

**WATER RESOURCE DECISION MAKING IN THE  
WESTERN CAPE SYSTEM ANALYSIS**

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School of Economics  
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## **ABBREVIATIONS**

<b>AHP</b>	-	<b>Analytical hierarchy process</b>
<b>BCR</b>	-	<b>Benefit-cost ratio</b>
<b>CBA</b>	-	<b>Cost-benefit analysis</b>
<b>CEA</b>	-	<b>Cost-effectiveness analysis</b>
<b>CPA</b>	-	<b>Cape provincial administration</b>
<b>CTWU</b>	-	<b>Cape Town Water Undertaking</b>
<b>CVM</b>	-	<b>Contingent valuation method</b>
<b>DWAF</b>	-	<b>Department of Water Affairs and Forestry</b>
<b>EES</b>	-	<b>Environmental Evaluation System</b>
<b>EIA</b>	-	<b>Environmental impact assessment</b>
<b>ELECTRE</b>	-	<b>Elimination Et Choisis Translation Realité (roughly translated from French as “elimination and choice translating algorithm)</b>
<b>GCTMA</b>	-	<b>Greater Cape Town Metropolitan Area</b>
<b>HEV</b>	-	<b>Hicksian equivalent variation</b>
<b>HCV</b>	-	<b>Hicksian compensating variation</b>
<b>HMT</b>	-	<b>Her Majesty’s Treasury</b>
<b>IEM</b>	-	<b>Integrated environmental management</b>
<b>IFR</b>	-	<b>Instream flow requirement</b>
<b>IRR</b>	-	<b>Internal rate of return</b>
<b>MAUT</b>	-	<b>Multi-attribute utility theory</b>
<b>MAVT</b>	-	<b>Multi-attribute value theory</b>
<b>MCDA</b>	-	<b>Multiple criteria decision analysis</b>
<b>MCDM</b>	-	<b>Multiple criteria decision making</b>
<b>MDF</b>	-	<b>Metropolitan development framework</b>
<b>NEPA</b>	-	<b>National Environmental Policy Act</b>
<b>NOAA</b>	-	<b>National Oceanic and Atmospheric Administration</b>
<b>NPV</b>	-	<b>Net present value</b>
<b>NSI</b>	-	<b>Ninham Shand Incorporated</b>

<b>NWC</b>	-	<b>National Water Commission</b>
<b>OECD</b>	-	<b>Organisation for Economic Co-operation and Development</b>
<b>RDP</b>	-	<b>Reconstruction and development programme</b>
<b>SAFCOL</b>	-	<b>South African Forestry Company</b>
<b>SCBA</b>	-	<b>Social cost-benefit analysis</b>
<b>SMART</b>	-	<b>Simple multi-attribute rating technique</b>
<b>TAMS</b>	-	<b>Tippetts-Abbett-McCarthy-Stratton</b>
<b>UNIDO</b>	-	<b>United Nations International Development Organisation</b>
<b>WCEDF</b>	-	<b>Western Cape Economic Development Forum</b>
<b>WCSA</b>	-	<b>Western Cape System Analysis</b>
<b>WESGRO</b>	-	<b>The Association for the Promotion of the Western Cape's Economic Growth</b>
<b>WRPOM</b>	-	<b>Water resources planning and operating model</b>
<b>WRYM</b>	-	<b>Water resources yield model</b>
<b>ZSA</b>	-	<b>Zille, Shandler and Associates</b>

## **INTRODUCTION**

The Greater Cape Town metropolitan area has limited water resources of good quality, but faces a rapidly increasing demand for water. Recognising this, in 1989 the Department of Water Affairs and Forestry (DWAF), together with the Cape Town City Council, initiated the Western Cape System Analysis (WCSA) to study the available water resources and needs of Greater Cape Town. The Analysis was intended to "...provide a detailed decision support facility to assist in the optimal future development of water supply to Greater Cape Town and its environs" (NSI, 1994, p. 1). Accordingly it identified and evaluated possible options for future supply including dams, diversions, aquifers, demand management, desalination and recycling.

Subsequent to the WCSA, a decision making process which included extensive public participation was initiated to screen the initial list of options and identify the most favourable options for further investigation. The principles and criteria which guided decision making were recognised as part of this process, yet they were applied in a relatively unstructured fashion and not as part of an overall formal framework.

Water resource decision making in Greater Cape Town is characterised by numerous, often conflicting goals. Among these are ensuring engineering feasibility and flexibility of supply, maximising water yield, minimising costs and minimising negative environmental and social impacts. Furthermore, in the face of ongoing development, decisions on future water supply options can be expected to increase in complexity along with the potential for conflict as natural resources become more scarce.

In the present political climate, the need to transform public sector decision making into a democratic and transparent process has been recognised. Stakeholder groups need to be satisfied that their interests are taken into account in decision making and that decision makers are accountable for their actions.

This thesis argues the case for the use of a formal framework to improve future decision making between water supply options in light of the above goals. After debating which type of framework would be most appropriate, the possible workings of a future system are briefly outlined.

Chapter 1 starts with an overview of the WCSA in which those of its main findings which are important to decision making between water supply options are presented. After looking at the current supply situation and projected demand, a brief outline of the water supply options under consideration is presented. An appendix to this chapter considers the evaluation of individual supply options which feed into the decision between options. It contains a more in-depth presentation of the evaluation of two of the options, namely the Skuifraam dam and water demand management. The Skuifraam dam study was chosen for investigation because it highlights the typical issues encountered in supply augmentation schemes and because it was recently approved. Water demand management is interesting from an economic point of view, and because it currently enjoys unanimous and intensifying support among stakeholders. Consideration is also given to the use of the transferable water use rights. This is an approach which should at least be considered, but has not been included under demand management in the WCSA. The chapter ends by outlining the decision making process initiated by the DWAF for screening the initial list of water supply options in order to identify the options which warranted further consideration. The public participation process that guided the DWAF in this respect is outlined in detail in order to gain insights that would potentially be useful in future decision making processes.

Chapter 2 provides an overview of the historical development of decision making in water resource planning. Starting in the 1930s, the evolution of decision making is traced from an early focus purely on engineering feasibility and financial considerations to the more holistic modern approach.

Chapter 3 presents a literature review of the specific frameworks that have been used historically to decide between water supply options, namely social cost-benefit analysis (SCBA),

multiple criteria decision analysis (MCDA) and environmental impact assessment (EIA) methods. The review offers:

1. Brief descriptions of their theoretical background and historical development.
2. Outlines of their basic workings.
3. Case studies showing their application in water resource planning and the lessons to be learnt from these.
4. Discussions of their strengths and weaknesses.

In Chapter 4 the context and characteristics of the decision situation when deciding between options is outlined in order to provide guidance for the choice of a framework. The context is divided into socio-economic, environmental, regulatory and political aspects. Together with the characteristics of the decision problem, they are intended to describe the overall setting within which decisions take place and the challenges a future decision making framework will have to deal with.

Finally, Chapter 5 moves from the descriptive to the prescriptive by discussing the choice and possible workings of an appropriate future decision making framework. The choice of an appropriate decision making framework, from those reviewed in Chapter 3 is debated considering the following factors dealt with in previous chapters:

- Methodological considerations including the context and characteristics of the decision making problem (outlined in Chapter 4).
- The decision making process for deciding between the options carried out thus far as part of the WCSA (outlined at the end of Chapter 1).
- Case studies on the application of decision making frameworks in deciding between water supply options (included in Chapter 3).

Once chosen, the possible workings of the suggested future framework is briefly outlined including a simulation of its application. This is followed by a discussion of possible constraints to its implementation.

# **CHAPTER 1**

## **THE WESTERN CAPE SYSTEM ANALYSIS (WCSA)**

### **INTRODUCTION<sup>1</sup>**

In April 1989, the Department of Water Affairs and Forestry (DWAF) and the Cape Town City Council initiated the Western Cape System Analysis (WCSA) in order to study the available water resources and water needs of the Western Cape. The study, conducted by Ninham Shand Incorporated Consulting Engineers (NSI) in association with BKS Incorporated, was intended to provide information and methodologies to assist in the optimal development of water supplies in the Greater Cape Town Metropolitan Area (NSI, 1994). The area covered by the study was defined broadly as the Cape Town Basin consisting of the basins of four major rivers; the Berg, the Palmiet, the Olifants and the Rivieronderend River as far as Theewaterskloof Dam.

The following five sections will outline the main findings of the WCSA relevant to the water resource planning process in the Western Cape and in particular, decision making between future water supply options. Firstly, the aims of the WCSA will be set out. Secondly, the present water supply situation in the Western Cape will be outlined and illustrated. Thirdly, future water demand projections will be presented. Then the procedure for optimising present supplies and meeting future demands will be discussed. Lastly, all the water supply options identified by the WCSA will be outlined and the decision making process used to screen a set of options for further study will be presented.

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<sup>1</sup>Sections 1.1 - 1.5 of this chapter provides background material only. Readers who are familiar with the area, its water use levels (current and projected), future supply options and the approach currently used in evaluating new water supply options, may omit it without loss of continuity.

## **1.1 WCSA AIMS**

The WCSA is made up of over fifty reports designed to act as a decision support facility. These comprise of:

1. A set of data relating to the water resources and water supply facilities presently existing in the region.
2. A means of predicting future changes in quantity and quality of the water resources, including data relating to expected changes and a method for updating predictions.
3. Forecasts of future urban and agricultural water demands.
4. An investigation of means of moderating water demands and the implications of restriction strategies.
5. Information regarding measures to conserve the environment and the social fabric in the face of changes caused by the development and use of water resources.
6. A comprehensive set of conceptual schemes for meeting forecast future water demands, including schemes that may be mutually exclusive or incompatible.
7. A means of determining the yields of individual schemes or sub-systems, with alternative degrees of reliability and in the face of changing land-use.
8. A means of optimising the selection, development and operation of successive schemes as a part of an integrated water supply system, including determining the risk of shortfall in the system under various conditions and alternative operating conditions.

(NSI, 1994)

As this study's focus is on the decision making process itself what follows will be a brief outline of the information gathered so far in the WCSA which is most relevant to this process.

## **1.2 THE PRESENT WATER SUPPLY SITUATION**

### ***Urban supply***

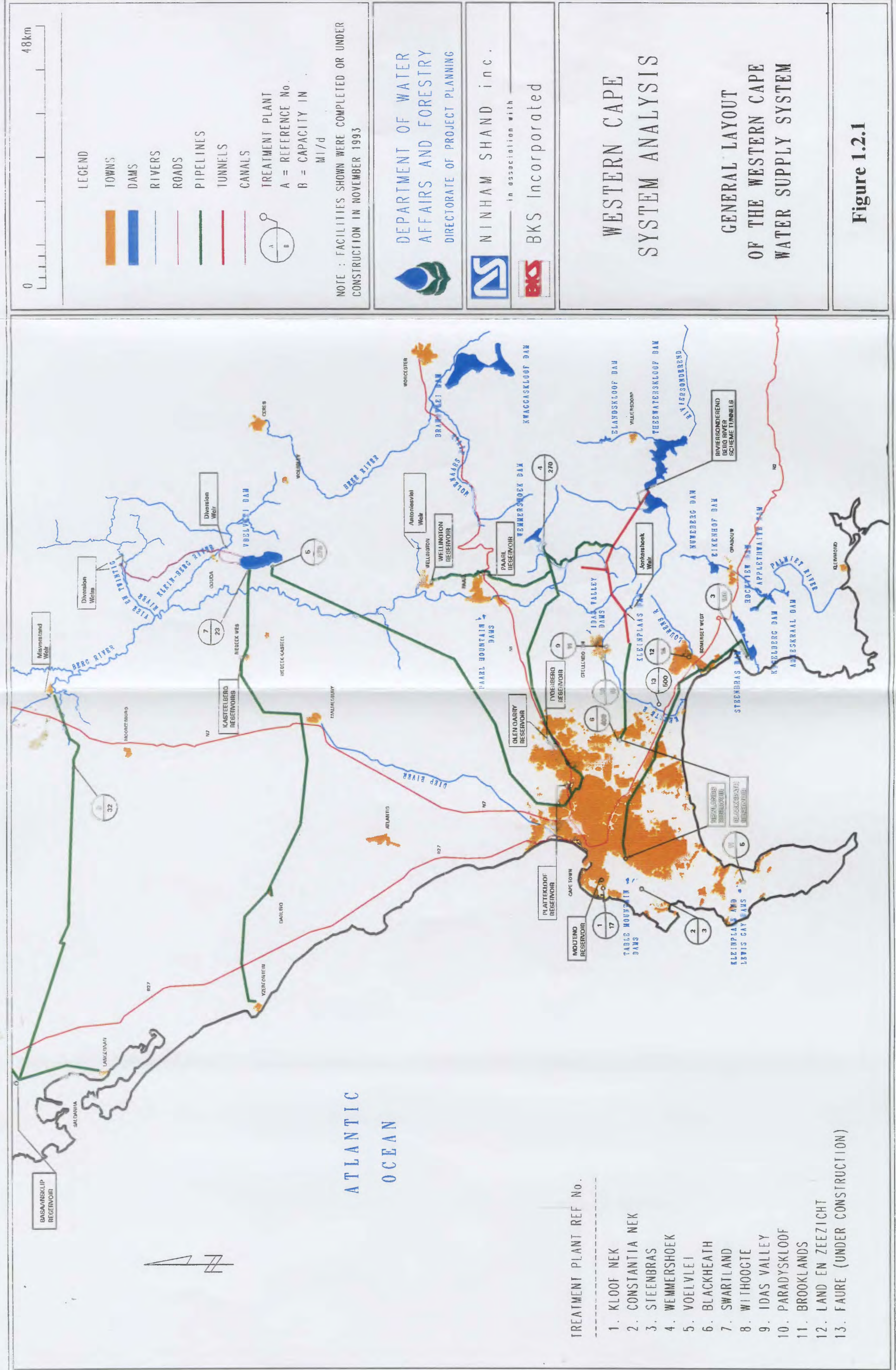
The estimate of water supplied in the WCSA study area for urban use in 1996 was 307 million cubic meters per year (Spies & Barriage, 1991).

