmark, Lundqvist and Widstrand propose a basic per capita water threshold of 1700 m^3/annum. This is based on estimates of household water requirements, the needs in the agricultural, industrial, and energy sectors, and the call for ecosystem maintenance. Areas for which the per capita (yearly) water availability falls below this figure are considered water stressed. Falkenmark et al., also set two additional marks to identify those areas which are water scarce and extremely water scarce, for which the basic water availability targets are $1000m^3$ and $500m^3$ respectively. These extremes will be employed as endpoints as indicated in Table H.13 (Rijsberman, 1994):

- Reliability or variability
  This explores both the short-term – daily and seasonal variability – as well as more long-term issues of water scarcity. Daily variability is mostly a result of failed management, and often occurs with little forewarning. Seasonal variability on the other hand, is expected, within acceptable limits, and planned for. Long-term variability links with the susceptibility to natural disasters (droughts) and climate changes. This issue has had some attention in recent times. Furthermore, the threat of climate changes and the resulting impact on water resources has and is being heatedly debated. It is important to maintain more than a 'curious eye' on this matter.

- Water quality
  The issue of water quality for supply is being thoroughly addressed, however here it is directly linked to source water. It gives an indication of the state of fresh water resources; the degree of pollution and ultimately the cost, to us, of treating for human use.

Table H.13: Resource quantity and quality

Per capita availability (m^3)	Reliability/ Variability	Water quality at source	Score
≥1700	100%	Excellent	5
1699-1500	99%-80%	Good	4
1499-1000	79%-60%	Adequate	3
999-700	59%-40%	Poor	2
699-500	39%-10%	Very poor	1
<500	<10%	Extremely polluted	0

C.2 Sustainability/feasibility of source

Feasibility is assessed on the basis of a number of criteria; whether water supply is local or 'imported', easily available, and whether it is abundant in its natural form and of good quality. A list of possible sources is presented and the variable is scored on the basis of what is employed and why.

Table H.14: Feasibility and sustainability of water source

%	Feasibility/sustainability of source	Score
	Local groundwater	5
	Rainwater Harvesting	5
	Local freshwater	4
	Imported groundwater	4
	Greywater	3
	Stormwater	3
	Imported freshwater	2
	Brackish water	2
	Wastewater	1
	Saltwater	1

C.3 Use

This indicator will illustrate the water distribution per category of user, highlighting the areas which are either under or over-consuming and the need for balanced (not equal) distribution.

- Domestic
  This is perhaps the most essential category because it addresses the basic human water requirements for drinking and hygiene maintenance. Under-consumption or over-consumption is undesirable since it can indicate that people either don't have access to sufficient water for their basic needs or have too much, in which case are wasting. An optimal threshold was established at 100l/person/day. This is double what is proposed by the World Health Organization as a minimum requirement. By doing so we propose that the limits account for more then the barest necessity and therefore consumption up to 100l/person/day has a positive correlation with sustainability. Conversely, exceeding this limit implies that there is potential for wastage and inefficient use. (Sullivan, Meigh & Fediw; 2002).

- Industrial
  Industrial water consumption varies significantly both across different regions, being strongly dependant on the level of the development, as well as across various industries. This variance does not permit the exact stipulation of a limit however guidelines were taken from the estimates provided by Rijsberman in his assessment of water consumption per category of users. He states that after agriculture, industry (including commercial units) is the second biggest consumer, at times accounting for more then two thirds of the total consumption for an area. Where data is not explicit, the guiding principle will be the rate of return for this category. There is generally good cost recovery from industrial consumers and therefore high payment rates will be indicative of high consumption rates (Rijsberman, 1994).

- Agricultural
  Here too, the variability of water consumption across different productions and crops makes it difficult to stipulate exact limits for water use, however, Rijsberman in his assessment of water scarcity issues provides a ballpark figure. His indication is that it takes on average seventy times more water for food production then for domestic purposes (Rijsberman, 1994). On an assumption of 50l/person/day for domestic use, the per capita food production requirement is 3500l/person/day. However he goes further to state that the diet of a typical person in the USA requires roughly 5400l of water, whereas that of a vegetarian with the same nutritional value requires 2600l of water per day. In poorer countries of the developing world, poor diets can result in water needs as less as half of those of an average person elsewhere, therefore an initial lower limit will be placed at 2600l/person/day and the upper bound at the already excessive per capita consumption of 5400l/day.

- Maintenance of ecosystems
  According to the precautionary measure, a basic share of freshwater should be reserved for the maintenance and preservation of ecosystems. Two studies in particular conducted by Seckler, (2000) and Seckler *et al.*, (1998) have emphasised the need for ecological preservation and maintenance of ecosystems, and the role of water in this. Elsewhere, Sullivan *et al.*, propose a ballpark figure of 25% for ecosystem maintenance (Sullivan, 2002).

  Such rigid limits do recognise the need for water allocation for ecological purposes however fail to address the spatial variability of water requirements for different ecosystems, as well as the seasonal variability factor and the longer-term climatic changes. In the absence of better estimates, 25% water allocation to ecosystems will be set as the optimal upper limit.

Table H.15: Water use per category of consumer

Domestic (l/person/day)		Industrial (%)	Agricultural (l/person/day)	Ecosystem Maintenance (%)	Score
100	100	60%	2600	25%	5
99-70	101-150	59%-40%	2599-2400	24%-20%	4
69-40	151-200	39%-20%	2399-2000	19%-15%	3
39-20	201-300	19%-10%	1999-1700	14%-10%	2
19-5	301-500	9%-5%	1699-1500	9%-5%	1
<5	>500	<5%	<1500	<5%	0

C.4 Wastewater management

This indicator monitors the discharges of wastewater, both in terms of quantity and quality, to the environment, proposing to monitor the potential detrimental effects. Following on standard guidelines, the variables enable an assessment of the current wastewater management practices, and in a sense can indicate whether there is compliance. While wastewater management is linked to the type of sanitation system employed, in the context of developing countries it is not uncommon to observe high service levels without the accompanying attention to wastewater management i.e. in Maputo good part of the wastewater generated is directly discharged into either the sea or surface waters, with very little attention to issues of quality and quantity. The detrimental impact on receiving environments is evident.

- Effluent quantity (l/person/day)
- Effluent quality
  Ammonia (mg/l)
  Phosphorus (mg/l)
  COD (mg/l)
  TSS (mg/l)

Table H.16: Wastewater quality guidelines

Quantity (l/person/day)	Quality (mg/l)				Score
	Ammonia	Phosphorus	COD	TSS	
<20	<1	<1	<75	<20	5
20-50	1-10	1-5	75-150	20-50	4
51-100	11-20	6-10	151-300	51-100	3
101-150	21-50	11-15	301-600	101-250	2
151-250	51-100	16-25	601-1200	251-500	1
>250	>100	>25	>1200	>500	0

C.5 Stormwater management

Assessment of stormwater management has been isolated from wastewater management for two reasons; firstly because in both case studies, and many cities elsewhere, they have been treated separately and are served by different systems. Secondly, although highly debatable, there are opportunities and potential for lowering costs of treating of stormwater.

In this research, performance of this variable is associated with the levels of service available to each area, although there are alternate measures such as; the percentage of the city covered by some form of drainage system; and frequency of flooding in urbanised areas, and the underlying causes. The assumption is that the higher the LOS, the more formalised the drainage system hence there are improvements in stormwater management. Drainage is a service which grossly under-managed, to the benefit of more highly prioritised services such as water supply, electricity, roads etc. The impacts of urbanisation on the natural environment are easily forgotten. It is only in extreme cases, where flood waters become a threat to humans and disruptive to societal functions, that drainage considerations take prominence. The two criteria observed are; effluent quantity and quality.

Table H.17: Stormwater quality monitoring criteria

%	LOS	Score	
		Effluent quantity	Effluent quality
	1	5	5
	2	4	4
	3	3	3
	4	1	1
	5	0	0

Going beyond the immediate provision of sanitation and drainage, both wastewater and stormwater management highlight the potential for linking with resource management towards; recharging, complementing or substituting current sources.

C.6 Compatibility of water systems with the surrounding environment

Compatibility of water supply with the surrounding environment explores whether considerations have been given to the likelihood of damage to the surrounding environment, focusing on pollution of water sources from proximate dump sites.

- Proximity to solid waste dump or landfill site

Table H.18: Compatibility of water systems

%	LOS	Compatibility of water supply with the surrounding environment
		Located close to dump/landfill
	1	5
	2	1
	3	0
	4	0
	5	0

C.7 Compatibility of sanitation system with the surrounding environment

This indicator assesses how suited sanitation systems are given their compatibility with the natural environment, taking into account the following geological and hydrological factors:

- located on floodplain
- steepness
- depth to groundwater table
- soils permeability
- ground stability

Table H.19: Compatibility of sanitation systems with the natural environment

%	LOS	Located on flood plain	Steepness (%)				Depth to GWT (m)			
			0-1	2-3	4-10	>10	0-0.5	0.6-1	1-1.5	>5
	1	4	3	4	3	1	4	4	4	4
	2	4	4	3	1	0	3	3	3	3
	3	2	4	3	1	0	2	3	4	5
	4	1	4	3	1	0	2	3	4	5
	5	0	4	4	4	4	0	1	2	2

%	LOS	Permeability				Ground stability			
		high	medium	Low	Impermeable	high	medium	low	unstable
	1	5	5	5	5	5	4	4	3
	2	1	2	3	4	4	4	3	0
	3	0	1	2	4	3	3	2	0
	4	0	1	1	1	4	4	4	4
	5	0	0	0	0	5	5	5	5

C.8 Environmental stresses

The indicator, environmental stresses, considers the strain on the environment due to man-induced pollution and natural water scarcity. It takes into account two variables; proportion or percentage of polluted sources as a function of the total resources, and an indication of natural water scarcity.

- Proportion of polluted water sources as a function of the total resources
  This variable looks at the percentage of water resources which are polluted beyond a state deemed fit for sustaining human activities and support species diversity.

- % of total area identified as severely water stressed
  This provides an indication of water scarcity, based on the Falkenmark indicator projections, the criticality ratio and the water poverty index.

Table H.20: Environmental water stresses

% of polluted sources	% of area severely water stressed	Scores
0%	0%	5
1%-10%	1%-10%	4
11%-20%	11%-20%	3
21%-30%	21%-30%	2
31%-50%	31%-50%	1
>50%	>50%	0

D. Political support and stewardship

The political dimension provides an indication of the level of political support, identifying whether, both international and national, development goals have been incorporated and applied in the relevant case studies. The measure of this is provided by two sub-indicators; governance and compliance.

D.1 Governance

The ideals of democracy and the precepts of sustainability are inherently connected. One can go so far as to say that democracy is the first step in ensuring that equality and sustainability issues are addressed. Corruption has long-since been identified as a major problem in African societies, however this has been more evident at government level. Corruption has, at every step, challenged any progress towards poverty eradication, it has benefited the more affluent and relegated the poor to greater depths of poverty, widening the inequality gap.

The three variables; democracy, corruption and definition of roles and responsibilities; can provide a basic measure of the level of support for the goals of sustainable development, towards the fulfilment of basic service provision; such as water and sanitation. In a general sense, society is almost always aware and lucid to the lack of representation and democracy, as well as to the phenomenon of corruption; however it is almost always very slow to react to it. This lack of action and response, coupled with the aspect of illegality and concealment have rendered these variables difficult to quantify; hence demanding a more qualitative assessment as seen on Table H.21.

- Democracy and representation
- Measure of corruption
- Defined roles and responsibilities

Table H.21: Assessing governance

Governance			
Democracy	**Corruption**	**Defined roles and responsibilities**	**Scores**
Full democracy	None	Supporting policy and legislation, and good implementability	5
Very good	Low	Inappropriate policy environment	4
Good	Medium	Poor implementation capacity in a good policy environment	3
Mediocre	High	Progress towards policy setting and capacity building	2
Bad	Very high	Inappropriate policy and poor capacity	1
None	Extremely corrupt	Inaction (sterile environment and no progress, regression)	0

D.2 Compliance with policy

A measure of compliance with legislative directives and international development goals provides an indication of commitment to addressing the issues at hand.

- Compliance with government policies and legislation
  This is an indication of compliance with policies such as South Africa's Free Basic Water (FBW) policy and the National Water Policy (NWP) adopted by cabinet in 1997 and legalised through the National Water Act. These recognise the needs and rights of citizens to have access to water. It also make provisions for the water share required to maintain the very systems humans depend on.

- Compliance with Millennium Development Goals
  It is also important to take heed of global initiatives and international development agendas. There are many reasons for his; securing financial aid,

ensuring the transfer of resources and skills, adopting well-researched and implemented practices are some of the more obvious. There are a number of such guiding international principles, two of which have been observed here; the basic water supply requirements stipulated by WHO and recent;y, the MDGs.

Compliance with both local and international policy priorities is assessed on the basis of the levels of service available to the population for the two major services; water supply and sanitation (including wastewater management). This is done on the presumption that better services signify better compliance (Table H.22).

Table H.22: Compliance of service provision with existing policy and guidelines

%	LOS	Rate					
		Water supply		**Sanitation**		**Wastewater management**	
		Policies	**MDGs**	**Policies**	**MDGs**	**Policies**	**MDGs**
	LOS1	5	5	5	5	5	5
	LOS2	5	5	4	4	4	4
	LOS3	4	4	3	3	3	3
	LOS4	2	2	1	1	1	1
	LOS5	0	0	0	0	0	0

E. Institutional capacity and technological progress

E.1 Institutional and technical capacity

The institutional consistency and technical aptitude of administrations is evaluated through the following variables:

- Adoption of IWRM approach (and WBOs)
  This looks at broader issue of water management, beyond the borders of the urban centre. It is complementary to IUWM and necessary to conflict free assurance of water supply for cities.

- No. of water management institutions (relating to all 3 services, as well as resource management and performance monitoring). Both under-management and over-crowding is undesirable in the context of administrative issues. We see these two extremes in the case studies selected. In Hermanus, the Overstrand municipality is singly charged with the administration of Hermanus and neighbouring towns. At present, the population size and density assist this situation, however with growing populations and economic prosperity, resources will become stressed and the municipality might very well not cope. In Maputo, the situation is reversed, the administrative environment is crowded by several institutions and yet service delivery has not benefited, on the contrary, this has hampered good coordination and integration. An arbitrary number of institutions (10) was selected to indicate best performance for the management of all three services; this might very well be exaggerated. Values above and below this limit will be assigned decreasing scores or zero.

- Adoption of alternative water supply technologies
- Adoption of sustainable sanitation

Adopting alternative methods of both water supply and sanitation shows a commitment to more sustainable resource management as well as a capacity to do so. It is however unrealistic to expect a 100% conversion to newer technologies, nor is it feasible, given the investments on more conventional approaches. This should be a gradual process which takes into account social adaptability and acceptability, economic stability and the pressure on the environment resulting from unsustainable practices.

- Corresponding education levels for staff (knowledge and expertise) assesses the compliance with requirements for operation and maintenance of systems. It is expected that staff be equipped and trained to perform their duties and operate and maintain urban water systems to the required standards. This is however not the case, especially in developing countries where skills shortages continues to present a major challenge to management of urban services. A proxy is used; the percentage of staff with secondary and tertiary education.

- Monitoring capability (data collection and storage facility)
  The following words have only too often been voiced, in one version or another, and these have compelled the inclusion of this variable: "Here we just do things, we don't really study or investigate; there is no time or money for that." This has been said in reference to queries in Maputo as to whether there were studies on: underground water pollution due to seepages from latrines, and contamination from waste dumps; regular monitoring of wastewater effluent; environmental impact studies from any of the above sources and more.

