LEAST COST PLANNING FOR THE WATER SERVICES SECTOR IN SOUTH AFRICA

MS Furumele

WRC Report No. 1274/1/04

Water Research Commission

LEAST COST PLANNING FOR THE WATER SERVICES SECTOR IN SOUTH AFRICA

Report to the
WATER RESEARCH COMMISSION

by

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WRC Report No 1274/1/04
ISBN No 1-77005-145-7

MARCH 2004

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Printed by Silowa Printers: 012 804 7565

EXECUTIVE SUMMARY

South Africa, whilst known for its vast mineral resources, it is a land of many contrasts with respect water resources and services. With its very low and highly variable rainfall as well as cyclical drought, South Africa has over the years, developed extensive infrastructure to meet the growing demand. Further investment in infrastructure historically tended to favour certain sections of society at the expense of others. The main challenges facing the country are water scarcity and access to basic waters services. It is therefore essential that the available resources be used equitably, efficiently and beneficially.

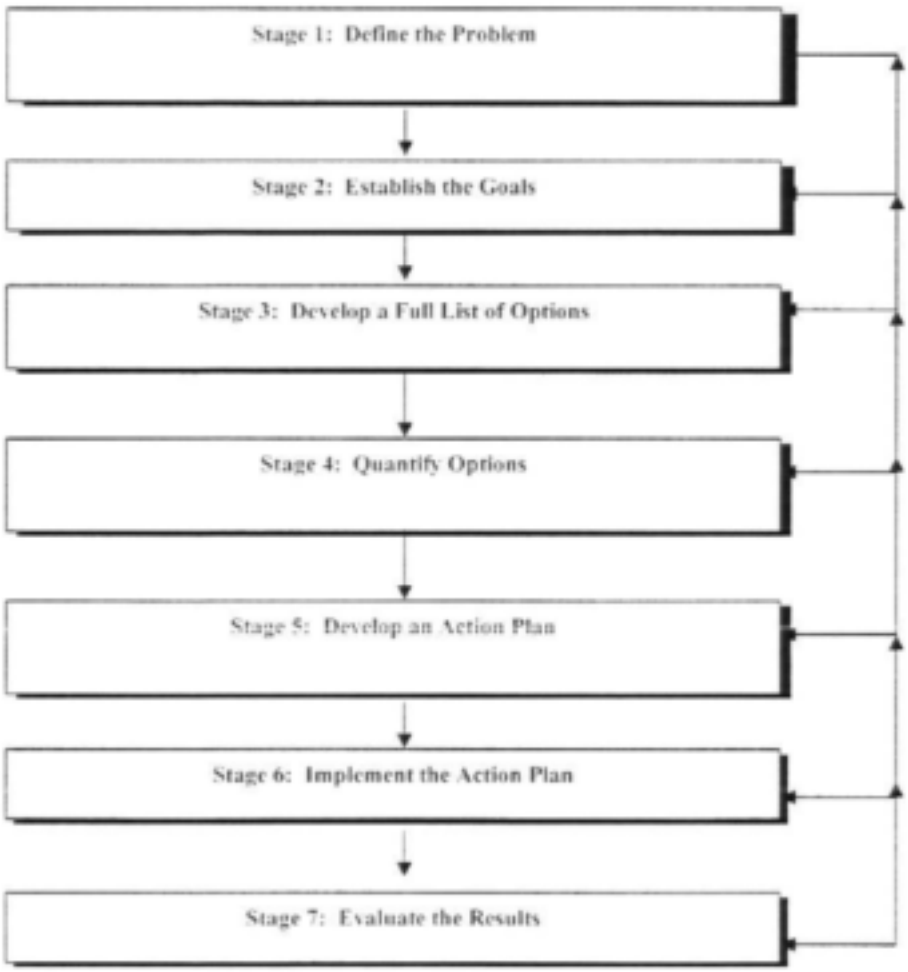
In a scenario of growing demand, limited resources, financial constraints, environmental concerns, and increasing public scrutiny, a paradigm shift in the planning of water services is inevitable. Traditional planning approaches for water services can no longer be as effective as they were in the past. Modern planning emphasising on forecasting with greater precision, using methodologically sophisticated approaches to risk and uncertainty are gaining ground. In other sectors, such as energy and transportation, and in other countries, Least Cost Planning (LCP) and Integrated Resource Planning (IRP) have emerged as indispensable planning tools in dealing with the prevailing challenges.

The objectives of the study were:

- To explore LCP in general and its application in the water sector
- To compare LCP with other planning approaches
- To review local and international LCP initiatives
- To provide an overview of water services development in South Africa;
- To explore an algorithm for LCP in the water services sector;
- To illustrate LCP through a hypothetical example.

The study traces the origins of (LCP) from the energy sector some two decades ago. LCP is defined, compared with other planning approaches. LCP lessons from various sectors are highlighted. The LCP initiatives, initially in transportation planning and recently in water sector, are attributable to its successful application in the energy sector. The water, sector was found to have more similarities with energy and as such experiences gained there provided a more useful analogy for the application of Least Cost Planning in the water sector. To bring LCP into the South African context, an overview of water services developments and restraints inherent in economic planning were also highlighted. This followed by an outline of principles and processes of economic evaluation in the planning of water services and finally an exploration of an algorithm application in water services.

LCP process commences with an upfront and clear statement of the problem. Here, the full set of options is reduced to potential options, which are relevant to the stated problem and can be feasibly implemented. The feasibility stage can be regarded as a more detailed options assessment stage and requires high quality data for the analysis, costs and the range of environmental and social impacts expected from the alternative options. The options analysed are grouped into alternative plans. Selection is based on a comparison of the different options in terms of their financial and environmental benefits, their cost and the flexibility. In establishing the best mix of options, the LCP procedure could link into the comprehensive methodology developed by Johnson et al (2002). The applicability of LCP to the water sector is illustrated through a hypothetical example.



The aims of the study were achieved through tracing the history of LCP and adoption of a definition applicable into the water services of South Africa. Lessons we drawn from the various sectors. Although some experience from the energy sector transferable to the water sector, certain aspects of water supply are dramatically different from energy supply, in particular the electricity utilities. For example, upstream use can affects downstream use and contamination can render a water supply source useless. Technical problems challenging the LCP approach, when it is applied in the water sector, unlike electricity utilities, water suppliers are not physically interconnected and it may be difficult for the supplier to meet developing or changing demands quickly. Certain load techniques used for electricity are therefore not applicable to the water sector. The regulatory structure of the water sector may create other limitations. Unlike electricity, natural gas and transportation utilities, which have regional transmission networks, regional water systems are constrained by the limited application of economies of scale.

The study recommends that the algorithm be tested through a "real life" case study with various stakeholders. The linkage with further research be encouraged to quantification of changes in services related welfare and environmental cost. The LCP approach is communicated to as many interested parties as possible.

ACKNOWLEDGEMENTS

The report emanates from the study undertaken for the Water Research Commission entitled:

LEAST COST PLANNING FOR THE WATER SERVICES SECTOR IN SOUTH AFRICA

The Steering Committee responsible for this project consisted of the following persons:

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The financing of the project by the Water Research Commission and the contributions from the Steering Committee, together with valuable input from Prof D Stephenson (Water Systems Research Group-University of the Witwatersrand) are gratefully acknowledged.

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GLOSSARY OF TERMS

The glossary of terms provides a definition or an explanation of terms commonly used in the water sector and mentioned in this report.

Alternatives - The different choice propositions or methods by which objectives may be attained.

Annuity - A series of equal payments or receipts to be paid or received at the end of successive periods of equal time.

Compound interest - Interest which is computed on both the original principal and its accrued interest.

Depreciation - The allocation of the original cost of a facility or equipment to those time periods in which the asset is used.

Economic Analysis - A technique which allows the assessment of proposed alternatives on the basis of considering their economic consequences over time.

Effectiveness and Efficiency - Effectiveness is the achievement of goals and efficiency is the ratio of effectiveness to the input required to achieve it. Efficiency can be broadly described as doing things right while effectiveness as doing the right things.

Financing Costs - Costs associated with financing capital investment in facilities. Includes both interest and over-time loan and finance charges.

Integrated Resources Planning (IRP) - IRP is a comprehensive form of planning that incorporates aspects of water supply and demand management for the various institutions within a catchment. IRP takes cognisance of participatory decision-making as well as applying risk and least-cost analysis.

Integrated Water Resources Management (IWRM) – IWRM is simultaneously a philosophy, a process and an implementation strategy to achieve equitable access to and sustainable use of water resources by all stakeholders at catchment, regional national and international level, while maintaining the characteristics and integrity of water resources at catchment level within agreed limits.

Interest Rate - The interest rate represents the annual time value of money and is referred to as discount rate.

Life Cycle Costing - A method of expenditure evaluation, which recognises the sum total of all costs associated with the expenditure during the time it is in use.

Net Present Cost - The amount of money needed now to cover the capital and operating costs of a measure over the lifetime of the alternative or the loan period using the discounted cash flow.

Present Value – The concept that a sum of money invested today will earn interest.

Rate of Return – The interest rate which, over a period of time' equates the benefits derived from an opportunity to the investment cost of the project.

Reliability – A measure of success. It is defined as the probability that a system will perform its intended function when required to do so if operated within its specified design limits.

Risk – The possibility of conditions that are different to those expected and that also result in loss or damage.

Sunk Cost - A cost which has already been made and should not be considered in measuring the economic performance of an investigation alternative.

Time Horizon – The end-point of the life cycle cost analysis. The cut-off, or last year, of the analysis.

Uncertainty - The possibility of conditions that are different to those expected (see also risk).

Useful Life - The period of time over which a building element may be expected to give service without major renewal. It may represent physical lifespan or time before technological obsolesce.

Water Conservation (WC) – The minimisation of loss or waste, care and protection of water resources and the efficient and effective us of water.

Water Cycle Management (WCM) - WCM concerns a strategic approach for equitable, efficient and sustainable management of water resources and services. WCM expresses the idea that water resources must be managed in a holistic way, co-ordinating and integrating all aspects and functions of water resources management, water containment, abstraction, control and related service delivery so as to bring sustainable and equitable benefits to all those dependent on the resources.

Water Demand Management (WDM) - The adaptation and implementation of a strategy by a water institution or consumer to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services, and political acceptability.

Water Services – Means both water supply services and sanitation services.

LIST OF ACRONYMS

AIDS	Acquired Immune Deficiency Syndrome
BOOT	Build, Operate, Train and Transfer
CAPEX	Capital Expenditure
CMA	Catchment Management Agency
CSIR	Council for Scientific and Industrial Research
CWSS	Community Water Supply and Sanitation
DBSA	Development Bank of South Africa
DWAF	Department of |Water Affairs and Forestry
EIA	Environment Impact Assessment
ESKOM	Electricity Supply Commission
FBW	Free Basic Water
GAAP	Generally Accepted Accounting Practices
GAMAP	Generally Accepted Municipal Accounting Policies
GIS	Geological Information System
IA	Implementing Agent / Agency
IDP	Integrated Development Plan
IRP	Integrated Resources Planning
IWRM	Integrated Water Resources Management
LCP	Least Cost Planning
MAR	Mean Annual Run-Off
MIP	Municipal Infrastructure Programme
NEPAP	New Partnership for Africa
NGOs	Non-Governmental Organisations
NIS	National Information System
O&M	Operation and Maintenance
OPEX	Operation Expenditure
PPP	Public-Private Partnership
RDP	Reconstruction and Development Program
RSA	Republic of South Africa
SADC	South African Development Community
SALGA	South African Local Government Association
SETA	Sector Education and Training Authority
WC	Water Conservation
WDM	Water Demand Management
WMA	Water Management Area
WRC	Water Research Commission
WSA	Water Services Authority
WSDP	Water Services Development Plan
WSI	Water Services Institution
WSP	Water Services Providers
WUA	Water User Association

1 INTRODUCTION

1.1 Background

Water is arguably amongst the most precious natural resources on earth whose fundamental importance needs minimal justification. Social and economic development would be almost impossible without an adequate supply of the right quality of water. Some 80 countries, accounting for 40% of the world's population, already suffer from severe water shortages (Stephenson, 1998). South Africa is no exception to this global scenario and probably amongst the worst countries. Although well-known for its vast mineral resources, South Africa is a land of many contrasts in respect to its water resources and services. **Box 1** presents some of South Africa's water resource characteristics as highlighted by DWAF (2001).

Box 1 : Water resource characteristics of South Africa

- Located largely in a semi-arid part of the world with scarce and limited resources.
- Average annual rainfall less than 500 mm versus a world average of some 860mm.
- Water resources are unevenly distributed across the country.
- Hydrological extremes with periodic severe and prolonged droughts and floods.
- Areas of economic development located remote from large watercourses.
- Groundwater supplies not abundant for use on a national scale.
- Water requirements far exceed availability in several catchments
- Available water resources inadequate to meet projected demand.
- Development costs have been rising in real terms in recent years.

This scenario is further aggravated by the influences of past political disposition which tended to favour certain sections of society at the expense of others. This has contributed to the vast backlog of service delivery in both urban and rural areas. Access to services in the domestic sector, a significant factor in water demand, is highly unequal, whereas access to water in the industrial and commercial sector is relatively good. PGD (1994) estimated that some 11 million people were without adequate water supplies whilst some 18 million people lacked adequate sanitation facilities. There were also indications that many schemes were not run as effectively and efficiently as they should be (Pybus, 1995). Failures have also become more apparent with major water losses and disruptions due to ageing infrastructure. Customer dissatisfaction and affordability, with a resultant culture of non-payment for services, will have profound impacts on the delivery of water services.

While the challenge to meet these demands remains, approaches used to assess these demands and to plan developments need to be adjusted to suit political, social and environmental circumstances. Improving water use efficiency has thus become more important in the light of the increasing water scarcity and the lack of sustainability of the strongly supply-oriented approaches to water provision. Sustainable water provision requires adequate environmental protection and lastly, but by no means least, needs to address equity concerns. To this end, strong emphasis has to be placed on taking water use efficiency into account in the planning of water services. Despite the drive to improve water use efficiency, DWAF (1999) has listed several generic constraints to the implementation of Water Conservation (WC) and Water Demand Management (WDM) in South Africa, as illustrated in **Box 2**.

Box 2 : Generic constraints to the implementation of WC/WDM in South Africa

- Bias towards supply-side measures:
  - Money is more readily available for supply-side interventions
  - Supply-side management options appear easier to implement
  - Promotion of development without adequately reviewing WC/WDM as an alternative.
- Perceptions and lack of understanding:
  - Resistance to change within institutions
  - WC measures are perceived only as drought relief mechanisms
  - WDM strategies are often incorrectly perceived and implemented as punitive measures.
- Lack of understanding of the principles, scope and potential of WDM.
- Lack of knowledge on consumer and water use patterns.

If water resources and services are not planned, managed and used wisely, the scarcity of water will inevitably hamper economic and social development in South Africa. As the shortages and needs increase, competition for water amongst the various sectors (i.e. urban, rural, industrial and agricultural) will also become more intense. In a scenario of growing demand, limited resources, financial constraints and environmental concerns, as well as increasing public scrutiny, a paradigm shift in the planning of water services is inevitable. Traditional planning approaches for water services can no longer be as effective as they were in the past (AWWA, 1997). Beecher (1995) also noted that modern utility planning should emphasise forecasting with greater precision, and use methodologically sophisticated approaches to risk and uncertainty. Whilst in most countries the instinctive response to water stress has been to augment water schemes, the new planning paradigm suggests first improving water use efficiency.

The shift from institutional arrangements, where the concepts of regulation, authority and responsibility were often confused with those of service delivery, is inevitable. In South Africa, the Water Services Act (Act 108 of 1997) and the National Water Act (Act 36 of 1998) have laid the legal and policy framework for dealing with these challenges. However, legislation does not deal explicitly with economics in water services, particularly the classification of water in economic terms. Thus, this study endeavours to open avenues towards this end. In other sectors, such as energy and transportation, and in other countries, Least Cost Planning (LCP) and Integrated Resource Planning (IRP) have emerged as indispensable planning tools in attending to the prevailing challenges. Both concepts have, to date, had limited application in the water services sector, particularly in South Africa and other developing countries.

1.2 Study objectives

The overarching objective of this study is to broaden the horizons of water institutions and to alert them to the variety of alternative planning approaches. Least Cost Planning (LCP) is explored in detail, with a view to proposing a framework for its implementation in the water services sector of South Africa.

The original study objectives were:

- To explore the substance of Least Cost Planning in general
- To review local and international Least Cost Planning initiatives
- To identify the constraints of, and opportunities for, Least Cost Planning
- To explore the interaction of Least Cost Planning with other planning practices
- To develop a framework for implementing Least Cost Planning in South Africa
- To illustrate Least Cost Planning through a selected case study
- To explore a computer model for Least Cost Planning in the water sector.

The study was further shaped by the processes of two other studies undertaken in parallel and funded by the Water Research Commission (WRC), namely:

- Development of a Methodology to Determine the Effectiveness of Water Conservation and Water Demand Management Measures (WRC K5/1273/1/02)
- Development of a Framework for the Economic Evaluation of Water Demand Management Measures (WRC K5/1275/0/1).

It was noted at an early stage that these studies had certain synergies and probably certain overlaps. To avoid duplication and to maximise the benefits, the three studies were therefore undertaken using an inclusive and consultative process. Through the guidance of the Project Steering Committee, this approach proved worthwhile in that the studies were integrated to build on each other in a complementary manner.

In view of this unfolding study context, the original study objectives were modified as follows:

- To explore LCP in general and its application in the water sector
- To compare LCP with other planning approaches
- To review local and international LCP initiatives
- To provide an overview of water services development in South Africa

- To explore an algorithm for LCP in the water services sector
- To illustrate LCP through a hypothetical example.

1.3 Report Structure

This document is intended to provide an overview of the implementation of LCP in the water services sector in South Africa. The target audience comprises policy makers, planners and practitioners in the South African water services field.

The document is structured in the following five chapters:

- **Chapter 1 -** The Introduction (this chapter) provides background, highlights study objectives and the report structure.
- **Chapter 2 -** Defines LCP, compares it with other planning approaches, and highlights lessons from various sectors. A synoptic overview is provided of water services development in South Africa.
- **Chapter 3 -** Outlines principles and processes of economic evaluation in the planning of water services and highlights restraints inherent in economic planning.
- **Chapter 4 -** Explores an algorithm for LCP in the water services sector and illustrates it through a hypothetical example.
- **Chapter 5 -** Summarises and concludes the report.

2 LEAST COST PLANNING IN DECISION-MAKING

2.1 Least Cost Planning defined

Least Cost Planning (LCP) was introduced by electricity providers in the early 1980s when decision-makers realised that it could be cheaper to invest in conservation than to build additional generation and distribution capacity. Before the introduction of this concept, project life-cycles incorporated few of the indirect costs of delivery (e.g. intervention by metering, energy conservation) (Beecher, 1995). The only aspect of interest to the planner was how to produce a commodity at the lowest cost. How the customer actually used this commodity was thus of limited concern to the planner and this aspect was left entirely to the customer.

Resource development planners started to progressively think in terms of simultaneously delivering services to the consumer at the lowest price whilst maintaining maximum efficiency, rather than treating these services as a mere commodity. Over the years, resource development planning thus evolved from simply minimising commodity costs to minimising society's total cost of delivering the services desired by the customer. This was made possible by economically balancing demand-side (customer) criteria with supply-side (supplier) criteria whilst, at the same time, complying with all the other constraints generated by environmental, political and social requirements.

Nelson *et al* (1994) defined LCP as a comprehensive, technically consistent planning method that provided an economic framework to assess the cost effectiveness of all services and management strategies whilst taking all societal costs into account. It has come to be understood as the comprehensive evaluation of all supply and demand alternatives in an attempt to minimise costs and to create a flexible plan that allowed for uncertainty and a changing economic environment (Beecher, 1995).

LCP is recognised by its procedure rather than as a universal definition and, in principle, its procedure or activities are identical in any sector. For consistency, Least Cost Planning (LCP) in this study is defined as:

"A process that identifies the optimal mix of supply-side and demand-side options while balancing system reliability and affordability, thereby producing planning alternatives with the lowest costs to the supplier and the customers."

LCP can be considered as a method that recognises the consumer's needs, accounts for uncertainty, embodies risk management and reviews available and reliable resources to meet future needs. It is understood as a process of comparing direct and indirect benefits and costs of any service provision to meet pre-determined goals and/or policies.

2.2 LCP compared with other planning approaches

A comparison between LCP and other planning approaches will assist the reader to understand why LCP is being promoted. Three planning approaches are available for use in the water sector today (Beecher, 1995), namely:

Traditional supply-side planning ("TSP")
Least Cost Planning (LCP)
Integrated Resources Planning (IRP).

Most planners use a hybrid of these approaches and combine elements of more than one approach. **Table 1** highlights similarities and differences between these planning approaches.

Table 1: Comparison between the processes used in planning approaches

Dimension	Type of planning process		
	LCP	"TSP"	IRP
Resources options	Demand and supply options (demand can be manipulated)	Supply options (demand is taken as a given)	Demand and supply options (demand can be manipulated)
Resources diversity	Diversity of resources including demand-side management	Utility owned and centralised	Diversity of resources including demand-side management
Resources ownership	Most infrastructure or resources owned by utility	All infrastructure or resources owned by utility	Much infrastructure or resources owned by other utilities, other producers
Resource selections criteria	Diverse criteria, including risk reduction, technological diversity, environmental quality, economic development	Minimise rates and maintain system reliability	Diverse criteria, including risk reduction, technological diversity, environmental quality, economic development
Focus of economic cost analysis	Multiple groups (society, programme participants, ratepayers, individuals, etc.)	Ratepayers	Multiple groups (society, programme participants, ratepayers, individuals, etc.)
Conduct of planning	Internal to the water industry, mainly system planning and water professionals	Internal to the utility, mainly operational and financial planning	Several utility departments as well as non-utility experts, commission staff, public
Planning horizon	Minimum of ten years	Five to ten years	Minimum of twenty-five years
Role of public groups	Advisors	Interveners	Participants
Judgement	More defined	Vague	Well-defined
Preferences	Well-defined	Vague	Well-defined
Objectives	Multiple	Single	Multiple
Reliability	Decision variable	Constraint	Decision variable
Environmental quality	Constraint	Constraint	Objective
Risk	Should be managed	Should be avoided	Should be managed

(Adapted from Hanson *et al*, 1991)

These planning approaches appear similar except that their processes, particularly the scope of their various activities, differ. LCP evolved from TSP whereas IRP is the amplification of LCP. LCP and IRP have at times been used interchangeably, for instance in the water sector, WSSA (1999) and Thomson (2000) prefixed LCP with the word "Integrated" when referring to IRP. Schoette (1999) also used the terms interchangeably in the modelling of energy emission. LCP (and IRP) incorporate many of the planning components that characterise a well-performed "TSP" effort. It should be noted that the shortcomings of traditional planning have increased interest in these relatively new approaches (LCP and IRP) due to the increased incorporation of significant economic and political externalities (AWWA, 1997).