The Cape Town Water Undertaking (CTWU) distributes water in bulk to the municipalities in the Greater Cape Town Metropolitan Area (GCTMA). The water is drawn from five large dams, several minor dams and a small spring. All water supplied by the CTWU is treated to potable (drinkable) standards at five major and two minor water treatment works owned by the Cape Town Municipality. Treated water is supplied, through treatment and distribution facilities owned by the DWAF, to many of the Swartland towns north of the GCTMA by means of two water schemes based on Voëlvelei Dam and the Berg River (NSI, 1994).

Several municipalities own and operate local water supplies in conjunction with the supplies obtained from the CTWU, with Simon's Town and Stellenbosch operating independently. Of the total water use in the GCTMA in 1990, 94% was supplied by the CTWU. The general layout of the urban water supply system in the Western Cape is shown in Figure 1.2.1, produced by NSI (1994).

### ***Agricultural supply***

Except for the Cape Flats vegetable growing region, water for agriculture is drawn almost entirely from surface water sources, i.e. from rivers, private dams, dams owned by



irrigation boards, and dams owned by the DWAF. In the later case, water rights may have been established by the Water Court or by means of a permit issued by the Minister of Water Affairs and Forestry. The system used to allocate water rights is under review by the DWAF at the moment (see the DWAF Water Law Review, 1996). The principles of the review process point towards more equitable water allocation in the future with water being increasingly treated as a national asset (see section 4.3 for an outline of the principles relevant to water resource planning).

### 1.3 WATER DEMAND PROJECTIONS

The projected supply to agriculture was 141 million cubic meters for 1996 (Spies & Barriage, 1991); combined urban and agricultural supply being 448 million cubic meters for the year in 1996.

The projected water demand in the Western Cape for the year 2000 is 546 million cubic meters its composition being:

**Table 1.3.1: Projected composition of water demand in the Western Cape for the year 2000**

<b>SECTOR</b>	<b>% OF DEMAND</b>
Agriculture	36
Domestic in-house	24
Domestic outdoor	13
Industrial	10
Commercial	4
Municipal	4
Sports bodies	3
Unaccounted for	6
<b>TOTAL</b>	<b>100</b>

(Source: NSI, 1994)

## Urban demand

Various forecast scenarios of water demand in the GCTMA and its hinterland were developed in detail and presented by Spies & Barriage (1991). These forecasts were based on assessed future population growth and alternative per capita water consumption rates under alternative macro-economic scenarios.<sup>2</sup> Table 1.3.2 is extracted from their report.

**Table 1.3.2: Water demand forecasts in the GCTMA**

SCENARIO	DEMAND FORECAST (10 <sup>6</sup> m <sup>3</sup> /annum)						
	1990	1995	2000	2005	2010	2015	2020
<b>1. Reference scenario (4% p.a. growth)</b>	243	295	362	444	544	666	815
<b>2. Return to the 1960's (high income growth)</b>	243	320	406	495	578	672	766
<b>3. Third World future (depressed economy)</b>	243	284	325	376	412	450	486
<b>4. Second World future (as 1970 to 1990 Ave.)</b>	243	296	351	407	456	509	561
<b>5. Population and gross l/c/d<sup>3</sup> (stable l/c/d of 290)</b>	243	284	319	352	380	408	435
<b>6. Local authorities' forecasts</b>	243	290	345	406	477	535	599

(Source: Spies & Barriage, 1991)

<sup>2</sup>It may be more accurate to call these projections, use projections instead of demand projections as they are simply based on time series projections taking historical use levels into consideration. They do not rely on actual demand functions.

<sup>3</sup> l/c/d - litres/capita/day

For the purposes of evaluating the various options for maintaining an adequate water supply in the Western Cape the scenario referred to as the “*Second World Future*” has been adopted.

It is recommended by NSI (1994) that the DWAF should be made aware as early as possible of potential industrial and urban developments requiring large water supplies, and that actual growth in water demand be closely monitored in order to give early warning of deviation from the forecasts. It would also be desirable to forecast and monitor population growth in the various areas as an additional aid and to assist in forecasting the distribution of water demands in CTWU’s area of supply.

### *Agricultural demand*

The following projections of water demand by agriculture were made by Spies & Barriage in 1991:

SOURCE	DEMAND FORECAST ( $10^6 \text{ m}^3/\text{annum}$ )		
	1991	2000	2010
<b>Riviersonderend Scheme</b>			
Eerste River	3	27	33
Upper Berg River	24	47	73
Vyeboom	0	10	11
Villiersdorp	1	3	5
Riviersonderend Valley	15	25	36
Rüens stock watering	3	3	3
<b>Sub-total</b>	<b>46</b>	<b>115</b>	<b>161</b>
<b>Voëlville Scheme</b>			
Lower Berg River	10	25	32
<b>Palmiet River</b>	<b>40</b>	<b>55</b>	<b>62</b>
<b>TOTAL</b>	<b>96</b>	<b>195</b>	<b>255</b>

(Source: Spies & Barriage, 1991)

The above forecasts were based primarily on the market potential for the agricultural produce, taking into account comparative advantages of competing regions and availability of suitable

land and water. The Riviersonderend scheme projection was based on an optimistic expectation of socio-political developments, on “medium” harvest targets with consequent relatively high water demand per unit of production and an assumption that 50% of the vegetable growing land in the area on the Cape Flats would be converted to urban use by the year 2010. The latter area is self-sufficient in water, and displacement of its market gardening would increase total water demand.

### ***Environmental demand***

The supply of water for the maintenance of environments (i.e. the maintenance of ecological functioning) has been recognised as vital in the WCSA. Though attention has been given to determining what those needs are - in quantity, quality and timing, absolute values cannot be established, - even approximations have generally been elusive. Consequently, attention has been given to the sensitivity of the environment to changes in water regime, as well as the general environmental impact. Since generalised quantitative rules cannot be applied, provisions made for environmental water needs are discussed in the WCSA under the descriptions of the various potential water supply schemes. In particular the measurement of instream flow requirements (IFRs) downstream of proposed dams have been used to determine the needs of rivers in terms of minimum water flow required for proper ecological functioning.

## **1.4 OPTIMISING PRESENT SUPPLY AND MEETING FUTURE DEMAND: THE WESTERN CAPE SYSTEM YIELD AND PLANNING MODEL**

The main bulk storage reservoirs which supply most of the water used in the Western Cape are widely spread throughout the area. There is benefit in operating a water supply system as a unit in order to obtain the benefits of conjunctive use and to spread the risk of water restrictions amongst all the Western Cape water users (NSI, 1994). Responding to this, a Water Resources Yield Model (WRYM) and a Water Resources Planning and Operating Model (WRPOM) were developed for the integrated management of water supplies in the Western Cape. The Yield Model was used to determine the firm yield versus reliability relationships for each of the water

supply sub-systems. The Planning Model was set up for the determination of annual integrated system operating rules, including the analysis of the need for and level of water restrictions, and the determination of the phasing of system augmentation.

The Water Resources Yield Model (WRYM) has been used to determine sub-system yields, and their corresponding reliabilities, from historical and stochastically generated streamflow sequences in the Western Cape System Analysis. These results provide valuable information regarding the long term supply potential of both existing and proposed water supply schemes and the need for further augmentation of existing supplies.

The (WRPOM) differs from the Yield Model, in that it is a dynamic model that allows the following additional facilities:

- Demands may be varied with time.
- New water supply schemes, reservoirs, pipelines, etc., may be phased in or out, as required.
- Variable water restrictions may be imposed on the systems' demands in order to ensure the supply of high priority water.
- The balancing of risk of water supply and required level of water restrictions across the integrated system by inter sub-system support or demand allocation.

The WRPOM is used as a planning tool to determine the phasing of the introduction of water supply augmentation schemes. It uses various demand growth scenarios and the criteria for the analysis of acceptable risks of various water restriction levels. With the introduction of restrictions in the Planning Model at least one annual decision date is required in order to determine: (1) whether a shortfall is imminent in any sub-system, (2) the level of support available from individual water resources and (3) a water restriction level that is balanced across all the sub-systems. In the WCSA this was chosen as 1 November each year as this is deemed to be the date at which the chance of further significant inflow is minimal before the following period of high demand.

(Source: NSI, 1994)

## **1.5 THE WATER SUPPLY OPTIONS**

One of the main objectives of the WCSA was to identify future water supply options. The options identified in the WCSA study have been evaluated to varying degrees of detail depending on their degree of potential as options for the near future. Table 1.5.1 (source: ZSA, 1996) briefly outlines all the options identified in the WCSA, focusing on cost, yield, socio-economic and environmental considerations. Figure 1.5.1 (source: ZSA, 1996) maps out the geographic location of the options.

Integral to the decision making process between supply options in the WCSA is the assessment of individual options. In light of this, two case studies of such assessments are presented in an Appendix. The first case study (Appendix 1) deals with the assessment of a typical supply augmentation scheme: the recently approved Skuifraam dam. The study is taken from the Environmental Impact Assessment conducted by Ninham Shand Consulting Engineers in which I contributed the specialist report on economic impacts. The demand management option is then investigated further in Appendix 2 as it is particularly interesting from a resource economics point of view and enjoys increasing support as an option. Special attention is given to economic demand management strategies.