Failure in service provision can result from two main factors: Ineptitude on the part of service providers, or inaptitude from providers of linked sectors such as the energy and transport sectors, hence the desegregation into the two following variables.

- Reliability of service provision
- Failure in service delivery due to dependence on other sectors

Table II.23: Criterion for assessing institutional and technical capacity for IUWM

Adoption of IWRM	No. of management institutions	Adoption of alternative water supply technologies	Adoption of 'sustainable' sanitation	Corresponding education levels for O&M	Monitoring capability (score out of 10)	Reliability of service provision	Failure in service delivery due to dependence on other sectors	Score
Implementation	10	50%	50%	100%	10	100%	Never	5
Planning	9-7	49%-40%	49%-40%	99%-70%	9-7	99%-80%	1-2 times per year	4
Developing the framework and addressing the legislative dimension	6-4	39%-20%	39%-20%	69%-50%	6-4	79%-50%	3-6 times per year	3
Consultation and exploration	3-2	19%-10%	19%-10%	49%-20%	3-2	49%-30%	>6 times	2
-	1	9%-1%	9%-1%	19%-1%	1	29%-10%	At least once a month	1
No progress	0 or >10	0%	0%	0%	0	<10%	Service is inconstant/infrequent	0

Appendix I: Ranked weighting sets

Table I.1: Ranking of variables from 1 to 5 according to different priority categories

Variable	Social	Weight	Economic	Weight	Environmental	Weight	Political	Weight	Institutional and technical	Weight
1.1 Total collection time	2	0.300	1	0.400	3	0.200	4	0.200	2	0.300
1.2 Gender bias	3	0.200	2	0.300	4	0.100	3	0.250	3	0.200
1.3 Conflict over water sources	4	0.100	3	0.150	2	0.300	1	0.300	4	0.200
1.4 % with access to protected water	1	0.400	4	0.150	1	0.400	2	0.250	1	0.300
		1.000		1.000		1.000		1.000		1.000
2.1 No. people per sanitation facility	3	0.200	1	0.500	1	0.400	1	0.400	1	0.350
2.2 Safety of use and safety to access facilities	1	0.500	2	0.300	2	0.300	2	0.300	2	0.350
2.3 Cultural and social acceptability	2	0.300	3	0.200	3	0.300	3	0.300	3	0.300
		1.000		1.000		1.000		1.000		1.000
3.1 Water supply	2	0.300	1	0.400	2	0.250	1	0.300	1	0.300
3.2 Sanitation	1	0.300	2	0.300	1	0.250	2	0.300	2	0.300
3.3 Drainage	4	0.200	4	0.100	3	0.250	4	0.200	3	0.200
3.4 Waste collection	3	0.200	3	0.200	4	0.250	3	0.200	4	0.200
		1.000		1.000		1.000		1.000		1.000
Susceptibility to natural disasters	2	0.500	2	0.400	1	0.600	2	0.400	2	0.350
4.1Dolines or sinkholes										
4.2Earth quakes										
4.3Droughts										
4.4Tornadoes										
4.5Hurricanes & floods										
4.6Tsunamis or shockwaves										
4.7Fires										

4.8 Risk management and disaster mitigation	1	0.500	1	0.600	2	0.400	1	0.600	1	0.650
		1.000		1.000		1.000		1.000		1.000
5.1 Under 5 mortality rate	1	0.300	4	0.200	1	0.300	2	0.200	3	0.250
5.2 Malaria-related mortality rate	3	0.250	3	0.200	2	0.300	3	0.250	1	0.250
5.3 Reported cases intestinal and infectious diseases per 1000	4	0.200	2	0.300	3	0.300	4	0.250	2	0.350
5.4 HIV/AIDS prevalence	2	0.250	1	0.300	4	0.100	1	0.300	4	0.150
		1.000		1.000		1.000		1.000		1.000
6.1 Level of dissemination	1	0.600	1	0.550	1	0.600	1	0.550	1	0.550
6.2 Level of consultation with stakeholders and public participation	2	0.400	2	0.450	2	0.400	2	0.450	2	0.450
		1.000		1.000		1.000		1.000		1.000
7.1 % people with secondary education	1	0.300	2	0.250	3	0.250	2	0.250	5	0.150
7.2 Unemployment rate	2	0.250	1	0.300	5	0.100	1	0.300	4	0.150
7.3 Income levels	4	0.150	3	0.200	4	0.100	4	0.150	3	0.150
7.4 Loss of income due to sickness	3	0.200	4	0.150	1	0.300	5	0.100	1	0.300
7.5 Min/Basic Water tariff	5	0.100	5	0.100	2	0.250	3	0.200	2	0.250
		1.000		1.000		1.000		1.000		1.000
8.1 % users paying for water	3	0.200	1	0.400	2	0.300	2	0.350	3	0.300
8.2 % UFW	2	0.300	2	0.350	1	0.600	3	0.250	1	0.500
8.3 % of free basic water	1	0.500	3	0.250	3	0.100	1	0.400	2	0.200
		1.000		1.000		1.000		1.000		1.000
9.1 % budget increase for water supply	2	0.300	3	0.250	2	0.300	1	0.250	1	0.275
9.2 % budget increase for sanitation	1	0.300	2	0.250	1	0.350	2	0.250	2	0.275
9.3 % of budget increase for O&M	3	0.250	4	0.100	3	0.250	4	0.200	3	0.250
9.4 Sources of Investment	4	0.150	1	0.400	4	0.100	3	0.300	4	0.200
		1.000		1.000		1.000		1.000		1.000
10.1 Available water (l/capita/day)	1	0.400	3	0.300	3	0.200	1	0.350	3	0.300
10.2 Reliability or variability	2	0.300	2	0.300	2	0.300	2	0.350	2	0.350
10.3 Water quality at source	3	0.300	1	0.400	1	0.500	3	0.300	1	0.350
		1.000		1.000		1.000		1.000		1.000
Sustainability/Feasibility of source		1.000		1.000		1.000		1.000		1.000

11.1 Local Groundwater										
11.2 Rainwater										
11.3 Local surface water										
11.4 Imported groundwater										
11.5 Stormwater										
11.6 Greywater										
11.7 Imported surface water										
11.8 Brackish water										
11.9 Wastewater										
11.10 Salt water										
12.1 Domestic	1	0.350	3	0.250	2	0.300	1	0.300	1	0.350
12.2 Industrial	3	0.200	2	0.300	4	0.050	3	0.200	2	0.300
12.3 Agricultural and livestock	2	0.350	1	0.300	3	0.150	2	0.300	4	0.100
12.4 Maintenance of ecosystems	4	0.100	4	0.150	1	0.500	4	0.200	3	0.250
		1.000		1.000		1.000		1.000		1.000
13.1 Effluent quantity	1	0.500	1	0.500	2	0.450	2	0.400	2	0.450
13.2 Effluent quality	2	0.500	2	0.500	1	0.550	1	0.600	1	0.550
						1.000		1.000		
14.1 Effluent quantity	1	0.500	1	0.500	2	0.450	2	0.400	2	0.450
14.2 Effluent quality	2	0.500	2	0.500	1	0.550	1	0.600	1	0.550
						1.000		1.000		1.000
15.1 Close to solid waste dump or landfill site		1.000		1.000		1.000		1.000		1.000
16.1 Located on flood prone area	1	0.250		0.250	4	0.150	1	0.250	2	0.200
16.2 Steepness	4	0.165		0.150	5	0.100	5	0.125	5	0.150
16.3 Depth to groundwater table	3	0.250		0.200	1	0.350	3	0.250	1	0.250
16.4 Soil permeability	5	0.165		0.150	2	0.250	4	0.125	3	0.250
16.5 Ground stability	2	0.170		0.250	3	0.150	2	0.250	4	0.150
		1.000		1.000		1.000		1.000		1.000
17.1 % of polluted water sources	2	0.400	2	0.450	1	0.550	2	0.500	1	0.600
17.2 % of total area identified as	1	0.600	1	0.550	2	0.450	1	0.500	2	0.400

severely water stressed										
				1.000		1.000				
18.1 Democracy and representation	1	0.400	2	0.350	3	0.200	1	0.350	3	0.300
18.2 Measure of corruption	2	0.350	1	0.400	2	0.300	2	0.350	2	0.300
18.3 Defined roles and responsibilities	3	0.250	3	0.250	1	0.500	3	0.300	1	0.400
		1.000		1.000		1.000		1.000		1.000
19.1 Government policies (compliance)	1	0.550	1	0.600	1	0.500	1	0.550	1	0.700
19.2 MDGs (compliance)	2	0.450	2	0.400	2	0.500	2	0.450	2	0.300
		1.000		1.000		1.000		1.000		1.000
20.1 Adoption of IWRM approach	5	0.100	8	0.050	1	0.300	1	0.200	1	0.250
20.2 No. of water management institutions	4	0.150	1	0.200	6	0.050	4	0.100	3	0.200
20.3 Adoption of alternative water supply technologies	6	0.075	3	0.150	2	0.200	7	0.100	5	0.100
20.4 Adoption of 'sustainable' sanitation	7	0.075	4	0.150	3	0.200	8	0.100	6	0.050
20.5 Corresponding education levels for O&M	3	0.150	2	0.200	5	0.050	5	0.100	7	0.040
20.6 Monitoring capability	8	0.050	7	0.050	4	0.100	6	0.100	4	0.150
20.7 Reliability of service provision	1	0.200	5	0.100	7	0.050	2	0.150	2	0.200
20.8 Failure in service delivery due to dependence on other sectors	2	0.200	6	0.100	8	0.050	3	0.150	8	0.010
		1.000		1.000		1.000		1.000		1.000

Appendix J
Sustainability Index application; Hermanus data sheet

I. SOCIAL

Population dynamics for Overstrand

Table J.1: Demographics for Overstrand Municipality
(Overberg District Municipality, 2004)

Service area	Permanent population	Population over holidays
Hangklip-Kleinmond	5243	40000
Hermanus	30659	75000
Stanford	5000	5500
Gansbaai	6730	46778
Rural areas	2571	2631
Total	**50 203**	**169 909**

* Current permanent population for Hermanus, 40000 (Stephen Muller, Overstrand Municipality)

* Current holiday population for Hermanus, ≥ 75000 (Stephen Muller, Overstrand Municipality)

1. Access to water supply

1.1 Total collection time: Dependant on LOS

1.2 Gender Bias: Dependant on LOS
Annual report indicates that a Overstrand Gender Task Team has been established to address gender issues such building capacity for effective participation and delivery (Overstrand Municipality, 2006c; pg 19).

1.3 Conflict over water sources
Assumed no conflict as the entire population is fully serviced. There are however issues regarding water tariffs and the cutting off of services due to non-payment (Deedat et al., 2001).

1.4 % with access to protected water
High quality of service provision and compliance with minimum service standards therefore 100% access to protected water.

2. Access and use of sanitation facilities

2.1 No. of people per sanitation facility: Dependant on LOS

2.2 Safety of use and to access facilities: Dependant on LOS

2.3 Cultural and social acceptability: Dependant on LOS
High levels of service which reflects both good accessibility and acceptability of sanitation services.

3. Levels of service

3.1 Water supply

Table J.2 Water services for urban residential units in Overstrand (Overberg District Municipality, 2004)

Service level per town	Communal water supply		Uncontrolled yard tap		Uncontrolled house connection	
	2003*	2008**	2003	2008	2003	2008
Hangklip-Kleinmond	311	0	220	220	4950	6 448
Hermanus	1300	0	460	600	10 207	14 819
Stanford	120	0	0	0	887	1 112
Gansbaai	513	0	0	0	3923	5 397
Total CUs per LOS	2244	0	680	820	19 967	27 777

* Based on 2003 WSDP

** Projected 5 year improvements

3.2 Sanitation

Table J.3: Sanitation services for urban residential units in Overstrand (Overberg District Municipality, 2004)

Service level per town	VIP or equivalent		Wet-septic /conservancy tanks		Discharge to WWTP	
	2003*	2008**	2003	2008	2003	2008
Hangklip-Kleinmond	311	0	4 433	5 370	737	1 298
Hermanus	1300	0	1 688	1 840	8 979	13 579
Stanford	120	0	485	687	402	425
Gansbaai	513	0	3 358	4 772	565	625
Total CUs per LOS	**2244**	**0**	**9 964**	**12 669**	**10 683**	**15 927**

* Based on 2003 WSDP

** Projected 5 year improvements

3.3 Drainage

Drainage is somewhat problematic in some areas of Hermanus, particularly in the informal settlement of Zwelihle and in Hawston. This is mainly due to poor housing design and planning. However, overall it is assumed that drainage coverage is adequate.

3.4 Waste collection

There is regular collection of waste in all areas of Hermanus (weekly), undertaken by the municipality.

4. Vulnerability

4.1 Susceptibility to disasters

4.2 Risk management and disaster mitigation

It was not possible to obtain the Disaster Management Plan however the Hermanus WSDP indicates good preparedness mostly to fires (Overstrand Municipality, 2006c; pg 26). The level of organisation and management observed in Hermanus indicates that there is a high state of preparedness for eventualities, risks and hazards. In terms of the actual disasters, Hermanus is not particularly prone to any of the mentioned below:

- **Dolines & sinkholes:** none (Kornelius, Umvoto).
- **Earthquakes** (not along any major fault lines).
- **Droughts** (previously water stressed but no longer the case).
- **Floods** (although the area is low-lying there is sufficient infrastructure to deal with minor floods, however in the case of large storms and backlashes of cyclones from the coast of Mozambique, have attributed this a 50% susceptibility).
- **Tsunamis/shockwaves:** this is not a major problem in the area, there are cases of very high waves during heavy sea storms however this does not reach this extreme.

Fires: there is sufficient provision and access to water to mitigate in the risk of fires, good fire fighting capabilities.

5. Health status

5.1 Under 5 mortality rate

5.2 Malaria-related mortality rate

The total number of reported malaria-related deaths for South Africa was 141 deaths in 2003. The reported national case rate is 0.30 (deaths per 1000 people) (Global Health Facts, 2007). This is extremely insignificant in the context of the entire population.

5.3 Reported cases of intestinal and infectious diseases per 1000

Haven't obtained health data however because the water sources are of good quality and reliable it is assumed that there are few if any incidences of water related diseases. If there are any, it is assumed that these may be due to extraordinary events such as pipe failures (wastewater contaminating water supplies) etc. Assumed mortality rates to be low; and that even though cases of malaria might occur, death incidences are very low (0%).

5.4 HIV/AIDS prevalence

Table J.4: HIV prevalence survey in ante-natal clinics around the country (DOH, 2005)

Province	2003	%	2004	%	2005	%
Eastern Cape	1919	11.5	1711	10.7	2189	13.3
Free State	1039	6.2	1016	6.3	935	5.7
Gauteng	3146	18.9	3169	19.7	3110	18.8
KwaZulu-Natal	3406	20.5	3522	21.9	3500	21.2
Limpopo	1890	11.4	1894	11.8	1897	11.5
Mpumalanga	1241	7.5	1114	6.9	1027	6.2
Northern Cape	623	3.7	494	3.1	567	3.4
North West	1388	8.3	1192	7.4	1325	8.0
Western Cape	1991	12.0	1952	12.2	1960	11.9
Total	**16643**		**16064**		**16510**	

Based on national survey in antenatal clinics in the 9 provinces, therefore it is a guest estimate. Extrapolated the results for the Western Cape to Hermanus however in future must try to validate this with more local data.

6. Education and awareness

6.1 Level of dissemination

6.2 Level of stakeholder consultation and public participation

Whilst the water conservation programme contained a very strong component of information dissemination and awareness campaigning this targeted the richer income groups and failed to be fully inclusive. Consultation and participation was also limited to higher income groups. Even in this case it was more a one-sided consultation approach rather then enabling input from the public.