"TSP" is often considered as a conventional planning process whereas LCP (and IRP) are viewed as relatively new approaches to planning ("LCP: An old concept with new relevance", Stephen,1990). However, the basic steps in any planning procedure are similar to those used in the LCP process. Although "TSP" has been applied in many fields with more or less good results for a long time, Nicols *et al* (1997) focused on two cross-cutting elements:

The iterative nature of planning, that is, at any of the logical stages of the planning process, experience and results are fed back to inform "earlier stages", so that the norms of the analyses at those stages are confirmed. Feedback and iteration are ongoing processes across all stages and throughout the planning cycle. Thus, the planning process is, or should be, a recurring one.

The collaborative character during the stages of the planning cycle. Throughout the planning process, analysts and decision-makers should maintain effective collaboration, and communication between the decisional and analytical processes should be key objectives. In this way, the principles of transparency and participation are attained.

In "TSP", or in planning relying on market-based competition, the lowest possible rates or the lowest short-term prices have been used as common measures of cost minimisation. By contrast, the costs of demand management in LCP options are incorporated into the consideration of alternatives and the focus of economic cost analysis shifts to a minimisation of total economic costs. This criterion is seldom reflected in planning methods focused solely on lowest rates or prices. LCP stresses the importance of minimising the present value of long-term costs whilst still maintaining services system reliability.

Further, although "TSP" also considers risk and uncertainty, LCP (and IRP) offers a treatise on these aspects. LCP (and IRP) focuses on identifying and managing risks by informing the decision-makers of the risks and the uncertainty inherent in each alternative. All assumptions, predictions and estimations are subjected to sensitivity analysis. The "TSP" process is mostly characterised by a single baseline forecast of expected conditions. The LCP (and IRP) process observes multiple baseline forecasts and reflects a wide range of possible future conditions. The process encourages feedback from implementation activities into a dynamic and adaptive planning process. In "TSP", the focus was placed significantly on structural facilities (e.g. water supply, power output) to meet end-user service needs. The LCP (and IRP) process, instead, examines and incorporates both supply-side and demand-side options (structural or non-structural) to meet end-user requirements.

2.3 LCP in the various sectors

As indicated earlier, LCP was initially applied more than twenty years ago in the energy sector where planners had the greatest knowledge of production and consumption. The benefits of the approach in this sector prompted researchers and practitioners to extend it to other sectors, such as gas supply, transportation and even the water sector. Highlights of lessons from the various sectorsectors follow.

2.3.1 LCP in the energy sector

The two areas, electricity and gas, where LCP has been successfully applied are highlighted separately.

Electricity supply

The key strategy for electricity supply was to implement demand-side management and energy services programmes that met consumers' needs in the most cost-effective way. Energy services providers set out to develop a process designed to maximise efficiency and, at the same time, reduce electricity costs to the customer (Stiles, 1998).

In the past, about 75 % of the United State of America's (USA) annual electricity production was "wasted" through the use of inefficient products and practices (EREC, 2001). Changing socio-economic conditions and regulatory environment of the 1970s, however, forced electricity providers to develop tools to balance their financial interests with society's goals of an energy-efficient economy and a clean environment. Some of the resource options for both demand- and supply-side in the electricity industry, based on experiences gained in the USA, are listed:

Demand–side options:

Consumer energy efficiency (e.g. home weatherproofing, energy-efficient appliances, lighting, heating, air conditioning, water heating, duct repair, motors, refrigeration, energy-efficient programmes, appliance timers and controls, thermal storage and geothermal heat pumps)

Service provider energy conservation (e.g. load management, high efficiency motors and reduced transmission and distribution losses)

Renewable energy applications (e.g. solar heating and cooling, photovoltaic, passive solar design and day lighting).

Supply-side options:
Conventional power plants (e.g. fossil fuel, nuclear, life extension of existing plants, hydro/pumped storage and re-powering and utility battery storage)
Privately-owned generation (e.g. co-generation, independent power producers)
Renewable energy applications (e.g. biomass, geothermal, solar thermal, photovoltaic).

With the expected growth in electricity consumption in the residential sector, it was estimated in 1997 for South Africa that, at 15% per year over 10 years (Africa, 2002), the implications for Eskom – the supplier - were profound. This new load type would have required the construction of new generation plant capable of running for relatively short periods during the day and only for a few months of the year. The capacity utilisation of this new plant would thus be very low compared with the currently installed capacity.

In considering the cost implications of new generation capacity provision to the country and its electricity consumers, demand management became an attractive alternative for Eskom (Africa, 2002). The lead times for new plant construction are lengthy (up to 10 years for pumped storage hydro capacity) and Eskom had to decide on whether or not to build new capacity by 2002. If demand-side management (DSM) can be used to limit residential demand growth or mitigate the impacts through the provision of incentives for industry/commerce to move load out of the peak periods, then substantial benefits for all customer groups could be derived. High price increases would thus be avoided through the deferment and probable avoidance of certain generation capacity construction. It was then noted that appropriate DSM may well achieve permanent avoidance of certain new plant.

Eskom geared itself to meet the challenge pro-actively, based on thorough and dedicated research and planning in the field of energy efficiency. In its demand management programme, Eskom now implements activities designed to influence the time, pattern and amount of electricity usage in such a way that it will increase customer satisfaction without loss in production and, at the same time, produce desired changes in the load shape (Africa, 2002).

- **Gas supply**

The USA and several countries in Europe recognised energy efficiency and renewable energy applications as some of the most effective resource options, and regulatory mechanisms were therefore adopted to provide financial incentives to those services providers which employed the LCP approach. It has, however, been recognised that conservation can have a negative impact on a provider's revenues by reducing demand. When a provider owns surplus generating capacity, conservation may also mean that a provider might operate at less than full capacity.

The LCP concept in gas supply (i.e. transmission and distribution) was thus recognised as a powerful tool. The goal for gas providers was generally to provide residential, commercial and industrial consumers with most of their energy services (i.e. gas for cooling, lighting and heating) at the least possible cost, assuming the inclusion of economic, environmental and social costs (Stephen, 1990).

In natural gas supply, optimised fracturing methods and secondary recovery of gas from existing fields could lead to increased efficiency in field development. More gas from each well drilled and completed and more optimal placement of each well means more gas per monetary unit invested. Fewer wells mean reduced environmental impact. The use of gathering systems, gas clean-ups and pipelines can save money and eliminate additional energy consumption (and emissions) needed to manufacture equipment for new fields while, at the same time, minimising the environmental impacts of developing new gas supplies.

The application of least cost methods in transmission and distribution technology has led to guided horizontal boring equipment, plastic pipe installation and quality control, and less labour-intensive excavation and repair concepts. Stephen (1990) found that interest had moved to natural gas (e.g. methane) which had minimal environmental impact compared with synthetic gas. The role of methane in global climate change and the environmental impacts associated with pipeline right-of-way construction have both contributed to finding the most cost-effective way to provide the most environmentally attractive energy supplies.

2.3.2 LCP in transportation planning

The search for traffic congestion mitigation strategies in the USA led to the emergence of LCP in transportation planning. (Nelson and Shakow, 1997). Political reality demanded that authorities respond to frustrated travellers who experience long delays in their weekday commuting and, increasingly, during off-peak and week-end trips. Nelson and Shakow emphasised that the lack of comprehensive transportation demand management (TDM) compounded the problem. They suggested that effective TDM be developed as an alternative, or even as a complement, to transport capacity and that public and private support be obtained for its implementation. They therefore proposed a new least-cost planning model for assessing the costs and benefits of solutions. This model was capable of searching across a large number of alternatives for the set of synergistic alternatives that provided the maximum amount of transport mobility or accessibility at the lowest investment cost. The model also applied full cost accounting and accounted for both direct capital and operating costs as well as indirect social and environmental costs.

Nelson (1996) observed that LCP provided a suitable methodology in the transportation sector by identifying demand management methods to balance available resources with capacity expansion. The most economically efficient aspect was investigated by using LCP rather than planning methods that restricted the range of solutions that could be applied to the transportation problems. Some of the impacts highlighted by using LCP were a reduction of total traffic, peak period traffic and freight traffic and shifts from peak to off-period periods.

From a financial perspective, benefits and costs, road risk and environmental costs tended to be reduced. The reduced costs included transition and other additional administrative activities. The benefits included congestion reduction, road and parking savings, consumer savings (i.e. tends to improve transport choice), road safety (i.e. tends to reduce automobile use), environmental protection (i.e. tends to reduce automobile use), efficient land use and community liveability. With regard to equity impacts, LCP indicated benefits by creating more neutral public policies in terms of transportation investments. Thus, a more efficient and diverse transportation system tended to benefit lower-income and transportation-disadvantaged people by improving their mobility options and increasing access for non-drivers. The equity impacts included:

Treats everyone equally
Individuals bear the costs they impose
LCP is progressive with respect to income
Benefits the transportation-disadvantaged
Improves basic mobility.

In South Africa, a number of major cities are now coming to terms with the LCP approach to transportation planning. For example, in the City of Johannesburg, the Johannesburg Roads Agency (JRA) has been entrusted with the responsibility of addressing the roads and storm-water function for the City. In defining the scope of this responsibility, the JRA realised that there was an inadvertent focus on the construction and maintenance of the roads, as defined by the pavement. The City had always managed this portfolio as though the provision of roads-related services was an end in itself yet the essence of the portfolio is a means to enhance transportation of people and goods across the City. It is in this context that the JRA is refocusing its outlook to capture the essence of this business, which is "Mobility".

The JRA has thus embarked on a plan that is premised on ensuring that the roads system that is already in place should be made to function in the most optimal manner, so that the development of new assets is conceptualized as augmenting current investments. In analysing business opportunities in the City, it has become apparent that the current network provides fairly good coverage (other than the obvious historical distortions of "where and what standard" infrastructure was developed). The one pressing omission from the previous investment strategy was the failure to create a platform for maximising functional use of the investment. In the past, the approach seems to have been that the existence of a road was sufficient to ensure mobility and further, depending on *ad hoc* and subjective human interfaces, to address operational deficiencies. The situation is characterised by the low levels of investment in the management of facilities (from vehicle database, intersection monitoring, travel information to operational mapping and tidal movement of vehicles in the City, amongst many other aspects). Without this baseline data, there is no reliable platform from which meaningful management and planning decisions can be made for future needs of the City.

The City has defined a new vision for a "World Class African City". This vision can be better realised if the City has modern management systems that ensure that investment and trading access to opportunity in the City takes place as a matter of course, rather than as a result of a mammoth struggle in accessing all sectors of the City. The best practice lessons from other cities, against which Johannesburg has to be benchmarked, will have to adopted and refined to suite specific Johannesburg conditions. This will not require the re-invention of systems or plans but rather the adaptation of different functional models from successful cities.

2.3.3 LCP in the water sector

LCP has not been particularly popular in the water sector until recently, as highlighted by Stiles (1998) in Southern Africa and Maddaus (1987) and Beecher (1995) elsewhere. A number of initiatives have, however, been reported both international and locally. The international experiences include the Sydney Study in Australia (WSAA, 1996) and the California Study in the USA (AWWA 1994). In South Africa, most initiatives only discretely highlight WC/WDM interventions and not the overall planning process. Summaries of some these interventions are provided in **Appendix B**.

The most relevant and comprehensive application of LCP (or IRP) by Rand Water (Thomson, 2000) and the City of Cape Town (CTT, 2002) are highlighted below.

Rand Water's Integrated Least Cost Planning Model

Rand Water supplies water to the end user mainly through a three-tier arrangement. It procures raw water from the Department of Water Affairs and Forestry, purifies, stores and then distributes it to municipalities, industries and irrigators. The municipalities store and distribute water to the end user.

A water loss study, undertaken by Rand Water in its supply area in 1997, indicated water use inefficiency in excess of 25% (Thomson, 2000). At that stage, water was already imported from neighbouring countries and the price had reached the elastic limit of certain users. It was noted that this level of inefficiency could have led to premature augmentation by some 13 years. Rand Water was faced with the challenge of attaching an economic value to inefficient water use in the three-tier operational environment. The additional challenge was to minimise water cost to the user as though the tiers were integrated into one body.

Rand Water therefore formed a task team, which developed a business study to determine the impact of premature supply augmentation on long term water tariffs and the subsequent expansion of a strategy to the full water supply chain. Integrated LCP was used to demonstrate the financial viability of WDM. This approach was also useful in enabling Water Services Authorities (WSA) within the supply area to determine their inefficient use and target losses. The model was, however, simplistic as it did not take into account additional operations and maintenance that could result from the system being overloaded.

City of Cape Town IWRP case study

In the context of the growing demand for water, limited water supplies and the anticipated need for water restrictions during the summer of 2000/1, the former Cape Metropolitan Council initiated an Integrated Water Resources Planning (IWRP) study to investigate alternative options for managing water demand and/or increasing water supply (CTT, 2000). The study included a component based on Multi Criteria Decision Analysis (MCDA) which allowed for the comparison of options using all criteria considered relevant (e.g. engineering, financial, environmental and social). Financial and economic criteria were analysed within the process using Cost-Benefit Analysis tools which thus formed part of the more comprehensive MCDA process.

The conclusions drawn by the study are summarised:

Pressure control, user education and replacement of automatic flushing systems came out as obvious priorities

Improved management of water services indicated that significant water savings could be achieved

In the short term, sewage treatment to potable water standards was found to be not a priority supply option

Promotion of any water use from private boreholes was ranked low.

Based on the lessons learned in the case study, Van Zyl and Leiman (2002) developed a framework for the financial and economic evaluation of WC/WDM measures.

Sydney Water IRP case study

The financial and economic evaluation for the formulation of Sydney Water's IRP took the form of a cost-benefit analysis (WSSA, 1998). The IRP aimed at finding ways to:

Reduce water demand by 25% by 2001

Reduce water demand by 35% by 2011 relative to the 1991 levels

Reduce unaccounted-for water to, at most, 15%.

After WC/WDM options had been identified, they were modelled by estimating the potential reduction in water demand that would be achieved at different levels of investment in each option. Options were selected based on a set of criteria, including:

Cost to the community to implement the option

Ability to provide a timely reduction in demand

Certainty about costs and benefits

Balance across consumer sectors

Equity between customers with different economic circumstances

Balance across option type (pricing, education, incentives, regulation).

All costs and benefits were indexed for comparative purposes, that is, the present value of the costs of the option were divided by the present value of the reduction in demand for water resulting from the option (Howe & White, 1999). The study yielded the following results:

Possible deferral of supply augmentation

Reduction of size of effluent reuse infrastructure

Reduction of greenhouse gas emission.

2.3.4 Summary of LCP experiences

The LCP initiatives, initially in transportation planning and more recently in the water sector, are both attributable to its successful application in the energy sector. As water resources development appears to have more similarities with energy than with any other sector, the experience gained in the energy sector can therefore provide a more useful analogy for the application of LCP in the water sector. Stiles (1998) recognised that the energy sector can provide special insights into how user needs can influence the resource management process. The process can lead to a profound change in financial management and investment patterns.

The parallels between the use of water and energy are summarised:

As with energy, water is commonly transmitted from its point of collection (generation) to its point of use. It is in the transmission process that substantial losses and inefficiencies are typically incurred.

The methods of transmission vary between water and energy resources. In the case of water, it ranges from fairly simple manual technologies, such as gravity-based irrigation canals, to highly complex-intensive transmission by pumps and pipelines. For both water and energy transmission, the transmitter and the user are faced with important technological choices that may affect overall technology efficiency.

Similar to energy use, the end-uses of water typically require some form of distribution technology. This can range from a simple tap or showerhead in domestic reticulation systems to canals and sprinkler irrigation in agriculture and to boilers and purifiers in industry.

Water must be often changed in form, for example, to potable quality, steam, hot water or pressurised, before it can be used effectively.

Similar to energy, water is a critical resource and lends itself to the imposition of control by authority and monopoly. Control over the supply of water requires water providers to consider efficient demand and supply management methods.

LCP for electricity has, for the most part, been able to focus almost entirely on market costs. The consumer is generally assumed to be indifferent as to how, for example, the comfort of his/her building is achieved, whether this is by supplying more electricity or by other means.

2.4 The need for LCP in the water sector

Water is critical for the health of both humans and ecological systems and it is a most important element in our economic and recreational activities. Despite its widespread scarcity, water is not necessarily recognised as an economic good or service. As water shortages increase and demand grows, competition amongst users can become very high. However, water is not renewable to the extent that its availability is fixed in quantity in given time and place. It can also be subject to pollution beyond pre-established standards. For potable purposes, water also requires non-renewable chemicals and energy to transform it into a form that meets public health and other standards.

With regard to the comparison between "TSP" and LCP, water services providers are mainly enfranchised by government to operate within a given territory, with or without limited competition. Traditionally, water services providers were supply-oriented and the incentives for investment in capacity to mitigate the risk of shortage or to increase returns have been significant. A further characteristic of traditional planning by water services providers is the cyclical pattern in which system design determines costs, thereby determining prices and ultimately demands. When determining the price-demand and demand management system capacity requirements, it is now necessary to evaluate inter-relations between all the variables. It is therefore of paramount importance to discard the old misconception of considering water as a simple commodity and to recognise the increments (and costs) associated with each step in water delivery.

Developing approaches to facilitate successful responses to these challenges is essential. There is also increasing public scrutiny on costs, benefits and cost effectiveness of options. There is broad recognition that other issues, such as preserving the environment, water conservation and demand management, must be considered in water supply planning and decision-making. As a result, there is a need for the adoption of more comprehensive approaches. Moreover, the various stakeholders in the water sector have an increasing desire to become involved in the decision-making process related to events that are likely to impact on their communities. For these reasons, "TSP" does not necessarily work as well as in the past.

These new approaches should be characterised by "best practices" of which Sant (1996) listed a number of key principles for good planning in today's context:

Transparency and participation, not because of their benefits but because they are inalienable rights in a democratic governance system

Perspectives of all those whose livelihood security is involved should be given the central place

Integration of the precautionary principle or the principle of error-friendliness

Distribution of cost and benefits across the various sections of society should be clearly articulated before and during the planning process

Participation of non-mainstream individuals and non-formal institutions in the articulation of planning objectives and identification of candidate options

The underlying implicit assumptions and conditions necessary for realising the claimed advantages and disadvantages for each option should be clearly articulated and presented to the public

Accountability of decision-making and executive agencies direct to the public, ensured through mandatory procedures and competent mechanisms that are completely open for intervention by the public.

LCP can easily fit within what is termed "best practices" planning. The concept of LCP should be adopted not only in places where water is scare and limited but also where there is poor management of the resource, inherent in most developing countries. It is recognised that one of the key opportunities for adopting LCP in the water sector is the high level of loss and inefficiency in using water. The concepts of efficiency and conservation will inevitably introduce economic use of existing resources. Consequently, the objective of LCP for the planner is one of meeting all the water-related needs of customers by not only seeking options for additional supply (e.g. groundwater, dams) but also, and importantly, investigating alternatives for improving the efficiency of water use.

Searching for solutions to the crisis at hand brings us to compare the recent experiences of developed countries with those of developing countries. The comparison is not necessarily helpful as the inefficiencies of developed countries have been just as large as those of developing countries. The advantages of developed countries are their adequate service coverage, stronger revenue base and better access to efficient technology.

2.5 LCP in the water sector of South Africa

2.5.1 Institutional Arrangements

In South Africa, water problems require actions by many role players but, without coordinated frameworks for action, grid-lock and conflict-filled decision processes will be inevitable. There are three spheres of government in South Africa - national, provincial and local - each with its specific functions and responsibilities with respect to water services. The Water Services Act (Act 108 of 1997) and the National Water Act (Act 36 of 1998) provide the legislative framework within which water services and water use need to take place.

The Water Services Act provides for water services institutions ((Water Services Authority *(WSA)*, Water Services Provider *(WSP)*, Water Board and Water Services Committee)) whereas the National Water Act provides for Water Management Institutions ((Catchment Management Agency *(CMA)* and Water User Association *(WUA)*)). The responsibilities of these institutions are:

- WSA is any institution responsible for ensuring access to water services and it must be a municipality
- WSP provides physical water services to end users under contract to the Water Services Authority, a municipality or any public body.
- As a public water services provider, a Water Board's primary function is to provide water services to other water services institutions. It may carry out secondary activities as long as there is no interference with its primary function and its activities are financially sound.

The water services business cycle comprises a number of separate components, which are linked into one business cycle, as illustrated in **Figure 1**.

Figure 1: Components of the water services business cycle

Rolfe (1998) summarised the most common institutional arrangements for water services in South Africa **(Figure 2)**:

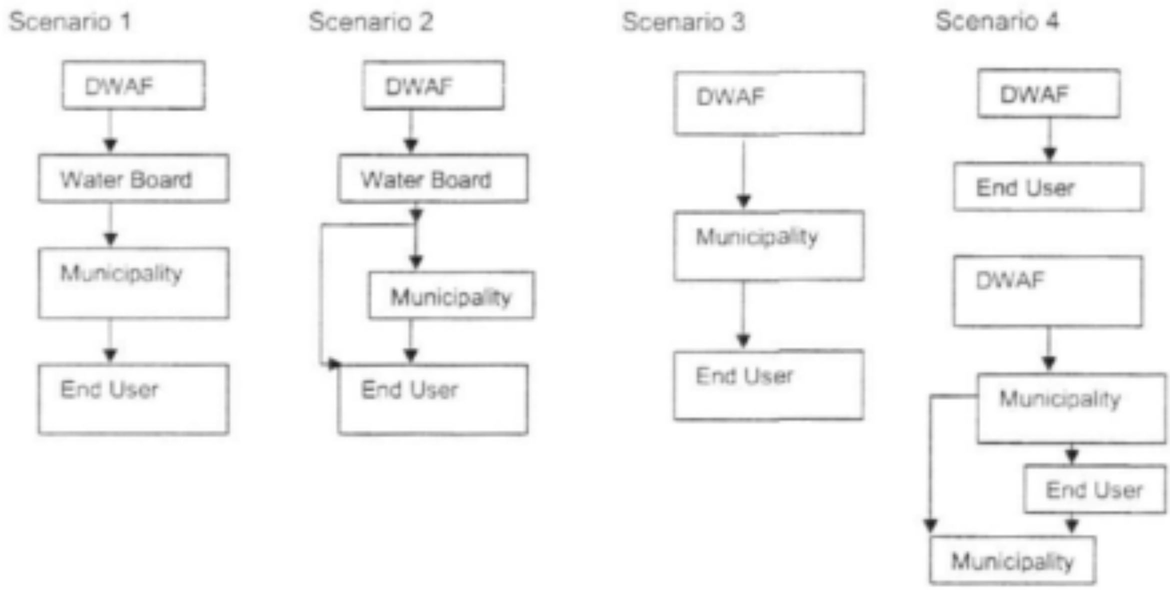

Figure 2: Most common institutional arrangements for water services in South Africa

In **Scenario 1**, DWAF supplies raw water to a Water Board whose function is water treatment and distribution to municipalities. In turn, the Water Board,Board distributes water to municipalities which distribute it to end users. This is the most common arrangement in South Africa

Scenario 2 is similar to Scenario 1, except that the Water Board supplies water direct to end users in addition to municipalities. Examples of this arrangement are Rand Water and Umgeni Water.