Figure 1.5.1: Location of Schemes and Geographical Areas

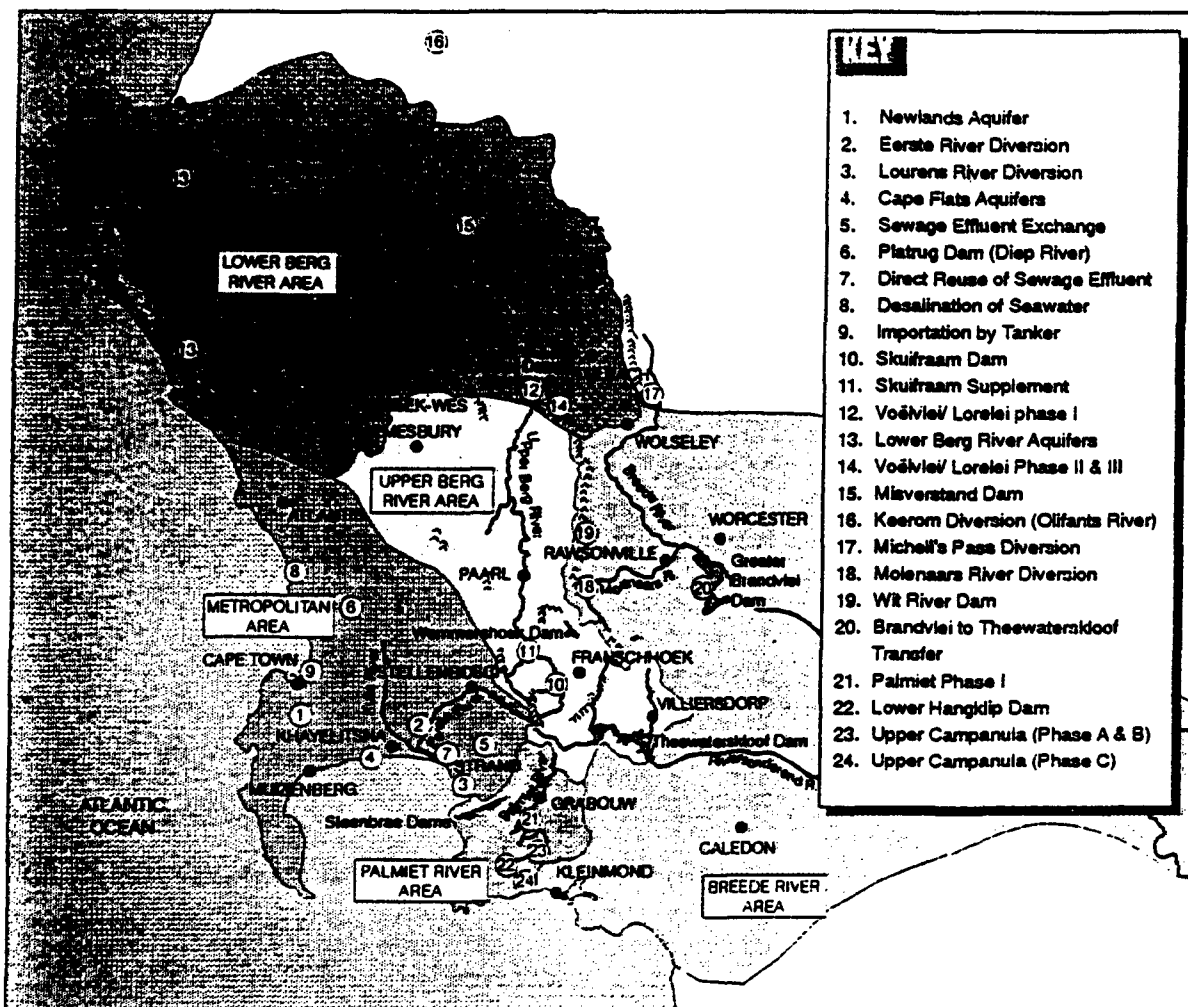


Table 1.1: Comparison of Schemes

AREA	METROPOLITAN AREA										UPPER BERG RIVER AREA					LOWER BERG RIVER AREA					BREEDER RIVER AREA					PALMIET RIVER AREA									
	SCHEME	REPORT REFERENCE	POTENTIAL BIOPHYSICAL IMPACTS	SEWAGE EFFLUENT EXCHANGE	CAPE FLATS FLATS AQUIFERS	LOURENS RIVER DIVERSION	EERSTE RIVER DIVERSION	NEWLANDS AQUIFER	DESALINATION OF SEAWATER	IMPORTATION BY TANKER	SKUIFRAAM DAM	SKUIFRAAM SUPPLEMENT	VOELVLEI/LORELEI PHASE I	LOWER BERG RIVER AQUIFERS	VOELVLEI/LORELEI PHASE II AND III	MISYERSTAND DAM	KEEROM DIVERSION (OLIFANTS RIVER)	MICHELL'S PASS DIVERSION	MOLEMAAPS RIVER DIVERSION	WIT RIVER DAM	BRANDVLEI TO THEEWATERSKLOOF TRANSFER	PALMIET PHASE I	LOWER HANGKLOOF DAM	UPPER CAMPANULA (PHASE A & B)	UPPER CAMPANULA (PHASE C)										
		Section 2.1.1	SLIGHT Possible lowering of water table - further drying of trees, reduction in springs and flow of livestock water	Section 2.1.4	SLIGHT Possible lowering of water table - further drying of trees, reduction in springs and flow of livestock water	Section 2.1.3	SLIGHT Further degradation of water quality, disturbance of degraded estuary	Section 2.1.2	SLIGHT-MODERATE Further degradation of water quality, disturbance of modified wetlands and estuary	Section 2.1.5	SLIGHT Impact on the Berg River	Section 2.5.1	SLIGHT Lowering of water table could impact on wetlands and Berg River estuary	Section 2.5.2	MODERATE-SEVERE Flooding of endangered vegetation and habitat of the endangered promeris worm; negative impact on downstream water quality; impact on ecologically important Berg River estuary	Section 2.5.4	SEVERE Potentially significant impact on water quality and ecologically important Berg River estuary	Section 2.5.5	SEVERE Flooding of area with high concentration value; threat to rare migratory fish; impact on downstream marine ecology and estuary	Section 2.4.1	SLIGHT-MODERATE Impact on Berg River; undisturbed areas may be used to replace pine plantation; impact on estuary	Section 2.4.2	SLIGHT Impact on the Berg River	Section 2.4.3	SEVERE Flooding of valuable fynbos; impact on relatively undisturbed river	Section 2.4.4	MODERATE-SEVERE Flooding of Pappanish wetland; impact on downstream riverine ecology	Section 2.7.1	SLIGHT-MODERATE Impact on relatively undisturbed river and ecologically important estuary	Section 2.7.2	SEVERE Flooding of rare plants and undisturbed river; undisturbed Palmiet River	Section 2.7.3	MODERATE-SEVERE Flooding of Palmiet river and impact on river and estuary; flooding of fynbos	Section 2.7.4	MODERATE-SEVERE Flooding of fynbos vegetation and the relatively undisturbed Palmiet River; impact on ecologically important estuary
		Section 2.1.8	SLIGHT-MODERATE High energy consumption; impact of salty effluent	Section 2.1.7	BENEFICIAL- SLIGHT Improvement of water quality in river and sea	Section 2.1.6	MODERATE-SEVERE Impact on Kieribi and estuary	Section 2.1.5	SLIGHT-MODERATE Adverse effects on agricultural users of this water	Section 2.5.3	MODERATE Flooding of yach club and other tourist infrastructure; impact on Nature Reserves	Section 2.5.4	MODERATE Flooding of vineyards and wheat fields; inundation of infrastructure	Section 2.5.5	MODERATE Inundation of area with high aesthetic value; impact on agriculture	Section 2.4.1	SLIGHT Reduce gravel supply to some crushing plants; impact on agriculture	Section 2.4.2	MODERATE Impact on trout fishing; taking from Breede River into Kieribi Dam	Section 2.4.3	MODERATE-SEVERE Impact on recreation; aesthetic and wilderness experience	Section 2.4.4	MODERATE Impact on windblown sand and recreation at Kieribi Dam; impact on agriculture	Section 2.7.1	SLIGHT Impact on recreation of estuary	Section 2.7.2	SEVERE Loss of wilderness; aesthetic impact; impact on recreation; impact on internationally important conservation area	Section 2.7.3	MODERATE Flooding of agricultural land; recreation facilities and pine plantation	Section 2.7.4	MODERATE Impact on wilderness experience; recreation and internationally important conservation area				
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## **1.6 THE DECISION MAKING PROCESS FOR DECIDING BETWEEN OPTIONS<sup>4</sup>**

This section describes the decision making process used by DWAF in order to generate a short list of options for further study from the original list of options generated in the WCSA and outlined in section 1.5. The process is not critically evaluated or commented on in this section. This is done in section 5.1.2 in order to guide the choice of an appropriate future decision making framework.

### **1.6.1 The initial DWAF short list**

After the had WCSA generated supply options, the focus shifted to deciding between options. By early 1996, the DWAF had already generated its own short list of favoured options that it thought warranted further investigation through an internal screening process:

- Water demand management
- Voëlvlei/Lorelei phase 1
- Skuifraam Dam
- Cape Flats aquifer
- Molenaars River diversion
- Eerste River diversion

In addition to the short list, five other relatively highly priced options were put forward for consideration in case the short listed schemes were not acceptable:

- Skuifraam supplement scheme
- Upper Campanula (phases A & B)
- Brandvlei Dam to Theewaterskloof Dam transfer

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<sup>4</sup>The information in this section was taken from handout documents prepared on behalf of the DWAF by the process facilitators and through attending the meeting at Goudini in April 1996(mentioned in section 1.6.2) and the subsequent meetings of the Task Group elected at Goudini.

- Lower Berg River aquifers
- Voëlvlei/Lorelei phase 2 & 3

The short list was generated internally by the DWAF using the following values and criteria (ZSA, 1996):

1. There is a need to meet the regional water demand.
2. Engineering feasibility is a must.
3. Money is a limited resource.
4. Long term solutions are required.
5. One big scheme is often better than several small ones.
6. The maintenance of flexibility is desirable.
7. Water is a national resource to be used effectively and efficiently.
8. The minimisation of environmental and social costs must be striven for.

#### **1.6.2 The public participation process**

This list was generated without public consultation. To remedy this, the DWAF in October 1995, initiated a process for involving the people of the Western Cape in the screening of the best options for further investigation. The process sought to:

- Involve interested and affected people and groups.
- Communicate all relevant information to affected people and groups.
- Use participatory methods which empowered and enabled all participants to interact as equals.
- Promote greater public awareness and responsibility about the Western Cape's water resources.
- Establish a close link with the Integrated Environmental Management (IEM) process on the proposed Skuifraam Dam.

(Source: ZSA, 1996)

The DWAF invited a broad spectrum of community representatives including local councils, farmers' associations (including established irrigation farmers and emerging farmers), irrigation boards, business organisations, environmental groups, development forums and other community-based organisations, and labour unions to participate in the evaluation process. Those that were interested in participating were given an information package containing a description of the water supply situation in the Western Cape and summary engineering, financial and environmental information on each of the options to be evaluated.<sup>5</sup> They were then all invited to an 'Evaluation of Options' conference at Goudini, in April 1996. Representatives from approximately 100 organisations attended. The conference participants thus represented all the major interest groups originally invited thereby achieving a high level of representativeness.

The conference started with short presentations by Ninham Shand representatives on each option to clarify any points of misunderstanding regarding information on the options. Most of the conference was spent reaching consensus on which principles and criteria should be used in evaluating the options. This was done by dividing the 100 organisations into broad interest groups (for example, the Wildlife Society, Cape Bird Club, Friends of Hangklip and others gathered under an environmental interest group). Each interest group then compiled its own list of principles and criteria. Later, all the interest groups gathered to decide on the final overall principles and criteria through a process of debate and compromise.

The final guiding principles agreed on were:

1. The water must be used efficiently/effectively.
2. The water must be used fairly.
3. Social and economic impacts must be assessed.
4. The option must be acceptable in terms of social, cultural & religious norms and practices.
5. The needs of all users within a catchment must be considered.
6. The efficiency of the current use of water resources must be maximised.

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<sup>5</sup>The summary information on each option consisted of a map and approximately one page of information.

7. The supply of water must be reliable and consistent.
8. Inclusive public participation must take place.
9. The public must be consulted on an ongoing basis.
10. The supply of water must be sustainable.
11. The diversity of river type, biological components of the ecosystem and habitats and socio-cultural elements must be conserved.
12. The option must allow sufficient water for the “reserve”, that is for basic needs of people and of the natural environment.

The final comparative criteria were as follows:

1. Will the water be affordable?
2. Will the option cause the price of water to change in a dramatic or unpredictable fashion?
3. Will the supply meet the needs of informal settlements?
4. Will the water be of good quality for informal settlements?
5. Will there be tangible job creation opportunities?
6. Will the option provide accessible water to emerging farmers?
7. Will the option contribute to self sufficient communities?
8. Will the donor basin’s needs be met before water is transferred?
9. Does the option affect the quality, availability and reliability of water for ecological functioning?
10. Will the option allow smaller towns and larger towns to receive equitable attention?
11. Does the option affect areas of exceptional environmental importance, such as sources of water, high biodiversity areas, and areas meeting criteria of international conventions?
12. Does the option use environmentally friendly technology?
13. Have the options been ranked according to financial cost, yield, longevity, as well as environmental and socio-economic affects?
14. Is there sufficient comparative information available for each option?
15. Does the option contribute to a long term solution to water demand?

### **1.6.3 The Task Group evaluation of the options**

As a final step in the conference, a Task Group was elected from among the representatives to take the evaluation process further. This was done due to the time and cost constraints of bringing all 100 groups together again. The Group was, however, subject to the endorsement of all present at Goudini. Its formation was also conditional on all groups being given a chance to comment on the further findings of the Task Group. The Task Group consisted of one representative from each of the following groups:

- Environmental
- Emerging farmers
- Irrigation farmers
- Labour
- Commerce and industry
- Breede River area
- Local authorities

Four representatives each for:

- Rural Community Based Organisations (This group consisted of one representative from each of the following organisations: The Kogelberg Biosphere Organisation, Rivieronderend Youth League, Velddrift RDP Forum, Friends of Hangklip.)
- Urban Community Based Organisations (This group consisted of one representative from each of the following organisations: Stellenbosch RDP, Cape Metro Region Interim Services Council, Wolfgat Interim Management Committee, Observatory CA.)

As well as two DWAF representatives making a total of 17 people.

At the first meeting of the Task Group in August 1996, discussions lead to an agreement that the following options should not be considered further:

- Keerom Diversion
- Platrug Dam
- Wit River Dam
- Misverstand Dam raising
- Importation by tankers
- Icebergs
- Table Mountain Sandstone aquifers
- Rainwater tanks
- Plastic containers

Due to the feeling that options not on the list of schemes in their own right would receive less attention, two options were added to the list of schemes:

1. Water demand management
2. Invasive alien catchment clearance

The Group then appointed consultants to get additional information on biophysical, social and engineering issues for each option before attempting an evaluation of the options. In October, having considered the additional information, a two-day workshop was held for the evaluation. The workshop began with a presentation of the additional information gathered and a revisiting of the comparative criteria. Following this, an anonymous vote was taken in which each Task Group member was given 7 votes to generate a preliminary short list. In this procedure, each scheme was written on a poster and Task Group members were given dot stickers to stick next to the seven schemes that they favoured most for inclusion on the short list of schemes to be studied further. The results of this procedure were as follow:

<b>SCHEME</b>	<b>VOTES</b>
Skuifraam Dam	11
Water Demand Management	10
Voëlvlei/Lorelei 1	8
Eerste River diversion	6
Alien vegetation clearance	6
Lourens River diversion	5
Cape Flats aquifer	4
Direct re-use of sewage effluent	4
Desalination of sea water	4
Skuifraam supplement	4
Michell's Pass	4
Sewage effluent exchange	3
Lower Berg aquifers	2
Voëlvlei/Lorelei 2 and 3	2
Theewaterskloof raising	2
Brandvlei to Theewaterskloof transfer	1
Upper Campunula A & B	1

After a brief period of debate, agreement was reached on dropping the last five options (Lower Berg aquifers, Voëlvlei/Lorelei 2 & 3, Theewaterskloof raising, Brandvlei to Theewaterskloof transfer and Upper Campunula A & B) from the list thus leaving a list of 12 options for further study. The relatively high number of votes assigned to the Skuifraam dam and water demand management indicates that these options were highly favoured. For the options in the middle of the list, the similar ranges of votes assigned to them indicate more difficult choices will be necessary in the future. The groups from the Goudini conference, which the Task Group was representing, endorsed the short list after which it was submitted to the Minister of Water Affairs and Forestry at the end of 1996. The Minister gave an undertaking to the Task Group that their findings would be considered in future decision making.

## **CONCLUDING REMARKS**

This chapter has provided an overview of the findings of the WCSA and the process used to aid decision making between options. This process will be revisited and commented on in Chapter 5 as part of the debate on the choice of a future decision making framework. The study will now proceed to focus on the decision making frameworks or processes that have been used

elsewhere and documented in the water resource decision making literature. The following two chapters survey the literature on decision making frameworks most commonly used in water resource planning.

## **CHAPTER 2**

# **THE HISTORICAL DEVELOPMENT OF DECISION MAKING IN WATER RESOURCE PLANNING**

### **INTRODUCTION**

Methods and frameworks of decision making have become a much studied topic particularly in the fields of economics, operations research, management science, behavioural science and environmental science. The literature on the topic is thus broad and widely dispersed. In order to stay within the bounds of what is relevant to decision making in water resource planning, the next two chapters focus on decision making related to development and environmental resources. Water resource planning is therefore seen as the planned development of an environmental resource.

Water resource planning is the process followed in order to ensure the optimal development of water supply in a given setting. Hydrological, environmental, engineering, financial, sociological, political and economic aspects, all form part of the planning process. The focus here is on the decision making processes that are used in water resource planning in order to achieve adequate supply. Although decision making occurs at many stages during the planning process, the application of decision making frameworks is usually reserved for final decisions between alternative plans or options. It is decision making during this stage which is the focus of the present discussion.

This chapter initially reviews the historical development of decision making and decision making methods in water resource planning. As water resource planning is concerned with development and environmental issues, the decision making in these two fields will be discussed as well as a discussion more focused on water resource planning. Water resource planning in South Africa has generally followed the main trends in water resource planning in the United States (Pers.

Comm. Peter van Niekerk, DWAF, 1997). What follows will thus rely heavily on the United States literature.

In Chapter 3, the decision making methods/frameworks that have been the most prevalent in water resource planning and environmental development planning are dealt with further, i.e. Social cost-benefit analysis (SCBA), multi-criteria decision analysis (MCDA), and environmental impact assessment (EIA) approaches (the Delphi and Sondheim techniques). This chapter provides more detailed investigations of their workings, a presentation of case studies on their application along with possible lessons from these case studies, and a discussion of their strengths and weaknesses.

## **2.1 EARLY WATER RESOURCE PLANNING**

According to Goodman (1984), modern water resource planning began with the enactment of the Flood Control Act of 1936 in the United States when, for the first time, formal cost-benefit analysis became a planning requirement - in this case to aid the decisions involved in instituting flood control measures. It marked the beginning of a broader approach, where in early water resource planning the tendency was to focus narrowly on engineering feasibility. The period following the Flood Control Act was characterised by large scale water related construction activity in the United States partly to provide jobs and stimulate the economy during the depression years. Six major dams with diverse objectives including flood control, irrigation, electricity generation, economic development, etc. were built during this period (Petersen, 1984).