II. ECONOMIC

7. Capacity (to pay for services)

7.1 % of people with secondary education:

Includes the following categories: Grade 12 certificate, grade 12 diploma, bachelor's degree, bachelors degree and diploma, honours degree, masters/doctorate (STATS SA, 2001 National Census).

7.2 Unemployment rate:

Includes only the categorically unemployed and not students, scholars, retired people, disabled people or housewives. Unemployed are people who are actively looking for work but cant find any, and have been previously employed.

7.3 Income levels:

Table J.5: Income categories for Overstrand

Settlement type	No. of households with monthly income of:					Affordability of tariffs	
	<R1000	R1000-R1500	R1500-R2500	R2500-R3500	Over R3500	Water	Sanitation
Urban Dense/Farmland	3223	1633	1667	1011	2938	-	-

*The low income values observed are general, despite the high incomes earned by a small fraction of the population. The categories chosen were done keeping in mind the ability to pay for water, above R3500 this is no longer much of a problem hence attributing it the highest score (5).

This variable takes into account the lowest income groups. According to the WSDP of 2004, the majority of households earn below R1000 (Overberg District Municipality, 2004). If these are grouped with the next income category, this gives an estimate of 47% of households earning below R1500.

7.4 No. of days taken off work due to water-related diseases

Assumed that a minimum number of days is lost. This is based on previous assessments of the Health Status and the quality of services.

Table J.6: Economic data (STATS SA, 2001 National Census)

Areas	People with higher education *	Unemployment levels **	Income levels ***	Loss of income
Fisher Haven	51	6	R 1500- R2499	
Hawston	214	590	R500-R999	
Hermanus	1396	1121	R500-R999	
Onrusrivier	912	67	>R3500	
Sandbaai	472	68	>R3500	
Zwelihle	94	1504	R500-R999	
Vermont				
Mount Pleasant				
TOTAL	**3139**	**3356**		
As a % of total population (30659)	10% (undercount, Vermont and Mt Pleasant are missing)	11% (undercount. Vermont and Mt Pleasant are missing)		

* The assumption is that these numbers are only inclusive of the 30659 permanent residents of Greater Hermanus and not the seasonal inhabitants. Need to include Vermont and Mount Pleasant.

** The assumption is that these numbers are only inclusive of the 30659 permanent residents of Greater Hermanus and not the seasonal inhabitants. Need to include Vermont and Mount Pleasant.

*** Lowest income category/area earned by majority of inhabitants. Must however look at this with regards to number

7.5 Minimum/Basic water tariff

Table J.7 Block water tariff for Hermanus

Quantity	Consumption		Additional		VAT
>0-5kl			R0.30/add kl	plus	14% VAT
>5-10kl	5kl@ R1.50	plus	R0.70/add kl	plus	14% VAT
>10-15kl	10kl@ R5	plus	R1.20/add kl	plus	14% VAT
>15-20kl	15kl@ R11	plus	R1.80/add kl	plus	14% VAT
>20-25kl	20kl@ R20	plus	R2.40/add kl	plus	14% VAT
>25-30kl	25kl@ R32	plus	R3.00/add kl	plus	14% VAT
>30-40kl	30kl@ R47	plus	R4.00/add kl	plus	14% VAT
>40-60kl	40kl@ R87	plus	R5.00/add kl	plus	14% VAT
>60-80kl	60kl@ R187	plus	R6.00/add kl	plus	14% VAT
>80-100kl	80kl@ R307	plus	R7.50/add kl	plus	14% VAT
>100kl	100kl@ R457	plus	R10.0/add kl	plus	14% VAT

8. Cost recovery

8.1 % of users paying for water:
The Status Quo Booklet prepared by DWAF (indicates that cost recovery rates are very good (assumed this is indicative of the higher part of the second quartile 75%-100%, the indicator range from 90%-99%).

8.2 % of UFW:15%
(Overberg District Municipality, 2004; Overstrand Municipality, 2006a)

8.3 FBW: 50l/person/day (6kl.household/month)
(DWAF, 2001; DWAF, 2004: National Free Basic Water Policy)

(See also Overstrand Municipality, 2006b)

9. Investment levels

9.1 % budget increase for water supply

Table J.8: Annual budgets for water supply (Overberg District Municipality, 2004)

Summary of current and future water capital budgets in ZAR (2002/2003-2007/2008)					
2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
4 980 000	5 985 000	4 787 000	6 880 000	7 325 000	5 185 000

Budgets in water supply do not display a common pattern; however there is an estimated increase for the past two consecutive budget years (2004/2005 – 2006/2007) of 30% and 6% respectively, the average being 18%.

9.2 % budget increase for sanitation

Table J.9: Annual budgets for sanitation supply
(Overberg District Municipality, 2004)

Summary of current and future sanitation capital budgets in ZAR (2002/2003-2007/2008)					
2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
3 826 000	2 682 000	3 760 000	5 471 000	8 475 000	8 325 000

Budgets for sanitation display more consistent patterns, and the average increase for the past two consecutive years (2004/2005 – 2006/2007) is 33%.

9.3 % budget increase for O&M

Table J.10: Annual budgets for operation and maintenance (O&M)
(Overberg District Municipality, 2004)

Actual operating cost s in ZAR (2002/2003-2007/2008)					
2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
12 749 002	14 577 650	15 743 862	17 003 371	18 363 641	19 832 732

Budgets for operating costs for the past two consecutive years (2004/2005 2006/2007) show an average 7% increase.

9.4 Sources of investment

Table J.11: Sources of capital for water supply
(Overberg District Municipality, 2004)

Capital source	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
DAWF rural water supply	0	2 050 000	0	0	0	0
Internal Fund	4 380 000	3 935 000	4 447 000	6 730 000	7 325 000	5 185 000
CMIP	0	0	0	0	0	0
Other-grants, revenues, funds etc…	600 000	0	340 000	150 000	0	0
Total Capital	4 980 000	5 985 000	4 787 000	6 880 000	7 325 000	5 185 000

For 2004/2005 and 2005/2006 it was estimated that 93% and 98% of the capital originated from internal funds.

Table J.12: Sources of capital for sanitation (Overberg District Municipality, 2004)

Capital source	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008
External loans	0	0	0	0	0	0
Internal Fund	3 276 000	2 682 000	3 221 000	5 226 000	8 475 000	8 325 000
CMIP	0	0	399 000	245 000	0	0
Other-grants, revenues, funds etc…	250 000	50 000	140 000	0	0	0
Total Capital	3 526 000	2 732 000	3 760 000	5 471 000	8475 000	8 325 000

For 2004/2005 and 2005/2006 it was estimated that 86% and 96% of the capital originated from internal funds. Overall, for both water and sanitation, the majority of funds originates from internal sources.

III. ENVIRONMENTAL

10. Fresh water resources

10.1 Per capita water availability
The studies conducted by Umvoto and SRK reveal that the underlying aquifer has sufficient capacity to supply water to that area for decades to come. it is therefore safe to assume that there is >1700 per capita availability.

10.2 Reliability (in terms of variability, seasonality etc…) at source
Whilst there were some concerns during the drier months, regarding the supply from the De Bos Dam, with the upcoming exploitation of the aquifer reliability issues are no longer valid. One must keep in mind the population boom during peak season, which coincides with the summer months, however it is not known what the variability might be.

10.3 Water quality at source
Water from both the De Bos Dam and the aquifer are of good quality, there is need for differentiated treatment however this is not problematic nor is it significantly more costly. Streams and estuaries are relatively unpolluted.

See the following reports for a detailed account of water resources for Hermanus: Umvoto, undated; Umvoto, 2005a; Umvoto, 2005b; Umvoto, 2006a; Umvoto, 2006b.

11. Sustainability/feasibility of water source

11.1 Sustainability/feasibility of water source
The Umvoto Inception report (pg 41-42) mentions that the current sources are split as follows:

68% De Bos Dam (surface water)

32% Groundwater (Hermanus aquifer)

(See also: Overberg District Municipality, 2004)

12. Use

Table J.13: Categories of water users

	Total Population	**No. of household CUs**	**No of industrial CUs**	**No. of commercial CUs**	**Other CUs**
Hangklip-Kleinmond	5243	5481	40	NA	44
Hermanus	30 659	11 967	78	NA	NA
Stanford	5000	1007	NA	25?	15?
Gansbaai	6730	4236	41	43	17
Total	47 632	22 691	159	?	?

12.1 Domestic:

Theoretical Unit Demand for modelling purposes 1kl/d (assume that this is for each household) (Overstrand Municipality, 2006a; Table OVW3)

1kl/household/day divided by on average 4 people per household (same as assumption for free basic water calculations) = 250l/person/day

12.2 Industrial: 0.6%

78 units represents less the 1% (78+11967 = 12045)

12.3 Agricultural:

<150Ol/person/day directly produced in the surrounding areas (Overstrand Municipality, 2006a; Table OVW3).

12.4 Maintenance of ecosystems: 24%

2.8 x 10^6 is withdrawn from the De Bos Dam but the dam has a capacity of 3.7 x 10^6, therefore assume that the remainder is set aside for the maintenance of the riverine systems (Umvoto Inception Report; pg 10 and 42).

13. Wastewater management

13.1 Effluent quantity

Used an estimate of 100l/person/day x 30659 people (full time residents) x 40% (assume that 40% gets flushed down the line, hence 40l/person/day) = 1226360L = 1226.4 kl.

13.2 Effluent quality.

Table J.14: Effluent quality at Hermanus WWTW
(A.L. Abbott & Associates, 2005)

	Raw Sewage	Anoxic Zones 1	2	Aer. Tank	Settling Tanks 3	4	5	Final Effluent	Permit 507 B
pH (at 25°C)	7,2	-	-	7,3	-	7,1	7,1	6,9	5,5-9,0
Settleable Solids (ml/l)	4,5	-	-	960	-	Nil	Nil	Nil	-
Conductivity (at 25°C) (mS/m)	-	-	-	-	-	-	-	115	-
E.Coli (org/100 ml)	-	-	-	-	-	-	-	20	-
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Chemical Oxygen Demand	290	-	-	64,5*	-	-	-	52,4	75 Max
Oxygen Absorbed	30,8	-	-	13,8*	-	13,8	13,0	5,8	10 Max
Kjeldahl Nitrogen	29,0	-	-	-	-	-	-	-	-
Ammonia Nitrogen	20,2	-	-	0,83	-	<0,15	<0,15	5,1	10 Max
Nitrate Nitrogen	-	1,6	<0,20	11,2	-	-	-	4,8	-
Nitrite Nitrogen	-	1,5	0,08	<0,08	-	-	-	0,36	-
Total Suspended Solids		-	-	4 260	-		-	9	25 Max
Volatile Suspended Solids	-	-	-	3 432	-	-	-	-	-
Dissolved Oxygen	-	Nil	Nil	1,4-5,8	-	3,0	3,3	5,6	7,5 Min

* Filtered
Underflow Sludge : 1. - 4. 9 640 mg/l
2. - 5. 9 280 mg/l
3. -

* Assumed best case scenario

Table J.15: Effluent quality at Hawston WWTW
(A.L Abbott & Associates. 2005)

	Raw Sewage	Aeration Tank	Settling Tank	Final Effluent	General Standard
pH (at 25°C)	7,0	7,5	7,0	7,3	5,5-9,0
Settleable Solids (ml/l)	18	970	Nil	Nil	-
Conductivity (at 25°C) (mS/m)	-	-	-	63,1	250 Max
E.Coli (org./ 100 ml)	-	-	-	Nil	Nil
Coliform Bacteria (org./100ml)	-	-	-	Nil	-
	mg/l	mg/l	mg/l	mg/l	mg/l
Chemical Oxygen Demand	831	40,3*	-	76,6 (56,4*)	75 Max
Oxygen Absorbed	62,2	7,8*	6,7	4,2 (11,6*)	10 Max
Kjeldahl Nitrogen	91,9				-
Ammonia Nitrogen	66,1	1,7	1,7	1,9	10 Max
Nitrate Nitrogen	-	10,8	-	<0,20	-
Nitrite Nitrogen	-	<0,08	-	<0,08	-
Total Suspended Solids		6 532	5 052■	14	25 Max
Volatile Suspended Solids	-	5 636	-	-	-
Dissolved Oxygen	-	3,8	1,6	4,6	7,5 Min

* Filtered

■ Underflow sludge

* Assumed worst case scenario

14. Stormwater management:

14.1 Effluent quantity: Dependant on LOS

14.2 Effluent quality: Dependant on LOS

15. Compatibility of water system with the surrounding environment

15.1 Proximity to solid waste dump or landfill site

There are areas located close to the landfill site near Fisherhaven for example, however these seem to create more of a public nuisance rather then directly affecting the water supply (van Vuuren, 2007).

16. Compatibility of sanitation systems with the surrounding environment

16.1 Located on flood prone area

Hermanus is low lying (coastal) and I've assumed that all the storm water draining from higher areas (surrounding mountains) discharge towards the bay area, therefore although drainage systems are in place and are effective in some areas, assumed that the entire area under study is flood prone.

16.2 Steepness of slope

Check contours for the site (Rough estimate from Google earth, 2007)

Highest point +/- 100 m above MSL and lowest point +/- 10 m above MSL over roughly 1 km. Max Slope = 0.09 (9%)

16.3 Depth to groundwater table

These vary. The scoping report prepared by Umvoto indicated that most of the more then 200 boreholes or so around Hermanus are no greater then 10m in depth and hit the primary alluvium aquifer, however some 40-50 are deeper but also no greater then 100m deep. The depths to the GWT vary from area to area however these significantly surpass the highest category provided in the Excel sheet which is indicative that it is not of main pollution concern.

16.4 Soil permeability: medium permeability

Sandstone is encountered (borehole drilling) from 10m – 125 m belonging to the Peninsula Formation of the Table Mountain Group. Overlaying that, one can find sand and boulders of the Bredasdorp Group (Umvoto, Inception Report). Aeolian sand deposits, littoral sandstone and limestone occur near the coast: (Umvoto scoping report, pg 3).

16.5 Ground stability

There are no major problems with ground stability (Personal communications with Kornelius Riman, Umvoto; and James van Der Linde).

17. Environmental stresses

17.1 % of polluted water sources

All reports indicate that all water sources are of generally good quality in the Hermanus area, despite needing some treatment for consumption purposes. There is also good indication of preservation of riverine systems.