In **Scenario 3**, DWAF supplies raw water direct to the municipality which, in turn, arranges its own treatment and bulk distribution and reticulation to end users. The City of Grahamstown is an example of this arrangement.

Scenario 4 is similar to Scenario 3, except that a municipality also has an option to supply other municipalities. Cape Town and Port Elizabeth provide examples of this arrangement.

2.5.2 Application of LCP in the water sector

The implication of these institutional arrangements is that each tier or sphere is autonomous and responsible for different components of the water services business cycle (**Figure 1**). LCP provides an avenue to minimise the cost of water to the end-user as though each tier or sphere is integrated into one unit.

The prime objective of a more advanced approach to planning for the sustainable development (or enhancement) of water services in South Africa is a mechanism providing full integration at all three key levels of water services provision, including State, Water Boards and Municipalities. Since 1994, national, provincial, district and local authorities have focused on the delivery of water services to previously disadvantaged people, predominantly in the rural and peri-urban areas. In support of the water services provision process, the State embarked on the formulation of a National Water Resources Strategy (NWRS) and has subsequently promulgated the Water Services Act (Act 108 of 1997) and the National Water Act (Act 36 of 1998). Both Acts focus on the fundamental principles of equity in access to water services and sustainability in the provision of water. The goals entrenched in this mechanism are primarily social and political in nature. However, in trying to rectify the legacy of the past short-sighted development approach, little attention is at times given to the economics of water services development to ensure efficient development of water services. There is also a need for efficient and user-friendly mechanisms to ensure that the capital invested in water services is managed according to economic principles. Such a mechanism should provide a balanced approach to water resources and services development, and the principles of engineering economics in the evaluation of water services development should not be sacrificed.

Advanced approaches to the development of water services must also accommodate a broader understanding and application of engineering economics, in particular the principles related to micro-economics theory. Two principles of micro-economics having special significance for the water services industry are "economies of scale" (i.e. increasing unit cost with decreasing capacity) and "price elasticity of demand" which is mainly inelastic in the water services industry.

The numerous management measures needed in water services should fit within a coordinated framework so that they can be harmonised. The attributes of management framework begin with inclusion, that is, the framework should be comprehensive, with extensive stakeholder involvement and collaboration. The decision making processes should be clear, action orientated and adaptive. Local control within a national policy framework helps to promote local incentives and to build capacity among appointed and volunteer leadership. Other desirable qualities of the framework include a focus on environmental integrity, effective integration of system components and management measures, and use of proven management practices. Management decisions should also be based on valid scientific and risk assessments. These attributes relate to exclusivity, process and control authority.

In the absence of central authority and when the marketplace does not coordinate solutions, the incentive structures of water agencies, regulators and political leaders may work against integrated and multifaceted solutions to large-scale and cross-cutting problems. As a result, people seeking solutions often yearn for a benevolent dictator, but the dictator should be the coordination mechanism, implemented under a management framework.

In addition to their principal roles, water services providers and regulators can take on extended citizenship roles to help resolve large-scale water issues. This notion may seem naive to some, but it is an important responsibility for public sector managers. The need for public agencies to take on better citizenship roles was explained by Peter Drucker (1995), who concluded that, while organisations are the necessary integrating mechanisms for social problems, they must also take social responsibility (such as promoting cooperation in the water sector) in addition to their intended functions (like providing a water supply).

Finding effective frameworks for coordination, cooperation and integration is a site-specific challenge that must take place in local areas, in catchments and with help from citizen leaders. Local authority implementation within a national policy framework is an important principle, although government may be required to provide a coordinating role. Voluntary forums are also desirable, if they can be made to work. Management conferences can be convened by government or non-government groups and reporting at such conferences and in technical papers can encourage integrated solutions.

The media play a surprisingly important role. Scorecards of progress on large-scale water problems could go a long way towards building public support and could assist the public in understanding the stakes involved and in supporting remediation efforts.

Education is also a tool for gaining support for comprehensive frameworks. Educators and public interest groups can teach students and the public can gain appreciation for the science and citizenship required to solve environmental problems, using local problems as examples. Engineering educators can use the case study approach to teach the complexities of large-scale water problems to future industry leaders.

2.5.3 Project (or system) development feasibility tests

Kuiper (1971) stated that, due to the lack of any direct method of determining the real value of domestic and industrial water, it is common practice to express the benefits of providing such water in terms of the cost determined from the least expensive alternative source of water supply. The basic criterion for evaluating benefits and costs can be the willingness of water users to pay a price for water supply development (or enhancement). If the willingness to pay is low, then there is a strong likelihood that water consumption (or demand for water) will be substantially reduced. Therefore, the benefits should be re-valued.

However, in most developing countries, decisions to provide water supplies for domestic consumption (i.e. municipal supplies) are commonly made without undertaking prior benefit-cost analysis, regardless of the fact that the main purpose of this method is to provide a meaningful decision-making process. James and Lee (1971) suggested five feasibility tests for evaluating water resource development projects:

Engineering feasibility Engineering design must be confined to technologically feasible regions, assured by the application of adequate standards and codes.

Economic feasibility The total benefits that result from implementing a project must exceed project costs. The level of economic feasibility is a function of engineering feasibility.

Financial feasibility Relies on sufficient funds and favourable financial elements (e.g. interest, time period for repayment, etc). A project may be economically non-feasible but financially feasible, if the cost of development of non-economic goods is covered.

Political feasibility The required political approval must be secured. Political support normally follows proof of economic and engineering feasibility but, in most developing countries, economic and engineering feasibility often come later.

Social feasibility Social feasibility is based on the pretext that potential users of a project will respond favourably to the development (or enhancement) of the project. However, the infusion of productive capital will not automatically gain the support of a tradition-bound community (e.g. cultural unacceptability).

Since the early 1970s when James and Lee (1971) introduced their five feasibility tests, environmental feasibility tests for development projects, involving an assessment of the environmental consequences of the proposed system development, have gained significant recognition worldwide. The Environmental Impact Assessment (EIA) has thus become a yardstick for the development and implementation of most engineering projects.

In its generic form, a benefit or cost can be measured in terms of a goal or set of objectives. The benefit or value of water in the development (or enhancement) of water services projects (or systems) is defined as a function of several variables (or objectives). The most important of these variables are:

- Quantity of water available and supplied
- Quality of water available and supplied
- Reliability of water supply
- Seasonal variation in demand for water
- Growing annual demand for water.

The level of water services based on technological development (i.e. economic consequences of advanced technology) and the degree of its application are also featured in determining indirect primary benefits. The benefits derived from the supply of good quality water are most important in the development of municipal water services systems. There are also other indicated primary benefits to be derived from urban water services projects, including employment, income redistribution and public benefits.

3 ECONOMIC EVALUATION IN PLANNING WATER SERVICES

3.1 Economics in the planning process

The process of planning for the development (or enhancement) of engineering projects (or systems) should primarily explore alternative solutions to a given situation – that is, with or without a project. The objective of analysing various alternatives by applying adequate economics methodology, engineering judgement and expertise enables the selection of a best, or least–cost, alternative.

The application of economics allows the planner to identify and select a solution for a system development (or enhancement) with the smallest overall expenditure over the system's expected lifespan, taking into account the time value of money. The following two cost categories are most relevant:

Cost of investment, or capital investment, needed up-front to plan, design and build the system and to start its operation

Recurring annual costs (i.e. annuities of operating and maintenance costs) to keep the system in operation and in a state of readiness.

Alternatively, when working with an annual income, the present value of an annuity (a recurring payment) over a time interval can be considered to be equivalent to the capital investment, while the amount of the annual annuity is the operating cost. If the capital investment and recurring annual costs are to be combined to provide the total cost, then both must be adjusted to an equivalent basis to realise the interest associated with the use of money. A capital investment cost is added directly to the present worth, but a recurring cost must be multiplied by a present worth factor (or present value of annuity).

Present Worth Factor (PWF)

$$\text{PWF} = \frac{1}{i}\left[1-\frac{1}{(1+i)^n}\right] = \frac{(1+i)^n-1}{i(1+i)^n} \qquad (3.1)$$

Where: PWF = Present Worth Factor

i = Interest rate per time period

n = Number of recurring payments (or the life span of the project in years).

Similarly, recurring costs may be added directly to obtain the series payment amount, but the Capital Recovery Factor must then be multiplied by the capital investment costs before both costs can be added together to determine the total series payment.

Capital Recovery Factor (CRF)

$$\text{CRF} = \frac{1}{PWF} = \frac{1}{1-\frac{1}{(1+i)^n}} = \frac{i(1+i)^n}{(1+i)^n - 1} \qquad (3.2)$$

Where: CRF = Capital Recovery Factor

i = Interest rate per time period

n = Lifespan of the project in years.

Individual payments are assumed to be constant amounts in order to provide a uniform series of payments.

Rate of interest

The rate of interest can be defined as a reward for having made capital available to someone who needs it. Kuiper (1971) outlined that the rate of interest depends primarily on three main factors:

The state of the national economy

The risk involved in the loan

Expected future rate of inflation.

When *i* represents the annual interest rate, P represents a present sum of money and *n* represents a number of years, then:

i P	=	Interest at the end of one year
$P(1+i)^2$	=	Interest after two years
$P(1+i)^3$	=	Interest after three years, and so on.

This means that the amount, A, of an original investment, P, can increase when compounded by the rate of interest, i, to: $A = P(1+i)^n$ after a period of n years. It is important to make distinction between the nominal and real rate of interest. The real rate of interest equals nominal rate of interest less inflation rate.

Rate of inflation

Kurtz (1984) defined inflation as the increase in price levels arising from a general increase in expenditures without corresponding increases in commodities. The rate of inflation for a given year is taken as the rate of the increase in the cost of a commodity during that year over its cost at the beginning of the year. Expressed symbolically, the following may apply:

$$g = \frac{C_r - C_{r-1}}{C_{r-1}} \qquad (3.3)$$

Where: g = (Effective) Rate of inflation

C_r = Cost of commodity at the end of the year

C_{r-1} = Cost of commodity at the beginning of the year.

Consequently, the cost of capital can be split into two elements representing the nominal cost of capital which equals the sum of the true cost of capital and inflation.

When payments are to be made during an inflationary period, the effects of inflation may be incorporated into the cost analysis by applying the above equation. However, it is common practice not to incorporate inflation into engineering costing procedure if the life-cycle costing principle is not applied in the process of planning for development (or enhancement) of an engineering project (or system).

Discounted cash flow (DCF)

The set of payments associated with an investment (money to earn interest) is referred to as cash flow. The present worth of an investment is sometimes referred to as the premium worth or discounted cash flow. Once a cost for cash flow has been determined, including both initial construction costs and future O&M costs, a discounted cash flow (DCF) calculation can be undertaken:

$$P = \frac{A}{(1+i)^n} \qquad (3.4)$$

Where: P = Net Present Value (NPV) of *A*

A = The sum paid in year *n*

i = The cost of capital or discount rate.

The discounted cash flow method is principally a rate-of-return method, although it implies a present worth analysis. The essential factors employed in this method are:

Use of continuous interest instead of discrete and continuous cash

Use of only one factor, the single payment present worth factor

Equating the extra investment to the present worth of the savings (i.e. cash flow).

The discounted cash flow method stems from the financial concept of "cash flowback" which refers to the cash flowing back to the service provider from net profits plus depreciation. It is therefore logical that this cash flow is the same as the difference in disbursements between alternatives.

Social time performance rate (STPR)

Although time performance feels natural to most people, and is often applied unconsciously, it is quite difficult to explain and justify why it should be applied systematically to collective decisions. It is even more difficult to set out a coherent and convincing justification for any particular discount rate.

This concept relates to people's decisions about how long they will wait for benefits. The STPR rate refers to the balance between consumption, savings and investments. In addition to technical considerations, the choice of STPR is also concerned with equity between generations and with ethical and political matters. Snell (1997) proposed that the decisions on discount rate - a common choice is within the range of 2% to 6% made on behalf of a community or society - should take social time preference rate into consideration.

3.2 Opportunity costs in water services development

3.2.1 Concept of opportunity cost

The concept of opportunity cost can be explained by considering the background of the cost of something that we have to give up in order to obtain that something. The fundamental reasoning of economic analysis is to determine if a particular investment in a development project (or system enhancement) is worthwhile. The commitment of investment requires a certain amount of sacrifice by the investor or, as an opportunity for choice, reducing the amount of productive capital invested in another development. The value of this sacrifice is the key to discount rate selection.

The inherent imbalances in the availability of water resources, as related to its demand, require large capital and human capacity and expertise to overcome such imbalances, particularly in the urban water services sector. Most water services systems depend on surface water storage (e.g. dams) for assured water supplies. The costs of water services provision are closely related to the seasonal imbalances in the availability of surface water. For that reason, water services cannot, in practical terms, be provided without assured and reliable availability of water quality and quantity, which must be maintained through capital investment into primary infrastructure (e.g. dams, reservoirs, bulk pipelines). The development of capital works will, in turn, generate quantitative and qualitative deterioration impacts on other economic and environmental processes and outputs.

The inputs from all those resources that contribute to the transformation of water from the natural state into an economic good are commonly evaluated by the opportunity costs principle. The pricing structure, according to the opportunity cost principle of allowing for adequate accounting of all costs incurred, is illustrated in **Figure 3.**

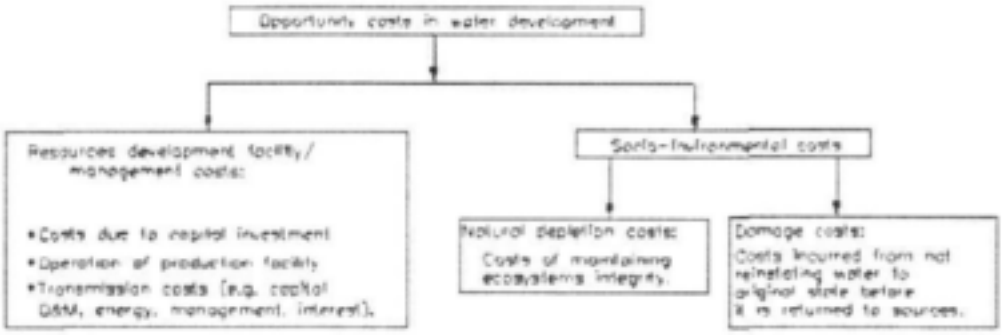

Figure 3 : Opportunity costs in water services development (adapted from OECD, 1987)

Opportunity Costs (OC) = Resources Development Costs (RDC) + Natural Depletion Costs (NDC) + Damage Costs (DC).

or:

Socio-Environmental Costs (SEC) = Natural Depletion Costs (NDC) + Damage Costs (DC) = Social Opportunity Costs (SOC).

Then: $OC = RDC + SOC$ (3.5)

The partial or complete restoration of water to its original state, or even the maintenance of damaged river systems, requires considerable economic resources which must be essentially recovered from those water services rendered within the economic systems (i.e. water services).

3.2.2 Shadow pricing methodology and application

Shadow pricing can be defined as a special evaluation technique using a Shadow Price Factor (SPF) to convert values in financial prices into values in economic prices. Theoretically, prices obtained in a free market are indicators of people's willingness to pay for different goods and are thus the correct measures of value to society.

In a perfect equilibrium market, the shadow price of a scarce resource will equal its real price. In an imperfect market situation, where prices are separated from taxes, duties and subsidies (i.e. transfer payments), prices for the scarce resource are usually determined from the economic benefit–cost analysis. The presence of scarce resources in the market therefore indicates the need for shadow pricing to be adopted. In principle, the economic analysis of water services development based on shadow prices cannot be dismissed in a developing country and should be integrated as an important tool within the overall development programme. Examples of shadow pricing, financial costs and economic costs are given in **Table 2.**

Table 2: Example of shadow pricing, financial costs and economic costs

Cost category	Financial cost estimate (R'000)	Shadow price factor (SPF)	Economic cost estimate (R'000)
Imported material	20	1,3	26
Local material	10	1,0	10
Skilled labour	10	1,1	11
Unskilled labour	30	0,6	18
Machinery usage	15	1,2	18
Taxes and duties	15	0	0
Other costs	20	1,0	20
Total	120	-	103

Source: Snell (1997)

If the shadow price equals the marginal productivity of water in a water services development project, then the net benefits can be maximised using this shadow price as the initial cost of water. The shadow price would be charged to the users of the water that is made available by the development project, and it would depend on the users themselves to negotiate whatever deal they could under the particular political circumstances. Users should be made aware that water, and particularly potable water, has a certain value and, if they receive it free, they should show a willingness to ensure that the water is not wasted and that optimal use is made of this scarce resource (commodity).

Essentially, if the shadow price is the real equilibrium price, then market supply and demand will balance out, with the demand for the scarce resource equalling its supply at this shadow price. If demand does not equal supply, the shadow price should be adjusted so that the two become equal. In this way, optimum allocation can be made of any scarce resource.

3.3 Marginal cost pricing principle

Marginal Cost Pricing (MCP) can be defined as a search for an optimum welfare condition, satisfying the principle that the additional consumption of goods or a service should be possible at a price not greater than the additional cost necessarily incurred in producing such goods or service. Marginal cost pricing will be manifested in the water services pricing structure, with water prices reflecting the costs of balanced commodity marginal demands. This will result in the correct message being conveyed to the users and subsequently in the efficient (optimal) use of water resources or services.

The MCP principle distinguishes between "current" and "past" opportunity cost. It is based on the assumption that, once sacrifices necessary to create durable and specific assets have been made, no further opportunity costs are incurred by its later use. This means that no account should be taken of past costs in deciding current prices. This principle is adopted in the mechanism of a perfectly competitive market economy. For the competitive service provider, it is an incidental property of the long-run equilibrium, meaning that:

- Marginal Cost (MC) = Average Cost (AC) = Price of service (PS) (3.6)

It should be noted that the above equation may create problems because water provision services are predominately provided by public or parastatal enterprises which are far from perfectly competitive. In such an environment, pricing structures based on a marginal cost pricing principle would inevitably lead to losses and there would consequently be a need for subsidisation of water services. This situation is inherent to water services provision in most developing countries. In recognising a general convention, it is suggested that marginal cost (MC) could provide a benchmark for water pricing as it indicates at what level water services might be priced with economic justification. In economic terms, the MC of water services is the cost of supplying a unit of water demanded by the users. If, at any time, a new project needs to be built to supply additional water, then the MC at that time would depend on the cost of the new project. MC thus takes into account the future cost of building new or providing enhancement of existing water services facilities, including the system's fixed, variable and total costs of commodity output.

Fixed, variable and total costs of commodity output

Fixed costs are those costs that were spent during the period of time under consideration and cannot be changed (e.g. loans, salaries, some maintenance).

Variable costs are those costs that change as output changes (e.g. energy, chemicals, some maintenance).

The total cost is the sum of fixed and variable costs. These and a procedure to determine the MC of commodity output are illustrated in **Table 3.**

- Total cost (TC) = Fixed costs (FC) + Variable costs (VC) (3.7)

Table 3: Example of marginal cost (MC) of commodity output determination

Output (Units)	Fixed costs (FC)	Variable costs (VC)	Total costs (TC)	Marginal cost (MC)
3	50	38	88	12
4	50	50	100	
9	50	100	150	8
10	50	108	158	
16	50	150	200	7
17	50	157	207	
22	50	200	250	10
23	50	210	260	
27	50	255	305	15
28	50	270	320	
32	50	350	400	

Note: Marginal cost is the increase (decrease) in total cost resulting from increasing (or decreasing) the level of output by one unit. Source: Snell (1997)

Total marginal cost (TMC) in water services tariff

The water tariff structure serves as an important policy instrument in regulating the demand for water services provision. The price of water services to the end user is based on the tariff structure as incurred by water services authorities and providers. However, the present price of water services provision should also reflect information about the cost of water over a number of years ahead, based on the projection of demand for those water services. The projections of future water demand are fundamental to the estimation of marginal costs. Both the forecast of future demand for a commodity and a prediction of the least-cost level of expenditure required to meet this demand are subjected to a number of constraints of, for example, an institutional, financial and contractual nature. In some instances, no explicit demand forecast will be available and a planned future investment in water services development may then substitute for a lack of implicit or explicit projections.

The total marginal cost (TMC) of water services can be derived from the sum of the marginal operating costs (MOC) and marginal capital costs (MCC):

- $$TMC = MOC + MCC \qquad (3.8)$$

Marginal Operating Cost (MOC). The most common approach to calculating marginal operating costs (MOC) is to assume that they are equal to current unit variable costs (UVC) of such inputs as power, chemicals, rates and abstraction charges of water supplied. UVC are calculated by dividing total demand-driven operating costs by the current output of processed water. UVC determination procedure should be carried out at the lowest possible level (i.e. at water user level).

Marginal Capital Cost (MCC). The capital expenditure related to the volume of water supplied includes source works, treatment works, pumping and booster stations, service reservoirs, trunk mains and distribution infrastructure. These costs are fundamental in determining marginal capital cost. To understand this concept, it is necessary to distinguish between the expansion costs of an overall system (or facility) and the expansion of the subsystems (e.g. the distribution network in the water services system). Generally, the subsystems will expand through a larger number of smaller investments, often separated by long periods of time.