A further attempt was made in the early 1950s to increase objectivity in planning and clarify approaches to decisions that are basically subjective. The result of which was the publication in 1958 of guidelines for planning by the Inter-Agency Committee on Water Resources entitled "Proposed Practices for Economic Analysis of River Basin Projects." Goodman (1984) identifies the 1950s as the period in which economists and natural resource planners extended their influence in water resource planning beyond the literature and into professional practice

and government policy making - both areas which had been dominated almost solely by engineers. As part of this process, interest in social cost-benefit analysis grew and research in it expanded. This was also about the time when the systems analysis approach to solving complex water resource planning problems emerged originating in operations research (Benedini, 1992).

## **2.2 THE DEVELOPMENT OF MORE HOLISTIC APPROACH**

In 1969, environmental considerations came to the fore in development planning (including water resource planning) with the passing of the National Environmental Policy Act. The Act made environmental impact statements/assessments mandatory for all significant federal actions in the United States thereby introducing environmental considerations as a more prominent concern in planning. During the ensuing period, planning benefited from a more holistic approach as ecologists, sociologists and other environmental and social scientists became involved in planning (Goodman, 1984). EIAs were introduced mainly to inform decision makers and have become a part of good development planning throughout the world (Fuggle & Rabie, 1992). In South Africa an initiative by the Council for the Environment led to the integrated environmental management (IEM) procedure in 1989 which is still used to guide EIAs in South Africa (Council for the Environment, 1989).<sup>6</sup> EIAs are not, however, required by law for major developments in South Africa.

The information contained in EIAs can be taken forward and used as an input into formal decision making frameworks such as cost-benefit analysis or multiple criteria decision analysis which both consider all decision factors including those affecting the environment. EIAs are not, however, strictly decision making methods, but rather information aides to decision making used to inform decision makers on the environmental aspects of a given project or plan. It must, however, be noted that decisions can naturally evolve over time as new information comes to light - often supplied by the EIA process. In this way, everyone involved in EIAs plays a part in shaping the decision to varying degrees even if they are not involved in making it (Munn, 1979).

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<sup>6</sup> 1970 is regarded as a watershed year in terms of the rise of environmental concern internationally and in South Africa (Fuggle & Rabie, 1992) even though Impact Assessment was not formalised in South Africa until 1989

The debate over how far EIAs should go in aiding decision making remains contentious. Is an explicit identification of the best option required in an EIA or is it adequate to merely identify and assess impacts? EIAs have a varied track record in producing a "...clear basis for choice among options for the decision maker and the public" (Council on Environmental Quality, 1987 in Gregory et al, 1992, p. 59). This lack of explicitness has become one of the major criticisms levelled against EIAs, as it leads to EIAs being less effective as decision aides (see Gregory et al, 1992).

EIAs can be presented in a way that represent an 'answer' on the desirability of a project from an environmental perspective when the information on impacts is taken further and presented in a way that makes an explicit judgement. The techniques (the Delphi and Sondheim) used in the field of impact assessment that take the information gathered in EIAs a step further into a decision making framework will be included in the analysis of Chapter 3. They are a form of decision making method that can be adapted and used to consider all the relevant decision factors and not only those concerning the environment.

The Environmental Evaluation System(EES) developed at the Battelle-Columbus laboratories in 1971 to evaluate the environmental impacts of water resource development is an example of an EIA technique which focuses solely on the environment. The technique provides for environmental impact evaluation using four major themes which are further broken down into 18 components and finally 78 parameters all of which represent aspects of environmental significance. It allows for the calculation of commensurate units called 'environmental impact units' for each project which can be used for comparing the impacts before and after a project and between projects (see Dee et al., 1973 for a detailed description of the EES).<sup>7</sup> All of the categories, components and parameters are pre-defined and specific to environmental considerations. They cannot be adapted to include other considerations such as financial aspects.

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<sup>7</sup>The technique is similar to the Sondheim and MCDA methods in that it makes use of attributes or components, scoring and weighting in determining the value of environmental impact units.

Interaction with the public in resource planning evolved gradually from nothing, to a situation in which it was thought adequate to merely notify the public of resource decisions, to the more participatory environment of today. This evolution occurred mainly as EIAs, which require public participation, became a more common practice. In the participatory setting, the public are given a chance to participate if they wish or are actively asked to make contributions. The efficacy of their inputs in actually influencing the decision making process and not merely raising issues has been varied. The efficacy issue arises in impact assessment settings in which people, after being asked to participate, cannot see how their contributions influenced decisions. This leaves them feeling that the public participation process was merely a 'window dressing' exercise and not an attempt at joint problem solving. During the 1970s, the National Water Commission (NWC) was active in making water planning policy recommendations in the United States. Among their recommendations were increased participation by local and intrastate planning authorities and the public in water resource planning (Petersen, 1984). Today participation is not applied consistently in South Africa for all projects yet the tendency is towards more direct influence from the public in public sector decision making.<sup>8</sup>

By the early 1980s, "...in the United States there was a generally recognised need to make the water resource planning process more economical and expeditious" (Petersen, 1984, p. 33). This was, at least in part, due to environmental impact statements ballooning into unreasonably expansive and unfocused studies that masked real decision making considerations. The Reagan administration tackled this problem and produced streamlined guidelines in 1983 entitled "Economic and Environmental Principles and Guidance for Water and Related Land Resources Implementation Studies." These guidelines stipulated that planning of alternatives for water supply was to take place in full consideration of the four criteria of completeness, efficiency, effectiveness and acceptability with mitigatory actions as integral. Impacts were to be evaluated in four 'accounts' or themes:

- National economic development

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<sup>8</sup> The encouragement of public participation in the WCSA is a case in point in this regard.

- Environmental quality
- Regional economic development
- Other social effects

Plans or options with the highest net economic benefits while protecting the environment were identified as those that would receive governmental approval. Any plans that were an exception to this rule had to be clearly explained and justified.

This system of evaluation forced multi-disciplinary problem solving. Water engineers/planners had to contact decision makers in order to find out their preferences and multi objective analysis was extended to include objectives of any type (Benedini, 1992). At this stage multi criteria decision analysis was gaining ground rapidly.

In South Africa, the late eighties saw the publication by the Department of Water Affairs of "Management of the Water Resources of the Republic of South Africa" (1986). This document served to confirm the shift to a more holistic approach being used by the Department. "The Department of Water Affairs is refining a flexible alternative (way of planning) that comprises a dynamic, holistic national water management strategy ... that uses optimal resource allocation principles" (DWA, 1986, p. 6.3).

### **2.3 THE 1990s**

Multiple criteria decision analysis found wider application in water resource planning during this period. In 1992, The Water Resources Bulletin journal of the American Water Resources Association devoted an entire volume to the application of MCDA in water resource planning. In the same year, decision support systems and expert systems were identified as the major methodological developments facing water resource planners. These are both computerised procedures based on System Analysis techniques used to aid decision making in water resource planning. They can be seen as a reaction to the complexity of modern water resource questions

which involve all professionals “called in by the complexity of the problem” as well as affected communities (Benedini, 1992, p. 8).

In terms of future challenges, Benedini (1992, p. 9) states the following: “It has to be kept in mind, however, that in spite of all theoretical advances the researchers have made in formulating a diversity of water resources management and planning models, there are still persistent inadequacies hampering the practical application of these models. This setback can be identified very often as due to inadequate fusion of the diverse phenomena characterising the complex nature of water resources management and planning, such as the hydrological processes, with the socio-political factors and the environmental aspects as well.”

In terms of current trends in water resources planning, McIntosh (1993, p. 415) states that “water resources planning must take a long-term view, balancing the sometimes conflicting interests of customer needs (for quantity, quality and reliability), environmental protection and cost-effectiveness.” Gleick et al. (1995) also identify three current trends in the transition towards sustainable water use in California: (1) the democratisation of the water planning process, (2) the incorporation of environmental values in water use decision-making, and (3) the emergence of market-based solutions that drive water conservation and efficiency.

## **CONCLUDING REMARKS**

Early water resource planning was dominated by efficiency considerations. With the passage of time, it was realised that a more holistic approach was necessary in the United States - after the passing of the National Environmental Protection Act this became a reality. More recent trends indicate that holistic planning is entrenched in the field and that public participation in decision making is regarded as vital to proper planning. The next chapter will investigate the specific decision making methods, mentioned in this chapter, that have been used in water resource decision making.

## **CHAPTER 3**

# **LITERATURE REVIEW OF DECISION MAKING FRAMEWORKS IN WATER RESOURCE PLANNING**

## **INTRODUCTION**

The previous chapter dealt broadly with the evolution of decision making in water resource planning. This chapter has a narrower focus and deals with the individual decision making methods that have been applied in water resource planning and general environmental development planning. These include:

1. Social Cost-benefit Analysis (SCBA)
2. Multi Criteria Decision Analysis (MCDA)
3. Environmental Impact Assessment methods (the Delphi and Sondheim techniques)

SCBA and MCDA will be dealt with in more detail than the other methods because they have been applied more widely in the recent water resource planning literature.

Each method is dealt with separately using the following format:

- Brief description of its theoretical background and historical development.
- Outline of the basic workings of the method.
- Case studies on the application of the method in water resource planning with possible lessons for the Western Cape.
- Discussion of the strengths and weaknesses of each method.

### **3.1 SOCIAL COST-BENEFIT ANALYSIS (SCBA)<sup>9</sup>**

#### **3.1.1 Theoretical background and historical development**

SCBA is a public sector decision procedure for:

1. “Measuring the gains and losses to individuals, using money as the measuring rod of those gains and losses.
2. Aggregating the money valuations of the gains and losses of individuals and expressing them as net social gains or losses” (Pearce, 1983, p. 3)

The beginnings of social cost-benefit analysis date back to 1844 when Jules Dupuit published his work on the benefits and costs of constructing a bridge. In his paper, ‘On the utility of public works’, Dupuit introduced the concept of consumer surplus as the excess of willingness to pay over actual payment (Johansson, 1993). For an individual:

Willingness to pay = Price paid + Consumer surplus

The development of the concept of willingness to pay formed the basis for benefit measurement in SCBA - measured as the aggregate willingness to pay of the beneficiaries (Pearce, 1983). The effect of a project or policy on consumer surplus could now be used to determine benefits. The measurement of consumer surplus was not, however, without its problems. Marshallian consumer surplus analysis ran into theoretical difficulty due to the fact that it incorporated both the income and substitution effects. The former effect arising when a fall in price raises the real income of the consumer. The incorporation of this effect implied that the area under a demand curve was measured as a gain in utility when one of the factors affecting the way utility is measured, namely income, was itself changing (Pearce, 1983). In order to deal with this shortcoming, Hicks (1941) developed Hicksian compensating variation (HCV) which used a

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<sup>9</sup> The distinction is made between social cost-benefit analysis which deals with the costs and benefits of a project from society’s point of view. This is opposed to cost-benefit analysis which looks at projects from a private perspective.

compensating variation demand curve, thereby only including the substitution effect and keeping the consumer on his or her original demand curve (Brown & Jackson, 1994).<sup>10</sup> He also developed Hicksian equivalent variation (HEV) which eliminated the income effect by adjusting the demand curve to keep the consumer on his or her subsequent demand curve. It was, however, forcibly argued by Willig (1976) that the errors occurring through the use of Marshallian consumer surplus would not be of any great significance. Debate still occurs on which of the three measures to use - HCV has, nonetheless, been most widely recommended in the theoretical literature (Pearce, 1983).

Eckstein's work in 1958 along with his work with Krutilla and McKean's work all in the same year was important as it used the theory of welfare economics as a theoretical foundation for SCBA. Pearce (1983) identifies three linkages in these works between SCBA and the theory of welfare economics:<sup>11</sup>

- (a) The construal of a benefit as a gain in welfare (utility) and a cost as any loss in welfare;
- (b) The concept of cost as opportunity cost;
- (c) The rooting of the idea of maximising net benefits in the Pareto improvement rule.

Due to it being unlikely that any project would satisfy the stringent requirements of the Pareto rule it was replaced by its more workable modification - the Kaldor/Hicks rule. This rule stated that a project should be approved if those that benefit are able to compensate loser and still have benefits left over. Reference was made to Scitovsky's criticism of the Kaldor-Hicks rule which pointed out that losers could subsequently compensate those who benefited from a project thus reverting to the situation before the project. This could happen if a project changed the distribution of income and hence relative prices. At a new set of prices, it could be possible to approve a project which would revert to the initial situation based on the same Kaldor-Hicks rule. Scitovsky's criticism was, however, largely ignored (Pearce, 1983).

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<sup>10</sup>Compensating variation is the method most widely recommended in the literature (Pearce, 1983).

<sup>11</sup> As developed by Barone (1935) and Arrow (1951) among others.

These developments occurred despite the highly negative comments of Samuelson (1947), Graaff (1957) and others who attacked the use of consumer surplus and welfare economics in general coming from a positivist standpoint focusing only on observable economic phenomena. The “cavalier” theoretical assumptions of welfare economics were brought into question by Graaff (1957). Its ethical basis rooted in subjective judgements of the nature of utility/welfare and the comparison of utilities was also criticised. The Paretian principle was criticised for its lack of workability as a guide for decisions aimed at improving welfare. Its alternative, the Hicks/Kaldor compensation principle, was also theoretically rejected and proven to be flawed by Scitovsky. Arrow (1951) contributed to the criticism of welfare economics by showing that it is impossible to derive a social welfare function without violating one or more of the four main features considered necessary for the function to be acceptable (i.e. transitivity, social preferences must respond in the same direction as individual preferences, social preferences must not be imposed upon consumers or dictated by any particular consumer and preferences must be independent of irrelevant alternatives) (Douglas, 1982).

As mentioned earlier, the first application of cost-benefit analysis occurred in 1936 as part of the United States Flood Control Act. It is interesting to note that this preceded developments in welfare economics that would become SCBA’s economic foundations (Pearce, 1983). The method was, however, very crude at this early stage and confusion existed over the precise meaning and thus measurement of benefits. This led to individual agencies approaching similar projects from different standpoints (Johansson, 1993).