17.2 % of total area identified as severely water stressed

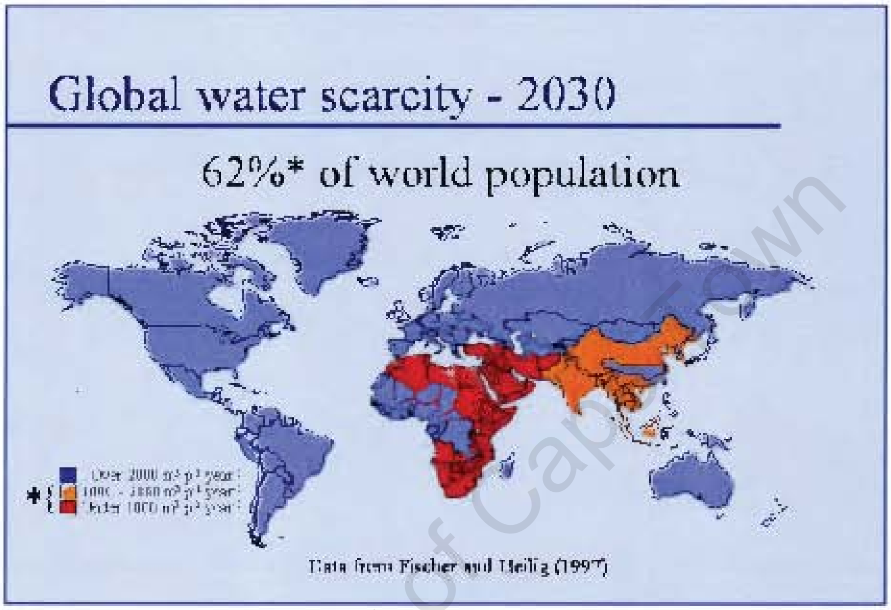

Figure J.1: Falkenmark water stress indicator
(Rijsberman, 2004: pg 5)

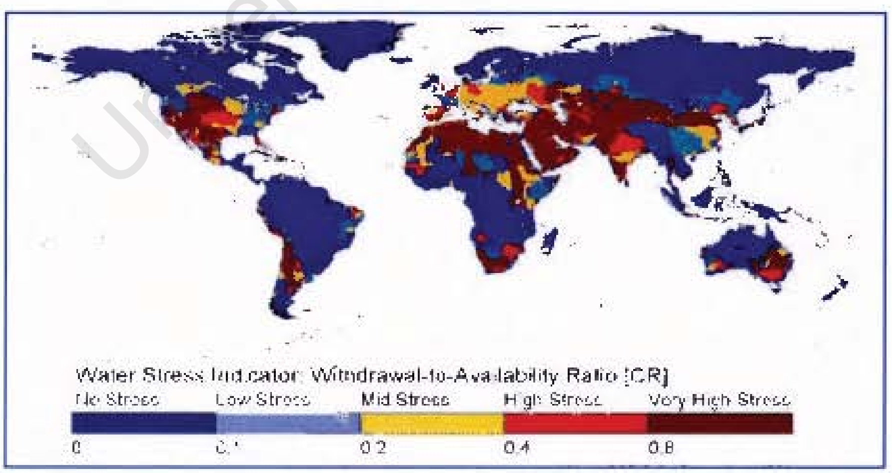

Figure J.2: Water stress analysis based on the criticality ratio
(Rijsberman, 2004; pg 6)

Whilst the map shows that generally speaking, the whole of South Africa is highly water stressed, more recent studies indicate that for Hermanus in particular, there are sufficient resources for the growing needs and for generations to come (Personal

Contact, Stephen Muller, Overstrand Municiplaity). Caution should be taken when mentioning these resources as there are extraction limits and such constraints. Hermanus has explored other possibilities for complementing water supply such as desalination for domestic purposes and treated effluent for irrigation.

IV. POLITICAL

18. Governance

Qualitative assessments for all three variables based on review of the literature, visits to Hermanus, consultation with the municipality and personal observations were made (including Mr van Der Linde).

18.1 Democracy and representation

18.2 Measure of corruption

18.3 Defined roles and responsibilities

19. Compliance with policy and regulation

19.1 Compliance with government policies: Dependant on LOS

19.2 Compliance with MDGs: Dependant on LOS

V. INSTITUTIONAL

20. Institutional and technical capacity

20.1 Adoption of IWRM approach

Both the reports and the meeting with Mr Kornelius confirmed that there is adoption of IWRM principles. DWAF acts as the policy setting and regulating authority as well as having a sort of 'inspector' role. The municipality then implements the necessary changes to ensure compliance with DWAF criteria or standards.

20.2 No of water management institutions

(1) Municipality is the main management authority, but it does sub-contract work when it is necessary.

20.3 Adoption of alternative water supply technologies

Water tanks (limited use capacity as in Durban's 200l/hhld/day), rain harvesting, dual reticulation and greywater reuse, low pressure showers are some of the examples which have been employed in other parts of the country, however this has been lacking in Hermanus. Although the GHWCP had a component which included such considerations, it was not implemented while the programme was running. Furthermore there is no indication that these are being implemented at present.

20.4 Adoption of sustainable sanitation

Use of salt or grey water for flushing (dual reticulation), low flush toilets, composting are again some examples of alternative and more sustainable types of sanitation. There is no indication in any of the reports that these were employed in Hermanus.

20.5 Corresponding education levels for staff

Table J.16: Staff expertise and skills levels
(Overstrand Municipality, 2006c; annual report 2006-20007; pg 16)

Occupational levels	Male			Female				Total
	A	C	I	A	C	I	W	
1. Top management	3	4	-	2	3	-	-	27
2. Senior management	-	2	-	-	1	-	4	25
3. Professionally qualified and experienced specialists	2	4	-	-	1	-	2	26
4. Skilled technical and academically qualified workers	3	17	-	4	5	-	16	72
5. Semi-skilled and discretionary decision making	48	97	-	8	46	-	42	256
6. Unskilled and defined decision making	177	145	-	6	15	-	1	349
Total	233	269	-	20	71	-	65	755

Considered the first five categories as sufficiently skilled labour to perform their jobs, therefore of a total of 755, 406 are skilled staff members, representing a 54% skilled workforce.

20.6 Monitoring capability

According to Mr Kornelius Riman, the fact that the municipality initiated monitoring of groundwater through Umvoto and is hoping to take on this role in future, is indicative of the capability for monitoring, albeit at a initial stage. There are other organisations involved in this. DWAF certainly has monitoring duties (ensures that the service provider is performing accordingly), interest groups, nature conservationist groups (Cape Nature Reserve) etc, DWAFs Working for Water Programme.

20.7 Reliability of service provision

This is very reliable. The only cases of service cuts are due to non-payment for services.

20.8 Failure in service delivery due to dependence on other sectors

Other sectors are equally well run; this might be largely because they are managed by the same institution which ensures an overall good performance. Budgets do however vary across different sectors and this can affect the performance of each sector as well as how performance in each sector can then influence the next. In future index assessments it is recommended that these discrepancies be assessed and accounted for in the case of significant cross-sectoral influences.

Appendix K

Sustainability Index application; Maputo data sheet

I. SOCIAL

Population dynamics for Mozambique: Urban Maputo

Table K.1: Population of Maputo City: Districts 1-5 (FIPAG Report, 2005; annex1)

	2005	2007	2012	2017
District 1:	202 954	209 715	223 908	237 425
District 2:	178 516	182 465	191 772	201 555
District 3:	230 948	236 056	248 098	260 753
District 4:	269 745	281 082	311 164	341 040
District 5:	291 741	310 620	361 779	403 571
TOTAL	1 173 904	1 322 528	1 336 721	1 444 344

Table K.2: National Population Statistics (INE Website: 03/05/07, 08:21)

Population	2001	2002	2003	2004	2005	2006	2007
Total	17.656.153	18.082.523	18.521.246	18.972.396	19.420.036	19.888.701	20.366.795
Men	8.488.658	8.700.900	8.919.315	9.143.838	9.368,425	9,603.031	9.842.760
Women	9.167.495	9,381.623	9.601,931	9.828.558	10.051.611	10.285.670	10.524.035
Provinces							
Niassa	893.126	916.672	941.195	966.579	999.332	1.027.037	1.055.482
Cabo Delgado	1.495.229	1.525.634	1.556.788	1.588.741	1.617165	1.650.270	1.683.681
Nampula	3.337.049	3.410.141	3.485.420	3.563.224	3.676.003	3.767.114	3.861.347
Zambézia	3.395.374	3.476.484	3.559.923	3.645.630	3.710011	3.794.509	3.880.184
Tete	1.353.436	1.388.205	1.424.263	1.461.650	1.511832	1551949	1.593.258
Manica	1.171.929	1.207.332	1.243.638	1.280.829	1.320232	1.359.923	1.400.415
Sofala	1.484.535	1.516.166	1,548.748	1.582.256	1.637821	1.67.6131	1.715.557
Inhambane	1.291.009	1.326.848	1.363.596	1.401.216	1.381023	1,412.349	1,444.282
Gaza	1.234.328	1.266.431	1.299.521	1.333.540	1.304798	1.333.106	1.362.174
Maputo Provincia *	968.844	1.003.992	1.039.321	1.074.793	1.044946	1.072,086	1.098.846
Maputo Cidade	1.031.294	1.044.618	1.058.833	1.073.938	1.216.873	1.244.227	1.271.569

* These values are lower then for Maputo City, therefore will assume that they exclude the population of Maputo City. The projections by INL and FIPAGs below differ somewhat.

1. Access to water supply

1.1 Total collection time: Dependant on LOS

This variable is calculated on the basis of the type and level of service available however some additional information was made available which indicates that on average households spend 15 minutes collecting water at distances no greater then 1 hours walk.

Table K.3: Time and distance constraints in accessing water (CRA, 2006 Beneficiary assessment: pg 45)

Sources	No.	Distance to source (minutes)			Waiting times (minutes)		
		Average	Deviation	Min/Max	Average	Deviation	Min/Max
Neighbours tap	155	8.36	8.7	1-60	9.00	13.69	0-90
AdeM taps	86	13.3	9.28	2-55	17.93	20.35	0-120
Private taps	68	11.39	8.21	2-45	15.22	30.14	0-180
Well	41	11.69	8.87	1-30	15.44	22.32	0-120
Communal well equipped with pump(s)	11	8.36	8.87	1-30	75.55	96.48	0-240
Total	**361**	**10.46**	**8.96**	**1-60**	**15.34**	**28.74**	**0-240**

1.2 Gender Bias: Dependant on LOS

There is no direct study looking at the responsibility of women in providing water for the household for this case study area. In general it is however widely recognised that given women's domestic roles, this burden falls heavily on them, and at times on young children who are not attending school. The health survey carried out by INE provides a understanding of the role of women (in terms of decision making) in the house, which then tells us whether their interests are well represented.

Table K.4: Women's point of view on women's decision-making authority in the household (INE, 2003: pg 44)

Province / Characteristic	Regarding womens Health care	Regarding grocery shopping for the house	Regarding the daily shopping requirements for the household	Regarding visits to family or friends	Regarding the daily meals	All specific household decisions	None of the household decisions
Maputo	62.7	47.3	68.0	58.6	74.9	41.3	19.3
Maputo City	52.3	32.4	47.0	49.6	55.7	20.7	24.0

* Looks at the percentage of women which contribute to making decision regarding the above mentioned issues.

Table K.5: Men's point of view on women's decision-making authority in the household (INE, 2003; pg 45)

Province / Characteristic	Regarding womens Health care	Regarding grocery shopping for the house	Regarding the daily shopping requirements for the household	Regarding visits to family or friends	Regarding the daily meals	All specific household decisions	None of the household decisions
Maputo	60.8	99.7	83.2	99.4	86.5	78.2	41.5
Maputo City	56.9	78.6	62.3	95.3	69.1	64	24.0

* Looks at the percentage of men which contribute to making decision regarding the above mentioned issues.

1.3 Conflict over water sources

At a river basin level, good communication and joint management of shared resources has reduced the potential for conflicts. However within the case study area (Maputo City) the potential for conflict or actual situations of conflict differ for different water users. The issue of conflict is not in terms of categories of users (domestic, industrial, commercial) but rather within the domestic category. In this category poor service provision to the majority of the population has resulted in some strained relationships between the provider and consumers, as well as across different consumers in different areas. The other potential cause of conflict is between the formal AdeM providers and the Small Scale Independent Providers (SSIPs). SSIPs have flourished in the face of considerable need for service provision and poor responses to this crisis from AdeM in the past. AdeM's current plans are to expand into areas which are currently served by SSIPs, as they are within their legal rights to do so. SSIPs while key role players, are not legally appointed for the provision of water services. The argument goes that small scale providers have done AdeM's job when the utility couldn't. Furthermore these are public enterprises which contribute significantly to poverty alleviation in those areas. Any court ruling would have to provide a good compromise for both parties. Currently FIPAG is attempting to initiate an amicable agreement between these two parties, one which might be satisfactory to all. It is not clear what this might entail but it is certainly a positive approach and one which can eliminate potential conflict. In light of all these considerations, it will be assumed that although there is potential for conflict, this is not present at the moment.

1.4 % with access to protected water

The national health survey conducted by INE, indicates that 95.7% of the population of Maputo City is making use of improved water supply sources (Uso de fontes de agua potavel melhorada). (INE Report, 2003; indicator lists)

2. Access and use of sanitation facilities

2.1 No. of people per sanitation facility: Dependant on LOS

2.2 Safety of use and to access facilities: Dependant on LOS

2.3 Cultural and social acceptability: Dependant on LOS

3. Levels of service

3.1 Water supply (AdeM, 2003; 2004; 2005; 2006; and 2007) (See also: UNICEF & WHO, 2006a, UNICEF & WHO, 2006b).

3.2 Sanitation (UNICEF & WHO, 2006a, UNICEF & WHO, 2006b)

3.3 Drainage (Consultec, 2005; DHV Engenheiros, 1984)

3.4 Waste collection

Table K.6: 2006 (Second) Beneficiary assessment (CRA; 2006)

Beneficiary assessment	2001	2006
Water sources?	32% had household connections or connections in the yard	22.8% had household connections or connections in the yard
	25% used the neighbours tap	26% used the neighbours tap
	9% were supplied by SSIPs via either house connections or standpipes	22.8% were supplied by SSIPs via either house connections (11.5%) or standpipes (11.3%)
	17% makes use of standpipes from AdeM's small systems	3.7% makes use of standpipes from AdeM's small systems
	12% makes use of standpipes from AdeM's formal network	10.7% makes use of standpipes from AdeM's formal network
	2.6% make use of private boreholes and wells	6.8% make use of private boreholes and wells
	2% household well	5.5% household well
	0.3% public well	1.8% public well
Payment levels	Average costs: 8.16MT/m^3 ($0.38 = R2.7/m^3)	Average costs: 19.6MT/m^3 ($0.75 = R5.3/m^3)
	51% of the population interviewed pays more then this More expensive in peri-urban areas	51% of the population interviewed pays more then this More expensive in peri-urban areas
Use	Average consumption for families with household connections (in-home or yard) 14.73m^3/family/month	Average consumption for families with household connections (in-home or yard) 11.9m^3/family/month
	Average consumption for families without household connections (in-home or yard) 4.83m^3/family/month	Average consumption for families without household connections (in-home or yard) 3.79m^3/family/month
	There is a high willingness to pay for household connections (in-home or yard) to reduce current rates of payment	There is a high willingness to pay for household connections (in-home or yard) to reduce current rates of payment

The governing criteria to determine LOS will be access to sanitation, which often lags behind water supply.

Table K.7: Levels of service (FIPAG Report, 2005: pg 62)

Type of service/% installation/family	Total	Peri-urban Areas		
		Internal	Intermediate	External
Sanitation				
• Improved latrines	47.1	44.2	52.5	47.1
• Traditional latrines	16.5	16.0	14.8	18.4
• None	0.2	0.0	0.0	0.5
Connections to the electricity network	47.2	52.0	52.5	38.5
Connections to the water supply network	32.3	32.1	42.6	26.6

Total Population = 1 322 528 (estimate) however 209 715 people live within district 1 (16% of the total population in our study area, district 1-5). The remainder 84% are situated in the peri-urban areas.

LOS 1: 16%

Currently only District 1 is fully serviced in terms of water supply (inside the home), water borne sewerage and drainage (primary). Will take the population in that district and divide by the total to get a % = (209 715) / (1 322 528) = 16%

The situation in the other districts is harder to categorise as there are large variations across neighbourhoods within the same urban district.