Average marginal incremental cost (AMIC). Assuming that appropriate cost and demand data are available, the following model provides a suitable method to determine this average cost:

- AMIC = MOC + MCP) (3.9)

Consequently:

- AMIC = MOC + (PW of system expansion – PW of difference in volume of water delivered) (3.10)

Where: PW = Present Worth of system costs

MOC = Marginal Operating Cost.

Information on the costs and quantities of water associated with the least-cost investment planned for a development is usually generated in the investment appraisal analysis. The difference in planned expansions of the water services system, that is, the difference between demand projections, should ideally be sufficiently large to be noticeable but small enough to be marginal. The principle of marginal capacity costs analysis is illustrated in **Figure 4**.

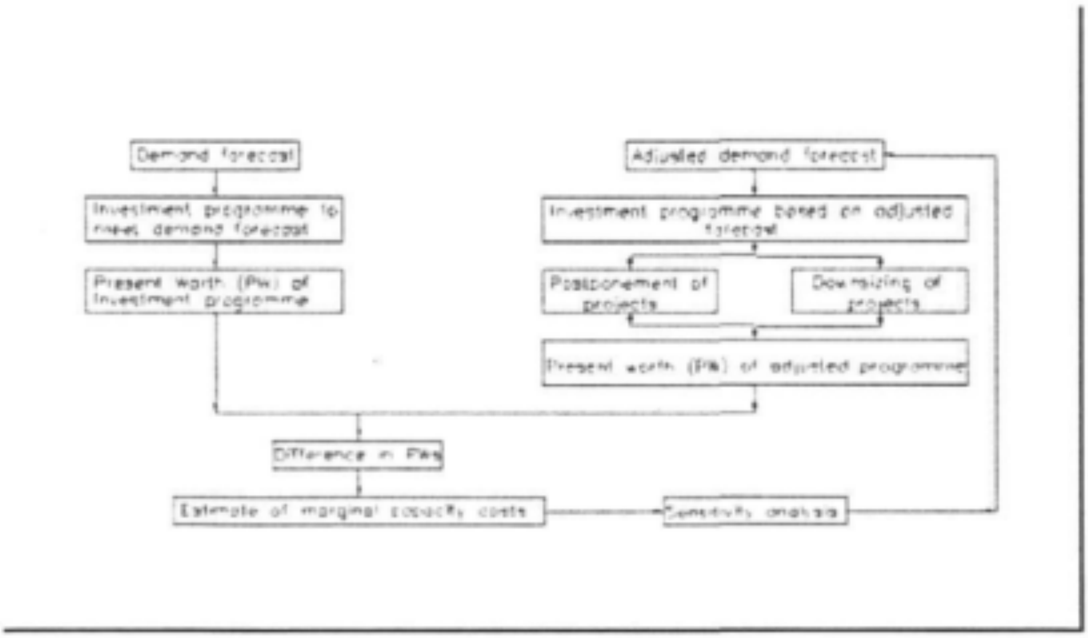

Figure 4: Analysis of marginal capital costs (adapted from UK Water Industry, 1994)

3.4 Rationale behind the marginal cost pricing of water services

Most water services providers in South Africa produce and sell large quantities of raw and/or potable water, usually at a constant price. Generally, there are large fixed costs associated with water services provision and therefore the service provider must produce and sell a certain amount of water (or unit service) merely to recoup its fixed cost repayments. Beyond the point of recovering fixed and variable costs, the water services provider starts to earn profit.

Profit (PRF) = TSL – TCP = p*X – TCP, (3.11)

Where: PRF = Profit on water sales

TSL = Total water sales

TCP = Total cost of production

p = Selling price/unit of service

X = Amount of water (or units of service) produced.

Then : $i_n = \dfrac{PRF}{TCP} = \dfrac{TSL}{TCP} - 1$ (3.12)

Where i_n = Investment rate

Note: For a given value of X, the marginal (or incremental) cost is the cost of producing one additional unit. If X is very large, it is necessary to equate the incremental cost to dTCP/dX. At the average unit cost level, it is possible to apply a ratio equal to TCP/X.

The incremental investment rate is the investment captured by producing one additional unit, determined as follows:

$i_i = \dfrac{P-c}{c} = \dfrac{P}{c}$ -1 or $i_i = \dfrac{P}{dTCP/dX}$ (3.13)

Where: P = Selling price

c = Incremental (or marginal) cost

i_i = Incremental investment rate.

It should be noted that marginal costing is a dynamic concept and marginal costs may vary significantly from one year to another. It is also a forward-looking concept in contrast to the accounting costs, which are a record of the past.

3.5 Life-cycle cost approach in economic analysis

3.5.1 Life-cycle costing concept

The life Cycle Costing (LCC) approach to economic analysis is recognised as an explicit approach dealing with periodic changes in benefits and costs as they are expected to occur over the service life of a system or a project. Of all the available methods for economic analysis, the life cycle approach is the most popular with industries and energy and water service providers.

The LCC approach is a dynamic approach, which deals with changing economic factors by accommodating year-by-year changes in price inflation, price changes, regulatory requirements and variations in replacement and O&M costs. The method allows for a conversion of changing future costs and benefits to a common time basis by means of the lump sum present worth method. Inflation in prices can be accommodated in this method by the escalation of costs and benefits to the time of their occurrence by application of a single payment compound amount factor. The conversion of future costs and benefits to their lump sum present worth equivalents and to their annual equivalents is accomplished through the respective use of a single payment present worth factor and a capital recovery factor. The LCC approach is primarily used to identify the long-term feasibility of various engineering projects (or systems). In particular, high-cost energy-dependent projects require the LCC approach in their economic analysis. Essentially, the life cycle costing concept allows for the examination of the economic feasibility of an engineering project (or system) and regards the total cost as a sum of present value of all expected costs incurred in all phases of the life cycle of a given system. The transformation processes in a given system can be designed for economic feasibility using the LCC method. In this way, the total costs of development and ownership over the full life span of a given system can be determined.

3.5.2 Life-Cycle Cost Analysis

The procedure of a Life-Cycle Cost Analysis (LCCA) may be defined as a systematic analytical process of evaluating various designs or alternative courses of action with the objective of choosing the best way to employ scarce resources. A typical engineering project (or system) development comprises four generic phases - concept, development (or procurement), implementation (or operation) and termination (or disposal). For different types of project development, these stages are usually broken down into stages specific to the industry or area of project application.

The process of LCCA estimation provides an economic insight into various cost components and identifies the specific information required to make alternative investments and management choices with the objective of minimising life-cycle costs.

The technical characteristics of a system (or product) will primarily dictate the output from the LCCA. The limitations of LCCA can be established through the definition of system performance constraints, operational requirements, the maintenance concept or advanced planning programmes. Each constraint might generate a different set of trade-offs. These trade-offs must be evaluated and weighted in alternative proposals. All feasible alternatives should be analysed and the most likely alternative selected for final evaluation.

3.5.3 Total system life-cycle cost

The detailed cost breakdown structure of the total system (product) life-cycle cost according to the four generic life-cycle phases is illustrated in **Table 4.**

Table 4: Total system (or product) life-cycle cost breakdown

Concept cost (c_c)	Procurement (c_p)	Operation Cost (c_o)	Disposal Cost (c_d)
• System management (Ccm) • System planning (Ccp) • System research (Ccr) • Engineering design (Cce) • Design documentation (Ccd) • System software (Ccs) • System testing (Cct)	• Construction management (Cpa) • Operational analysis (Cpo) • Manufacturing (Cpm) • Construction (Cps) • Quality control (Cps) • Logistic support (Cps)	• System LC management (Coa) • System operations (Coo) • System (product) distribution (Cod) • System maintenance & repair (Com) • Spares & material support (Coi) • Operate training (Cot) • Technical database (Cop) • System modification (Cou)	• System disposal (C_{ds}) • System items recycling (Cdr) • Retirement and documentation (C_{dd})

Source: Fabrycky and Blanchard (1991)

The following model can represent the total life-cycle cost:

$$TLCC \quad = \quad LC + LCC_O + LCC_m + LCC_{e\&d} \qquad (3.14)$$

Where:

	TLCC	=	Total life cycle costs
	LIC	=	Life cycle investment costs = ($LCC_C + LCC_P$)
	LCC_o	=	Life cycle operating energy costs = ($LCC_{oa} + LCC_{oo} + LCC_{oi} + LCC_{ot} + LCC_{op} + LCC_{ou}$)
	LCC_m	=	Life cycle maintenance and repair costs = (LCC_{om})
	$LCC_{e\&d}$	=	Environmental an disposal costs = ($LCC_{ds} + LCC_{dr} + LCC_{dd}$) + Reinstatement cost.

Traditionally, life cycle costing analysis of overall costs has suggested opportunities for realising substantial savings in operating and maintenance costs by making design changes involving relatively small increases in construction costs.

3.5.4 Planned and unplanned life-cycle costs

In recent years, the life cycle cost concept has been expanded to include system user costs in addition to the costs incurred exclusively by the owner (or developer) of a given system. User costs represent the social costs that are imposed on users when the serviceability of a system is reduced due to maintenance, rehabilitation and/or replacement works. The serviceability of large engineering systems will possibly be reduced by the effects of regular maintenance procedures, natural disasters (e.g. floods, storms, earthquakes) and even terrorist attack over their lifespan. Due to the uncertain nature of such events, system life-cycle costs assessment associated with such disasters is usually neglected in life-cycle costing.

The incorporation of natural hazards into life cycle costing needs to be considered in the context of planned and unplanned life cycle costs pertaining to both the owner (or developer) of the system and its users.

- **Planned costs.** Planned costs include expenditures and user costs related to the procurement and maintenance phases of the system's life span (i.e. capital costs and maintenance).

- **Unplanned costs.** Unplanned costs are those costs related to damages which can occur to a system primarily due to natural hazards or unexpected terrorist attack on a system or its key components.

Total life-cycle costs in an extended form are represented by:

$$TLCC = CPO + CPU + CUO + CUC \quad (3.15)$$

Where: TLCC	=	Total life-cycle costs
CPO	=	Planned costs incurred by the system owner/developer
CPU	=	User costs associated with CPO
CUO	=	Unplanned costs induced upon the owner/developer of a system
CUC	=	User costs associated with CUO.

In the main, planned and unplanned life-cycle costs estimation provides economic insight into the various cost components of a system and identifies the specific information required to make such estimates into the future. The unplanned life-cycle cost component relates to the estimating of the mechanical integrity of a system with regard to repair costs incurred due to natural hazards or unexpected terrorist attack upon a system.

3.6 Evaluation of restraints and externalities in planning

It should be noted that economic analysis is only useful as a decision-making tool if it is realistic and based on the pragmatic selection of all the relevant restraints and externalities that influence the development of water services (i.e. water supply and sanitation). Costs and benefits of both permanent or temporary restraints and externalities should be valued using a pragmatic and realistic assessment of realistic conditions and supported by experience and judgment, preferably separated from direct political influences. However, all technical and economic solutions must also be both socially and politically feasible.

To form a balanced view about the restraints and impacts relevant to the planning processes, risk and uncertainty are two key elements that feature prominently in economic analysis. The characteristics of economic development are influenced by various restraints and impacts, including natural, cultural, technical/ technological, political, socio-economic, financial, institutional, environmental and legal influences. Both direct and indirect restraints and externalities can influence both present and future water services development and management in various ways and magnitudes of impact. For that reason, they must be identified, evaluated, prioritised and incorporated into the benefit-cost analysis of alternative project development. Most relevant restraints and externalities to the water services sector are presented in the following paragraphs.

Table 5 summarises the most significant restraints and impacts on water services development and management that are applicable to any water services system in South Africa. Most of these restraints are external to the processes and activities of water services providers but, as much as they appear external, they still influence the system processes indirectly.

The magnitude (low, medium, high) of relevant restraints and externalities can be somewhat subjective to the decision-making process. However, the priority and magnitude of each externality can be tested by using techniques of multi-criteria decision analysis (e.g. scaling, scoring, evaluating, weighted averages). Within the context of economic analysis, the concept of externalities addresses those activities that create side-effects or trade-offs.

Externalities will typically relate to issues such as pollution, occupational risk, health and safety, as well as production processes involving employment, competitiveness, productivity, economic growth and energy savings. Externalities may be positive, negative or negligible.

The large number of factors inherent in a complex urban water services system requires the application of an analytical chain process. In this way, a large number of water services development constraints and impacts can be identified as criteria and grouped at different logic levels to form a hierarchical chain. This ranking is then used to evaluate the intensity of importance of the various factors.

Table 5: Summary of the most significant restraints and externalities in water services provision in South Africa.

Water services restraint/impact	Magnitude of restraint/impact			Consequences on water services (externalities)
	Low	Medium	High	
Stochastic distribution of precipitation			X	Uneven rainfall patterns/lack of drought management programmes
Highly variable temperatures, variable peak demands		X		Evaporation exceeding precipitation
High population growth rate/AIDS			X	High natural growth and unabated population influx, declining demand
Shortage of capital resources and institutional capacity			X	Competition between established and emerging communities
Culture of non-payment for services/low cost recovery			X	Non-sustainability in maintenance and expansion of infrastructure
Direct and indirect subsidisation		X		Least contributing users get largest share
Ongoing restructuring of local government, lack of capacity			X	Serious discontinuity in services and development
One WSP accounts for 97% of all water supplies		X		A pure monopoly of potable water supply
Fragmentation in management of metropolitan services		X		Lack of conjunctive management actions, *ad hoc* solutions
Absence of an overall master management plan		X		Crisis management approach to water services
Large volumes of water pumped over long distances and heads		X		Excessive demand for energy due to pumping heads
Inadequate water demand assessment methods and economic analysis			X	Inadequate methods affect capacity expansion and timing of development
Absence of economic analysis from established procedures			X	Selection of alternative project is based exclusively on costing analysis only
Lack of training capacity and suitable learning mechanisms			X	Slow and inadequate application of advanced technology
Water conservation and demand management principles overlooked		X		Effect of conservation not accounted for in capacity expansion
Inconsistent technology transfer and promotion		X		Changes in water technology overlooked or neglected
Absence of assets management at all levels of urban management		X		Non-methodical financial management, lack of optimisation incentives
Contaminated urban run-off and excessive pumping of mineralised mining water	X			Unattended urban hydrology problems

Note: WSP = Water Services Provider
Source: Barta (2000)

4 LEAST COST PLANNING FRAMEWORK IN WATER SERVICES

4.1 Conceptual Algorithm for Least Cost Planning

The conceptual algorithm for LCP was informed by lessons from other sectors, initiatives in the water sector and methodology presented by Johnson *et al* (2002). As indicated, LCP is recognised by its procedure rather by a universal definition. The LCP process is summarised in seven basic stages as illustrated in **Figure 5.**

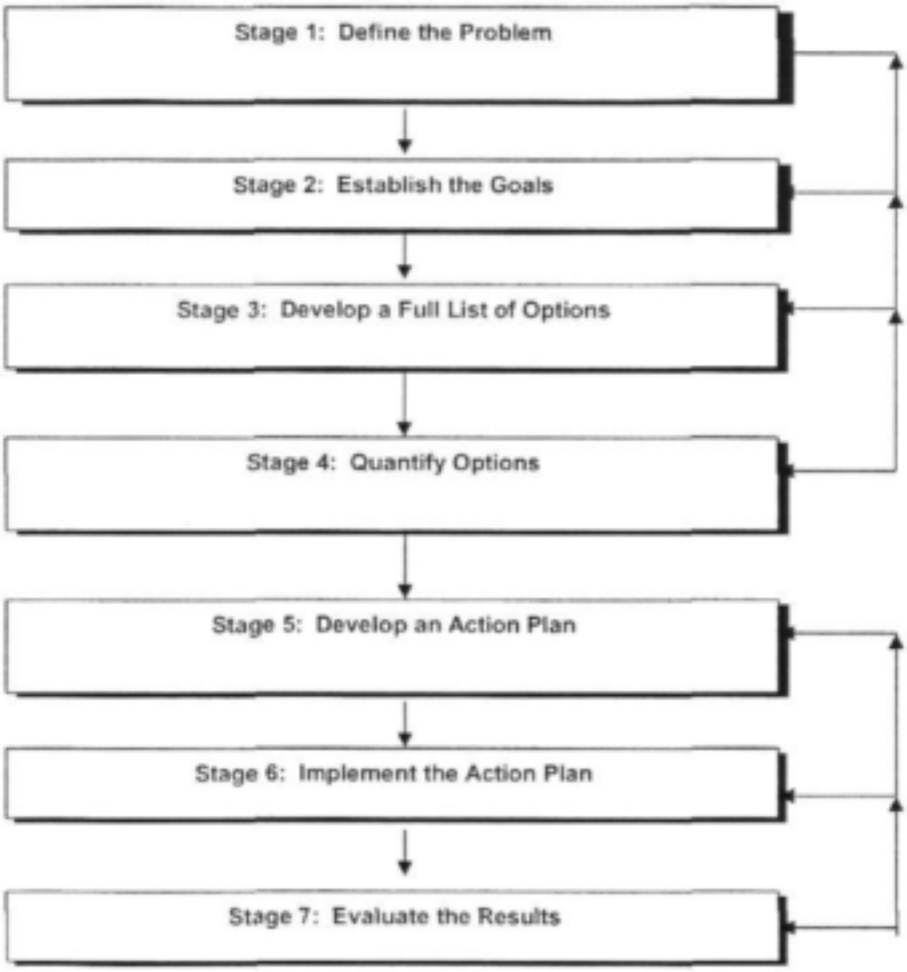

Figure 5: Least Cost Planning procedures (adapted from Mount Baker Region, 2000)

The details of each stage are:

Problem definition (Stage 1)

The LCP process starts with a clear upfront statement of the problem. The planner then identifies the specific characteristics of the problem at each location. The problem may also be defined by forecasting the customer's needs over time. There are different types of forecast - short-term, real-time or long-term - and correct selection will depend on the problem at hand. Generally, forecasts are made from past records and analyses of the current situation and relevant constraints. The planner then identifies the main contributing factors to the problem which can also be defined at different levels - national, regional or project. The planner will also identify the constraints associated with specifically resolving the problem.

Goals establishment (Stage 2)

The goals to be established relate directly to the problem at hand and should be defined to meet user needs. The planner should then formulate explicit objectives in qualitative terms and should not generally quantify the level of output or service to be provided. However, criteria must be established by which the achievement of each objective may be measured. National policy and planning will affect the objectives addressed in regional planning, which should focus on the economic development and environmental protection policies. These should be supplemented by provincial-level policies and should also influence the structuring of regional planning.

Options development (Stage 3)

The planner should develop alternative courses of action to achieve the goals and objectives effectively. Here, the full set of options should be reduced to those potential options which are relevant to the stated problem and which can be feasibly implemented. At the feasibility stage, the planner should examine one or more options that will be capable of meeting the objectives and comply with the identified constraints.

In selecting potential options, the LCP procedure could link into the comprehensive methodology developed by Johnson *et al* (2002). This methodology evaluates other related factors in more detail, including environmental, social and institutional issues. A comprehensive summary – as a flow diagram - of the methodology, indicating each step, sub-step, objective/goal, process and associated tool or method is given in **Figure 6.**

The feasibility stage can be regarded as a more detailed options assessment stage and requires high quality data for the analysis, costing and identification of the range of environmental and social impacts expected from the alternative options. The analysed options are then grouped into alternative plans.

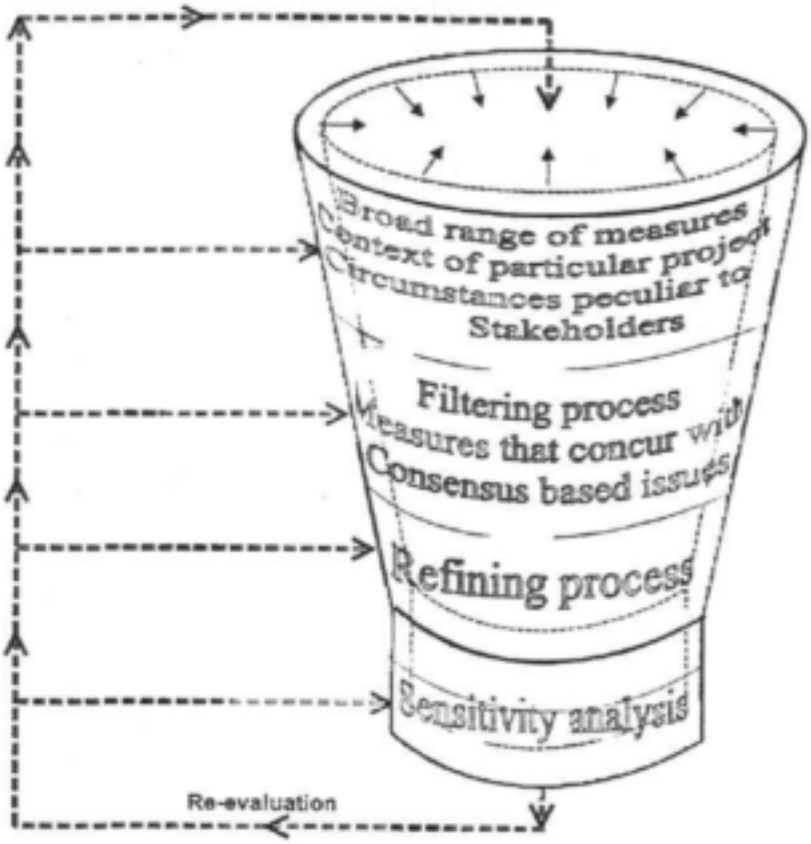

Figure 6: Funneling process (adapted from Johnson et al, 2002)

The focus of this stage is the selection of the most effective mix of options formulated during the previous stage. Selection is based on a comparison of the different options in terms of their financial and environmental benefits, their cost and the flexibility of these options in the uncertain future.

Quantify costs of options (Stage 4)

This stage involves the quantification of impacts and their valuation in terms of costs and benefits, and of the risks of the various options. The factors to be considered are:

Impacts on water demand or supply
Financial costs
Environmental costs and benefit
Changes in services-related welfare.

In many cases, these factors may be uncertain and risks not explicit. Ideally, this should involve some form of risk analysis, including the estimation of the likelihood that a particular impact will occur. The costs and benefits should be estimated for each year over the life cycle of the option, and a Net Present Value (NPV) of costs (net of benefits) is calculated for each option. **Figure 7** outlines a process of approaching a least cost option by showing how the various costs and benefits of the specific impacts of an option are quantified. The details of the various steps in the algorithm are:

Estimate financial costs

Each of the options will have associated financial costs, including:

Capital expenditure (Capex) – non-recurring costs, usually incurred towards the start of an option or programme

Operational expenditure (Opex) – costs incurred during the operation of the option or programme, which may be divided into *direct operating costs* (which vary with the size of the option or programme) and *overheads* (which are incurred regardless of the size of the option or programme).