The refining of the procedures to be followed in comparing costs to benefits was taken a step further in 1950 by the US Federal Inter-Agency River Basin Committee in a SCBA guideline document commonly known as the ‘Green Book’ which was later revised in 1958 (Pearce, 1983). This document was aimed at setting consistent rules to be used in carrying out SCBAs thus exerting significant influence on the practical development of SCBA. It focused on economic efficiency although acknowledging the possible influence of non-economic factors in public policy (Goodman, 1984).

The number of publications in the academic literature focusing on public investment decisions grew enormously in the 1950s and 1960s. Irvin (1978) points out that the surge in interest in SCBA was not only influenced by developments in the academic literature, but also by failures in the national development plans launched in the previous decade and an increasing need among aid agencies to evaluate development assistance options.

In 1958 Eckstein published 'Water Resource Development' in which he critically evaluated cost-benefit analyses undertaken up to that point and presented standardised methodologies to test the quality of a project and select the most desirable project from the standpoint of economic efficiency.<sup>12</sup> At the time it was felt judgements about income distributional changes, political objectives and social objectives were better left to government. Accordingly these issues were not included in cost-benefit analysis leaving the focus squarely on economic efficiency. The exclusion of the distributive equity objective was justified (and still is by some) on the grounds that the government would be able to redistribute project income through fiscal and other measures.

The distinction must be made here between SCBA and cost effectiveness analysis (CEA). While SCBA focuses on comparing cost and benefits, CEA is used to determine the cheapest (most cost effective) way of achieving the goals of a project. This is done by simply calculating all the costs of each alternative, applying the appropriate shadow prices, and discounting to obtain the present value of costs (OECD, 1995). CEA can thus only be applied when all of the alternatives under consideration can achieve the project goals with equal success (i.e. the benefits are the same for all options). Unfortunately CEA is also used, by default as it were, where there is no agreement on how to measure project benefits (Randall, 1981).

Tinbergen (1956, 1967) was amongst the first to argue the case for the use of 'accounting pricing' later referred to as 'shadow pricing'. Others who made significant contributions in this

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<sup>12</sup> In the same year Eckstein published 'Multiple Purpose River Development' with John Krutilla. The focus of which was broader basin development as opposed to individual project evaluation

regard were Marglin (1963), Sen (1968) and later Little & Scott (1976) and Srinivasan & Bhagwati (1978).

According to Irvin (1978), the early (late 1950s, early 1960s) work in SCBA was mainly concerned with establishing the scope of costs and benefits to be taken into account, popularising discounting and related decision rules and valuing particular types of costs and benefits not readily priced by the market. It was somewhat surprising that SCBA survived and flourished through the 1960s despite the theoretical attack on welfare economics (Pearce, 1983).<sup>13</sup> Krutilla (1981) suggested the reason for this was that SCBA evaluated projects not policies and thus focused on the relatively minor distributional issues associated with projects thereby avoiding the major distributional issues involved in policy evaluation.<sup>14</sup> Pearce (1983) suggests that in addition to this it was the purely practical appeal of SCBA that made it popular with decision makers not involved in academic debates.

Towards the end of the 1960s, the first set of guidelines for SCBA were published by the Organisation for Economic Co-operation and Development (OECD) compiled by Little & Mirrlees (1969).<sup>15</sup> These were followed by the United Nations International Development Organisation (UNIDO) guidelines compiled by Dasgupta et al. in 1972 and the World Bank guidelines in 1975 compiled by Squire and van der Tak. There were other texts on CBA methodology by Marglin (1967), Mishan (1972), Harberger (1973), Lesourne (1975), Sassone & Schaffer (1978), Pearce & Nash (1981), Gittinger (1982) and Drèze & Stern (1987). The OECD, UNIDO and World Bank documents, however, had the most influence on how SCBAs were conducted at the time particularly in less developed countries. In South Africa, Central Economic Advisory Services (CEAS) published a set of broad guidelines in the late 1980s. They did not advocate an explicit consideration of income distributional considerations which is not surprising given the existence of apartheid. These guidelines are, however, no longer in use.

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<sup>13</sup>See Samuelson (1947) and Graaff (1957) for the main theoretical objections to welfare economics.

<sup>14</sup>It is ironic that currently major federal government policies in the United States now also require social cost-benefit analysis.

<sup>15</sup> Little and Mirrlees published a revised version of their OECD guidelines in 1974.

Other contributors to SCBA theory include Maas (1966), Musgrave (1969), Arrow & Kurz (1970) and Scott et al (1976).

The literature in the 1980s and 1990s has tended to focus on comparisons of different SCBA methodologies and theoretical debates for and against the method. Diewert (1983) and Thirlwall (1994) wrote on a comparison between the OECD and UNIDO approaches. Leff (1985) and later Little & Mirrlees (1990) wrote on the application of SCBA with particular reference to its application in the World Bank. Both authors pointed to the fact that SCBA had not been as widely or thoroughly applied in the World Bank as expected. The majority of the reasons given for this were institutional and not inadequacies in the SCBA method itself. More recently, SCBA has experienced a resurgence in the Bank albeit with a slightly different focus. Devarajan, Squire et al. (1997) called for a reorientation of project appraisal in the World Bank Research Observer saying that traditional approaches often fail to answer fundamental questions of concern to policy makers today. "Among these questions two of the most important are whether a project belongs in the public or private sector and what the effect has been on the development of the external assistance (if any) associated with the project" (Devarajan, Squire et al., 1997, p. 36).<sup>16</sup>

### **3.1.2 Methodology**

What follows is a step-wise outline of the basic methodology of SCBA with a discussion of some of the main issues arising from the evaluation process (step 3 below).<sup>17</sup>

#### **1. Define the objectives**

This is an important first step in the process as it should set out a clear course for the evaluation process and provide a terms of reference for the analyst indicating what information will be

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<sup>16</sup>One could, however, argue that these issues are essentially financing issues that should be dealt with separately from a SCBA analysis. SCBAs should focus only on the desirability of projects to society and not on what sources of funding are used.

<sup>17</sup>Taken partly from Her Majesty's Treasury guidelines for economic appraisal in central government, 1991.

necessary for a decision. Objectives will differ between projects and policies. As an example, two primary societal objectives for most countries are to increase growth and to improve the distribution of income.

2. Consider the options

Once clear objectives have been established, options for the achievement of these objectives need to be identified. Feasible alternatives need to be considered without bias towards a certain option that may seem ideal.

3. Evaluate the options

This involves identifying and then monetising costs and benefits in order for them to be directly comparable in today's terms. This important step is elaborated on in the next section.

4. Weigh up the uncertainties

SCBA involves making assumptions about the future that may or may not be correct. The effects of different assumptions on the results need to be considered through sensitivity analysis. At a minimum this should include a sensitivity analysis of the use of different discount rates.

5. Assess the balance between options

Some SCBAs will produce clear results, but in cases where the preferred option is not clear this needs to be drawn out of the analysis. "For each option examined, the full impact of uncertain elements should be set out systematically and an assessment made of where the balance of advantage lies, drawing out which elements and which judgements about uncertainty are critical to the result" (HMT, 1991, p. 14).

## 6. Present the results

The results should set out:

- the objectives
- the options considered
- the results obtained
- the preferred option
- how this option compares with important alternatives
- how the outcome of the proposal would be later evaluated (HMT, 1991)

### ***The evaluation process elaborated on:***

#### **Identification of costs and benefits**

Each project option's costs and benefits are weighed up in the evaluation process. This starts with an identification of the costs and benefits to be weighed up including direct and indirect impacts in order to cover all cost and benefits to society. Brown & Jackson (1994) point out that because SCBA is concerned with allocative and efficiency aspects, technological and not pecuniary externalities need to be considered. Thirlwall (1994) identifies three major indirect effects to consider:

1. Economic impacts of the project in the immediate vicinity of the project (for example a new road may indirectly increase output in an area).
2. Price effects on local markets.
3. Consequences of the project on other sectors that supply inputs to the project.

Randall (1981) cautions that increased economic activity in a region should not be included as a benefit. This is because increased activity merely represents a transfer of economic activity between regions in an economy where resources are mobile and fully employed. In economies

where resources are underemployed, an argument can, however, be made that some proportion of increased economic activity represent benefits and should be included in the analysis. Whether these benefits should be included in the main analysis of the SCBA or merely mentioned is open to debate.

### **Shadow pricing**

Once the relevant costs and benefits have been identified they need to be measured in terms of their effect on society. If perfect markets existed this would be possible looking at market prices. Efficiency would be achieved by the market mechanism and true costs and benefits would be reflected in market prices. This is, however, often not the case, and therefore a method is needed that will take this into account and adjust market prices to the levels that they would be at in a perfect market. "The question is: how should a project's social benefits and costs be measured, and what common unit of account (or numéraire) should the benefits and costs be expressed in, given a society's objectives and the fact that it has trading opportunities with the rest of the world" (Thirlwall, 1994, p. 198). SCBA focuses on social costs and benefits which may not be reflected by market prices thus necessitating their replacement with shadow prices (also known as social or accounting prices). Market prices may not reflect their social value for a number of reasons mentioned by Thirlwall (1994):

1. Taxes, subsidies, tariffs and controls of various kinds distort free market prices. Opportunity costs must be measured without them being influenced by taxes and subsidies.
2. Market imperfections such as monopolies may distort prices and raise them above the marginal cost of production.
3. Externalities will cause the prices of goods and services not to reflect their true value to society.

Shadow prices need to be used if any of the following apply:

1. The market price of factors of production may not reflect the opportunity cost of using them measured by their marginal product in alternative uses.
2. Industrial wages are likely to be higher than the societal cost of using labour in the presence of unemployment.
3. The market price of capital will be below its social cost if subsidised.
4. If the exchange rate is kept low or high (through exchange control), foreign exchange may be too cheap or expensive from a social point of view.
5. Aggregate saving and investment in an economy may be sub-optimal with the market not reflecting individual preferences for a higher rate of investment and capital accumulation.

Two methods have emerged to present a true representation of the economic costs and benefits of projects through shadow pricing. First, the *OECD approach* of Little & Mirrlees (1969 and 1974) advocates the use of foreign exchange as a numéraire. In this approach costs and benefits are measured at world prices (still using their equivalent in domestic currency) to reflect true opportunity costs using a shadow foreign exchange rate. Goods and services that are non-tradables are broken down into tradable components. The World Bank guidelines (Squire & Van der Tak, 1975) also follow the OECD approach.

Second, the *UNIDO approach* of Dasgupta et al (1972) advocates the measurement of costs and benefits at domestic prices using domestic consumption as a numéraire. This approach makes domestic and foreign resources comparable using a shadow price of foreign exchange.

Both the OECD and UNIDO approach necessitate the valuation of unpriced costs and benefits. Bojö et al. (1992) list these methods as follows:

Valuations using:

Methods:

(1) Conventional markets - Change in production approach

Replacement cost approach

Preventive expenditure approach

Human capital approach

- (2) Implicit markets
  - Travel-cost approach
  - Property value approach (Hedonic pricing)
  - Conjoint analysis
  
- (3) Artificial markets
  - Contingent valuation method

These methods are contentious (in principle as well as from a theoretical point of view) to varying degrees. Particularly in the case of environmental evaluation, opponents claim that it is both unethical and impossible to put a price on the environment. Aside from ethical considerations, valuation methods are viewed with scepticism by numerous economists and the debate continues over whether they represent good economics (see the discussion in section 3.1.4 for more on this). The determination of use values is generally a far simpler matter than determining non-use values (Arrow et al., 1993). Often conventional market approaches can be used to determine use values which are the least contentious out of the three approaches above. Even if implicit market approaches are required, their assumptions are still not too contentious. When measuring non-use values, however, the artificial market approach of contingent valuation has to be used. This approach has attracted the highest degree of debate as to its validity.

### **Discounting**

The costs and benefits associated with projects are usually spread over a period of time. They will, however, not be valued equally if they occur at different times due to time preference (costs and benefits have lower subjective values the later they arise) and because of the opportunity cost of capital (money can be invested to gain interest) (OECD, 1995). Once economic costs and benefits have been calculated, they need to be discounted to their present

values to reflect this. This is done by applying a social discount rate to all costs and benefits. The rate reflects (1) a proxy for the social opportunity cost of capital, (2) a rate based on social time preference or (3) a synthetic discount rate (OECD, 1995).

The choice of a discount rate needs to take into account factors related to the context in which the project is being evaluated. Projects taking place in developing country contexts tend to have higher discount rates reflecting more pressing immediate needs and a less predictable future.

Barbier et al. (1990, p. 1259) list three ways in which conventional discounting procedures are widely thought to discriminate against future generations and sustainability by “(1) rapidly depleting exhaustible resources, (2) ‘shifting’ the burden of distant costs to future generations, and (3) not sanctioning investments with benefits that are subject to long gestation periods (for instance forestry).” To remedy this discrimination, different rates of discount (as opposed to a consistent national figure) can be applied to projects depending on the nature of costs and benefits. Kula (1984) suggested the use of a lower rate for environmentally beneficial projects as opposed to those that generate environmental damage. This would, however, involve highly complex calculations of adjustments with “impossible informational demands” (Markandya & Pearce, 1988, p. 1265) while making it more difficult to compare projects directly. Differential rates would also create inefficiencies as over-investment would be encouraged in projects and sectors with low rates (Bojő et al., 1992).

It has also been suggested that a lower discount rate be applied to all projects in order to further sustainability. Markandya & Pearce (1988) point out that this would counter sustainability by leading to a larger total of investment ‘dragging’ through the system more materials and energy and hence more waste. This would certainly be true of low interest rates. It is, however, questionable whether low discount rates would lead to larger total investment. They would merely place more focus on longer term considerations, but would not make it cheaper to borrow money in order to actually invest. The variability of results introduced by discounting and the debate surround the issue illustrates the importance of proper sensitivity analysis using different discount rates.