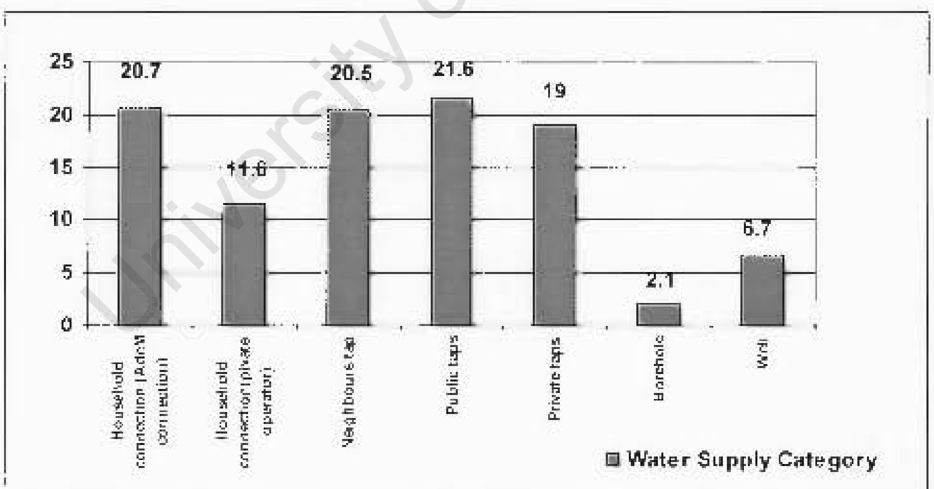

Figure K.1: Breakdown of water supply/service category
(FIPAG Report, 2005; pg 63)

LOS 2: 30%

In the remaining districts (the peri-urban areas), there is considerable water supply infrastructure, provided by both the formal supplier (AdeM) and SSIPs.

Water supply: 32.3% (Figure K.1: 20.7% +11.6% = 32.3%)

Sanitation: 36.2% (accounting for septic tanks)

The governing criteria to determine LOS will be access to sanitation (36%), which often lags behind water supply. Plus the 32.3% represents in-house connections however there are some 20.5% with access to yard taps/neighbours taps (FIPAG Report, 2005; pg 63).

84% of population is in peri-urban areas and of these 36.2% have access to LOS2, therefore 36% of 84% = **30.2%** (round it down to 30%).

LOS 3: 39%
47.1% (Table K.7: improved pit latrines)
84% x 47.1% = **39.5%** (round it down to 39%)

LOS 4: 13%
16.5% (traditional latrines)
84% x 16.5% = **13.9%** (round it down to 13%)

LOS 5: 2%
0.2% (none)
84% x 0.2% = **1.7%** (round it up to 2%)

With regards to drainage and waste collection, only District 1 if fully covered. Peripheral areas benefit very little from formal services. Nevertheless in certain neighbourhoods there are informal means of drainage (locally built with low quality materials), as well as mechanisms to deal with waste disposal (often involves burning the waste or a common yet unusual practice of surreptitiously dumping waste in neighbouring houses). The formal drainage system does cover some parts of the peripheral city, however not significantly. Furthermore good drainage capacity (high soil permeability), less built up spaces (underdeveloped) and good drainage slopes indicate that drainage is not a major problem, except in the case of major flooding hence LOS will consider the first two services (Lahmeyer International *et al*., 2004; pg 2.2).

For a more detailed account of water supply by AdeM refer to the yearly technical and financial reports by AdeM (AdeM, 2003; AdeM, 2004; AdeM, 2005; AdeM, 2006; AdeM, 2007).

4. Vulnerability

4.1 Susceptibility to disasters:

- **Dolines & sinkholes:** none
- **Earthquakes:** yes (Hartnady, 2002; Hartnady, undated; Hartnady *et al*., undated)

Papers by Hartnady indicate that the world has largely underestimated seismic activity in the African continent. The re-defining of plates in this region and the discovery of a plate running through Mozambique (Rovuma plate) has suggested that there is risk of earthquakes in the area. This is corroborated by the earthquake which was felt in the south and central areas of Mozambique in February 2006 (22 February 2006), of magnitude 7.

- **Droughts**: yes

In parts of Maputo Province, the rate of evapo-transpiration exceeds the annual average rainfall, even in the wet season (December to March). This is cause for concern as many rivers or tributaries are then seasonal and the availability of water resources is not only variable but also questionable, hence the high drought susceptibility of the Province (and the country in general) (Euroconsult, 1989; pg 4). Floods and droughts are important features in this basin (Umbeluzi River basin). Floods have various peaks as a result of the contributions of different tributaries which have different rainfall patterns. There are extensive periods of drought. The years 1982 and 1983 were extremely dry, the flows decreasing to $0.2m^3/s$ at the border (between Mozambique and Swaziland) (Euroconsult, 1989; pg 7).

- **Tropical cyclones and Floods**: yes

As evidenced by the recent cyclone occurrences and resulting floods, the South and Centre (particularly) parts of Mozambique are highly susceptible to these events. The maps provided by CENOE (2002) on the 2001 floods indicates that Maputo Province and Maputo city are moderately vulnerable to cyclones and highly vulnerable floods (UN Mozambique, 2007).

- **Tsunamis/shockwaves:** no

- **Fires:** yes, but not aware of the effects.

Although there are certainly cases of fire in the city, there are some alleviating factors such as low wind conditions and high humidity which contribute to reducing the effects and frequency of fires; whereas in areas of the Western Cape, particularly in Cape Town, opposing factors such as high wind velocities, high densities in informal areas and the extensive use of paraffin and oil contribute significantly to the occurrence and spread of fires.

4.2 Risk management and disaster mitigation

The 2001 floods highlighted just how unprepared the country was to respond to natural disaster. The lack of rescue personnel and equipment, as well lack of funding and expertise for this were the main contributors. The rescue efforts and aftermath mitigation measures were largely possible due to the intervention of NGOs, foreign governments and institutions; as well as some support from civil society. More recent events; 2006-2007 flooding; showed better preparedness and responsiveness from the Mozambican government. There is however much work that needs to be done in this regard; primarily addressing the features (infrastructure) and safety nets of cities which enable them to cope with the effects of natural disasters.

5. Health status

5.1 Under 5 mortality rate: 8.9%

(Taxa de mortalidade infanto-juvenil) is 89 (obitos por 1000 nascimentos) therefore 89/1000 x 100 = 8.9% (INE. 2003; Indicator table, introductory pages)

5.2 Malaria-related Deaths: 0.04%

560 in 2003, marking a decrease from previous years. Assuming that this decline continues, in the absence of up-to-date data it is reasonable to use the above figure for 2006-2007.

560/ 1 3 22 528 = 0.04%

5.3 Water-related diseases: 62

The following three water related diseases will provide an indication of the overall state of water diseases. i.e. cholera, diarrhoea, dysentery ...

Cholera 4553 / 1 322 528 = 0.3%

Diarrhoea 63 456 / 1 322 528 = 5%

Dysentery 13 311 / 1 322 528 = 1%

4553 + 63 456 + 13 311 = 81 320 combined incidences of the above diseases. Assuming that there is no duplication in the aggregation of the above numbers (the same person contracting more then one of the diseases), the above figure represents a total of 62 incidences (81 320/1 322 528 = 0.0615 x 1000 = 61.5 = 62 cases/1000 inhabitants) (REDE, 2004; pg 8).

Will use data on cholera for now = 1157 reported cases in 2002 for a 2007 population of 1 322 528 = 0.08% or (1157/1 322 528= 0.0008 cases for total population therefore 0.8 per 1000 people, say 1 in every 1000).

5.4 HIV/AIDS: 20.7%

The 200-2003 statistical sanitary profile for the City of Maputo indicated a HIV/AIDS prevalence rate of 17.3% (REDE, 2004; pg 5-8). More recent reports from MISAU indicate that this value has risen to 20.7, Maputo then having the second highest HIV/AIDS prevalence in the country, superseded only by Sofala (REDE, 2004; MISAU, 2007).

Table K.8: Incidences of water related diseases in Maputo City

	Malaria		Diarrhoea		Cholera	
	Incidence	Death	Incidence	Death	Incidence	Death
2001*	297 520	1149	59 876	255	3 244.	25
2002*	308 822	969	53 740	256	1 157	15
2006**	-	-	-	-	-	-
2007**	-	-	-	-	-	-

Table K.9: Incidences of water related diseases in Maputo Province; Maputo City Statistics (REDE, 2004; pg 5-8)

Year	Malaria		Cholera		Diarrhoea		Dysentery		HIV/AIDS
	Incidence	Death	Incidence	Death	Incidence	Death	Incidence	Death	Reported Cases
2000	256 356	484	10 629	257	68 032	234	7 044	1	3500
2001	297 520	1 307	3 244	25	59 876	255	4 714	0	6158
2002	308 822	969	1 159	15	53 740	256	4 735	n/a	6593
2003	273 921	560	4 553	35	63 456	153	13 311	0	9467
2004	-	-	-	-	-	-	-	-	-
2005	-	-	-	-	-	-	-	-	-

6. Education and awareness

6.1 Level of dissemination

6.2 Level of stakeholder consultation and public participation

The following is a list of projects undertaken by AdeM as a means to promote wider dissemination and awareness of water supply and associated health issues (AdeM, Relatório annual, 2006; pg16):

- Conception and installation of the AdeM pavillion at Feira Popular de Maputo (FACIM).
- Development of a brochure in partnership with PAYSHOP for the disclosure of agents and payment locations for water services.
- Conception and coordination of the informative AdeM webpage.
- Participation on the educational environmentally-related programme of MuGeDe – Mulher Género e Desenvolvimento, where issues of water wastage were addressed as well as the need to address the vast expansion of illegal connections towards the adequate maintenance of domestic water supply services. As a result of this project, cases and areas of water wastage were identified for further improvement. This was indicative of a good collaborative project between citizens and service provider.

The following table goes further to explore from a social perspective, the population which has access to forms media. In this way giving an indication of the means of dissemination available.

Table K.10: Media coverage (%)
(INE, 2003; pg 34-35)

Characteristics	Newspaper	TV	Radio	All	None	No. of women
			WOMEN			
Residence						
Rural	0.4	1.9	36.9	0.1	62.6	7870
Urban	9.9	37.0	62.8	6.9	29.2	4548
Province						
Maputo	8.4	35.3	64.9	6.2	30.2	1050
Maputo City	17.0	59.8	62.6	12.2	19.0	1059
Richness quintile						
1st	0.0	0.4	20.9	0.0	79.0	2814
2nd	0.2	1.0	32.2	0.1	67.4	2166
3rd	0.5	1.9	49.4	0.1	50.0	2333
4th	2.4	9.8	57.1	1.1	41.1	2251
5th	14.5	53.8	71.4	10.4	16.8	2854

MEN						
Residence						
Rural	2.2	3.1	68.1	0.4	31.2	1705
Urban	24.8	50.1	84.9	17.1	9.0	1195
Province						
Maputo	22.1	50.1	88.4	12.3	5.1	197
Maputo City	38.6	80.3	88.1	30.8	3.0	261
Richness quintile						
1st	1.6	0.7	58.2	0.0	41.7	660
2nd	2.9	3.5	62.6	0.3	35.4	483
3rd	3.4	4.2	79.0	0.3	20.0	528
4th	10.5	22.1	84.3	6.2	12.5	489
5th	32.4	67.5	89.2	24.0	3.5	741

The total number of people with access and who make use of mass media (news paper, television and radio) as shown above is: 12.2% (female) + 30.8% (male) = 42.2% (total). This shows that a significant number of people have access and the means to be informed however it does not indicative of actual dissemination of information (advertising, programmes…). It is necessary to include both elements in such assessments, the means and the programmes, in order to ensure that there is awareness. The following organisations have endeavoured to address information and education programmes in the following manners:

FIPAG: Consultation with SSIPs on expanding the water supply networks. Through these discussions there is dissemination, consultation and participation.

CRA: Broadcasting information on taxes, conducting surveys to determine peoples capacity and willingness to pay, conducting surveys on user satisfaction (beneficiary assessment) etc.

AdeM: Social programmes for awareness creation and information dissemination.

Water Aid: A component of hygiene education, information dissemination in their water and sanitation projects in some peri-urban neighbourhoods i.e. Urbanização.

NICEF: Hygiene education.

MISAU: Aids awareness campaigns and hygiene campaigns (stronger in rural areas).

II. ECONOMIC

7. Capacity (to pay for services)

7.1 % of people with secondary education

From Table K.11 it is possible to estimate the percentage of people with higher education. The total female population in Maputo city with secondary education and more is – 2.0% (secondary education complete) – 1.7% (other) = 3.7%

Table K.11: Education levels; percentage of women and men with different education levels for Maputo City (INE, 2003)

Characteristics	Complete and incomplete education levels								
	No schooling	Incomplete primary school	Complete primary school	Incomplete secondary school	Complete secondary school	Secondary schooling and above	No information	Total	No of women
					WOMEN				
Province									
Maputo	20.5	64.9	4.1	9.4	0.8	0.2	0.2	100	1822
Maputo City	10.8	61.6	3.9	19.2	2.0	1.7	0.7	100	1740
					MEN				
Province									
Maputo	6.8	68.5	5.1	16.4	1.8	0.9	0.4	100	1604
Maputo City	3.4	60.8	5.1	21.[illegible]	4.3	3.3	2.0	100	1547

The total male population with secondary education and more = 4.3% + 3.3% = 7.6%. From same statistics there are roughly the same number of males and females which make up the total population of the city, therefore roughly 10.9% (3.3% + 7.6%) of the population has secondary schooling or higher.

7.2 Unemployment rate: 40%

Table K.12: Working force per categories (INE Website, 2007)

Characteristics	Sex		
	Men	Women	Total
Total	**14.7**	**21.7**	**18.7**
Per residence area			
Urban	25.6	35.7	**31.0**
Rural	9.1	15.7	**12.9**
Provinces			
Maputo Province	35.5	37.1	**36.3**
Maputo City	35.2	44.2	**40.0**
Education levels			
None	8.0	15.7	**13.9**
Primary education, level 1	11.6	21.1	**16.5**
Primary education, level 2	20.2	38.1	**27.0**
Secondary education	27.7	45.8	**34.2**
No info available	0.0	9.6	**5.5**

7.3 Income levels

Table K.13: Household income levels per richness quintile (INE, 2003; pg 19)

	Country		Maputo	
	Rural	Urban	Province	City
Richness quintile				
1st	26.8	3.6	1.7	0.0
2nd	30.0	7.4	4.5	0.1
3rd	25.8	9.8	7.1	0.4
4th	15.9	29.5	33.6	7.0
5th	1.5	49.6	53.0	92.5

Additional reports provide more concrete information: "In Maputo City 40% (of the population) is defined as poor by country standards", (Sweco *et al.*, 2005; pg 8). The score card report produced by Métier for the City for Maputo indicates that households earn on average $250 per month (R1775), however 56% of families earn below $100 per month. This translates to an average of R710/household/month (current exchange rate is $1 – R7.1) (Métier, 2006; pg 2). The assumption made here is that a R1179 [(R1775 x 44%) + (R710 x 56%)] average income can be expected.

7.4 No. of days taken off work due to water-related diseases: Guesstimate was employed here as there is no data on this. Estimates were based on the incidence of water-related diseases proposed in tables K.8 and K.9.

7.5 Minimum/Basic water tariff: R5.3/m^3

2006 tariffs quoted from Beneficiary Assessment (CRA, 2006): R5.3/m^3 (0.75m^3$)
Older tariffs quoted by FIPAG (2005): R2.98/m^3 ($0.42/$m^3$)

Table K.14: Water tariffs
(FIPAG Report, 2005: pg 54)

Tariff (US/m^3)	2003	2004	2005	2006	2007	2008
Price/m^3						
Average domestic tariff	0.29	0.34	0.37	0.39	0.42	0.42
Public taps	0.17	0.20	0.22	0.23	0.25	0.25
Non-domestic	0.57	0.69	0.74	0.79	0.84	0.84
Average 'global' tariff	0.38	0.46	0.49	0.52	0.55	0.54

The minimum tariff for household access (the aim is to provide full access to all inhabitants therefore this will be the restrictive tariff and not public standpipes or other sources) – $0.42 x 7.1 (current exchange rate to Rands) = R2.98/m^3

8. Cost recovery

8.1 % of users paying for water: 73%

Table K.15: Users paying for water
(FIPAG Report, 2005; pg48)

% of users paying for water per category			
	2002	2003	
Domestic	70%	69%	-1%
Public	62%	57%	-8%
Commercial	74%	76%	2%
Industrial	94%	91%	-3%
Taps	37%	44%	16%
Total	76%	73%	-4%

The above values indicate the percentage of billed (invoiced amount) water that was in fact collected for 2002-2003. This figure will be used for 2006-2007.