Financial costs should be estimated for each year (or other designated time period) over the life of the option. The costs incurred by an option will vary according to the particular scenario being considered. For example, less-than-expected water saving from a water demand management programme could result in periodic supply shortfalls and additional water management costs, perhaps including the cost of additional publicity campaigns to counter adverse public reactions and additional water supply provision.

Alternative scenarios should be presented in a matrix, providing the financial costs incurred over the life of the option. It may be possible that, in the process of quantifying financial costs, options are identified that would breach the water manager's financial constraints. These options could then be eliminated.

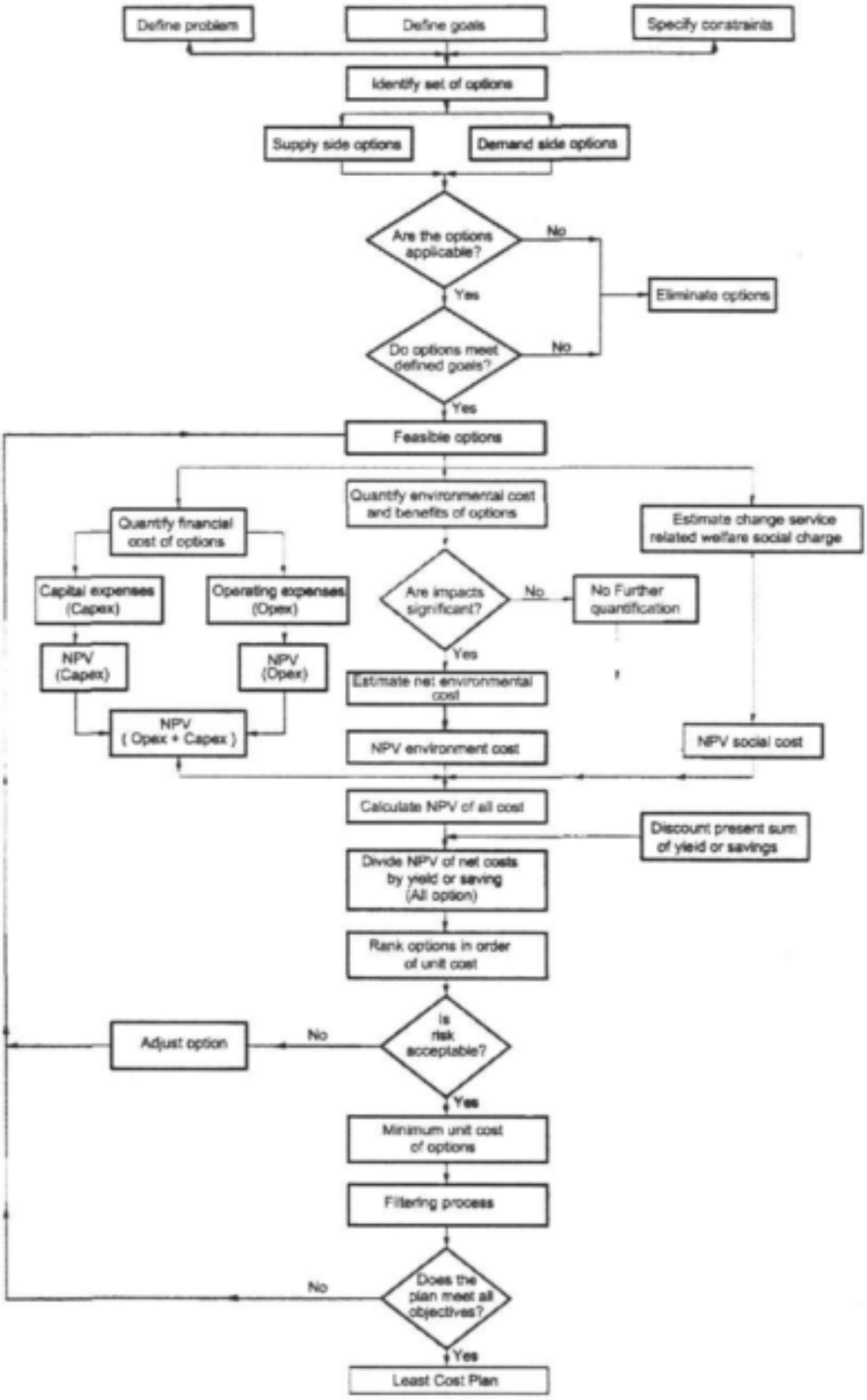

Figure 7:Least Cost Planning Process Algorithm

Estimate environmental costs and benefits

The main steps involved in quantifying environmental impacts, from identifying the impacts to quantifying them in physical terms and, finally, placing a monetary value on them, are summarised:

Identify likely impacts

The planner should consider the full range of potential environmental impacts and determine which are relevant for each option. It is usually helpful to classify the types of environmental impact in terms of both environmental receptors (e.g. air, water and other living creatures) and type of human activity (e.g. users, non-users). All stages of option implementation should be examined and both direct and indirect potential impacts should be considered, at least initially. Some indication should also be given at this stage as to whether the potential impacts will be included as costs or benefits for the purpose of the appraisal.

As with all other costs and benefits, there is little need to focus on impacts that are likely to be minimal. For example, it is not suggested that second-order effects such as impacts on global warming should be taken into account. There is a large element of professional judgment in determining which impacts are sufficiently significant to be quantified and which are not. In deciding which impacts to include, the significance of the impacts should be considered in the specific context of the problem (e.g. they may be significant at the local level but not at the national level). If there is doubt, assume that an impact may be significant and then quantify it further.

As a general rule, if the identified physical impacts are likely to breach any environmental laws or regulations or other environmental constraints to an unacceptable level of probability, then that option should not be considered further. If, however, these types of constraint are impeding the implementation of imaginative and realistic projects or programmes, then this should be pointed out to regulators with a view to beneficial changes to legislation and/or regulations.

Value the environmental impacts

In order to incorporate environmental impacts *directly* into an appraisal of options, it is necessary to place monetary values on those environmental impacts so that they can be compared with other types of impact such as the financial costs of a particular measure.

Economists have developed a number of different techniques for the valuation of environmental impacts. These techniques usually derive values for environmental impacts by assigning values from peoples' actual behaviour (revealed preference) or by asking people directly about how they value the environment (stated preference). Alternative valuation techniques are described in more detail by Jordan (1995).

In some circumstances, for example, where there are tight time constraints, a full valuation of environmental impacts are taken into consideration in the decision-making process in some other way. At the very least, the impacts should be described and, as far as possible, should be quantified in physical terms. A record of the assessment of impacts should be made and presented with the relevant option before any final decision on options is taken.

Quantify service-related welfare change

The welfare implications of changes in water services received by people may need to be established and included in the evaluation. Quantification of the welfare change for each relevant option will require an estimation of the demand curve for water and an estimation of the area under the curve for two cases:

The base case, where the volume of water enjoyed is unaffected by the proposed options, and the welfare quantum is the area under the demand curve to the left of that volume
The case for the option where the welfare quantum is the area under the demand curve to the left of the new volume of water enjoyed.

The welfare change resulting from implementation of the option is the difference between the two areas under the demand curve.

Calculate total NPV of costs and benefits

The costs and benefits of each option within a specified scenario can now be totalled over the life of the option. Since costs and benefits are incurred at different points in time, they must therefore be discounted. Discounting allows for the fact that people prefer to incur costs later in time and receive benefits sooner. Those costs and benefits that occur sooner in the life of an option are therefore given more weight than those costs and benefits that occur later in its life.

The discounted Net Present Value (NPV) of an option can be calculated as follows:

$$NPV_i = \sum_t Pv_{it} = \sum_t (B_{it}-C_{it})/(1+r)^{t-1}$$

NPV_i = Net present value of Option I,
Pv_{it} = Present value of Option I in Year t,
B_{it} = Benefits of Option I in Year t,
C_{it} = Costs of Option I in Year t,
R = percentage discount rate.

If the discount rate is expressed in real terms (i.e. not taking inflation into account), then costs and benefits should also be in real terms (by expressing future costs and benefits at today's prices).

Unit Costs (UCs) are derived as the ratio of Present Net Social Costs over Net Present Value of water savings or yields. The initial programme of options is then obtained by selecting options in order of their UCs, up to the point where supply and demand balance.

Examine whether risks can be reduced without cost

During the quantification process, it may be useful for planners to examine whether or not it is possible to reduce the potential risk of any of the considered options without incurring substantial additional cost. In this framework, it is generally assumed that the options considered are specified according to their most cost-effective and risk-minimising methods of implementation. However, it is possible that the quantification process could reveal scope for further reducing the costs of an option and/or reducing the uncertainty of an option at very little additional cost. For example, the "riskiness" of an option could be reduced by gathering additional information or by bringing forward the timing of the option (to allow more time for water savings to be achieved).

Once the feasible options and their impacts have been quantified, a first attempt can be made to derive an optimal solution – a final set of options in a definitive programme.

- **Implementation Action Plan (Stage 6)**

The adoption of LCP is a decisional milestone in the planning process, but it is not the end of the process as implementation still lies ahead. LCP serves as benchmark against which actual utility system performance can be measured.

- **Evaluate Results (Stage 7)**

During implementation of the latest LCP, ongoing evaluation of the effectiveness of the whole plan is useful. Evaluation should enable planners to know whether the goals established have been reached and if not, what corrections must be made. Monitoring of implementation is therefore critical to assure responsible agencies and participants in the planning process that the agreed steps have been carried out and objectives reached.

The LCP needs to be revised as conditions change and new information becomes available and reconfigured in the light of lessons learned from the implementation experience. The results are then combined with the new demand forecasts and the process begins again. All the steps mentioned above are then repeated and the LCP becomes a dynamical process.

4.2 LCP Hypothetical Example

A settlement of some 3 000 houses is supplied with water from a reservoir and abstraction from a nearby river. The population is estimated at five people per household with an average per capita consumption of 140 litres per day.

Problem statement

Due to expansion (an additional 500 houses) and increasing economic activity in the area, additional water supplies will be required over the next 4 to 5 years. The water supply is currently un-metered and high levels of loss (estimated at an average 80 litres per day per household) have been reported. The goal of the Water Services Authority (WSA) is to meet the growing demand by implementing water demand measures and/or considering supply augmentation within its financial capacity. The target is to achieve a capacity of 170 million litres per year within a period of five years.

Identify options

The WSA has an opportunity to select options from a checklist categorised as:

Water resources measurement
Distribution management
Consumer demand management
Return flow management.

The details of these options have been highlighted by Johnson *et al* (2002). The WSA explored and screened the options (following the process outlined in **Figure 6**) to meet the requirements. The filtering process resulted in selection of the following four feasible options:

Option A: Install water meters to all households; implement compulsory metering; introduce charges at a lower tariff rate (say R 0.23 per litre); promote WC/DM through education over a period.
Option B: Install water meters to all households; implement compulsory metering; introduce charges at a higher tariff rate (say R 0.39 per litre); promote WC/DM through education over a period.
Option C: Embark on water loss control measures; retrofitting; extensive educational campaign.
Option D: Augment abstracting additional supplies from the river; install new pipelines; build a new reservoir (scheme estimated at R 7 million).

Goal establishment

The challenge of the WSA is to decide on a mix of options (Least Cost Plan) to meet the capacity goal of 170 million litres per year within five years.

Quantity costs of options

The summary of available information and assumptions is given in **Table 6.**

Table 6 : Example - Information and assumptions

		Option A	Option B	Option C	Option D
Number of households		3 500	3 500	3 500	3 500
Total population		17 500	17 500	17 500	17 500
Average per capita consumption (ppc) in litres/day	l	140	140	140	140
Average water loss in litres/household/day	l	80	80	80	80
Consumption reduction after installation	%	10	15	10	0
Average water loss reduction after installation	%	30	40	50	0
Capacity of new augmentation in Ml/year	Ml	0	0	0	60
Capital expenditure:					
-per household	R	3 000	3 500	5 000	0
-per scheme	R	0	0	0	7 000 000
Operating expenditure:					
-treatment, pumping, replacement, management per kilolitre	R	0	0	0	3
-metering, billing, replacement	R	160.00	320.00	0	0
-educational campaign: household/year (first 6 years)	R	16.00	32.00	32	2
-education campaign: household/year (subsequent years)	R	8.00	8.00	10	1
Charges per litres	R	0.23	0.39	0	0
Environmental benefits:					
-due to avoided abstraction per kl/day of water saved	R	3 200	3 200	3 200	0
-due to reduced river flows per Ml/day of water abstracted	R	0	0	0	1 900
-due to new construction per Ml/day	R	0	0	0	900
Change in social welfare per person metered/day	R	22.24	43.00	0	0
Discount rate per annum	%	10	10	10	10

The assumptions contained in **Table 6** are subjected to the algorithm (**Figure 7**). The financial (capital and operating) cost of the four options are quantified and their NPV calculated. The net environment benefits are quantified, the change in service-related cost is estimated and the NPV of each is calculated. Further, the changes in service-related cost and NPV are calculated. The total NPV of all the costs is then calculated and divided by the discounted present sum of yield or savings to determine a unit cost of each option. The options are then ranked in order of increasing unit costs. The risk of each option is assessed. If the risk is unacceptable, the option is adjusted to suit or else discarded. In this case, all the options had an acceptable risk.

The calculations are provided in the spreadsheet in **Appendix A**. The spreadsheet contains 11 sub-sheets made up as follows:

Sheet 1: Assumption. All data and assumptions are captured in this sheet.

Sheets 2, 3, 4 and 5. Calculations. For each of the four options, A, B, C and D; the number of calculations could increase or decrease depending on the number of options selected.

Sheets 6, 7, 8 and 9. Summary reports. Options A, B, C and D.

Sheets 10 and 11. Comparison and ranking. The information from the report sheets is summarised, compared and ranked.

Result of analysis

It is evident from **Table 7** that there are a number of option combinations that will meet the capacity target of 170 Ml/year within five years. The combinations are:

Option A plus Option C will achieve target capacity by year 5.
Option A plus Option C plus Option D will achieve target capacity by year 4.
Option A plus Option D will achieve target capacity by year 5.
Option B plus Option C plus Option D will achieve target capacity by year 4.
Option B plus Option C will achieve target capacity by year 4.
Option B plus Option D will achieve target capacity by year 4.

Table 7: Summary of LCP results (ex spreadsheet)

	Year 1	Year 2	Year 3	Year 4	Year 5	....	Year 10	....	Year 20	....	Year 30	Unit Cost
Option A	12	24	49	97	115	....	115	....	115	....	115	**11.5**
Option B	17	33	66	133	158	....	156	....	158	....	158	**14.2**
Option C	6	11	23	46	55	....	55	....	55	....	55	**22.3**
Option D	0	0	60	60	60	....	60	....	60	....	60	**28.0**

WSA Objective: 170 Ml/year in 5 years

Programme 1 to Meet Objective
Water Savings or Supply Augmentation

Totals	Year 1	Year 2	Year 3	Year 4	Year 5	....	Year 10	....	Year 20	....	Year 30	Cost (million)
A	12	24	49	97	115	....	115	....	115	....	115	R 9.87
A+C	18	36	72	143	170	....	170	....	170	....	170	R 18.90
A+C+D	18	36	132	203	230	....	230	....	230	....	230	R 31.81
A+D	12	24	109	157	175	....	175	....	175	....	175	R 22.77

Programme 2 to Meet Objective
Water Savings or Supply Augmentation

Totals	Year 1	Year 2	Year 3	Year 4	Year 5	....	Year 10	....	Year 20	....	Year 30	Cost (million)
B	17	33	66	133	158	....	158	....	158	....	156	R 16.63
B+C	22	45	89	179	212	....	212	....	212	....	212	R 25.66
B+C+D	22	45	149	239	272	....	272	....	272	....	272	R 38.56
B+D	17	33	126	193	218	....	218	....	218	....	218	R 29.53

If the selected mixes of options are considered feasible and acceptable through the necessary participatory processes, then final selection will be made on the cost differentials between the options. In this example, the selected Least Cost Plan would be a combination of Option A and Option C because they meet the objective at the lowest cost.

5 SUMMARY AND CONCLUSIONS

With growing water demand, limited resources, financial constraints, environmental awareness and increasing public scrutiny, a paradigm shift in water planning in South Africa is inevitable. The key objective of this report was to explore the applicability of Least Cost Planning (LCP) in the water sector as it has been applied successfully to other sectors. Although some experience is transferable to the water sector, certain aspects of water supply are dramatically different from energy supply, in particular the electricity utilities.

The study traces the history of LCP and the adoption of a definition of LCP applicable to the water services of South Africa. Lessons were drawn from the various sectors and an overview of water services development identified key issues to be taken into account in the use of LCP. It was noted that, while planning approaches were similar, their process and treatment of various aspects, such as risk, varied.

The principles and process of economic evaluation in planning are examined and inherent restraints in economic planning highlighted. A conceptual LCP algorithm was presented and tested through a hypothetical example.

This report focuses on the evaluation of methodology for option identification and decision-making in water services development and enhancement. A detailed knowledge of end-uses, or customer consumption patterns, is a precondition for successful LCP programming, as suppliers should be able to target specific customer classes.

Although water is a renewable resource, making it different from other resources, natural and artificial constraints can still occur and can limit the quality required and the quantity available. Most natural resources are common to more than one user and the development and use of a particular water supply can affect the ability of others to develop and use that same supply. For example, upstream use can affect downstream use and contamination can render a water supply source useless.

When it is applied in the water sector, technical problems challenge the LCP approach. Unlike electricity utilities, water utilities are not physically interconnected and it may be difficult for the supplier to meet developing or changing demands quickly. The relatively low price of water in many areas may prove to be a disincentive for consumers to invest in demand-management measures. On the other hand, if consumers adopt "best practices" (e.g. water conservation), the water utilities may have difficulty meeting overall revenue requirements and covering their fixed costs under current tariff structures. This could be of particular concern because of the relatively high fixed costs and stable demand.

Similar to the electricity sector, the water sector is subject to seasonality of both supply and demand. Because water can be stored, seasonal variations are more relevant than daily or hourly variations. Certain load techniques used for electricity are therefore not applicable to the water sector. The regulatory structure of the water sector may create other limitations. Given the regulatory disincentives and the uncertain impact of demand management on revenues, some water services providers may be reluctant to implement efficiency programmes.

Unlike electricity, natural gas and transportation utilities, which have regional transmission networks, regional water systems are constrained by the limited application of economies of scale. For example, it is not generally cost-effective to move treated water over long distances. In any event, transporting water from one catchment to another is somewhat controversial. The competition among users can be intense and highly political. Water markets and trading may not be appropriate for developing countries. Pricing distortions currently exist because of the historical role of the government in water development. All these factors present a barrier to any proposals designed to achieve LCP.

Although limited, the application of LCP in the water sector was found to be encouraging. The financial viability of Water Demand Management was demonstrated by Rand Water through the use of LCP. LCP allowed Rand Water to combine all its component water services in its supply area, as though all of its water services were integrated into one body. This benefited the WSAs in the area as it allowed them to determine their water use inefficiencies and to target water losses. As a result, the LCP approach directly facilitated the avoidance of premature augmentation. In Cape Town, the LCP (or IRP) approached highlighted priority measures to deal with water shortages.

The planning of water services requires action by many role-players but, without coordinated frameworks for action, conflict-filled decision processes will be inevitable. The application of LCP in the water sector of South Africa is feasible and is supported by the legal framework. The successful application of LCP will require coordinated frameworks and an inclusive process.

Trans-boundary, or regional, water resource exploitation will be a great challenge to the LCP approach. An extended body of participants will be required in order to facilitate regular and effective communication.

The study recommends that the algorithm be tested through a "real life" case study with various stakeholders. Further research and study of LCP should be encouraged in order to quantify changes in both services-related welfare and environmental costs. The LCP approach should be communicated to as many interested parties as possible.