## **Distributional considerations**

Once it was realised that the ability of governments (particularly those in developing countries) to redistribute income may be limited and that the prevailing income distribution could influence and be influenced by SCBA results, income distributional issues came to the fore in SCBA. Bojö et al. (1992, p. 63) identified three approaches to dealing with income distribution:

1. "To ignore the issue without further comment. This approach is rarely defended, but is often practised.
2. To explicitly confine the economic analysis to one of efficiency rather than equity. Possibly present the distribution of significant costs and benefits among income groups (households or regions) but to refrain from introducing explicit distributional weights.
3. To introduce distributional weights explicitly to illustrate switching values. These are values on the income distribution weights that make the decision switch from "accept" to "reject" according to some evaluation criteria, e.g. that NPV should be positive. The weights are derived by repeatedly facing decision-makers with the necessity to weigh efficiency and equity together."

Musgrave (1969) supported by Harberger (1971) argued the case for concentrating solely on allocative efficiency. On the other hand, Eckstein (1959) and Marglin (1967) have been among those arguing the case for the inclusion of distributional issues in SCBA. Both the OECD and UNIDO approaches recommended the use of distributional weights by attaching suitable weights to benefits and costs dependent on which income groups they accrued to. No specific procedure has emerged for determining appropriate weights although many economists have recommended Benthamite and modified Benthamite weighting patterns (Chakravarty, 1989).

Attaching weights to the welfare of different groups presents theoretical problems as well as being a politically charged issue. Theoretically it is difficult to 'objectively' decide on appropriate weights and to identify the distribution of costs and benefits among income groups.

Bojö et al. (1992) point out that it may be considered naive to believe that decision makers would explicitly assign weights to different groups or regions given the politically sensitive nature of doing so. These factors have unfortunately contributed to analysts and decision makers shying away from the use of weights despite widespread recognition of their importance.

The theoretical debate continues on whether distributional weights should be used in SCBA. The context within which the SCBA takes place seems to be the major consideration in this regard. In developed countries such as the United States, distribution is not a pressing consideration due to a fairly even distribution of income (in comparison with developing countries) and a highly developed taxation system. Income distributional weights are thus explicitly omitted as a rule.<sup>18</sup> In developing countries, distributional considerations are more important and a more even income distribution is not easily achieved through taxation thus necessitating the inclusion of distributional considerations. For example, it would be difficult to argue that SCBAs undertaken in South Africa with its highly uneven income distribution should exclude distributional weighting.

### **Decision rules in SCBA**

Three main decision rules are typically calculated and presented in a SCBA:

1. Net present value (NPV) which is simply the sum of the discounted net benefits (benefits minus costs),
2. Benefit-cost ratio (BCR) which is the ratio of benefits to costs in present value terms and
3. Internal rate of return (IRR) which is the discount rate at which the streams of costs and benefits are equal.

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<sup>18</sup>A January 1996 debate on trends in American CBA held by the American Economic Association suggested that the latest consensus was to omit distributional weights (Joubert et al., 1997).

Decision rules may have to be applied somewhat differently when evaluating multiple purpose projects such as river basin developments supplying water, flood control and hydro-electric power. Gittinger (1982) suggests that if a multiple purpose project has a greater net present value with an additional purpose than without it, then an additional purpose is justified.

The IRR criterion has fallen out of favour to some extent in SCBA due to it being seen as misleading in some instances as it can produce multiple answers. "The use of an IRR criterion tends to put arbitrarily lower weights on longer term costs and benefits. Some unusual cases, with net costs in later years, can even have two quite different IRRs. Where there is a well defined discount rate the role of IRR is at most that of an occasional supporting indicator" (HMT, 1990, p. 26).

#### *The case of irreversibilities, risk and uncertainty*

Standard procedure in SCBA is to choose the project or policy with the maximum NPV, BCR or IRR. Risk can be dealt with by attaching probabilities of occurrence to outcomes and then making decisions based on these (maximising expected NPV is known as the Bayesian rule).<sup>19</sup> These probabilities can be attached using the normative scientific approach based on the assigning of specific probabilities or through qualitative human reasoning (Lein, 1992). However, in evaluating projects with irreversibilities or outright uncertainty, the alternative decision rules of *maximin* and *minimax regret* can be applied. These rules allow for irreversibilities and uncertainties to be formally dealt with in a SCBA framework.

The maximin criterion assumes that the decision maker is risk averse and therefore expects the worst outcomes. After the decision maker has determined the worst possible payoff (result) for each project, the project with the maximum of the minimum (worst possible) payoffs is chosen (i.e., the project that has the best result of the worst possible scenario). This rule thus represents a highly conservative (risk averse) attitude towards uncertainty on the part of the decision maker.

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<sup>19</sup> Risk is sometimes also dealt with by using a higher discount rate that incorporates a risk premium.

When using the minimax regret rule a regret matrix is constructed for each project to determine the maximum regret associated with it based on the separate project components (actions).<sup>20</sup> Each element of the regret matrix is the cost of making a wrong choice which causes the decision maker to choose the project with the lowest maximum regret (Brown & Jackson, 1994). Thus, this rule, also represents a highly risk averse attitude.

### 3.1.3 Case studies

This section presents four illustrative case studies on the application of SCBA in water resource planning and attempts to draw lessons from them for the Western Cape. SCBA has been used selectively in South Africa by the DWAF for the evaluation of infrastructural developments in the form of new impoundments and irrigation schemes. The technique has however been used in the narrow sense in that only directly measurable costs and benefits have been considered (Mirrilees et al., 1994). In addition, the decision rule employed has been that "...where (directly measurable) benefits are roughly sufficient to balance the costs, the proposed project has been approved on the assumption that indirect and non-monetary benefits would be sufficient to tip the scales" (Mirrilees et al., 1994, app. C).

SCBA is one of the tools used in DWAF planning. It is usually reserved for the evaluation of larger projects where difficulty is experienced in determining their desirability. Irrigation projects, for example, tend to require an SCBA as they are often not vital to society or obviously beneficial.<sup>21</sup> Decisions on the allocation of irrigation water have also been subject to SCBA in the past (see for example Pansegrouw & Groenewald, 1987 for an application of this in the Western Cape). In the case of the Skuifraam dam feasibility, the decision to proceed was obviously not considered difficult enough by DWAF to warrant a SCBA or any other additional analysis.

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<sup>20</sup>This is related to regret theory (Loomes & Sudgen, 1982) which is based on the assumption that an individual will try to maximise his or her modified utility, i.e. modified by the chance of regret or rejoicing occurring.

<sup>21</sup>Pers. comm. Johan van Rooyen, DWAF planning, 1997.

It is important to note that a comprehensive SCBA containing the properties described here, is an expansive study. In cases where relatively small projects are being considered, it may not be necessary or financially viable to conduct a comprehensive SCBA. Evaluation costs should never exceed a certain maximum percentage of project costs.

### **3.1.3.1 Case study 1: The Gordon-below-Franklin Dam<sup>22</sup>**

#### **Background**

In the early 1980s, a hydro-electric dam was proposed for the Gordon-below-Franklin section of the Gordon River in Tasmania. The area to be inundated by the dam was valued because of its wilderness character and areas of archaeological and anthropological interest. On the other hand, there was a need for electricity and the unemployment rate was high in Tasmania. The project thus represented a trade-off between preservation and direct economic benefits

#### **Methodology and results**

The main benefit was naturally electricity generated. In terms of making comparisons with alternatives for the generation of electricity, a comparison was made with coal-fired power, but it was found to be significantly more expensive than hydro-power. In order to estimate the consumer surplus gained from the hydro option, the equivalent consumer surplus loss from the more expensive coal-fired option was calculated. The results of consumer surplus calculations done by an independent economist for the life of the project were as follows:

\$189 million at a 5% discount rate

\$11 million at a 10% discount rate

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<sup>22</sup> For an in-depth look at this case study see Saddler et al. (1981) presented in Pearce (1983)

(The Hydro-electricity Commission did their own calculations and came up with a significantly higher figure of \$345 million. It was, however, based on faulty methodology as the surplus calculated failed to take into account the effect of the higher price on demand.)

Capital and operating costs were implicit in the prices used to calculate the consumer surplus - thus benefits were measured net of the capital and operating costs. This allowed the focus to be shifted to the question of whether the external costs (loss of wilderness, etc.) exceeded the \$189 million in benefits. As the area did not have a high use value, the analysis focused on option value.

Pearce (1983) notes the difficulty of valuing a wilderness area that is not used for recreation as there are no users to interview, but points out that wilderness areas have other forms of value - i.e. option and existence value.<sup>23</sup> These forms of value are, however, notoriously difficult to measure and generally produce results more controversial than use value results (Pearce, 1983). The analysis of Saddler et al. was able to avoid the controversy of attempting to value the option or existence value of the Gordon river wilderness area by simply asking whether the benefits obtained from the dam would be worth the loss in wilderness. This should be a valuable lesson in the context of the Western Cape where the high option values of wilderness areas could be understated because conventional valuation techniques such as contingent valuation do not reveal them adequately (see Leiman, 1995 for an example of this).

In order to estimate external costs, Saddler et al. (1980) made use of an argument developed by Krutilla & Fisher (1975) based on their analysis, along with Cicchetti, of the feasibility of developing Hells Canyon in the United States for hydro electricity (Fisher, Krutilla & Cicchetti, 1972). Krutilla & Fisher argued two main points on the nature of preservation benefits in the face of irreversible changes to the environment - (1) The price of preservation benefits relative to the general price level is likely to rise with time as natural environments become less and less abundant. (2) Development schemes based on present technology will become less attractive

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<sup>23</sup> Option value is defined as the value people attach to having the option to benefit (directly or indirectly) from something at some point in the future. Existence value is the value people attach to the pleasure in something's existence even if they will never be able to benefit (directly or indirectly) from it.

through time as technology advances. (for example, if nuclear energy advances as a low cost source of energy, hydro-electricity may become less attractive).

Saddler et al. used the first argument and adapted the second to establish the 'relative price effect', claiming that "technological change will simply permit an increased availability of manufactured goods and services from a given resource base, while the supply of the natural environment cannot be increased (Saddler et al., 1980, p. 81)." With a 'relative price effect' of 4% per annum, a discount rate of 5% and assuming that the capacity of the region to absorb visitors would be reached in 30 years, the present value of \$1 of initial-year preservation benefits was calculated as \$259.8 for the life of the project. By dividing consumer surplus benefits of \$189 million by the present value of the preservation benefits, it was possible to calculate an estimate of what preservation benefits would have to be for them to equal the benefits of the hydro project. The result of this calculation was \$0.72 million. Thus, if the initial year's preservation benefits exceeded this figure, the present value of the preservation benefits would be greater than that of the project benefits. The results favoured preservation.

Saddler et al. made no mention of positive employment benefits which could be seen as a shortcoming given Tasmanian concern with this issue at the time. However, a (further) negative factor which would tend to over-ride this was the fact that demand for electricity was dropping at the time thus making the project look less attractive (Pearce, 1983). The project was eventually cancelled by the new Australian administration in 1983 resulting in the payment of £180 million in compensation to the State Government of Tasmania.

### **3.1.3.2 Case Study 2: The Komati river basin development**

#### **Background**

In 1990 Gibb consulting engineers were commissioned to conduct a feasibility study of the proposed Maguga dam on the Komati river in Swaziland. The study focused only on the Maguga dam even though the Maguga and Driekoppies dams should be seen as an integrated

system for the development of the Komati river basin. As a result of the positive findings of the Gibb study, construction on the Driekoppies dam was approved and a commitment was made to proceed with the Maguga dam in the future. Then, in 1993, the World Bank fielded a mission to appraise the Gibb report. In 1996, in view of the issues raised by the mission, the Swaziland Government decided to appoint Conningarth consultants (with the support of the Development Bank of South Africa) to perform a SCBA analysing the Maguga and Driekoppies dams as a unit.

**Methodology and results**

The SCBA took the following costs and benefits into account:

Costs

Benefits

- Dams capital, operation and maintenance
- Hydropower installation
- Irrigation development
- Infrastructure
- Resettlement
- Agricultural equipment
- Additional sugar milling plant
- Institutional and environmental support

- Agricultural water (irrigation crop gross margins)
- Domestic and industrial water
- SACU receipts on crop production
- Hydropower
- Infrastructure services

It also divided the costs and benefits up between South Africa and Swaziland in order to look at the project in an overall sense and from the point of view of both countries. Table 3.1.3.2.1 shows the result of the analysis.

**Table 3.1.3.2.1: Komati river basin SCBA results**

	Total project	South Africa	Swaziland	Water not allocated
IRR	12 %	11.5%	9.8%	NA
Project benefits (PV at 10%)	E2 559	E1 640	E470	E449
Percentage distribution	100%	64%	18%	18%
Project costs (PV at 10%)	E2 142	E 1421	E479	E242
Percentage distribution	100%	66%	22%	12%
Net Benefits (NPV at 10%)	E417	E219	(E9)	E207

(Source: Conningarth, 1996)

The IRR for Swaziland was lower than the 10% benchmark figure set by the World Bank. The authors did not recommend that this be viewed as significant for the following two reasons. Firstly, the project was considered as one project by South Africa and Swaziland making the differentiation in costs between the two somewhat artificial. Secondly, the net benefits of the unallocated water were not considered. If a scenario, based on the Komati water allocation treaty, was used to allocate this water, the IRR for Swaziland would change from 9.8% to 10.8%.

The sensitivity analysis of the total project showed that adjusting the results for an alternative shadow price structure did not have a significant effect. The projects viability was also relatively insensitive to cost increases (a 21 % increase could be tolerated). Changes in agricultural markets were, however, found to have a significant influence. For example, if prices and yields for all the crops were to decrease by 20 %, the IRR would drop from 12 % to 5.2 %. This was thought to be unlikely, because of the wide variety of crops included in the project.

The study investigated the distribution of project benefits between smallholder and commercial farmers. It was found that for South Africa, the benefits for smallholder farmers were significantly higher than for commercial farmers. For Swaziland, on the other hand, the benefits were found to be similar for both groups. This aspect of the study introduced a form of distributional consideration. Comprehensive consideration of income distribution through the use of weights was, however, not included in the study.

In terms of environmental issues, the study did not address these directly through the use of valuation techniques. Instead, the initiatives launched to deal with these issues were outlined. These included the preparation of a comprehensive resettlement and compensation plan as well as a more comprehensive basin EIA and management plan. This approach implies the tenuous assumption that these issues would be taken care of by these initiatives and thus did not warrant full consideration in the SCBA.