8.2 % of UFW: 58% (AdeM, 2006). (see also FIPAG, 2007).

8.3 FBW: 0l/person/day

0 l/person/day (not a policy initiative however the number of illegal connections indicates that a good proportion of the population obtains water for free, albeit illegally). There is no formal decree that people shall be provided free basic water every month however in some peri-urban neighbourhoods there are initiatives to provide poorer income groups with a minimum water supply from public standpipes at no charge. The volumes vary from neighbourhood to neighbourhood. The Beneficiary Assessment (CRA, 2006) indicates that of 21 neighbourhoods interviewed in the Greater Maputo area, 52% of which provide free water. The following table indicates which of the 21neighbourhoods are located within Maputo City boundaries as defined here (Districts 1-5).

Table K.16: Free basic water (informal)

Neighbourhoods	Free water
Chamanculo C	No
Chamanculo D	No
Aeroporto B	Provide to the more needy
Micadjuine	Provide 2 tin containers per day to the needy
Maxaquene D	No
Polana Caniço B	Provide to the more needy
Luís Cabral	Provide to the more needy
Malhapwene	No public sources
Sikuama	No public sources
Mussumbuluco	No
Singatela	Provide to the more needy
Bunhiça	No
3 de Fevereiro	Provide to the more needy
Malhazine	Provide to the more needy
Laulane	No
Mahotas	Provide to the more needy
Albasine	Provide 1 tin container per day to the needy
Congolote	No
Bairro 1 Boane	No
Bairro 2 Boane	Provide 2 tin containers per day to the needy
Bairro 3 Boane	Provide to the more needy

9. Investment levels

Government Expenditures: Water and other public works.

Table K.17: Water provision and related works expenditure levels for Mozambique (Research by government of Mozambique)

	2001	2002	2003	2004
Water and other Public works Expenditure/Total Investment Expenditure	15.5%	16.4%	7.6%	16.3%
Expenditure in Water and other Public Works/Total Expenditure	8.4%	8.5%	4.1%	7.4%

Source: PRSP (2004). 2003 Review done by the Mozambique Government

9.1 % budget increase for water supply (Table K.18)

9.2 % budget increase for sanitation (Table K.19)

9.3 % budget increase for O&M (table K.20)

There is difficulty in determining budgetary increases, mainly because the information is not easily accessible, but also because investments in the area of water supply and sanitation is dominated by many institutions, which perform similar tasks. In the case of water supply, FIPAG is the major investment agency and others work through or with FIPAG. However there are small scale projects implemented and financed by institutions, particularly NGOs which do not conform to this practice.

In the sanitation arena, the main institution is the municipality and it was extremely difficult to obtain specific data from the CMM in the short period of research in Maputo. The following values represent estimates.

A viable option was to look at the percentage increase/decrease in investments from (the) previous year(s). This shows whether there is increasing/decreasing commitment to investing on service provision. Caution is advised in drawing straightforward conclusions because increased/decreased expenditure with time may be as a result of many factors. In the case of operation and maintenance in particular, this can be indicative of the degradation of the system due to aging infrastructure rather then expansions. This is nonetheless positive, as increased investments to repair and improve supply systems and infrastructure is indicative of greater concern and appreciation for the services they provide. Inflation can also be a contributor.

9.4 Sources of investment: external and/or international

Municipal funds are largely dependant on cash inputs from national government (Métier, 2004; pg 7). At national level however, there are significant capital injections from international donor organisations and foreign governments such as the World Bank, UN, BAD, Swiss Corporation (Swedish Government), American and British Governments…

Table K.18: Water supply projects in Maputo City, 2005-2006

Project 2006 (AdeM, relatorio annual, 2006; pg 18-19)	**Investments 2006**	**Project 2005** (AdeM, relatorio annual, 2005; pg 11-12)	**Investments 2005**	**Investor**	**Implementing agency**
Improved water supply to the neighbourhoods of Mazaquene B and C, Urbanizacao, and Aeroporto	$ 250 000 **(R1 775 000)***	• Aeroporto & Urbanização- 12,6Km • Estádio da Machava- 1Km • Matola Rio Djuba- 4Km • Boane- 20Km • Machava Sede- 2Km	MT 16.6 billion = R4 742 857	IPAD (Instituto Português de Apoio ao Desenvolvimento)	AdeM
Upgrade of the laboratory	€ 250 000 **(R2 400 000)** **			IPAD	AdeM
Rehabilatation of the Maputo Water supply network	$350 000 000 (spread over a at least 3 years: 2005-2007) (R2 485 000 000/3 = **R828 333 333**)		**R828 333 333**	BAD (Banco Africano de Desenvolvimento) /WB (World Bank)	FIPAG
Rehabilitation of the Matola Shop	$ 120 000 (**R852 000**)			FIPAG/AdeM	AdeM
Others	n/a		n/a	n/a	n/a
TOTAL	R833 360 333		R828 333 333		

*$1 = R7.1

** €1 = R9.6; (R833 360 333 - R828 333 333)/ R828 333 333 = 0,61%

% of budget increase for sanitation provision: Qualitative assessment (CMM, 2007; Nhampossa, 2007)

This is based on the concluded and currently running projects for 2006

Table K.19: Sanitation projects in Maputo City, 2005-2006

Project 2006	Investments 2006	Project 2005	Investments 2005	Investor	Implementing agency
-	-	-	-	-	-
-	-	-	-	-	-

Budget increase for O&M: 21%

(518 196 - 428 680)/ 428 680 – 20.88%

Table K.20: Operation and maintenance budgets (AdeM, 2006; annex, financial data)

	2005	2006	Deviation	% deviation
Total	518196	428680	89516	21%

III. ENVIRONMENTAL

10. Fresh water resources

10.1 Per capita water availability: roughly 2482 m^3/person/day

Maputo City makes use of two main sources of water supply: the Umbeluzi River and the Maputo Aquifer. However potential sources include the Incomati River Basin and the Maputo River Basin, and surrounding underground water supplies.

The following is an inventory of the possible water sources for Maputo Province and potentially for Maputo City. These combined will give an idea of the potential per capita water availability (this is simply theoretical as the resources and capacity to exploit these does not exist, that being the biggest constraint to supply).

Umbeluzi River basin (Euroconsult, 1989; pg 12)

- 434 MCM (at Pequenos Libombos)
- small groundwater supplies

Incomati River Basin (Euroconsult, 1989; pg 9-10)
Incomati River:

- 025 MCM (at Ressano Garcia)
- 630 MCM (Sabie at Machatuine)
- Groundwater:

Aquifer downstream of Magude 60 MCM/year
Mahotas-Marracuene 24 000 m^3/ day
Marracuene- Pateque (Bobole) 31 000 m^3/ day
Pateque- Manhiça 30 000 m^3/ day

Maputo River basin (Euroconsult, 1989; pg 13)
Maputo River:

- MAR is 2 770 MCM (at Madubula)

"Because of the dependency on upstream developments, the necessity of flood protection and the problem of saline intrusion in the lower section of the river, it is not likely that large scale irrigation development along the Maputo river will become feasible in the near future" (Euroconsult, 1989; pg 13).

- 2 principal ground water formations, namely; salamanga limestone formation and alluvial deposits in the Maputo and Tembe rivers. Both shoe high salinity levels and relatively small yields. (Euroconsult, 1989; pg 13)

Keeping in mind that the above figures are based on records from 1989 and that since then there have been developments and meteorological changes in all three countries which have altered the runoff to Maputo Province, this data will be cross-checked with more recent data, where available. In the limited time available (2 weeks in Maputo) it was not possible to obtain more up-to-date data on resources and information from DNA's Department of Water Resources. Talks with officials at DNA led to an understanding that on the groundwater resources side at least, there is a deficit of information.

Total potential resource availability for Maputo Province = (434 000 000 m^3/yr) 1 189 041 m^3/day + (2025 000 000 m^3/yr) 5 547 945 m^3/day + (630 000 000 m^3/yr) 1 726 027 m^3/day + 24 000 m^3/day + 31 000 m^3/day + 30 000 m^3/day + (2770 000 000 m^3/yr) 7 589 041 m^3/day = 16 137 054 m^3/day.

Per capita potential resource availability for Maputo Province = 16 137 054 m^3/day/2 370 415 people (total population for the Province of Maputo, who will benefit from the collective of resources accounted for above) = 6.8 m^3/person/day = 2482 m^3/person/year.

The above per capita water availability value is quite high. It represents the estimated volumes of water available in the province, from both groundwater and surface water however there are factors which need to be taken into account: firstly the above figure does not take into account spatial variations in resource availability; secondly, it does not take into account seasonal variations in water availability, which is a strong determinant of water stress, particularly on the Mozambican side of all three basins mentioned; and thirdly, it doesn't account for the prohibitive costs and resources need to access great part of that water. During dry periods, the upstream intakes from South Africa and Swaziland and the adverse climatological conditions in Maputo combine to result in a decrease in the volume of water available to Maputo Province. Finally the above figure assumes that all water resources can and will be reserved for human use, however both policy and practice (not always) stipulates that a certain percentage is to be reserved for ecological preservation.

The above factors are of such importance that they can contribute to a state of water stress or scarcity in areas of the Province. The report by Sweco *et al.* (2005), indicates that the current formal source of water to Maputo City, the Umbeluzi River, does not have sufficient capacity to supply the projected populations beyond 2025, assuming that this source would serve Mozambique alone. However this is not the case, the source supplies parts of Swaziland, in which case the capacity for supply is exceeded by the demands of both countries. The report also mentions that although the Maputo Water supply scheme could be supplemented by supplies from the Incomati Basin, both the implementation and management time-frames do not fall in the short to medium-term (Sweco *et al.*, 2005).

In addition, the information provided by Euroconsult (1989) might very well be outdated. Therefore although the appraisal of resources carried out here might be realistic, it will be assumed that the resources accounted for at that time can be extended to the present day. Moreover although the above assessment takes into account provincial resources, these will be used for Maputo City, especially given that current resources from the Umbeluzi River Basin alone will not suffice for the city-scale supply required in future.

10.2 Reliability at source (in terms of variability, seasonality etc)

High seasonal variability as well as yearly variations in water resources jeopardise the security of water supply to Maputo. In parts of Maputo Province, the rate of evapo-transpiration exceeds the annual average rainfall, even in the wet season (December to March). This is cause for concern as many rivers and/or tributaries are then seasonal and the availability of water resources is not only variable but also questionable, hence the high drought susceptibility of the Province (and the country in general) (Euroconsult, 1989; pg 4).

10.3 Source water quality: adequate

Water quality in all three river basins is variable however due to the seasonal nature of most rivers, during the dry months water quality is very poor. (Euroconsult, 1989; pg 11, 12, 14); (FIPAG, 2005; pg 79); (FIPAG, 2005; Annex 8.2- Conductivity); (AdeM, 2006; pg 10).

"The Mbuluzi River basin contains a wide diversity of aquatic habitats and associated biota. These can be grouped into seven ecologically distinct areas (excluding the estuary), referred to as Preliminary Resource Units. The Present Ecological State of some areas has been severely degraded to the extent that they are no longer ecologically sustainable." (Sweco *et al.*, 2005; pg 9) According to Sweco *et al.* (2005) the most serious pressures include:

- cessation of flow
- dams and weirs that inundate riverine habitats, retard migration of fish, and change downstream flow patterns
- the spread of alien vegetation that lead to significantly reduced low flows, unstable banks and reduced biodiversity
- the removal of natural riparian vegetation and associated bank erosion
- water quality problems associated with agricultural return flows and industrial and domestic wastewaters that lead to proliferation of benthic algae and in the lower reaches, the proliferation of the floating aquatic alien weed, Salvinia molesta.

The above information gives a good idea of the state of degradation of the Umbeluzi River. The category E rating downstream of Pequenos Limbombos is of major concern, as this is probably a direct consequence of the Dam and the over-exploitation of water to Maputo City and surrounding areas. This has consequences for many ecosystems as well as for the continual sustainable supply of water to Maputo City and surrounds.

11. Sustainability/feasibility of water source

11.1 Sustainability/feasibility of water source: Approximations based on the number of people (excluding illegal connections and secondary sales) served by the formal network, indicates the following breakdown:

- Groundwater: 65%
- Surface water: 35%

This is obviously an under-assumption as many more have illegal access to water from the network. See also Smidt *et al.* (1989).

12. Use

12.1 Domestic: assumed a medium of 69-40l/person/day consumption ((79.33 l/person/day – 25.3 l/person/day)/2) ≈ R52.3 l/person/day (CRA, 2006; pg 10). See BA, pg 10: households with house connections use on average $11.9m^3$/month ≈ 79.33 l/person/day in a household of 5; and households with access outside the house use $3.79m^3$/month ≈ 25.3 l/person/day)

12.2 Industrial: Estimate used based on the extent of industrial development in the area.

12.3 Agricultural: 620 l/person/day
Unsure where the 17 300 000 from the FIPAG table comes from and as this is a very high figure, parallel to water consumption in more developed countries of the North, the data provided by AdeM, will be used instead.

12.4 Maintenance of ecosystems: 35%

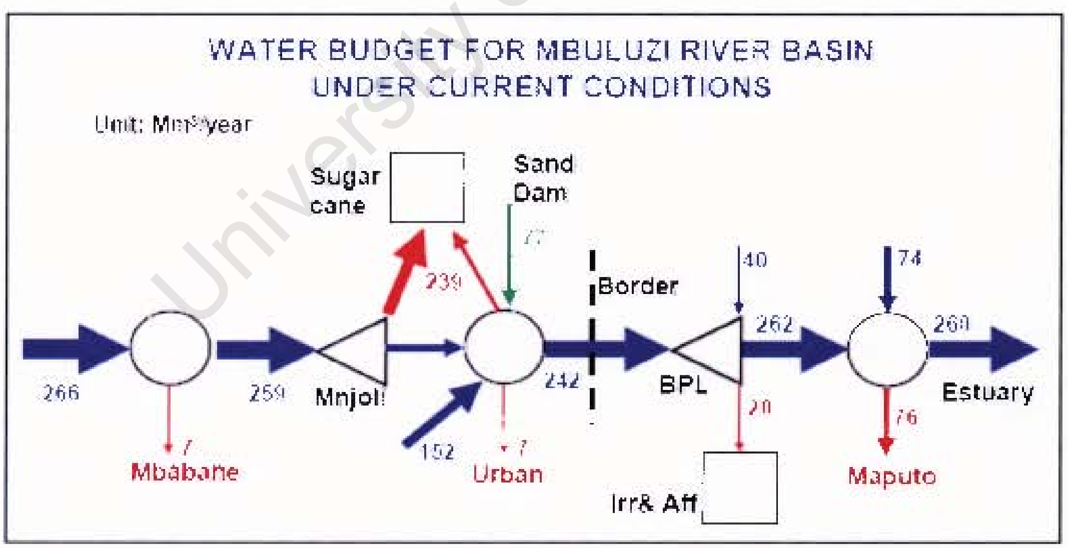

Figure K.2: Water budget for Umbeluzi River Basin (Sweco *et al.*, 2005; pg 13)

Total entries = 266 (Swaziland) + 77 (Sand Dam, SA) + 152 (Swaziland) + 40 (Pequenos Libombos, Mozambique) = 535 Mm^3/year.