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APPENDIX A
LCP HYPOTHETICAL EXAMPLE

LEAST COST PLANNING EXAMPLE

	Option A	Option B	Option C	Option D	Units
Assumptions	Quantity	Quantity	Quantity	Quantity	
Total population	17500	17500	17500	17500	
People per household	5	5	5	5	
Number of household	3500	3500	3500	3500	
Average per capita consumption (ppc)	140	140	140	140	litres/day
Average water losses	80	80	80	80	litres/house/day
Reduction in average ppc after installation	10%	15%	10%	0%	
Average ppc after installation	126	119	126	140	litres/day
Average water losses after installation	55	55	35	0	litres/house/day
Capacity of augmentation scheme	0	0	0	60	Ml/year
Capital Expenditure					
- per household	R 3,000	R 3,500	R 5,000	R -	per household
- per scheme	R -	R -	R -	R 7,000,000	per scheme
Operating Expenditure					
- treatment, pumping, management, replacement	R -	R -	R -	R 3.00	per kl
- metering, billing, replacement	R 160.00	R 320.00	R -	R -	per metered connection/year
- education campaign	R 16.00	R 32.00	R 32.00	R 2.00	per house/year for first 6 years
	R 8.00	R 8.00	R 10.00	R 1.00	per house/year subsequently
Volumetric charge	R 0.23	R 0.39	R -	R -	per litre
Environmental benefits					
- due to avoided abstraction	R 3,200	R 3,200	R 3,200	R -	per kl/day of water saved
- due to reduced river flows	R -	R -	R -	R 1,900	per Ml/day of water abstracted
- due to new construction	R -	R -	R -	R 900	per Ml/day
Change in social welfare	R 23.00	R 43.00	R -	R -	per person metered/day
Discount Factor	10%	10%	10%	10%	per annum

LEAST COST PLANNING EXAMPLE

Option A - Compulsory metering (at lower rates) and education

Assumptions		Quantity																
Total population		17500		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Number of houses		3500		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Average per capita consumption (ppc)		140	litres/day	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Average customer leakage losses		80	litres/house/day	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reduction in average ppc after installation		10%		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Average per capita consumption after metering		126	litres/day	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Average water losses after installation		55	litres/house/day	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Capital Expenditure	R	3,000	per household	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Operating Expenditure				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- metering, billing, replacement	R	160.00	per metered connection/year	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
- education campaign	R	16.00	per house/year for first 6 years	16	16	16	16	16	16	1	1	1	1	1	1	1	1	1
	R	8.00	per house/year subsequently	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Volumetric charge	R	0.23	per litre	[illegible]	[illegible]	[illegible]	[illegible]	0.23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.23	[illegible]	0.23	0.23	[illegible]
Environmental benefits	R	3,200,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3E+06	3E+06
Change in social welfare	R	23.00	[illegible]	[illegible]	23	[illegible]	[illegible]	[illegible]	[illegible]	23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23	23	23

NPV calculation																	
Year			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Discount factor	10.0%	[illegible]	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%
Rate of return factor			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Description	Units	Discounted present sum of impacts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Present consumption	Ml/year		894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25
Present leakage losses	Ml/year		102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2
Meter penetration	% Households		10	20	40	80	95	95	95	95	95	95	95	95	95	95	95
Consumption (after metering)	Ml/year		885	876	858	823	809	809	809	809	809	809	809	809	809	809	809
Customer leakage (after metering)	Ml/year		99.0	95.8	89.4	76.7	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9
Total water saving	Ml/year		12	24	49	97	115	115	115	115	115	115	115	115	115	115	115
Discounted present sum of water savings	Ml	855	11.03	20.06	36.47	66.31	71.50	65.08	59.16	53.78	48.90	44.45	40.41	36.74	33.40	30.36	27.60
Financial Costs																	
Capex	R/Year		1050000	1050000	2100000	4200000	1575000	0	0	0	0	0	0	0	0	0	0
Opex - metering, billing, replacement	R/Year		56000	112000	224000	448000	532000	532000	532000	532000	532000	532000	532000	532000	532000	532000	532000
Opex - education campaign (< 6 years)	R/Year		56000	56000	56000	56000	56000	56000	3500	3500	3500	3500	3500	3500	3500	3500	3500
Total financial costs	R/Year		1162000	1218000	2380000	4704000	2163000	588000	535500	535500	535500	535500	535500	535500	535500	535500	535500
NPV of financial costs	Rmillion/Year	11.45	1056363.6	1006612	1788129	3212895	1343052.82	331910.671	274798.172	249814.702	227104.275	206458.431	187689.483	170626.803	155115.275	141014	128194
Environmental Costs																	
Net Costs (due to avoided abstraction)	R/Year		-106400	-212800	-425600	-851200	-1010800	-1010800	-1010800	-1010800	-1010800	-1010800	-1010800	-1010800	-1010800	-1E+06	-1E+06
Net Costs (due to construction of new link)	R/Year																
Net Costs (due to reduced river flows)	R/Year																
Costs of net benefits	R/Year		-106400	-212800	-425600	-851200	-1010800	-1010800	-1010800	-1010800	-1010800	-1010800	-1010800	-1010800	-1010800	-1E+06	-1E+06
NPV of environmental net costs	Rmillion/Year	-7.50	-96727.273	-175867.8	-319759.6	-581381.1	-627627.27	-570570.25	-518700.23	-471545.65	-428677.87	-389707.16	-354279.23	-322072.03	-292792.76	-266175	-241977
Social Costs																	
Total change in welfare	R/year		83950	167900	335800	671600	797525	797525	797525	797525	797525	797525	797525	797525	797525	797525	797525
NPV of social costs	Rmillion/Year	5.92	76318.182	138760.3	252291.5	458711.8	495200.278	450182.071	409256.428	372051.298	338228.453	307480.412	279527.647	254116.043	231014.584	210013	190921
NPV of costs net of benefits	Rmillion	9.87															
Discounted present sum of water savings	Ml	855															
Unit Cost Ratio	Rmillion/Ml	0.011543222															
Unit Cost Ratio	R/kl	11.54															

LEAST COST PLANNING EXAMPLE

Option B - Compulsory metering (at higher rates) and education

Assumptions		Quantity																	
Total population		17500			17500	17500	17500	17500	17500	17500	17500	17500	17500	17500	17500	17500	17500	17500	17500
Number of household		3500			3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
Average per capita consumption (ppc)		140	litres/day		140	140	140	140	140	140	140	140	140	140	140	140	140	140	140
Average water losses		80	litres/house/day		80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Reduction in average ppc after installation		15%			0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Average ppc after installation		119	litres/day		119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Average water losses after installation		55	litres/house/day		55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
Capital Expenditure	R	3,000	R	3,500	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Operating Expenditure					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- metering, billing, replacement	R	320	per metered connection/year		320	320	320	320	320	320	320	320	320	320	320	320	320	320	320
- education campaign	R	44	per house/year for first 6 years		44	44	44	44	44	44	1	1	1	1	1	1	1	1	1
	0 R	16	per house/year subsequently		16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Environmental benefits	R	0.39	per litre		0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Change in social welfare	R	3,200,000	per Ml/day of water saved		3200000	3200000	3200000	3200000	3200000	3200000	3200000	3200000	3200000	3200000	3200000	3200000	3200000	3E+06	3E+06
Discount Factor	R	43.00	per person metered/day		43	43	43	43	43	43	43	43	43	43	43	43	43	43	43

NPV calculation																
Ca																
Year			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Discount factor	10.00%	per annum	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%
Rate of return factor			0.9090909	0.8264463	0.7513148	0.6830135	0.62092132	0.56447393	0.51315812	0.46650738	0.42409762	0.38554329	0.35049935	0.31863082	0.28966438	0.2633	0.2394

Description	Units	Discounted present sum of impacts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Present Consumption	Ml/year		894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25
Present Customer-side leakage losses	Ml/year		102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2
Meter Presentation	% Households		10	20	40	80	95	95	95	95	95	95	95	95	95	95	95
Consumption (after new raw water supply)	Ml/year		881	867	841	787	767	767	767	767	767	767	767	767	767	767	767
Customer leakage (after new raw water supply)	Ml/year		99.0	95.8	89.4	76.7	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9
Total water saving	Ml/year		17	33	66	133	158	158	158	158	158	158	158	158	158	158	158
Discounted present sum of water savings	Ml	1170	15.10	27.46	49.81	90.75	97.96	89.06	80.96	73.60	66.91	60.83	55.30	50.27	45.70	41.55	37.77
Financial Costs																	
Capex	R/Year		1050000	1050000	2100000	4200000	1575000	0	0	0	0	0	0	0	0	0	0
Opex - metering, billing, replacement	R/Year		112000	224000	448000	896000	1064000	1064000	1064000	1064000	1064000	1064000	1064000	1064000	1064000	1E+06	1E+06
Opex - education campaign (< 6 years)	R/Year		154000	154000	154000	154000	154000	154000	3500	3500	3500	3500	3500	3500	3500	3500	3500
Total financial costs	R/Year		1316000	1428000	2702000	5250000	2793000	1218000	1067500	1067500	1067500	1067500	1067500	1067500	1067500	1E+06	1E+06
NPV of financial costs	Rmillion/Year	15.83	1196363.6	1180165.3	2030052.6	3585820.6	1734233.26	687529.347	547796.291	497986.628	452724.208	411587.461	374162.238	340138.398	309216.725	281106	255551
Environmental Costs																	
Net Costs (due to avoided abstraction)	R/Year		-145600	-291200	-582400	-1164800	-1383200	-1383200	-1383200	-1383200	-1383200	-1383200	-1383200	-1383200	-1383200	-1E+06	-1E+06
Net Costs (due to construction of new link)	R/Year																
Net Costs (due to reduced river flows)	R/Year																
Costs of net benefits	R/Year		-145600	-291200	-582400	-1164800	-1383200	-1383200	-1383200	-1383200	-1383200	-1383200	-1383200	-1383200	-1383200	-1E+06	-1E+06
NPV of environmental net costs	Rmillion/Year	-10.25	-132363.64	-240661.2	-437565.7	-795574.1	-858858.37	-780780.34	-709800.31	-645273.01	-586611.83	-533283.48	-484803.16	-440730.15	-400663.77	-364240	-331127
Social Costs																	
Total change in welfare	R/year		156950	313900	627800	1255600	1491025	1491025	1491025	1491025	1491025	1491025	1491025	1491025	1491025	1E+06	1E+06
Discounted NPV of social costs	Rmillion/Year	11.06	142681.82	259421.49	471675.43	857591.68	925809.216	841644.742	765131.583	695574.167	632340.151	574854.683	522595.168	475086.515	431896.832	392633	356940
Discounted NPV of costs net of benefits	Rmillion	16.63															
Discounted present sum of water savings	Ml	1170															
Unit Cost Ratio	Rmillion/Ml	0.014207307															
Unit Cost Ratio	R/kl	14.21															

LEAST COST PLANNING EXAMPLE

Option C - Retrofiting and education

Assumptions		Quantity																	
Total population		17500			17500	17500	17500	17500	17500	17500	17500	17500	17500	17500	17500	17500	17500	17500	17500
Number of household		3500			3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
Average per capita consumption (ppc)		140	litres/day		140	140	140	140	140	140	140	140	140	140	140	140	140	140	140
Average water losses		80	litres/house/day		80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Reduction in average ppc after installation		10%			0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Average ppc after installation		126	litres/day		126	126	126	126	126	126	126	126	126	126	126	126	126	126	126
Average water losses after installation		35	litres/house/day		35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Capital Expenditure	R	5,000	per household	R	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Operating Expenditure					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- metering, billing, replacement	R	-	per metered connection/year		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- education campaign	R	32	per house/year for first 6 years		32	32	[illegible]	[illegible]	[illegible]	[illegible]	1	1	1	1	1	1	1	1	1
	R	10	per house/year subsequently		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Volumetric charge	R	-	per litre		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Environmental benefits	R	3,200,000	per Ml/day of water saved		3200000	3200000	3200000	3200000	3200000	3200000	3200000	3200000	3200000	3200000	3200000	3200000	3200000	3E+06	3E+06
Change in social welfare	R	-	per person metered/day		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NPV calculation																
Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Discount factor	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%
Rate of return factor		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Description	Units	Discounted present sum of impacts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Present Consumption	Ml/year		894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25
Present Customer-side leakage losses	Ml/year		102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2	102.2
Target houses	% Households		10	20	40	80	95	95	95	95	95	95	95	95	95	95	95
Customer leakage (after retrofit)	Ml/year		96.5	90.7	79.2	56.2	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6
Total water saving	Ml/year		5.7	11.5	23.0	46.0	54.6	54.6	54.6	54.6	54.6	54.6	54.6	54.6	54.6	54.6	54.6
Discounted present sum of water savings	Ml	405	5.23	9.50	17.28	31.41	33.91	30.83	28.03	25.48	23.16	21.06	19.14	17.40	15.82	14.38	13.07
Financial Costs																	
Capex	R/Year		1750000	1750000	3500000	7000000	2625000	0	0	0	0	0	0	0	0	0	0
Opex - metering, billing, replacement	R/Year		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Opex - education campaign (< 6 years)	R/Year		112000	112000	112000	112000	112000	112000	3500	3500	3500	3500	3500	3500	3500	3500	3500
Total financial costs	R/Year		1862000	1862000	3612000	7112000	2737000	112000	3500	3500	3500	3500	3500	3500	3500	3500	3500
NPV of financial costs	Rmillion/Year	12.58	1692727.273	1538843	2713749.1	4857591.7	1699461.7	63221.08	1796.0534	1632.7758	1484.3417	1349.4015	1226.7286	1115.2079	1013.8253	921.66	837.87
Environmental Costs																	
Net Costs (due to avoided abstraction)	R/Year		-50400	-100800	-201600	-403200	-478800	-478800	-478800	-478800	-478800	-478800	-478800	-478800	-478800	-5E+05	-5E+05
Net Costs (due to construction of new link)	R/Year																
Net Costs (due to reduced river flows)	R/Year																
Costs of net benefits	R/Year		-50400	-100800	-201600	-403200	-478800	-478800	-478800	-478800	-478800	-478800	-478800	-478800	-478800	-5E+05	-5E+05
NPV of environmental net costs	Rmillion/Year	-3.55	-45818.18182	-83305.79	-151465.1	-275391	-297297.1	-270270.1	-245700.1	-223363.7	-203057.9	-184598.1	-167816.5	-152560.4	-138691.3	-1E+05	-1E+05
Social Costs																	
Total change in welfare	R/year		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NPV of social costs	Rmillion/Year	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NPV of costs net of benefits	Rmillion	9.03															
Discounted present sum of water savings	Ml	405															
Unit Cost Ratio	Rmillion/Ml	0.022292627															
Unit Cost Ratio	R/kl	22.29															

LEAST COST PLANNING EXAMPLE

Option D - Suppy Augmentation

Assumptions		Quantity		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Total population		17500		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Number of households		3500		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Average per capita consumption (ppc)		140	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Average water losses		80	[illegible]															
Reduction in average ppc after installation		0.0%																
Average water losses after installation		0	[illegible]															
Capacity of augmentation scheme		60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Capital Expenditure	R	7,000,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Operating Expenditure																		
- treatment, pumping, management, replacement	R	3.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
- education campaign	R	2.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Volumetric charge	R	-	[illegible]															
Environmental benefits																		
- due to reduced river flows	R	693,500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
- due to new construction	R	328,500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]									
Change in social welfare	R	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

NPV calculation			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Year			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Discount factor	10.0%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rate of return factor			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Description	Units	Discounted present sum of impacts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Present Consumption	Ml/year		894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25	894.25
Increased supply	Ml/year		0	0	60	60	60	60	60	60	60	60	60	60	60	60	60
Consumption (after new raw water supply)	Ml/year		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Customer leakage (after new raw water supply)	Ml/year		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total water saving or increased supply	Ml/year		0	0	60	60	60	60	60	60	60	60	60	60	60	60	60
Discounted present sum of water savings	**Ml**	**451**	**0.00**	**0.00**	**45.08**	**40.98**	**37.26**	**33.87**	**30.79**	**27.99**	**25.45**	**23.13**	**21.03**	**19.12**	**17.38**	**15.80**	**14.36**
Financial Costs																	
Capex - new link	R/Year		R 4,900,000	R 1,400,000	R 700,000	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -
Opex - treatment and pumping	R/Year		R -	R -	R 180,000	R 180,000	R 180,000	R 180,000	R 180,000	R 180,000	R 180,000	R 180,000	R 180,000	R 180,000	R 180,000	R 180,000	R 180,000
Opex - education campaign (< 6 years)	R/Year		R 7,000.00	R 7,000.00	R 7,000.00	R 7,000.00	R 7,000.00	R 7,000.00	R -	R -	R -	R -	R -	R -	R -	R -	R -
Total financial costs	R/Year		R 4,907,000	R 1,407,000	R 887,000	R 187,000	R 187,000	R 187,000	R 180,000	R 180,000	R 180,000	R 180,000	R 180,000	R 180,000	R 180,000	R 180,000	R 180,000
NPV of financial costs	**R million/Year**	**7.33**	**R 4,460,909**	**R 1,162,810**	**R 666,416**	**R 127,724**	**R 116,113**	**R 105,557**	**R 92,368**	**R 83,971**	**R 76,338**	**R 69,398**	**R 63,089**	**R 57,354**	**R 52,140**	**R 47,400**	**R 43,091**
Environmental Costs																	
Net Costs (due to avoided abstraction)	R/Year		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Net Costs (due to construction)	R/Year		R 526,500	R 197,100	R 98,550												
Net Costs (due to reduced river flows)	R/Year		R -	R -	R -	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500
Costs of net benefits	R/Year		R 526,500	R 197,100	R 98,550	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500	R 693,500
NPV of costs net of benefits	**R million/Year**	**5.31**	**238636.3636**	**162892.562**	**74042.07361**	**473669.8315**	**430608.9379**	**391462.6708**	**355876.108**	**323522.8662**	**294111.7085**	**267374.2712**	**243067.5195**	**220970.4721**	**200882.2478**	**182620.2249**	**166018.3862**
Social Costs																	
Total change in welfare	R/year		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NPV of social costs	**R million/Year**	**0.00**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Discounted NPV of costs net of benefits	R million	12.60															
Discounted present sum of water savings	Ml	451															
Unit Cost Ratio	R million/Ml	0.027951598															
Unit Cost Ratio	**R/kl**	**28.0**															

LEAST COST PLANNING EXAMPLE

Option A - Summary and Report

Description	Units	Discounted present sum of impacts	1	2	3	4	5	...	10	...	20	...	30
Present consumption	Ml/year	0	894.25	894.25	894.25	894.25	894.25	...	894.25	...	894.25	...	894.25
Present leakage losses	Ml/year	0	102.2	102.2	102.2	102.2	102.2	...	102.2	...	102.2	...	102.2
Meter penetration	% Households	0	10	20	40	80	95	...	95	...	95	...	95
Consumption (after metering)	Ml/year	0	885	876	858	823	809	...	809	...	809	...	809
Customer leakage (after metering)	Ml/year	0	99.0	95.8	89.4	76.7	71.9	...	71.9	...	71.9	...	71.9
Total water saving	Ml/year	0	12	24	49	97	115	...	115	...	115	...	115
Discounted present sum of water savings	Ml	855	11.03	20.06	36.47	66.31	71.69	...	44.45	...	17.14	...	6.61
Financial Costs													
Capex	R/Year	0	1050000	1050000	2100000	4200000	1575000	...	0	...	0	...	0
Opex - metering, billing, replacement	R/Year	0	56000	112000	224000	448000	532000	...	532000	...	532000	...	532000
Opex - education campaign (< 6 years)	R/Year	0	56000	56000	56000	56000	56000	...	3500	...	3500	...	3500
Total financial costs	R/Year	0	1162000	1218000	2380000	4704000	2163000	...	535500	...	535500	...	535500
0													
NPV of financial costs	Rmillion/Year	11.45	1056364	1006612	1788129	3212895	1343053	...	206458	...	79599	...	30689
Environmental Costs													
Net Costs (due to avoided abstraction)	R/Year	0	-106400	-212800	-425600	-851200	-1010800	...	-1010800	...	-1010800	...	-1010800
Net Costs (due to construction of new link)	R/Year	0	0	0	0	0	0	...	0	...	0	...	0
Net Costs (due to reduced river flows)	R/Year	0	0	0	0	0	0	...	0	...	0	...	0
Costs of net benefits	R/Year	0	-106400	-212800	-425600	-851200	-1010800	...	-1010800	...	-1010800	...	-1010800
NPV of environmental net costs	Rmillion/Year	-7.50	-96727	-175868	-319760	-581381	-627627	...	-389707	...	-150249	...	-57927
Social Costs	0	0	0	0	0	0	0	...	0	...	0	...	0
Total change in welfare	R/year	0	83950	167900	335800	671600	797525	...	797525	...	797525	...	797525
NPV of social costs	Rmillion/Year	5.92	76318	138760	252292	458712	495200	...					
NPV of costs net of benefits	Rmillion	9.87											
Discounted present sum of water savings	Ml	855											
Unit Cost Ratio	Rmillion/Ml	0.011543222											
Unit Cost Ratio	R/kl	**11.54**											

LEAST COST PLANNING EXAMPLE

Option B - Summary and Report

Description	Units	Discounted present sum of impacts	1	2	3	4	5	...	10	...	20	...	30
Present Consumption	Ml/year	0	894.25	894.25	894.25	894.25	894.25	...	894.25	...	894.25	...	894.25
Present Customer-side leakage losses	Ml/year	0	102.2	102.2	102.2	102.2	102.2	...	102.2	...	102.2	...	102.2
Meter Presentation	% Households	0	10	20	40	80	95	...	95	...	95	...	95
Consumption (after new raw water supply)	Ml/year	0	881	867	841	787	767	...	767	...	767	...	767
Customer leakage (after new raw water supply)	Ml/year	0	99.0	95.8	89.4	76.7	71.9	...	71.9	...	71.9	...	71.9
Total water saving	Ml/year	0	17	33	66	133	158	...	158	...	158	...	158
Discounted present sum of water savings	Ml	1170	15.10	27.45	49.91	90.75	97.96	...	60.83	...	23.46	...	9.04
Financial Costs													
Capex	R/Year	0	1050000	1050000	2100000	4200000	1575000	...	0	...	0	...	0
Opex - metering, billing, replacement	R/Year	0	112000	224000	448000	896000	1064000	...	1064000	...	1064000	...	1064000
Opex - education campaign (< 6 years)	R/Year	0	154000	154000	154000	154000	154000	...	3500	...	3500	...	3500
Total financial costs	R/Year	0	1316000	1428000	2702000	5250000	2793000	...	1067500	...	1067500	...	1067500
NPV of financial costs	Rmillion/Year	15.83	1196364	1180165	2030053	3585821	1734233	...	411567	...	158677	...	61177
Environmental Costs													
Net Costs (due to avoided abstraction)	R/Year	0	-145600	-291200	-582400	-1164800	-1383200	...	-1383200	...	-1383200	...	-1383200
Net Costs (due to construction of new link)	R/Year	0	0	0	0	0	0	...	0	...	0	...	0
Net Costs (due to reduced river flows)	R/Year	0	0	0	0	0	0	...	0	...	0	...	0
Costs of net benefits	R/Year	0	-145600	-291200	-582400	-1164800	-1383200	...	-1383200	...	-1383200	...	-1383200
NPV of environmental net costs	Rmillion/Year	-10.26	-132364	-240661	-437566	-795574	-858858	...	-533283	...	-205604	...	-79269
Social Costs	0	0	0	0	0	0	0	...	0	...	0	...	0
Total change in welfare	R/year	0	156950	313900	627800	1255600	1491025	...	1491025	...	1491025	...	1491025
Discounted NPV of social costs	Rmillion/Year	11.06	142682	259421	471675	857592	925809	...		...		...	
Discounted NPV of costs net of benefits	Rmillion	16.63											
Discounted present sum of water savings	Ml	1170											
Unit Cost Ratio	Rmillion/Ml	0.014207307											
Unit Cost Ratio	R/kl	**14.21**											