### **3.1.3.3 Case Study 3: Watershed conservation in Ecuador**

#### **Background**

In the first five years of its operation, the Poza Honda watershed reservoir in Ecuador displayed accelerated sedimentation and eutrophication due to the tropical climate and intensive land use in critical areas. After five years, it was established that 20 % of the volume of the reservoir was filled with sediment and that sedimentation was occurring at 4 % per annum (ten times the anticipated rate) shortening the projected life of the reservoir to 25 years.

In 1979, Fleming conducted a SCBA of a watershed conservation program aimed at extending the life of the reservoir to 50 years. The proposed program consisted of land use changes, conservation of habitats, management, etc. all aimed at halving sedimentation rates.

## Methodology and results

The benefit was the extension of the productive life of the reservoir from 25 to 50 years helping to maintain the agricultural potential of the watershed.

The summarised costs of the conservation program were:

<b>Program component</b>	<b>Cost (million sucre)</b>
Reforestation	9.12
Planting of new production forests	14.79
Terracing	0.64
Grazing control	6.48
Forest management	3.87
Administration	10.56
<b>TOTAL</b>	<b>45.56</b>

(Source: Flemming, 1979)

In order to establish the economic impacts of the conservation program a comparison was made between the costs and benefits associated with the reservoir with and without the conservation program.

The *with conservation* option yielded a net benefit of 456.45 million sucres and a benefit/cost ratio of 1.43/1. This was calculated by adding irrigation benefits of 823.56 million sucres to water supply benefits of 683.92 million sucres to get a total of 1 507.48 million sucres in benefits. Capital costs of 728.06 million sucres, operational costs of 277.41 million sucres and conservation program costs of 45.56 million sucres added up to a total of 1051.03 million sucres.

The *without conservation* option on the other hand showed a negative net benefit of 311.92 million sucres and a benefit cost ratio of 0.67/1. Irrigation benefits were only 414.94 million sucres while water supply benefits were 205.55 million sucres adding up to a total of 620.49 million sucres. Capital costs of 723.15 million sucres and operational costs of 209.26 million sucres added up to a total of 932.41 million sucres (Flemming, 1979).

Although a relatively high degree of uncertainty was indicated for the costs of the conservation programme, the benefits were far enough in excess of the costs to suggest the success of the project. The study illustrated the substantial gains that can be reaped from a proper holistic management programme to accompany dam construction. It also showed that large, ecologically disturbing, constructions such as dam can have profound and costly environmental impacts that are difficult to anticipate. The general lack of good quality information on the effects of dams, particularly on the environment and society, has led to the formation of the World Commission for Dams. In September 1997, under the chairmanship of the South African Minister of Water Affairs and Forestry, Dr. Kadar Asmal, the commission set itself the goal of investigating these effects in order to make recommendations on the improvement of dam feasibility studies.

#### **3.1.3.4 Case Study 4: Municipal water supply development in Kingston, Jamaica<sup>24</sup>**

##### **Background**

In 1977, Tippetts-Abbett-McCarthy-Stratton (TAMS) produced a CBA aimed at aiding the selection of the first priority water supply project for Kingston to last for seven years and form part of a 20 years plan. Three groundwater and six surface impoundments were identified as possibilities and the following analysis was performed on the dam that was eventually chosen. Similar analyses were performed on the other options showing them to be inferior.

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<sup>24</sup> Adapted from Goodman, 1983.

## **Methodology and results**

“The analysis treated costs and benefits of each project on an incremental basis. Thus, the costs of implementing and operating the project were measured against the benefits derived from the project’s capabilities to satisfy incremental needs for water supply” (Goodman, 1984, p. 206). Benefits were limited to returns from water tariff revenue and thus represented a minimum not including consumer surplus. In order to be more comprehensive, the analysis would have had to include other benefits such as health improvements and commercial benefits from a more reliable water supply. Costs included construction, operation, maintenance, renewal and replacements, treatment and distribution costs.

Annual net incremental benefits obtained by subtracting annual costs from minimum annual benefits at a tariff of \$1.52 per thousand gallons yielded an internal rate of return of 8.9 % for the priority project.

The analysis in this case was highly simplified and focused purely on engineering feasibility and financial return. In terms of measuring benefits, this should not be seen as a significant shortcoming as other benefits additional to water supply are not likely to be significant. Focusing purely on measurable construction and operational costs is, however, bound to run into problems given the often significant unquantified costs (externalities) associated with the construction of water supply options.<sup>25</sup> The exclusion of external costs, furthermore, made it impossible to compare the internal rate of return with those of alternative investments in the nation’s economic sectors (Goodman, 1978). Such a narrow focus should be avoided in any analyses in the Western Cape.

The following table taken from Dixon et al. (1996) outlines the unpriced environmental costs and benefits associated with dam construction in general and suggests ways in which they can be valued for inclusion in SCBAs. It has been included due to the particular importance of these

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<sup>25</sup>See case study 4 for details on possible external costs.

issues in the Western Cape and because it was felt that the other case studies did not treat environmental costs satisfactorily.

**Table 3.1.3.4.1: Unpriced environmental effects associated with dams and suggestions for their valuation (Source: Dixon et al., 1996, p. 16)**

<b>Environmental Effect</b>	<b>Economic Impact</b>	<b>Benefit (B) Cost (C)</b>	<b>Suggested Possible Valuation Methods</b>
Chemical water quality - changes in reservoir and downstream	Increased/reduced treatment cost, reduced fish catch, loss of production	B, C	Preventive expenditures, changes in production
Reduction in silt load, downstream	Loss of fertiliser (silt), reduced salination of canals, better water control	B, C	Replacement costs, preventive expenditures avoided
Water temperature changes (drop)	Reduction of crop yields (esp. rice)	C	Changes in production
Health - water related diseases (humans and animals)	Sickness, hospital care, death; decreased meat and milk production	B, C	Cost of illness
Fishery - impacts on fish irrigation, spawning	Both loss and increase in fish production	B, C	Changes in production, preventive expenditures
Recreation - in the reservoir or river	Value of recreation opportunities gained or lost, tourism	B, C	Travel cost approach, property value approach
Wildlife and biodiversity	Creation or loss of species, habitat and genetic resources	B, C	Opportunity cost approach, tourism values lost, replacement costs
Involuntary resettlement	Cost of new infrastructure, social costs	C	Replacement cost approach, 'social costs', relocation costs
Discharge variations, excessive diurnal variation	Disturbs flora and fauna, human use, drownings, recession in agriculture	C	Relocation costs, changes in production
Flood attenuation	Reduces after flood cultivation; reduces flood damage	B, C	Changes in production, flood damages avoided

### **3.1.4 Discussion**

#### **3.1.4.1 Strengths**

When faced with an investment decision, an obvious question to consider would be - to what degree the overall benefits of the investment outweigh the costs? One of the major strengths of SCBA is its intuitive appeal as it produces a comprehensive framework for public sector decision making aimed at answering this question. "It provides a coherent framework within which the various arguments relating to the costs and benefits involved in a trade-off can be assessed" (Angelsen & Sumaila, 1995, p. 1). The fact that trade-offs are made is important as it forces decision makers to make 'hard' choices.

SCBA provides for the clear comparison of projects using decision rules such as net present value, benefit/cost ratio and internal rate of return. In this way investment decisions can be aided through direct comparisons between the relative strengths of projects within sectors as well as between sectors. Decisions involving the allocation of funds can thus be made easier.

SCBA's use of money as a common yardstick for all costs and benefits enhances its appeal in decision making as it allows for direct comparisons to be made between costs and benefits. Apart from the fact that monetary units are the only practically useful yardstick (or numéraire) it is also a 'bottom line' measure that decision makers should have no problems interpreting as opposed to qualitative descriptions.

SCBA's often extensive data requirements forces investigation into issues that are critical to decision making. Without SCBA, necessary research may be ignored in favour of educated guesses that are error prone and may harm decision making. In cases where SCBA does not directly prompt the collection of data, it can, nevertheless, be useful as a tool which converts data into an accessible format focused on the issues relevant to decision making. For example, an environmental impact assessment may prompt the collection of volumes of data. This data

may, however, be presented in a format that does not allow for the evaluation of the relative impacts of alternatives.

Perhaps the most telling evidence in support of the overall strength of SCBA is the fact that the method has stood the test of time and continues to find wide application. "Little-Mirrlees' methods have stood up to intensive theoretical discussion remarkably well, and on balance the large outpouring of theory consequent on the original publication has confirmed the correctness of the authors' original intuitions" (Little & Mirrlees, 1990, p. 366).

### **3.1.4.2 Weaknesses and criticisms**

One of SCBA's main strengths, its rigour and comprehensiveness, has also been a factor limiting its application.<sup>26</sup> The intricate and time consuming analysis required in SCBA requires a specialist understanding of the method - this makes it a relatively inaccessible method. The failure of SCBAs attempted by those with inadequate training has proven this and done nothing to enhance the reputation of the method itself. Sander (1985) discusses this problem, and citing the low quality of SCBAs in water resource planning in the United States recommends that more money be spent on training SCBA analysts.

The treatment of unpriced environmental costs and benefits is an area where SCBA has been criticised heavily. Schulze (1994) points out the following three features of SCBAs that cause them to underestimate the significance of environmental impacts:

- Omissions of impacts due to difficulties in ascribing monetary values. When unpriced costs or benefits are not quantified, these aspects are often not assigned equal importance because of this. Clough (1972) goes so far as to say that not quantifying in SCBA is tantamount to assigning zero values.
- Undervaluation of poorly understood impacts.

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<sup>26</sup> However, if an environmental impact assessment is carried out for a project prior to a SCBA, the work load is reduced substantially.

- Discounting and analysis focusing on short time horizons causing short-term perspectives that underestimate persistent environmental damages.

The contentious field of valuation has made many advances in the recent past and has been the subject of extensive research, yet levels of confidence in valuation results remains mixed and they are often refutable.<sup>27</sup> Detractors of the environmental valuation claim that it is fundamentally flawed and should not be attempted as part of a SCBA or for any other reason. Some argue that valuation is morally wrong as it assumes that 'everything has a price' (Schumacher, 1972). This view lost ground as it was realised that money is used for valuation purely because it is the most practical yardstick for comparing values. Valuation has also been applied to widely varying degrees (for example, SCBAs in the United States have a higher tendency to include valuation than those performed in the United Kingdom) which has not increased confidence in it.

Others argue on methodological grounds, particularly with respect to the valuation of non-use values.<sup>28</sup> Adams (1996) claims that people cannot and will not give meaningful answers to certain willingness to pay questions such as those regarding losses of important cultural and sentimentally valued sites. Splash and Hanley (1993) found that a significant number of respondents refused to make trade-offs between biodiversity and market goods. Vatn & Bromley (1994, p. 130) state that "...environmental goods and services embody characteristics that present serious complications when collective choices are to be made on the basis of recommendations derived from the aggregation of individual values (or prices) elicited by contingent valuation methods." The characteristics referred to are basically the complex, indivisible and interrelated nature of the environment which, they feel, cannot be accurately reflected by a simple monetary value.<sup>29</sup> They go on to warn that the context in which values are elicited can influence valuation results. Their point being that the social context determines whose interests are to count. Gowdy (1997, p. 26) also points out that "...many economists fail

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<sup>27</sup>McManus (1994) states that the conflicting results found in the CVM literature provide ample refutable evidence to challenge CVM estimates in court.

<sup>28</sup>Also known as passive-use values.

<sup>29</sup>These assertions have been backed up by biologists such as Wilson (1992).

to realise the limitations of basing values entirely on the preferences of isolated individuals acting as consumers at a specific point in time.” The idea here is that private decisions cannot capture collective choices.

The NOAA panel guidelines on the use of contingent valuation raised the following concerns regarding the technique (Arrow et al., 1993, p. 9):

1. “The method can produce results that appear to be inconsistent with assumptions of rational choice. For example people can make inconsistent choice.
2. Responses to contingent valuation surveys seem implausibly large in view of the many programs for which individuals might be asked to contribute and the existence of both public and private goods that might be substitutes for the resource(s) in question.
3. Relatively few previous applications of the contingent valuation method have reminded respondents forcefully of the budget constraints under which all must operate.
4. It is difficult in contingent valuation surveys to provide adequate information to respondents about the policy or program for which values are being elicited and to be sure they have absorbed and accepted this information as the basis for their responses.
5. In generating aggregate estimates using the contingent valuation technique, it is sometimes difficult determining the “extent of the market”.
6. Respondents in contingent valuation surveys may actually be expressing feelings about public spiritedness or the “warm glow” of giving, rather than actual willingness to pay for the program in question.”

The panel concluded that only contingent valuation studies that are carefully constructed, administered and analysed can be used as evidence in United States courts in combination with other evidence including the testimony of expert witnesses (Arrow et al., 1993). The guidelines are, however, stringent in terms of specifying what constitutes an acceptable contingent valuation that would adequately deal with the above concerns.

Willingness to pay or accept can be used as a measure of value in contingent valuation, however, a number of cautions apply. A person's willingness to pay depends on that person's income level which may lead to a bias in favour of the more affluent members of society who generally have higher willingness' to pay. In the South African context, where a more even distribution of income is a high priority, this potential bias should not be acceptable. Willingness to accept, on the other hand, has been criticised due to the fact that it tends to overstate values. This is mainly because it is not constrained by income level and the value function is steeper for losses than for gains.<sup>30</sup> Willingness to pay or accept measures can run into difficulties when evaluating environmental goods or services to which people feel they have a fundamental right. If individuals feels that they have a right to, say, clean air or water, they will not be inclined to offer much in the way of willingness to pay. They would, however, probably have a very high willingness to accept (Vatn & Bromley, 1994).