Total exits = 7 (Mbabane, Swaziland) + 239 (Sugar Cane, Swaziland) + 7 (Urban, Swaziland) + 20 (Irrigation, Mozambique) + 76 (Maputo, Mozambique) = 349 Mm^3/year

Water available for the ecosystem = (535-349)/(535) = **35%** is currently not utilised and therefore it is available for ecosystem maintenance. This seems like a very optimistic figure.

13. Wastewater management

13.1 Effluent quantity: 40%

The consumption volume for domestic in-house connection water users was taken because it is expected that these will be the biggest contributors to the wastewater stream (formal network). Average water consumption = 100l/day (including drinking, personal hygiene, cooking, clothes washing, gardening and other domestic activities such as cleaning). Therefore roughly 40l/person/day is discharged down the drain.

13.2 Effluent quality

Table K.21: Analysis of wastewater quality in the combined system (Lahmeyer International *et al.*, 2004: annex, Table 5.2-A1)

Location/Parameter	Av. Guerra Popular/Av 24 de Julho	Av. Marginal (frente ao Gabinete do 1º ministro)	Descarga da Ponta Vermelha (proximo ao Velube Naval)
Turvação NTU			
pH	7.35	7.35	7.76
Condutividade eléctrica (umhos/cm)	1099/24.4C°	1253/24.4C°	1088/24.4C°
Coliformes total NMP/100ml	>2 400	>2 400	>2 400
Coliformes fecais NMP/100ml	>2 400	>2 400	>2 400
Nitrato NO_3 (mg/l)	18.48	20.70	22.8
Nitrito NO_2 (mg/l)	0.1	0.35	0.07
Cloretos Cl (mg/l)			
Amónio NH_4 (mg/l)	92.5	70.87	69.94
NKG (mg/l de O_2)			
COD (mg/l)	113	116	108.8
BOD (mg/l)	175	125	120
TSS (mg/l)	200	600	590

Table K.22: Analysis of wastewater quality at ETAR
(Lahmeyer International *et al.*, 2004; annex, Table 5.2-A2)

Location/Parameter	Entrance		Anaerobic Pond/Facultative Pond		Discharge	
	Jul 03	Nov 03	Jul 03	Nov 03	Jul 03	Nov 03
Turvação NTU	32.0	-	17.0	-	12.0	-
pH	7.66	-	7.44	-	8.10	-
Condutividade eléctrica (umhos/cm)	1027/20.6C°	-	1063/20.6C°	-	1065/20.8C°	-
Coliformes total NMP/100ml	>2.4x10^5	>2.4x10^5	>2.4x10^5	>2.4x10^5	>2.4x10^5	>2.4x10^5
Coliformes fecais NMP/100ml	>2.4x10^5	>2.4x10^5	>2.4x10^5	>2.4x10^5	>2.4x10^5	>2.4x10^5
Nitrato NO_3 (mg/l)	18.09	22.00	14.94	-	15.56	18.8
Cloretos Cl (mg/l)	140.4	-	143.9	-	147.4	-
Amónio NH_4 (mg/l)	83.55	-	54.83	-	54.83	1.26
NKG (mg/l de O_2)	128.7	0.74	84.43	-	84.43	-
COD (mg/l)	986.7	966.0	1091.0	-	667.0	728.0
BOD (mg/l)	-	100.0	-	-	-	50.0
TSS (mg/l)	1200.0	170.0	700.0	-	1000.0	217.0

COD: On average >1091 mg/l (worst case condition at ETAR)

Ammonia: ≥70 mg/l

P: 15 mg/l (common to have between 10-20mg/l of P in domestic waters (Personal Contact: Pierre Van Zyl; UCT Water Research Group; 2007)

TSS: 1200 mg/l (worst case condition at ETAR)

This data is based on tests done in certain areas of the combined sewerage and stormwater system covering the majority of the developed parts of the city (cidade cimento), as well as at ETAR (Estação de Tratamento de Águas Risiduais). Two of the three test sites are close to/at the discharge points and therefore will be indicative of the highest pollution levels in the system.

14. Stormwater management

14.1 Effluent quantity: Dependant on LOS

14.2 Effluent quality: Dependant on LOS

15. Compatibility of water system with the surrounding environment

15.1 Proximity to solid waste dump or landfill site (for lack of adequate knowledge assumed 0, closest dump site that I am aware of is in Matola, along the Highway to Komati port).

16. Compatibility of sanitation systems with the surrounding environment

16.1 Located on flood prone area: see notes below
Generally flooding is not a problem in the peri-urban areas due to good soil permeability and low infrastructure development (hard surfaces) (Lahmeyer International *et al.*, 2004: pg 5-1).

16.2 Steepness of slope: see notes below
In the majority, the slopes fall within the 2%-5% ranges however there are cases when these reach extremes of 10% and contrarily decrease to 0.8% (basin 1), however on average they fallen within the above range.

16.3 Depth to groundwater table

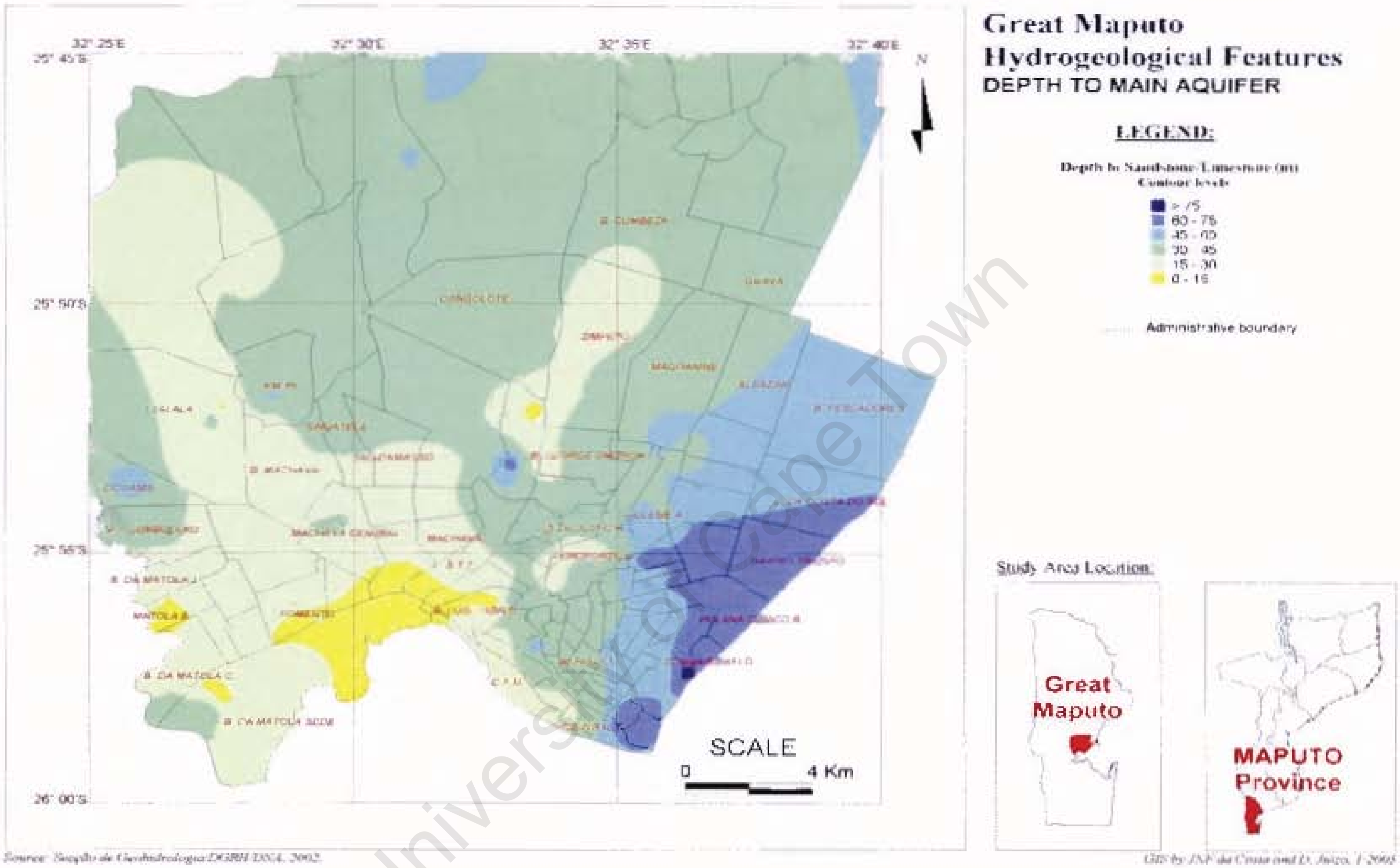

Figure K.3: Depth to main aquifer (FIPAG, 2005; annex 18.2)

16.4 Soil permeability: see notes below

16.5 Ground stability: assumed relatively good based on very basic visual inspections. The following is a summary description of each drainage basin in Maputo City provided by Lahmeyer International *et al.* (2004).

Basin A (Lahmeyer International *et al.*, 2004; pg 5-3)
The % of paved surfaces (low) and low population densities permit good stormwater infiltration. This is on the proviso that the soil permeability is also good.

Roughly 0.1% inclines (plain)

Basin B and C (Lahmeyer International *et al.*, 2004; pg 5-3)
Soils of good permeability but very unstable, hence problems with soil erosion and the formation of ravines.
Generally 2%-8% inclines

Basin D (Lahmeyer International *et al.*, 2004; pg 5-4)
Good drainage system covering the entire area, as evidenced by the low flooding levels and the visually good quality water discharges
Generally 0.8%-1.5% declines westwards

Basin E (Lahmeyer International *et al.*, 2004; pg 5-4)
Good drainage system covering the entire area, as evidenced by the low flooding levels and the visually good quality water discharges
Generally flat building up to a steep 4% decline towards the Maputo Bay.

Basin F (Lahmeyer International *et al.*, 2004; pg 5-5)

Basin G and H (Lahmeyer International *et al.*, 2004; pg 5-5)

Basin I (Lahmeyer International *et al.*, 2004; pg 5-5)
Excellent infiltration capacity (c=0.05), hence good soil permeability.
Inclinations varying from 0.8%-5%

Basin J (Lahmeyer International *et al.*, 2004; pg 5-6)
Roughly 2.2% inclination throuhgout

Basin K (Lahmeyer International *et al.*, 2004; pg 5-6)
Poor natural drainage due to no general sloping direction.

Basin L and M (Lahmeyer International *et al.*, 2004; pg 5-6)
This basin is situated in very densely populated neighbourhoods which complicates natural drainage of stormwaters.

Natural inclination of 1%-3.5% for basin L and 0.6%-3% for basin M.

Basin N (Lahmeyer International *et al.*, 2004; pg 5-7)

Natural inclination of 1.4%-2.8%

Basin O (Lahmeyer International *et al.*, 2004; pg 5-7)

Natural inclination of 0.7%-1.5% and a decline of 2.7%.

Basin P, Q, and R (Lahmeyer International *et al.*, 2004; pg 5-7)
Sufficient infiltration in all three basins, with good permeability soils and low densities and development levels.
There are some depressions in all three basins which complicate the adoption of canalised drainage systems however due to existing natural and development conditions this is currently not a big problem.

Basin S (Lahmeyer International *et al.*, 2004; pg 5-4)

Basin T (Lahmeyer International *et al.*, 2004; pg 5-4)

Eastwards inclination of 1.8%-2.5% and in some places up to 4.8%

17. Environmental stresses

17.1 % of polluted water sources

Based on data of resource variability and water quality it was assumed that at least 20% of water resources have been compromised. This is an arbitrary figure. Groundwater in the immediate vicinity of the coast has displayed some problems with salt intrusion and high salinity (see map on electric conductivity; Figure K.3). Further inland, disregard for latrine maintenance and water pollution has resulted in pollution of groundwater, the extent of which is not fully known. There are tests done by MISAU on the quality of groundwater at specific extraction sites and these would have provided better clarity in this regard, however time constraints did not permit the attainment of this data. With regards to surface water, seasonal variability in the Umbeluzi River has had consequences for water quality and ecosystem vitality. In the Pequenos Libombos area, alien plant invasion (algae) has resulted in higher maintenance and treatment requirements. See also Smidt *et al.* (1989).

17.2 % of total area identified as severely water stressed

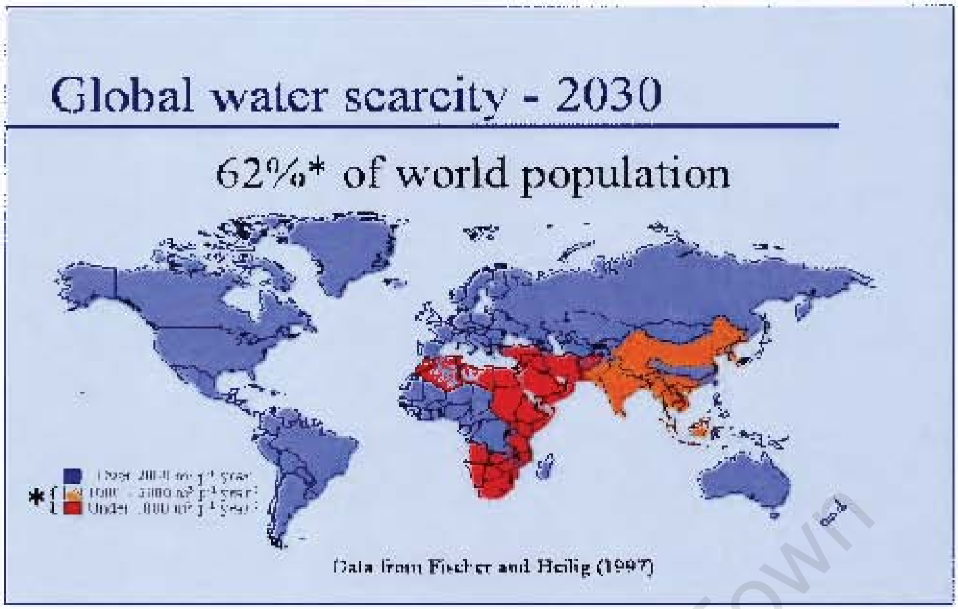

Figure K.4: Falkenmark water stress indicator
(Rijsberman, 2004; pg 5)

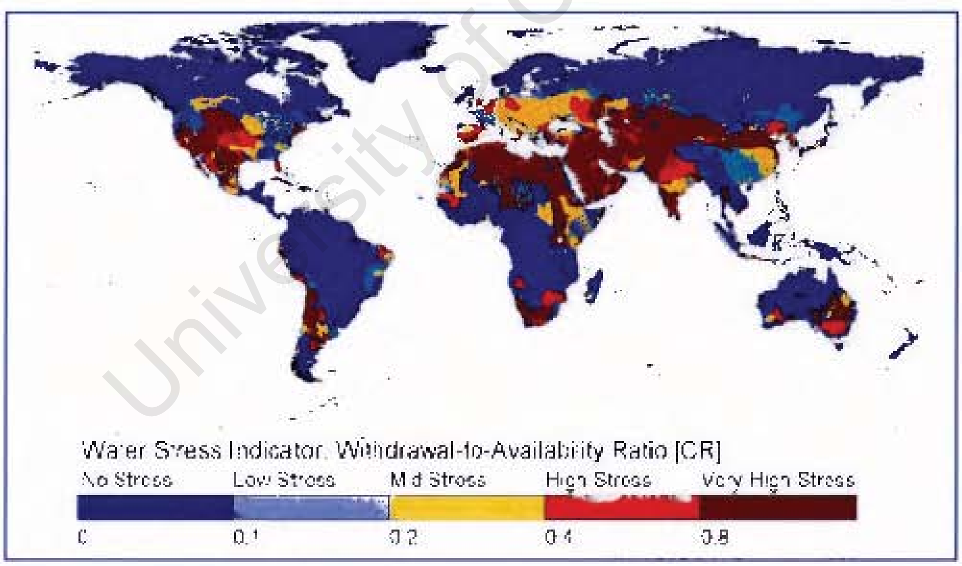

Figure K.5: Water stress analysis based on the criticality ratio
(Rijsberman, 2004; pg 6)

Figure K.6: Water Poverty Index (WPI)
(Rijsberman. 2004: pg 9)

Figure K.4 indicates that most, in fact all, of Mozambique is under severe water stress from the point of view of the Falkenmark index of water stress. Other indicators such as the Criticality Ratio and the WPI highlight a slightly different situation (Figures K.5 and K.6). The national Criticality Ratio results indicate that significant parts of South Africa are very highly water stressed and whilst most of Mozambique shows no water stress, there is a significant portion in the South which is highly stressed. Maputo is affected by the water stress in the South of Mozambique. As a major attraction zone, it takes in a significant proportion of the countries urban population, many of which come from the South and Centre of Mozambique. This growth pattern is expected to continue, if not increase, and therefore the projected future water security situation presents an issue. On the other hand, the WPI results for Mozambique significantly coincide with the findings from Falkenmark index in that they indicate severe water stress for the whole of Mozambique. One must however take into account the difference in measurements of these indicators and keep in mind that they provide guidance and are not direct representations of the real situation on the ground. Furthermore these national ratings hide significant spatial differences, which are of great concern with for the local-level applications of the SI.