LEAST COST PLANNING EXAMPLE

Option C - Summary and Report

Description	Units	Discounted present sum of impacts	1	2	3	4	5	...	10	...	20	...	30
Present Consumption	Ml/year	0	894.25	894.25	894.25	894.25	894.25	...	894.25	...	894.25	...	894.25
Present Customer-side leakage losses	Ml/year	0	102.2	102.2	102.2	102.2	102.2	...	102.2	...	102.2	...	102.2
Target houses	% Households	0	10	20	40	80	95	...	95	...	95	...	95
Customer leakage (after retrofit)	Ml/year	0	96.5	90.7	79.2	56.2	47.6	...	47.6	...	47.6	...	47.6
Total water saving	Ml/year	0	6	11	23	46	55	...	55	...	55	...	55
Discounted present sum of water savings	Ml	405	5.23	9.50	17.28	31.41	33.91	...	21.06	...	8.12	...	3.13
Financial Costs													
Capex	R/Year	0	1750000	1750000	3500000	7000000	2625000	...	0	...	0	...	0
Opex - metering, billing, replacement	R/Year	0	0	0	0	0	0	...	0	...	0	...	0
Opex - education campaign (< 6 years)	R/Year	0	112000	112000	112000	112000	112000	...	3500	...	3500	...	3500
Total financial costs	R/Year	0	1862000	1862000	3612000	7112000	2737000	...	3500	...	3500	...	3500
0													
NPV of financial costs	Rmillion/Year	12.58	1692727	1538843	2713749	4857592	1699462	...	1349	...	520	...	201
Environmental Costs													
Net Costs (due to avoided abstraction)	R/Year	0	-50400	-100800	-201600	-403200	-478800	...	-478800	...	-478800	...	-478800
Net Costs (due to construction of new link)	R/Year	0	0	0	0	0	0	...	0	...	0	...	0
Net Costs (due to reduced river flows)	R/Year	0	0	0	0	0	0	...	0	...	0	...	0
Costs of net benefits	R/Year	0	-50400	-100800	-201600	-403200	-478800	...	-476800	...	-478800	...	-478800
NPV of environmental net costs	Rmillion/Year	-3.55	-45818	-83306	-151465	-275391	-297297	...	-184598	...	-71171	...	-27439
Social Costs	0	0	0	0	0	0	0	...	0	...	0	...	0
Total change in welfare	R/year	0	0	0	0	0	0	...	0	...	0	...	0
NPV of social costs	Rmillion/Year	0.00	0	0	0	0	0	...		...		...	
NPV of costs net of benefits	Rmillion	9.03											
Discounted present sum of water savings	Ml	405											
Unit Cost Ratio	Rmillion/Ml	0.022292627											
Unit Cost Ratio	R/kl	**22.29**											

LEAST COST PLANNING EXAMPLE

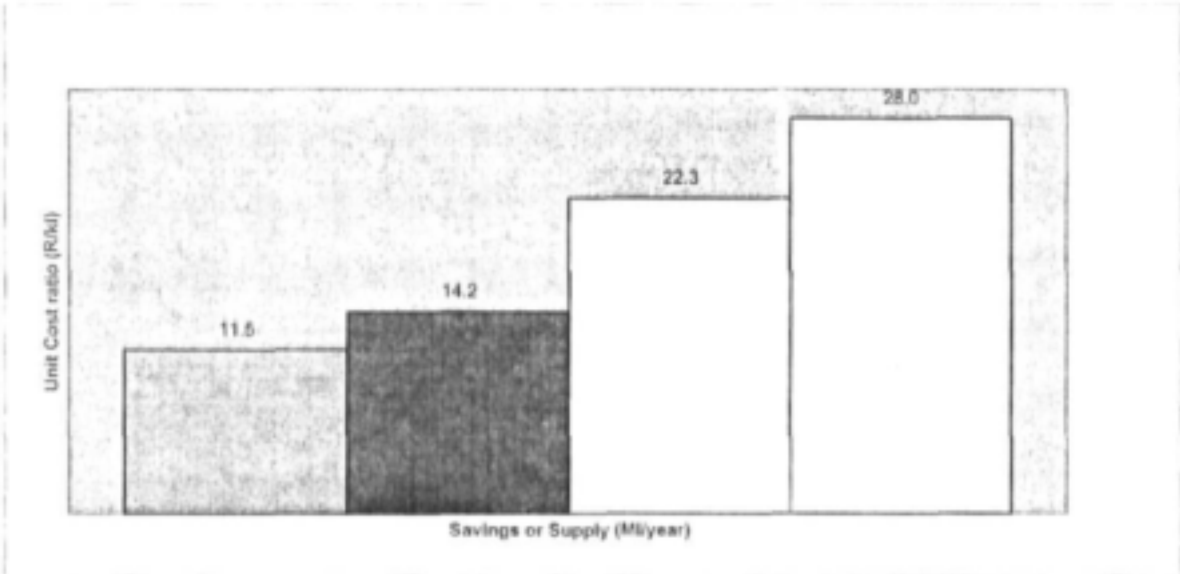
Option D - Summary and Report

Description	Units	Discounted present sum of impacts	1	2	3	4	5	...	10	...	20	...	30
Present Consumption	Ml/year	0	894.25	894.25	894.25	894.25	894.25	...	894.25	...	894.25	...	894.25
Increased supply	Ml/year	0	0	0	60	60	60	...	60	...	60	...	60
Consumption (after new raw water supply)	Ml/year	0	0	0	0	0	0	...	0	...	0	...	0
Customer leakage (after new raw water supply)	Ml/year	0	0.0	0.0	0.0	0.0	0.0	...	0.0	...	0.0	...	0.0
Total water saving or increased supply	Ml/year	0	0	0	60	60	60	...	60	...	60	...	60
Discounted present sum of water savings	Ml	461	0.00	0.00	45.08	40.98	37.26	...	23.13	...	8.92	...	3.44
Financial Costs													
Capex - new link	R/Year	0	4900000	1400000	700000	0	0	...	0	...	0	...	0
Opex - treatment and pumping	R/Year	0	0	0	180000	180000	180000	...	180000	...	180000	...	180000
Opex - education campaign (< 6 years)	R/Year	0	7000	7000	7000	7000	7000	...	0	...	0	...	0
Total financial costs	R/Year	0	4907000	1407000	887000	187000	187000	...	180000	...	180000	...	180000
0													
NPV of financial costs	Rmillion/Year	7.55	4460909	1162810	660416	127724	116112	...	69398	...	26756	...	10316
Environmental Costs													
Net Costs (due to avoided abstraction)	R/Year	0	0	0	0	0	0	...	0	...	0	...	0
Net Costs (due to construction)	R/Year	0	328500	197100	98550	0	0	...	0	...	0	...	0
Net Costs (due to reduced river flows)	R/Year	0	0	0	0	693500	693500	...	693500	...	693500	...	693500
Costs of net benefits	R/Year	0	328500	197100	98550	693500	693500	...	693500	...	693500	...	693500
NPV of costs net of benefits	Rmillion/Year	5.35	298636	162893	74042	473670	430609	...	267374	...	103084	...	39743
Social Costs	0	0	0	0	0	0	0	...	0	...	0	...	0
Total change in welfare	R/year	0	0	0	0	0	0	...	0	...	0	...	0
NPV of social costs	Rmillion/Year	0.00	0	0	0	0	0	...		...		...	
Discounted NPV of costs net of benefits	Rmillion	12.90											
Discounted present sum of water savings	Ml	461											
Unit Cost Ratio	Rmillion/Ml	0.027955396											
Unit Cost Ratio	R/kl	**27.96**											

LEAST COST PLANNING EXAMPLE

Option Comparison

Description	Option A	Option B	Option C	Option D
Discounted present sum of impacts				
Discounted present sum of water savings	855	1170	405	461
NPV of financial costs	11.45	15.83	12.58	7.55
NPV of costs net of benefits	-7.50	-10.26	-3.55	5.35
NPV of social costs	5.92	11.06	0.00	0.00
Total costs net of benefits - Rmillion	9.87	16.63	9.03	12.90
Discounted present sum of water savings or yield - Ml	855.28	1170.39	405.13	461.48
Unit Cost Ratio R/kl	**11.6**	**14.2**	**22.3**	**28.0**



LEAST COST PLANNING EXAMPLE

Selection of Least Cost Programme

Water Savings or Supply Augmentation

	Year 1	Year 2	Year 3	Year 4	Year 5	...	Year 10	...	Year 20	...	Year 30	Unit Cost
Option A	12	24	49	97	115	...	115	...	115	...	115	**11.5**
Option B	17	33	66	133	158	...	158	...	158	...	158	**14.2**
Option C	6	11	23	46	55	...	55	...	55	...	55	**22.3**
Option D	0	0	60	60	60	...	60	...	60	...	60	**28.0**

Option A	**11.5**	1	A
Option B	**14.2**	2	B
Option C	**22.3**	3	C
Option D	**28.0**	4	D

WSA Objective	170	Ml/year	in 5 years

Programme 1 to Meet Objective

Water Savings or Supply Augmentation

Totals	Year 1	Year 2	Year 3	Year 4	Year 5	...	Year 10	...	Year 20	...	Year 30	Cost (million)	
A	12	24	49	97	115	...	115	...	115	...	115	R	9.87
A+C	18	36	72	143	170	...	170	...	170	...	170	R	18.90
A+C+D	18	36	132	203	230	...	230	...	230	...	230	R	31.81
A+D	12	24	109	157	175	...	175	...	175	...	175	R	22.77

Programme 2 to Meet Objective

Water Savings or Supply Augmentation

Totals	Year 1	Year 2	Year 3	Year 4	Year 5	...	Year 10	...	Year 20	...	Year 30	Cost (million)	
B	17	33	66	133	158	...	158	...	158	...	158	R	16.63
B+C	22	45	89	179	212	...	212	...	212	...	212	R	25.66
B+C+D	22	45	149	239	272	...	272	...	272	...	272	R	38.56
B+D	17	33	126	193	218	...	218	...	218	...	218	R	29.53

Programme 3 to Meet Objective

Water Savings or Supply Augmentation

Totals	Year 1	Year 2	Year 3	Year 4	Year 5	...	Year 10	...	Year 20	...	Year 30	Cost (million)	
C	6	11	23	46	55	...	55	...	55	...	55	R	9.03
C+D	6	11	83	106	115	...	115	...	115	...	115	R	21.93

APPENDIX B
WC/WDM PILOT STUDIES

The pilot study sheets have been split into the following:

Effective Distribution and Operation

Reference	Study Details	Source of Information	Comments
A1: Creation of Management Zones			
A2: Monitoring of Unaccounted-for water in each zone			
A2-01	Ga-Rankuwa : Rand Water	IUCN Report	Incomplete Information
A2-02	Kimberley Municipality	IUCN Report/Kimberley Municipality	Minimal Information
A2-03	Greater Bloemfontein LC/Mangaung Local Municipality	IUCN Report/ Greater Bloemfontein LC/Mangaung Local Municipality	Project in progress
A2-04	Greater Hermanus	IUCN Report/Overstrand	Incomplete Information
A2-05	ODI Retail Water	IUCN Report/Stewart Scott	Incomplete Information
A2-06	Rustenburg Pilot Project	IUCN Report/Stewart Scott	Incomplete Information
A3: Pressure Management			
A3-01	East London	WRP Pty Ltd	Project in progress
A3-02	Johannesburg	WRP Pty Ltd	6 month payback
A3-03	Tembisa TLC	WRP Pty Ltd	Project in progress
A3-04	Khayelitsha	WRP Pty Ltd	Project in progress
A3-05	Klerksdorp	WRP Pty Ltd	No Information available
A3-06	Pretoria	WRP Pty Ltd	No Information available
A3-07	Oostenberg	WRP Pty Ltd	No Information available
A3-08	Krugersdorp Town Council/Kagiso	Mahlota City Local Municipality	Incomplete Information
A3-09	Slovoville and Albertsville	WRP Pty Ltd	Incomplete Information
A3-10	Umgeni Water Supply Area	IUCN Report/Umgeni Water	Project not started
A3-11	Leeukop Prison	Pressure management Systems	
A4: Management Meters			
A4-01	Greater Bloemfontein LC/Mangaung Local Municipality	IUCN Report/Greater Bloemfontein LC/Mangaung Local Municipality	Incomplete Information
A4-02	East London City/Buffalo City Municipality	IUCN Report/ East London City/Buffalo City Municipality	Incomplete Information
A4-03	Kimberley Municipality	IUCN Report/Kimberley Municipality	Project in Progress
A4-04	South Coast KZN	IUCN Report	Minimal Information
A4-05	Tlhabane: Rand Water	IUCN Report/Rand Water	Incomplete Information
A5: Consumer Meters			
A5-02	East London City/Buffalo City Municipality	IUCN Report/ East London City/Buffalo City Municipality	Incomplete Information
A5-03	Krugersdorp Town Council/Kagiso	IUCN Report/Mahlota City Local Municipality	Incomplete Information
A5-04	Motherwell Water Loss Investigation	IUCN Report/Nelson Mandela Municipality	Incomplete Information
A5-05	UMzinyathi/Thukela Regional Council	IUCN Report/AquaManzi	Incomplete Information
A6: Mains Replacement			

A7: Active and Passive Leakage Control			
A7-01			
A7-02	Ga-Rankuwa : Rand Water	IUCN Report	Incomplete Information
A7-03	Greater Bloemfontein LC/Mangaung Local Municipality	IUCN Report/Greater Bloemfontein LC/Mangaung Local Municipality	Incomplete Information
A7-04	East London City/Buffalo City Municipality	IUCN Report/ East London City/Buffalo City Municipality	Incomplete Information
A7-05	Motherwell Water Loss Investigation	IUCN Report/Nelson Mandela Municipality	Incomplete Information
A7-06	Boksburg	IUCN Report/Rand Water	Minimal Information

B1: Retrofitting and Removal of Wasteful Devices			
B1-01			
B1-02	Sebokeng/Thembisa	IUCN Report/Rand Water	Incomplete Information
B1-03	Kgiso Siyong'Amanzi	IUCN Report/Rand Water	Incomplete Information
B1-04			
B1-05	Boksburg	IUCN Report/Rand Water	Minimal Information
B1-06			
B1-07			
B1-08			
B1-09	Greater Hermanus	IUCN Report/Overstrand	Incomplete Information
B1-10	Inner City: Rand Water	Rand Water/Inner City	Incomplete Information
B1-11	Mpumalanga	Stewart Scott	Minimal Information
B1-12	New Homes: Rand Water/Eskom	Rand Water	Incomplete Information
B2: Recycling of waste effluent			
B3: Grey Water Use			
B3-01	New Homes: Rand Water/Eskom	Rand Water	Minimal Information
B4: Tariff Structures and Billing Procedures			
B4-01	Durban Metro	IUCN Report/Durban Metro Water Services	Minimal Information
B4-02	*Greater Hermanus*	*IUCN Report/Overstrand*	*Minimal Information*
B4-03	Rustenburg Pilot Project	IUCN Report/Stewart Scott	Incomplete Information
B5: General Education and Public Involvement			
B5-01	Greater Hermanus	IUCN Report/Overstrand	Incomplete Information
B5-02	Sebokeng/Thembisa	IUCN Report/Rand Water	Incomplete Information
B5-03	ODI Retail Water	IUCN Report/Stewart Scott	Incomplete Information
B6: Payment for Water and Illegal Use			
B7: Schools Education Campaigns			
B7-01	Greater Hermanus	IUCN Report/Overstrand	Incomplete Information
B8: Legislation			
B8-01	Greater Hermanus	IUCN Report/Overstrand	Minimal Information
C1: Water Audits			
C1-01	Rustenburg Pilot Project	IUCN Report/Stewart Scott	Incomplete Information
C3: Reconciling Water Meters			
C3-01	Rustenburg Pilot Project	IUCN Report/Stewart Scott	Incomplete Information

Greater Bloemfontein LC/Mangaung Local Municipality Information from: IUCN report- Water conservation & water demand management in SA: Case study analysis Interview with the Assistant City Engineer, Greater Bloemfontein Local Council	**A2-03** Monitoring unaccounted for Water in each zone

PROJECT DESCRIPTION

General Details:

This initiative was part of a project whose objectives were:

- To actively reduce unaccounted for water to an acceptable level.
- To set up a management system that will enable the service provider to effectively manage the water distribution network in the long term.

. The following initiatives on monitoring unaccounted for water in zones were implemented:

- Installation of zone meters.
- Installation of automated data loggers
- Replacement of faulty meters
- Use of statistical methods to isolate problem areas
- Follow up on meter readers
- Improvements on delivery of bills to users

Implementation costs:

In 98/99,99/00,00/01, about R500 000, R300 000 and R300 000 respectively spend on water loss management (including management meters).

Savings:

Value of savings from water loss management since 99/00 is estimated to be R4 million.

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

Significant investment would be required in rectifying the problem of unaccounted for water considering the size of the water supply network. Most of the water distribution system data is now available and a number of water supply zones have been implemented throughout the city. Base data for night flows and comparison purposes has been gathered. Water loss management is a concrete and effective method of saving the service provider and end user money and resources. The more technical solutions were considered expensive and less effective in the short term.

Social impact and equity issues:

Problems identified included illegal connections. Some of these connections were for irrigation connections could never be detected. People had been misguided to accept that these. This problem was prevalent even in affluent areas. The heavy fines imposed discouraged neighbours from revealing their situation to others. As a result more illegal water connections were uncovered.

Expertise required:

To avoid negative reaction from consumers several months were dedicated to raising public awareness on this initiative. Extensive use of the media was made. This was augmented by public awareness workshops. The meter readers were inspected and the City Treasurer's accounting system was used to verify statistics on water use and detect illegal connections stretching over periods of up to three years. Innovative ways are still required to claim back the monies owed especially from low-income groups. In house expertise was used to reduce costs. Consultants were used in preparing status quo reports.

Institutional requirements:

In this initiative the municipality depended mostly on in house capacity and the media but political support was found to be necessary.

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Greater Hermanus

Information from: IUCN report- Water conservation & water demand management in SA. Case study analysis
Information provide by Overstrand Town Engineer

A2-04

Monitoring of unaccounted for water in each zone

PROJECT DESCRIPTION

General Details:

The project objectives are summarised as:

- To achieve savings of 30% in water consumption over three years (1997-1999)
- To increase the water revenue during these three years by R 1.1 million per year to fund some of the components of the conservation program.

The following was adopted as part of a 12-point conservation programme:

1. Intensive public awareness campaign
2. Water audits
3. Water loss management

Implementation costs:

No data provided

Savings:

- Within one year the unaccounted for water dropped from 18% to 11% due to public reporting of leaks and bursts and faulty meters being reported.

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- There is need for public support and commitment to reduce unaccounted for water.
- Public support can only be obtained through a comprehensive communication programme.

Social impact and equity issues:

- Poor groups cannot afford high water tariffs and benefits in reduction unaccounted for water need to be passed on to them

Expertise required:

- Specialist skills in public awareness and water loss audits.
- Contractors or in house teams to undertake necessary repairs

Institutional requirements:

- Institutional co-ordination within local authorities is essential especially on education and awareness programs.

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ODI Retail Water

Information from: IUCN report- Water conservation & water demand management in SA. Case study analysis
Interview with SSI Consultant

A2-05

Monitoring of unaccounted for water

PROJECT DESCRIPTION

General Details:

This project was implemented from 1998 to 2000. Its objective was:

- To address the focus areas relating to institutional, social, water infrastructure and financial to reduce unaccounted for water and to improve cost recovery (billing).

The approach on monitoring and control of unaccounted for water involved:

- Installation of pre-payment meters where requested by consumers
- Upgrading existing unauthorised connections where necessary
- Establishment of network of bailiffs and vendors to control payment for and operation of pre-payments metering system
- Zonal/District control was established. Water was supplied for 56 hours per 7day week.

Implementation costs:

Total project cost was R1,6 million but detail on investment on monitoring unaccounted for water was not provided.

Savings:

Total savings of 80 000 cubic metres per day (29,2 million m^3 per annum) on whole project and contribution form unaccounted for water was not provided.

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- Conventional metering supported by hand-held electronic data capture devices linked to a central billing system was used to track unauthorised connections
- Prior to commencement of project almost 85% of the cost of water purchased by ODI Retail Water from Rand Water was not recovered and/or accounted for
- Zonal/District control has resulted in the average daily demand to about 20000 households been reduced from 16 to 12 cubic metres.

Social impact and equity issues:

- Customer satisfaction from equitable water service.

Expertise required:

Water Demand Management, Water Conservation and water meter expertise provided by the consultant

Institutional requirements:

Institutional strengthening of ODI Retail Water established as an area of need.

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Rustenburg Pilot Project

Information from: IUCN report- Water conservation & water demand management in SA. Case study analysis. Interview with SSI Consultant

PROJECT DESCRIPTION

General Details:

The first phase of this project was implemented from 1998 to 2000 for the suburb of Tlhabane. A second phase was planned for 2000 to 2001, which included detection and repair of leakages within properties ended prematurely because of lack of funds. The objectives of the project were:

- To develop skills and methodologies under the Town Care range of products and services which are currently under development by Rand Water through various field projects
- To reduce the losses and wastage in the reticulation network.

Approaches used on monitoring unaccounted for water in each zone included:

- Establishment of water management zones, metering and data logging for water balance and minimum night flow measurement
- Investigation of meter inaccuracies and discrepancies in water meter readings
- Empirical measurement of minimum night flows, domestic night usage/wastage, institutional night usage/wastage and commercial/industrial night usage/wastage

Tools deployed included:

- Management/District/Sub-district metering and data logging for water balance and minimum night flow measurement
- Design and implementation of Water Management Districts.
- Surveys of consumer meters
- Development and implementation of a computerised management system for incidents complaints, leakage control and water meter management (Integrated Water Asset Management System, IWAMS)
- Computerised water audit program (SABS 0306)
- Training of Rustenburg Council Staff

Implementation costs:

Part of R998350 which also included water audit, leakage control and reconciling water meters

Savings:

No data was available

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- IWAMS can facilitate cost-effective management of services and resources by providing for information storage, processing and retrieval for monitoring unaccounted for water in different zones.
- Significant water losses from reticulation network were identified.
- No information provided on measures taken to reduce unaccounted water.

Social impact and equity issues:

- Its not evident that measures to reduce unaccounted for water were implemented

Expertise required:

- Water demand management and Water Conservation specialists supplied by Consultant

Institutional requirements:

- Institutional strengthening of the Local Authority required to monitor water supplied and taken up by users in each management zone and take measures to reduce unaccounted for water

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Krugersdorp TC/Kagiso

All information from IUCN report, Water Conservation & water demand management in SA: Case study analysis

A3-08

Pressure Management

PROJECT DESCRIPTION

General Details:

The municipality implemented a pressure management project. Controllers were installed to automatically reduce pressure at night. This was combined with an *ad hoc* leak repair operation was on private properties following complaints by consumers about excessively high water bills. Repairs were done for close to 4000 house stands.

Implementation costs:

Data not available

Savings:

12 000kl month savings achieved

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):
Data not available

Social impact and equity issues:

Data not available

Expertise required:

Data not available

Institutional requirements:

Data not available

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Umgeni Water Supply Area Information from: IUCN report- Water Conservation & water demand management in SA: Case study analysis Umgeni Water	**A3-10** Pressure Management

PROJECT DESCRIPTION

General Details:

This project intended to implement Umngeni Water's Water Conservation Policy. Umngeni Water's objectives on water conservation are:

- To achieve efficient and effective operation of the water supply and water resources within its area of jurisdiction
- To assist third tier water service providers in implementing water demand management practices in the areas under their control and in preparation of their related water conservation plans
- To assist Catchment Management Agencies in managing and conserving water resources in the areas under their control and in the preparation of their water related conservation plans; and
- To attain optimal economic balance between infrastructure development and resource utilisation

A proposed approach, which covers a whole range of water demand management issues has been put forward and a Water Demand Management Programme document is currently being drafted.

Implementation costs:

No data available

Savings:

No data available

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

Project not yet implemented

Social impact and equity issues:

Project not yet implemented

Expertise required:

Project not yet implemented

Institutional requirements:

Project not yet implemented

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Greater Bloemfontein LC/Mangaung Local Municipality

Information from: IUCN report- Water conservation & water demand management in SA: Case study analysis
Interview with the Assistant City Engineer, Greater Bloemfontein Local Council

A4-01

Management Meters

PROJECT DESCRIPTION

GENERAL DETAILS:

This initiative was part of a project whose objectives were:

- To actively reduce unaccounted for water to an acceptable level.
- To set up a management system that will enable the service provider to effectively manage the water distribution network in the long term.

The following initiatives on management meters were implemented:

- A status quo report was prepared on the water services within the municipal area
- Installation of zone meters.
- Installation of automated data loggers

Implementation costs:

In 98/99,99/00,00/01, about R500 000, R300 000 and R300 000 respectively spend on water loss management (including monitoring of unaccounted for water).

Savings:

No data available on contribution of investment in management meters to overall savings of R4million achieved from water loss management since 99/00.

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):
A number of meters were installed on inlets to water supply zones. Base data for night flows and comparison purposes has been gathered. Problem zones were identified through balancing zone and sub-zone meter readings.

Social impact and equity issues:

The social impact has been limited. The benefits to be passed on to water users are not yet clear but more income for the water service provider can enable it to meet the cost of the service.

Expertise required:

Consultants were engaged to prepare a status quo report. Equipment installers and data analysts. Consultants required for capacity building on data capture, analysis and interpretation.

Institutional requirements:

In this initiative the municipality build its in house capacity to monitor water supply to different zones.

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East London City/Buffalo City Municipality
Information from: IUCN report: Water conservation & water demand management in SA: Case study analysis Telephone interviews with Water Distribution Engineer for East London City

A4-02
Management Meters

PROJECT DESCRIPTION

General Details:

This is part of a larger project whose objectives are to:

- To reduce wastage of water.
- To encourage consumers to accept responsibility for paying for water.
- To collect income from the sale of water to finance the operation of water supply system.

The approach being followed by the municipality on management meters was:

- To install meters at inlets to major consumer areas
- Tele-metering to get reliable real time data

Implementation costs:

Data not provided

Savings:

Savings not quantified

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- Meters installed at inlets to five main zones in Mdantsane.
- Demarcation of sub-zones still in progress
- Remote meters reading enables increased reliability of observations

Social impact and equity issues:

- Impact not yet quantified

Expertise required:

- Data processing, analysis skills, water distribution engineers

Institutional requirements:

- Institutional capacity to demarcate water supply zones, analyse and interpret meter records.

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Kimberley Municipality Information from: IUCN report- Water conservation & water demand management in SA: Case study analysis Interview with Assistant City Engineer	**A4-03** Management Meters

PROJECT DESCRIPTION

General Details:

Kimberley Municipality supplies water to industrial and domestic consumers via Council Pipeline systems. Unaccounted for water in the last four years has been an average of 13.49%. The objective of the project was to reduce unaccounted for water and investigate the council's reverse flow system.

- As part of this project bulk water meters were to be installed at strategic points to be able to measure inflow into the various districts and determine losses in the water supply mains.

Implementation costs:

It is not clear how much money was allocated to management meters.

Savings:

No data available. Savings can only be quantified once district metering is in place.

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- Zoning of outlying consumer areas has been difficult because of the need to redefine the networks
- Although the metered network supplies 50% of the population it accounts for far less than 50% of the total water consumed.
- The project has not been fully implemented because of budgetary constraints.
- Further work is required to meter the remaining districts
- Municipal water accounting software to be used to correlate bulk meter readings and district metering.

Social impact and equity issues:

- No data available as project has been hardly implemented.

Expertise required:

- Expertise required to measure night flows, pressures and to calibrate model is available in house but is constrained by other responsibilities

Institutional requirements:

- Computer hardware and software required to capture, store and process data.

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South Coast KZN

Information from: IUCN report- Water conservation & water demand management in SA. Case study analysis

A4-04

Management Meters

PROJECT DESCRIPTION

GENERAL DETAILS:

The aim of the project was to reduce unaccounted for water, however the project was aborted because of a technical oversight.

The approach applied involved use of portable insertion meters for accurate determination of field flow measurements.

Implementation costs:

Data not available

Savings:

Data not available

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- The use of portable insertion meters to calibrate permanent meters in the field is only valid for pipes larger than 300mm nominal diameter. Meters for small bulk mains require removal and calibration in a laboratory. 80% of the meters fell in this category.

Social impact and equity issues:

Data not available

Expertise required:

- Details of bulk water system and water supply network are essential before defining intervention strategies

Institutional requirements:

Data not available

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Tlhabane Project

Information from: IUCN report- Water conservation & water demand management in SA: Case study analysis

Interview with Water Conservation Officer

A4-05

Management Meters

PROJECT DESCRIPTION

GENERAL DETAILS:

The project ran for 2 years and was implemented in phases as follows:

- Project Plan Development
- Installation of management meters, valves and a monitoring system
- Implementation of water loss and leak detection procedures
- Results analysis, and water audit

The objectives of the project were to reduce and manage the water losses within the distribution network of Tlhabane and to illustrate the economical viability of such interventions.

Implementation costs:

R 1 138 119.00

Savings:

Minimum night flows reduced by 11.2 m^3/hr

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- The project identified that about 11% of Minimum Night Flow (MNF) is the result of leakages in the distribution network, 89% was attributed to leaks within properties. Wastage within properties amounted to 595 417m^3 per annum.
- Stewart Scott assessed and trained the Council's meter readers in Tlhabane to reduce overcome anomalies that were discovered including stopped and unread meters.
- The Water Audit Management System was implemented for both the water balance determination as well as water audits.

Social impact and equity issues:

- Members of the community were employed by the project, especially for data collection.

Expertise required:

- Engineers and meter readers

Institutional requirements:

- Computer s and appropriate software required to capture and analyse data

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East London City/Buffalo City Municipality	A5-02
Information from IUCN report- Water conservation & water demand management in SA: Case study analysis Telephone interviews with Principal Water Engineer for East London City	Consumer Meters

PROJECT DESCRIPTION

GENERAL DETAILS:

This is part of a larger project whose objectives are to:

- To reduce wastage of water.
- To encourage consumers to accept responsibility for paying for water.
- To collect income from the sale of water to finance the operation of water supply system.

The municipality has adopted a pre-payment meter system for communal water standpipes. The following approach has been adopted

- Workshops with communal users to raise awareness on prepayment meters
- Installation of pre-payment meters at communal standpipes first as pilot activities. Initially 4 were installed in Mdantsane and 2 were installed in Duncan village.
- Commissioning of a project to install 150 more prepayment meters at communal standpipes
- Replacement of old malfunctioning meters. 1220 damaged meters were replaced
- Installation of prepayment yard meters. Six meters were installed on a pilot activity.
- Installation of 500 new meters

Implementation costs:

R800 000 on consultants and contractors. Consumers paid a nominal connection fee.

Savings:

No review has been done to quantify savings but in general income has increased as more people are paying for water services

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

Investment in education and awareness is essential for consumers to accept interventions.

It has been difficult for most consumers to pay for water services however the situation is improving and situations where people (even those with prepayment meters fail to pay) have to be handled carefully.

Social impact and equity issues:

Most users have accepted pre-payment meters. There are very few cases of vandalism. Communal standpipes are well maintained.

Expertise required:

Honest and committed meters readers are required. Good public relations especially on workshops with consumers to introduce prepayment meters. Special skills are required for credit control.

Institutional requirements:

The municipality has been quite aggressive on this initiative and any improvements have been communicated to consumers as motivation. Co-operation from consumers has increased chances for success of the interventions. However, it has proved difficult to plan and follow up on every aspect of this initiative because of shortage of personnel.

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Krugersdorp TC/Kagiso

Information from IUCN report- Water conservation & water demand management in SA: Case study analysis

Mahlota City Local Municipality

A5-

Consumer Meters

PROJECT DESCRIPTION

General Details:

The project objective of the project was to obtain revenue for water services. This was to be achieved through the following approaches:

- Credit control
- Installation of prepaid meters

Residents who defaulted on paying water accounts were subjected to restriction. Further continued defaulting resulted in water being cut off. About 10 000 prepaid metes were installed free of charge to consumers.

Implementation costs:

Data not available

Savings:

Data not available

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- Income increased from R9 000/month to R105 000/month attributed to introduction of prepaid meters

Social impact and equity issues:

Data not available

Expertise required:

Data not available

Institutional requirements:

Data not available

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Motherwell Water Loss Investigation

Information from: IUCN report- Water conservation & water demand management in SA: Case study analysis

Interview with Municipal Water Engineer

A5-04

Consumer Meters

PROJECT DESCRIPTION

General Details:

This project was implemented from 1999 and its objectives were:

- To minimise losses from reticulation mains as the minimum night-flow was 400 kl/hour
- To reduce on-site wastage by consumers
- To improve payment for water

Approaches used involved:

- Data loggers and flow meters, using step-testing method to locate losses
- A meter replacement programme was initiated

Implementation costs:

Total project cost since inception in 1999 is about R468 000 but no details have been provided on costs incurred on consumer meters

Savings:

- Possible savings on project estimated at about R14 500/day or R5.3million per year with a sizeable contribution from correct metering, billing, active and passive leakage control

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- Motherwell, being a former apartheid municipality, had a huge backlog of maintenance and metering
- Investigative work on metering can be costly

Social impact and equity issues:

- Improvement of metering often confronts non-payment culture and a "we don't care" attitude.

Expertise required:

- Knowledge of meter reading and evaluating results is essential.
- Computer knowledge.

Institutional requirements:

- The correct data logging equipment and personnel is essential

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A5-05

Consumer Meters

PROJECT DESCRIPTION

General Details:

To build and operate rural community water infrastructure through the development of local community and government capacity to operate and maintain projects. Approximately 30 projects are being implemented, ensuring water supply to some 200 000 people on completion. The following approaches and tools have been implemented in the initiative:

- Build operate train and transfer (BOTT) methodology implemented through an active partnership with the DWAF and local government.
- Prepaid meter systems installed
- Minekon Data loggers used to assess water usage.

Implementation costs:

Costs range from R 4 – 60 million dependent on community profile and density, geographic conditions and the nature of the service provided.

Savings:

No data available but revenue collection improved through use of pre-payment meters

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- Focus is on attempting to use water available through the pre-payment mechanism i.e. on water sales and on easy access to safe water sources.
- The BOTT system enables effective monitoring of water saving through water loss management system – regular logging is undertaken on a project specific basis of projects such as Nqutu, which are fully operational. Results are submitted to DWAF monthly.

Social impact and equity issues:

- Water management skills developed at local government level.

Expertise required:

- Skills to install and calibrate pre-peyment meters

Institutional requirements:

- Capacity to handle pre-payments and meet demand for prepayment meters

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All information from IUCN report: Water conservation & water demand management in SA: Case study analysis

A7-02

Active and Passive Leakage Control

PROJECT DESCRIPTION

General Details:

The project objectives is summarised below:

- To actively reduce unaccounted for water to an acceptable level.
- Provide training to in-house staff members to enable the Service Provider to establish his own Water Loss Management programme, and manage the program autonomously.

On this project one of the approaches followed to achieve the objective was to detect and repair leaks.

Implementation costs:

No data available

Savings:

If leaks found they had gone for at least one year undetected. Based on this the savings achieved were estimated at approximately R 2.28 million.

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

Leakage detection and can result in concrete water savings for the user and Service Provider

Social impact and equity issues:

No data available

Expertise required:

No data available

Institutional requirements:

No data available

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Greater Bloemfontein LC/Mangaung Local Municipality

Information from: IUCN report: Water conservation & water demand management in SA: Case study analysis. Interview with the Assistant City Engineer, Greater Bloemfontein Local Council

A7-03

Active and Passive Leakage Control

PROJECT DESCRIPTION

General Details:

This initiative was part of a project whose objectives were:

- To actively reduce unaccounted for water to an acceptable level.
- To set up a management system that will enable the service provider to effectively manage the water distribution network in the long term.

Leak detection and repair is done as part of regular maintenance work. However losses from leaks are generally lower than from unaccounted for water. Thus emphasis has been put on the later.

Implementation costs:

No data available

Savings:

No data is available on savings from attending to active and passive leakage control.

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- Passive and active leakage control done as a regular activity

Social impact and equity issues:

- Detailed information not available but increased assurance of water service generally welcomed by users.

Expertise required:

- In-house maintenance team, which includes plumbers and engineers.

Institutional requirements:

- Institutional capacity to prioritise interventions (i.e. attend to areas of greatest wastage) against pressing resources

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East London City/Buffalo City Municipality

Information from BCCN report- Water conservation & water demand management in SA: Case study analysis
Telephone interviews with Water Distribution Engineer for East London City

A7-04

Active and Passive Leakage Control

PROJECT DESCRIPTION

General Details:

This is part of a larger project whose objectives are to:

- To reduce wastage of water.
- To encourage consumers to accept responsibility for paying for water.
- To collect income from the sale of water to finance the operation of water supply system.

The approach being followed by the municipality on active and passive leakage control was:

- To carry out pressure and night flow measurement surveys through tele-metering
- To acquire and install electronically controlled pressure flow regulators. Between 8 and ten units are required

Implementation costs:

Total cost so far was R1 300 000 but in-house costs not included.

Savings:

Savings have not yet been quantified and project is on-going.

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- Convincing information is required to justify investment into active and passive leakage control if figures involved are far less than water, which is consumed but not paid for.
- Poor payment for water is quite evident through unpaid bills and problems in reconciling meter readings, which are already part of water accounting. However, passive and active leakage control may need to be preceded by collection of accurate data.

Social impact and equity issues:

- No data available. Getting more people to access clean water closer to their homes and installation/repair of meters appears to be a higher priority.
- Most active leakage control is done as an on going maintenance activity.

Expertise required:

- Specialised kills from consultants on leak detection surveys and contractors on leakage repairs. In house skills can be developed within water service provider to detect leaks and repair them.
- Specialised skills in analysis and interpretation of data.

Institutional requirements:

- It can be more cost-effective for the water service provider to monitor active and passive leakage.

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Motherwell Water Loss Investigation

Information from: IUCN report- Water conservation & water demand management in SA: Case study analysis
Interview with Municipal Water Engineer

A7-

Active and passive leakage control

PROJECT DESCRIPTION

General Details:

This project was implemented from 1999 and its objectives were:

- To minimise losses from reticulation mains as the minimum night-flow was 400 kl/hour
- To reduce on-site wastage by consumers

This project is still in progress.
Approaches used involved:

- Establishing a leak detection team for an area of some 18 000 consumer points
- Data loggers and flow meters, using step-testing method to locate losses
  Schools have been visited and areas that have communal taps
  Many existing metered connections had leaking stopcocks. The head parts of these stopcocks were replaced.

Implementation costs:

R 468 000-00 since inception during October 1999

Savings:

- Minimum Night Flow to be reduced from 400 to 60kl/hour
- Possible savings of about R14 500/day or R5.3million per year

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- Continuous monitoring of Minimum Night Flow is essential to detect major pipe breaks or leaks
- Use of non-specialised expertise using non-sophisticated equipment for leak detection and repairs can be successful but demands diligent official follow-up
- Prior to any water loss investigation identification and inspection of all valves is essential
- Motherwell, being a former apartheid municipality, had a huge backlog of maintenance, which took two months to undertake and is ongoing. This phase can be time consuming and frustrating and generally such investigations are costly and need strong motivation.

Social impact and equity issues:

- Educating the local population about the value of water.
- Apathy on the part of the community towards conserving water reporting visible leaks.
- Non-payment culture and a "we don't care" attitude.
- Water problems, i.e. low pressure, not being reported.

Expertise required:

- Non-specialised expertise using non-sophisticated equipment for leak detection and repairs.
- Knowledge of data logging and evaluating results is essential.
- Computer knowledge.
- Knowledge of the area and water reticulation lay-out.
- Sounds of leaks through valves, and other transmitting areas, and the leak noise of different pipe materials.

Institutional requirements:

A dedicated team to perform the step testing and locate breaks / leaks is essential for success. The backup of the workshops to repair these leaks promptly is a further requirement. The correct logging equipment and personnel to operate the equipment is vital. Authority by management to provide the resources.

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Boksburg Project

Information from IUCN report- Water conservation & water demand management in SA. Case study analysis
Interview with Water Conservation Officer

A7-

Active and Passive Leakage Control

PROJECT DESCRIPTION

General Details:

This pilot project was undertaken so as to develop best practices guidelines for retrofitting schools and similar establishments. The objectives of this project were:

- To reduce consumption or wastage and enhance awareness on need for water conservation
- To promote partnership between Rand Water and Boksburg Local Council
- To create job opportunities within the council
- To increase payment levels of communities associated with schools
- To increase the affordability of water supply

Approaches used involved:

- Identifying and repairing leaks within the water distribution system and water connections within the schools
- Review of water pressure within the network
- Repair of leaks

Implementation costs:

Data on amount of money spend on active and passive leakage control not available

Savings:

No data available.

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- Lack of proper maintenance of the facilities lead to wastages due to leakages.
- In one school meter reading dropped from 500m^3 to 60 m^3 in one month due to leakage repairs
- In other schools 50% reduction in water consumption was achieved

Social impact and equity issues:

Data not available

Expertise required:

Data not available

Institutional requirements:

Data not available

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Kimberley Municipality

Information from IUCN report: Water conservation & water demand management in SA: Case study analysis. Interviews with Assistant City Engineer

A4-03

Management Meters

PROJECT DESCRIPTION

General Details:

Kimberley Municipality supplies water to industrial and domestic consumers via Council Pipeline systems. Unaccounted for water in the last four years has been an average of 13,49%. The objective of the project was to reduce unaccounted for water and investigate the council's reverse flow system.

The approach by the municipality is to install management meters at strategic points. These meters also capture data for monitoring unaccounted for water.

Implementation costs:

Approximately R 500 000 was allocated from the Local Authority budget.

Savings:

No data available. Savings can only be quantified once district metering is in place.

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- Bulk meters have been installed at inlets to outlying consumer areas but these areas are not well defined.
- The project has not been fully implemented because of budgetary constraints.
- Further work is required to meter the remaining districts
- Convincing data is required to support investment decisions.

Social impact and equity issues:

- No data available as project has been hardly implemented.

Expertise required:

- Expertise is required to analyse data and define priorities on water conservation

Institutional requirements:

- Computer hardware and software required to capture, store and process data.

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Sebokeng/Thembisa

Information from: ECN report- Water conservation & water demand management in SA: Case study analysis
Interview with Water Conservation Officer

B1-

Retrofitting and Removal of Wasteful Devices

PROJECT DESCRIPTION

General Details:

This project started in 1997 and was completed in 1990. Its objectives were:

- To demonstrate to local councils that repairing leaks on private plots can significantly reduce water consumption.
- To build partnership with local councils
- To intervene with the water wastage of consumers
- To intervene with non-payment aspects
- To educate the community on water awareness

On retrofitting and removal of wasteful devices the approach followed involved:

- Repair of leaks on taps and pipe work
- Replacement of 13litre toilet cisterns with 4.5/9litre dual flush units

8800 houses were retrofitted with dual flush cisterns and taps were either repaired or replaced.

Implementation costs:

The total project cost was about R2.1million

Savings:

- In Sebokeng Zone 12 water consumption decreased by 36.5%. This was also attributed to greater public awareness

KEY FINDINGS

General (technical, implementation, operational, sustainability etc.):

- Residents benefited through lower water bills
- Payback period of 18 to 24 months achieved
- Local income levels and unemployment hinder improvements in payments for service
- Residents resisted replacement of steel cistern with dual flush plastic cistern

Social impact and equity issues:

- It was observed that while people may be aware that they have to pay for water they still do not do so

Expertise required:

- Transfer of plumbing skills to council employees to sustain initiative, however quality of workmanship not always satisfactory
- Ability to do minor repairs required at the household level

Institutional requirements:

- It is essential to build in a training component to bring down low level maintenance down to the user

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Other related WRC reports available:

Development of a framework for the economic evaluation of water conservation/water demand management measures with specific application to decision-making in Cape Town

Hugo van Zyl; Anthony Leiman

For many years the primary focus of water resource planning in South Africa was the expansion of supply. Only fairly recently with the promulgation of the Water Act (Act 108 of 1998) has the importance of water conservation / water demand management (WC/WDM) been recognised. In consequence, techniques for the evaluation of WC/WDM measures are less sophisticated than those for the evaluation of new sources of supply. This study develops a framework for the financial and economic evaluation of WC/WDM measures.

An investigation of the available literature indicates that cost-benefit analysis (CBA) remains the technique favoured for the analysis of the bulk of public sector investment decisions. It was also the method most commonly appearing in the literature on guidelines for the financial and economic evaluation of WC/WDM measures. Linking this to the Cape Town Integrated Water Resources Planning, the process and results show that study participants indicated satisfaction with the MCDA (multicriteria decision analysis) process used as it encouraged a holistic approach in which participants were prompted to appreciate each other's points of view and build consensus. The parts of the process dealing with financial and economic evaluation relied heavily on CBA principles.

At a local policy level, CBA remains the preferred technique for financial and economic evaluation of water projects. The framework for the evaluation of WC/WDM measures presented by this study needs to be consistent with CBA principles given the likelihood that revised CBA guidelines would be accepted by DWAF and possibly more widely. Through these procedures the study has developed a framework for economic evaluation of WC/WDM measures.

Report Number: 1275/1/03 **ISBN: 1 86845 929 2**

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