The Integrated Water Management Institute (IWMI) has projected a future state of economic water insecurity for the whole country, meaning that there will be sufficient resources for human consumption but not sufficient for socio-economic development (Rijsberman. 2004).

IV. POLITICAL

18. Governance

Austral conducted an extensive study into the issues of governance and corruption in Mozambique. To this end, three separate and yet parallel surveys were employed. A total of 2447 families, 486 companies and 992 employees were interviewed at a national level. Information for the following variables, towards the assessment of governance in the country will be largely informed by the findings of that study. Although the application of the indicator is only relevant to Maputo, great part of the National institutions in question are involved in water management, and other sectors at local, regional and national scales. The findings will therefore be applicable.

18.1 Democracy and representation: Mediocre, despite vast improvements, mainly due to lack of accountability and transparency as well as poor participation and consultation with the public. Since the 1994 democratic elections, Mozambique has taken great strides towards democracy in all facets of society, however in practical terms Mozambique continues to score lowly with regards to good governance and leadership. A study conducted by the World Bank Institute (WBI) indicates that it is the third lowest ranking country in Sub-Saharan Africa, superseded only by Zimbabwe and Angola, for whom political and economic unrest justifies the low levels of governance. The report by Austral Consultoria indicates that whilst corruption is certainly a big contributor in this, it is supported by a weak legal system and inappropriate policy backdrop. In this report, they have also indicated how Mozambique performs inline with several indicators produced by WBI, the table below illustrates:

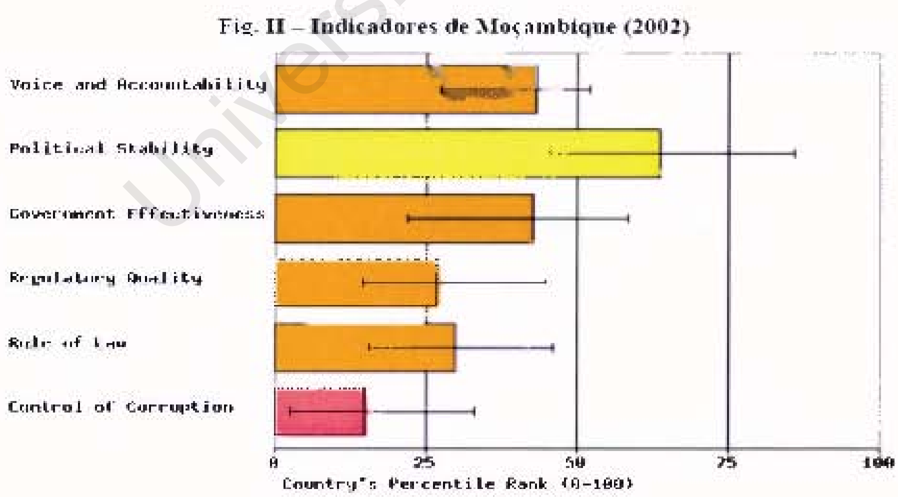

Figure K.7: Indicators on governance
(Austral, undated; pg 6)

There is a positive indication of political stability which can be indicative and contribute to a stable and democratic nation, however both voice and accountability as well as rule of law, which ensures that there is an appropriate regulatory environment and that the precepts of which are implemented, score poorly in the second lowest percentile (<40%).

Furthermore the study indicates that elemental aspects like accessibility and approachability of institution rank/score quite lowly, with the judicial, tribunal, municipal and assembly bodies/institutions scoring the lowest. This is cause of great concern, given that these are departments for whom members are directly elected by the people, meanwhile they are the least approachable (Austral, undated; pg 12).

18.2 Measure of corruption: Highly corrupt, although there has also been some progress in this regard, Mozambique remains amongst one of the most corrupt nations in Sub-Saharan Africa, and certainly in the world.

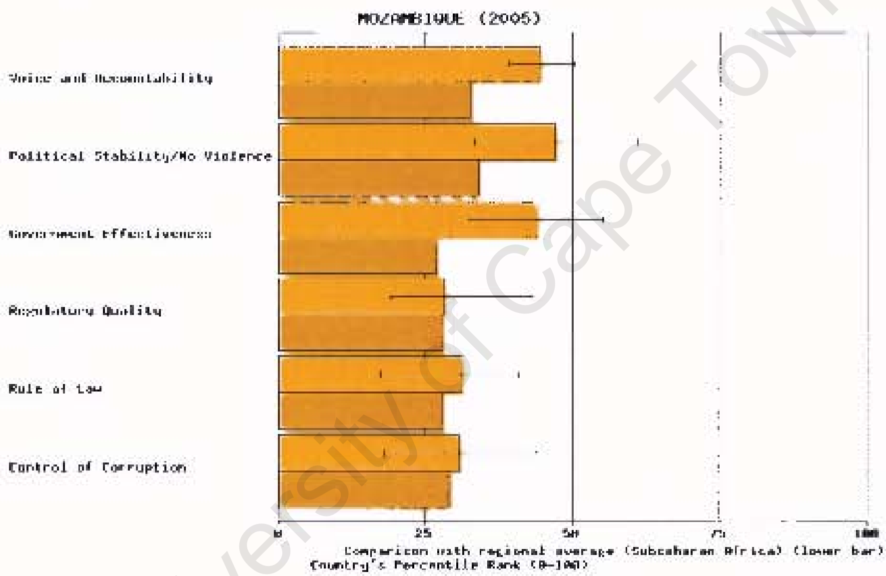

Figure K.8: Governance indicator rankings for Mozambique in comparison to Sub-Saharan averages (Kaufmann *et al.*, 2005; Kaufmann *et al.*, 2006)

From the above figure it is possible to see that control of corruption is extremely low, falling in the lowest percentile category.

From personal experience, being a citizen of The Republic of Mozambique, there is a heightened awareness of the issues of poor governance and extreme corruption, however simultaneously there is an attitude of "deixa andar" (let go, let flow). It is only in extreme cases, where one may observe a blatant disregard for the law, society and its principles, that one can elicit a reaction from the Mozambican people. This is not to say that there is satisfaction with the current state of affairs, rather this apathy has permeated deep into the fabric of the Mozambican society and the mode of living that it has become just that, 'a way of life' (Austral, undated).

It is interesting to contrast these findings with other studies, such as the one conducted by Kaufmann *et al.* (2005 and 2006). Their findings indicate that Mozambique's performance with regards to governance has significantly improved over the last decade or so of democracy. In fact, they go so far as to say that in three out of the six assessment categories, Mozambique ranks better then more then ¼ of the 213 countries analysed. In fact, the 2005 analysis shows an improvement across all the indicators previously displayed.

The corruption report by USAID (2005) makes the following fitting statement: *"Corruption in Mozambique is largely symptomatic of a lack of checks and balances among the three branches of government, limited transparency and access to information, minimal accountability of elected officials, and a culture of impunity where corruption persists because it is seen as a low-risk, high-reward activity. Unfortunately, because of corruption's corrosive effects on transparency, accountability, and the credibility of government, if left unchecked, it will inevitably erode the legitimacy of elected officials and further weaken democratic values and participation in policymaking, effectiveness of public institutions, and the rule of law".*

18.3 Defined roles and responsibilities: the policy environment is good however policies and legislation are not fully adjusted/regulated for the socio-political and economic environment of the country decades after colonialisation. Given Mozambique's history and relationship with Portugal, one is aware of the significant import of policy. There is also considerable international influence from western countries and international institutions which contributed to the current political and legislative framework operational in Mozambique. Therefore the validity and relevance of policy is questionable. With regards to implementation, there are insufficient resources and human capacity to match the need.

19. Compliance with policy and regulation

19.1 Compliance with government policies: Dependant on LOS

19.2 Compliance with MDGs: Dependant on LOS

V. INSTITUTIONAL

20. Institutional and technical capacity

20.1 Adoption of IWRM approach: Three major river basins in the Maputo Province are part of international river basins, incorporating the following countries; Mozambique, Swaziland and South Africa. This draws attention to the need for shared resource management to ensure proper management, equitable distribution and conflict avoidance/resolution. The three countries have since the 70s engaged in joint management forums. For example: *"Mozambique has* *reached an agreement with Swaziland on the sharing of water of the Umbeluzi river and talks continue through the Joint Permanent Technical Committee (JPTC), while talks on the Incomati and the Maputo rivers are going on in the Tripartite Permanent Technical Committee (TPTC) with South Africa and Swaziland"*, (Euroconsult, 1989; pg 1). See also Sweco *et al.* (2005; pg 56). Therefore to a large extent there has been good cooperation for IWRM between these three countries. Whilst the history of shared resource management is apparent there is low capacity for implementation both on the Mozambican side as well as in Swaziland. South Africa is better resources in this regard.

20.1 No of water management institutions

This includes the organisations directly involved and tasked with the different aspects of water management (primary participants) as well as those which have significantly contributed to progress in this sector (secondary participants). He following is a list of these institutions according to the services they address.

Water Supply (9):

- DNA (management at national level hence looks at the broader IWRM)
- AdeM (service provision and works)
- FIPAG (investment for urban centres- IUWM)
- CRA (regulation and monitoring)
- CMM (management and service provision for Maputo)
- Water Aid (financing, implementation and research)
- World Bank (financing and research)
- ARA-SUL (management for the Southern parts of Mozambique)
- Unicef

Sanitation (5):

- CMM
- DNA
- Water Aid (financing, implementation and research)
- Unicef (including hygiene education)
- DANIDA

There are many more organisations, NGOs and CBOs involved in this sector however they do not play direct roles, but rather provide assistance to one of the above. It is possible to note that there are several stakeholders in the water sector, a fact which at times complicates and hinders the coordination and efficient management of water and its services. This is because there is lack of communication, consequently information is often dispersed/scattered amongst the various organisations involved, investment and monitoring can and has been duplicated, leading to inefficiencies.

20.2 Adoption of alternative water supply technologies: Guesstimate (See UNDP Mozambique, 2005 for sustainable water supply initiative)

20.3 Adoption of sustainable sanitation: Guesstimate

20.4 Corresponding education levels for staff: 18%

Table K.23: Corresponding education levels for service provision; AdeM staff (water supply only) (AdeM, 2006; pg7)

Academic level	2005	2006	Deviation	% deviation
Superior technical	21	23	2	10
Medium technical	83	83	0	0
Basic technical	87	86	-1	-1
Auxiliaries	395	377	-18	-5
Total	586	569	-17	-3

In 2006, 23 out of the 569 total employees have a higher education (university level), whereas 83 have achieved their secondary education levels. For our purposes, both categories will be included, therefore (23+83)/569 = 18.6%

20.5 Monitoring capability: Scored 2 out of 10

20.6 Reliability of service provision: <50% (accounting for the low service times and taking cognisance of even lower supply times in peri-urban areas).

FIPAG's data (FIPAG, 2007) is based on data from AdeM. There is an indicator; "Reliability of Service" however no information is provided. This indicator is based on two assessments: firstly, on the basis of 24hr service connections and 10m head pressure, and secondly based on connections with less than 4 hours of service per day. These indicate two extremes.

Table K.24: Average water distribution times (AdeM, 2006; spreadsheet on technical information)

Supply centre	Distribution area	Distribution hours/day	
		2005	2006
CD-Matola	Zona alta (10h)	13	11
	Zona baixa (12h)	12	11
CD-Machava	(15h)	14	14
CD-Chamanculo	(12h)	11	10
CD-Maxaquene	Zona alta (14h)	13	13
	Zona baixa (10h)	12	12
CD-Alto Mae	Zona alta	8	10
	Zona baixa	6	7

From the above Table K.24 it is possible to see that most areas have on average 10-12 hour supply per day, with the exception of Zona Baixa supplied via the Alto – Maé distribution centre. In peri-urban areas, low pressures in many areas significantly reduce this supply time. Water shortages in these areas can account for short periods of a couple of hours to extended periods of a day or more. While SSIPs are more reliable in peri-urban areas, the higher costs of supply may be prohibitive for some inhabitants and this limits the access to water and hence controls the reliability of supply. See also Beneficiary Assessment: Refers to poor improvements in supply hours, walking distances, waiting times and time lost collecting water (CRA, 2006).

The second point refers to 50% of public stands being out of operation in Maputo, Boane and Matola due to low/insufficient pressure, poor maintenance, no operators, closure due to non-payment and illegal connections (CRA, 2006).

20.7 Failure in service delivery due to dependence on other sectors: inconstant due to power failures, both planned and unplanned cuts.

AdeM Provides data on the number of water supply failures due to power cuts (No of power cuts per year).

With regards to sanitation, particularly in the peri-urban areas which are not covered by the sewerage system, the general impression from municipality officials was that this service is sporadic at best. Emptying of latrines is undertaken by the municipality on an irregular basis due to shortage of equipment (trucks, tankers, vacuums, petrol etc). Pit emptying is not undertaken by the authorities at all and where CBOs perform this function (ADASBU) these are either dependant on donor funds which is far from a long-term sustainable option, or they rely on the municipality to transport the waste from certain locations to the Infulene treatment works (infrequent at best).

From the table below it can be seen that there are frequent power cuts, not only at the treatment station- ETA- but also in all distribution centres and in some of the smaller systems which supply the peripheral areas. AdeM reports that there are on average 30-1200 power cuts per month throughout the various systems. The small systems (peripheral networks) show the highest incidence of power failures. One is not certain to what extent this disrupts the supply of water but the assumption is that this high incidence contributes to inconsistency and at times infrequency of supply.

Table K.25: Power failures in Maputo City

Area	Types of failure	Total	Average monthly for 2006
ETA	Planned	0	0
	Unplanned	1611	201
	Sub-total	**1611**	**201**
CD Matola	Planned	710	89
	Unplanned	1110	139
	Sub-total	**1820**	**228**
CD Machava	Planned	311	39
	Unplanned	2373	297
	Sub-total	**2684**	**336**
CD Chamanculo	Planned	0	0
	Unplanned	743	93
	Sub-total	**743**	**93**
CD Alto Mae	Planned	0	0
	Unplanned	262	33
	Sub-total	**262**	**33**
CD Maxaquene	Planned	70	9
	Unplanned	570	71
	Sub-total	**640**	**80**