Joubert et al. (1997) point out that in the Western Cape, the valuation techniques available to SCBA are unlikely to be adequate in assessing the "true" value of the fynbos areas that are likely to be affected by water supply projects in the future. The use values of certain pristine fynbos areas can effectively be zero in situations where catchment maintenance is not provided by the fynbos, access is restricted and wildflower harvesting is forbidden (Joubert et al., 1997). This leaves only non-use values (option and existence value) which have been measured as very low for pristine areas using the contingent valuation technique (see Leiman, 1995). This has occurred despite environmentalists putting a high option and existence value on fynbos because of its high levels of biodiversity and endemism. Thus conventional market based valuation techniques would not necessarily put a value on pristine fynbos areas within the range acceptable to environmentalists. Gowdy (1997) points out that the value of biodiversity should be considered at different levels in a hierarchical framework in order to be more accurate in estimating it. Market-based value being the first level, its value to the survival of the human species being the second and its value in terms of ensuring continued ecosystem viability the last. Market-based values are thus only a part of total value. It has also been argued that

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<sup>30</sup>After reviewing the literature, Gregory (1986) concludes that willingness to accept measures generally seem to exceed willingness to pay measures by a minimum factor of three.

biodiversity and 'uniqueness' values are not fully captured at a local level using conventional valuation techniques, but at an international level as evidenced by arrangements such as the Global Environmental Facility which donates funds for the conservation of areas of high biodiversity and endemism (Joubert et al., 1997).

The fact that different valuation techniques have produced different results when valuing the same thing has not increased confidence in valuation. Shabman & Stephenson (1996), however, claim that the credibility of valuation is not enhanced by the current focus on the search for a single "true" value in valuation studies. They argue that different benefit estimates should not be explained away, but rather expected. This does not add to decision maker confidence as similar values are seen as logical and are therefore expected.

The Neo-classical welfare economics foundation of SCBA means that its acceptability is closely linked to the acceptability of traditional welfare economics. This remains a liability as welfare economics continues to be questioned on various grounds as outlined in section 3.1.1.

SCBA has been applied in a 'narrow' sense, focusing almost exclusively on cost effectiveness as well as in a 'broader' sense, incorporating factors such as externalities and distributional issues. It is a relatively flexible tool which allows the analyst to decide what is appropriate for inclusion in an analysis. This characteristic of SCBA can be regarded as a strength. At the same time it is a potential weakness as it allows analysts to do the bare minimum and still call their work a SCBA even if this is not strictly the case. In this way sub-standard SCBAs are associated with the SCBA field in general and are used to fuel criticism.

Although SCBA uses inputs from other disciplines, the actual analysis is in the hands of an individual. It is thus not a participatory process increasing the risk of individual bias. Politically, SCBA may encounter opposition if the public feel that the ability to influence important public investment decisions is in the hands of one analyst. This may run counter to the public's need to be involved in a transparent and democratic process.

## **3.2 MULTIPLE CRITERIA DECISION ANALYSIS (MCDA)**

### **3.2.1 Theoretical background and historical development**

World War 2 saw the advent of operations research as a tool to increase operating efficiency in the United States Navy. Following this, a variety of systematic procedures and mathematical tools were developed to compare alternative solutions in the face of limited resources. They were applied in various different fields such as management science, systems engineering, water resources, transportation engineering, systems analysis and industrial engineering (Hipel, 1992). They all, however, used the formulation of a *single criterion* or objective function which could be optimised subject to a set of constraints (Goicoechea et al., 1982).

MCDA emerged approximately thirty years ago in the operations research field as a response to increased awareness of the need to consider several objectives at the same time (Goicoechea et al., 1982). MCDA can thus be viewed as a part of the transformation from single objective methods such as cost-benefit analysis to multiobjective analysis. "The key philosophical departure point defining MCDM as a formal approach to types of problem solving (or mess reduction), lies in attempting to represent such imprecise goals in terms of *a number of individual (relatively precise, but generally conflicting) criteria*" (Stewart, 1992, p. 569). This was in contrast with optimising approaches that attempted to find solutions in terms of a single criterion.

MCDA developed more in line with the idea of satisficing developed by Simon (1953). The focus was on finding satisfactory alternatives that were acceptable across a number of objectives as opposed to optimal solutions that dealt with single objective functions (Goicoechea, 1982). Zeleny (1974) points out that Charnes & Cooper (1961) were the first to formally introduce (lengthy informal discussions preceded this step) the use of multiple versus single objective functions. This signalled the departure from the use of the single Pareto optimality criterion which was in favour in the discipline prior to this point.

In the United States, the emergence of MCDA had strong links with water resource management as much of its early explicit development occurred through the Harvard Water Programme whose findings were published by Maass et al. (1962). Later on, the 1970 report of the United States Water Resource Council outlined a commitment to the use of multiple objectives. In the ensuing period, multi-objective methods became widely applied in the water resources field as they are today.

Goicoechea (1982) drew attention to the significant influence that the National Environmental Policy Act (NEPA) of 1969 had on the recognition of multiple criteria in project planning. As in the case of the development of cost-benefit analysis, this act led to a broadening of the facets or objectives that were to be considered.

Over the years a large number of MCDA methods emerged based on the common goal of aiding complex decision making with multiple objectives. Literature reviews of MCDA have been published which give a comprehensive treatment of the field and these methods and the reader is referred to them for a comprehensive appraisal. Among these are Goicoechea et al. (1982), Changkong et al. (1985), Steuer (1986), Zionts & Lotfi (1989), Bana e Costa (1990) and Stewart (1992). The number of MCDA methods is so extensive that a literature has developed which deals solely with the choice of an appropriate method. In water resource planning this literature includes Cohon & Marks (1972) who reviewed and evaluated multiobjective programming techniques for water resource problems. Gershon & Duckstein (1984) developed a procedure for selecting a multiobjective technique in water and mineral resource questions. Goicoechea et al. (1992) conducted an experimental evaluation of four MCDA methods used in water resource planning. Hobbs et al. (1992) investigated whether the choice of multicriteria method matters in water resource planning.

More recent trends in the MCDA literature have seen a renewed emphasis on problem structuring, a need having been identified for a more thorough understanding of the situation before any MCDA method is applied (see Belton, 1997 and Henig & Buchanan, 1996).

### **3.2.2 Methodology**

A large number of MCDA methods have evolved over the years, each with different strengths and weaknesses. This section will not attempt to cover all the methods, but will present a basic MCDA methodology based on the multi-attribute value or utility theory (MAVT or MAUT) and briefly discuss the other main methods available using the format of Stewart et al. (1993). This is done due to space limitations and because MAVT can be made simple and transparent through approaches such as SMART - qualities that planners and decision makers prefer (Hobbs et al., 1992). The technique has also been successfully applied by Stewart et al. (1993) in a South African water planning context.

#### **Multi-attribute value or utility approaches**

The Simple Multi-attribute Rating Technique (SMART) originally developed by Edwards (1971) consists of eight stages articulated by Goodwin & Wright (1992) as follows:

*Stage 1:* Identify the decision maker, or decision makers. In a group decision making context involving multiple stakeholders, the decision maker could be the group itself.

*Stage 2:* Identify the alternative courses of action or options.

*Stage 3:* Identify the attributes (also referred to as criteria) which will be used to measure performance in relation to the objectives of the project.

Once this is done each alternative ( $a$ ) can be described by a vector of attributes:

$$z^a = (z^a_1, z^a_2, \dots, z^a_p)$$

where  $p$  is the number of attributes and  $z^a_i$  is the attribute representing the outcome of decision alternative  $a$  as it effects attribute  $i$  (Stewart, 1992). The identification process should be done in consultation with the relevant stakeholders.

**Stage 4:** For each attribute, assign values to measure the performance of the alternative on that attribute.

This is done using an interval scale of say 0 to 100. The worst alternative ( $a$ ) measured against attribute  $i$  is given a score of 0 ( $V^a_i(z_i) = 0$ ) and the best alternative ( $b$ ) based on attribute  $i$  is given a score of 100 ( $V^b_i(z_i) = 100$ ). The scores of the other alternatives are ranged in-between so that the gaps indicate the strength of preference for that alternative, based on that attribute. In this way the alternatives are not simply ranked and an approximate value function  $V_i(z_i)$  can be derived for each attribute (Joubert et al., 1997).

It is also possible to derive utility functions in place of value functions following the work of von Neumann & Morgenstern (1947) and later Keeney and Raiffa (1976). According to Stewart (1992), however, these are rather tedious and often mystifying to the decision maker. In addition, they do not ensure improved results over value functions.

**Stage 5:** Determine a weight for each attribute.

This can be done using swing weights which are derived by asking the decision maker to compare the change (swing) from the least-preferred to the most-preferred value on one attribute to a similar change in another attribute (Goodwin & Wright, 1991). The decision maker is given a hypothetical alternative and asked which attribute he or she would prefer to raise to its best level while all the others stayed at their worst levels. The chosen attribute is then

given a weight of 100. The second most influential attribute is then weighted according to its impact compared to that of the first and so on for each attribute relative to the others. By using this method, the weighting of each attribute is made directly comparable.

Weighting techniques differ for each MCDA method and have generated substantial debate on their merits. See Roy & Mousseau (1996) for a comparison of the different techniques.

**Stage 6:** For each alternative, take a weighted average of the values assigned to that alternative.

This involves combining stages 4 and 5 in order to determine comparable scores for each alternative that can be used to determine preferences.

The interpretation of the scores should be in terms of the value profiles. This will give a more holistic impression of the performance of alternatives as it will highlight cases where alternatives might score highly overall, but zero for one attribute (Joubert et al., 1997). In cases such as these, an alternative with a slightly lower overall score might be preferred to one which scores zero on an attribute.

**Stage 7:** Make a provisional decision.

Based on the scores obtained in stage 6, it should be possible to make a provisional decision on the most preferred alternative(s).

**Stage 8:** Perform sensitivity analysis.

Before a final decision can be made, a sensitivity analysis should be performed to highlight how the analysis is affected by changing scores (stage 4) and weights (stage 5).

### *The group decision making case*

In group decision making situations with conflicting objectives, Joubert et al. (1997) suggest that each stakeholder group should complete the above stages and then be brought together to look for compromise solutions. It is hoped that going through the stages may make stakeholders more willing to explore compromises.

### **The analytic hierarchy process (AHP)**

The AHP (Saaty, 1980) is a form of value function approach that has attracted a great deal of controversy. It has been criticised by numerous authors mentioned in Stewart (1992) for the lack of a sound basis for many of its assumptions and the methods of estimation it uses. Due to its controversial nature it will not be considered further here.

### **Goal programming and reference point approaches**

Goal programming starts by the decision maker specifying target levels (goals) of achievement for each attribute/criteria. These levels typically take one of three forms (Stewart et al., 1993):

1. Goals or aspiration levels which represent an ideal towards which the decision maker is striving.
2. Veto or exclusion levels which are performance levels which if violated for even one criteria would render the entire option unacceptable.
3. Reference levels which represent a realistic expectation from the decision maker as to what would be acceptable compromises between the conflicting demands of the different criteria

Once goals have been set, the approach looks for options which minimise the measured underachievement of the goals.

The reference point approach developed by Wierzbicki (1980), on the other hand, tries to both minimise underachievement and maximise overachievement with the greatest weight being placed on the largest underachievements.

### **Outranking approaches**

These approaches were developed in Europe (they are sometimes referred to as the European school of MCDA) by Roy and colleagues. Stewart et al. (1993, p. A8) summarise the method as follows:

“In the basic ELECTRE outranking approach, evidence in favour of the assertion that one alternative is at least as good as another (or “concordance”) is summarised in terms of a form of voting scheme between criteria, i.e. each criterion is awarded a voting weight, which is allocated to the alternative that is judged to be the best according to this criterion (with votes shared in the case of a tie). Evidence against the same assertion (or “discordance”) is summarised by a form of veto accorded to any criterion for which the first alternative is worse than the second by more than a prescribed margin.”

### **Game theory**

Game theory was originally developed by Neumann & Morgenstern (1944) whose initial insight was that many social conflicts are similar to parlour games. Using payoff matrices for each player, the theory of games attempts to describe the most likely strategy a player will adopt to maximise his or her benefit. It can thus be used to identify compromise solutions among players in a conflict situation by looking at their most likely optimal strategies. It forces players to look at the most likely strategies of other players making it possible to gain insights into the way they are thinking and hopefully to appreciate their standpoints in seeking compromise.

In terms of methodology, "Multi-person game theory assumes in effect that each criterion is associated with a particular "player" (a person or group), and that marginal utilities can be associated with each policy scenario or option" (Stewart et al., 1993 p. A9). The Nash Solution is the basic game theory solution which leads to the selection of the option/policy which maximises the product of the marginal utilities of all the players assuming they have equal influence. Formally, the Nash equilibrium is "...the combination of strategies in a game such that neither player has any incentives to change strategies given the strategy of his opponent" (Frank, 1991, p. 457). It is possible to attach importance weights to each player and then maximise the product of marginal utilities. As in most situations where weighting is called for, this a difficult and controversial procedure due to its subjective nature and the potential conflicts it can lead to.

### **Fuzzy set theory**

Fuzzy set theory was developed by Zadeh in an attempt to deal with the lack of accurate human preferences in multi-criteria decision making. "In fuzzy set terms, each alternative would have some degree of membership in the fuzzy set of good (or acceptable, or satisfactory) solutions for each criterion taken in turn. The alternative's membership in the fuzzy intersection of all these single-criterion fuzzy sets then indicates the strength of its claim to being good (or acceptable, or satisfactory) overall" (Stewart, 1992, p. 581). It becomes possible to rank alternatives after comparing their varying degrees of membership in a set of satisfactory solutions.

Fuzzy set theory has been criticised on the grounds that the technique is similar to goal programming or value function approaches, but merely masks the inputs required from the decision maker behind a language which may seem more 'natural' yet easily leads to misunderstandings (Stewart, 1992). In other words, the way in which it attempts to deal with inaccurate human preferences can lead to inaccuracies and misunderstandings in the analysis itself. Stewart (1992) points out that the imprecise specification by decision makers of the necessary inputs in MCDA are better handled by sensitivity analysis. It has also, however, been

argued by Lein (1992), that 'fuzzy' need not mean 'imprecise' and that there are ways of modelling inexactness so that human judgements which defy precise definition or measurement (i.e. precise normative values cannot be attached to them) can be incorporated in a formal analysis.

### **3.2.3 Case studies**

MCDA has some of its origins in the water resources planning field and has been applied extensively in it. The case studies presented here however will focus specifically on case studies dealing with decision making between alternative water supply options. Other case studies that have dealt with this question, but are not included here due to a lack of space, include:

- Haimes et al. (1979) used the surrogate worth trade-off method for the Maumee river basin, U.S.A.
- Gershon et al. (1982) considered basin planning in Santa Cruz, Arizona comparing the use of ELECTRE, compromise programming and MAUT.
- Gershon & Duckstein (1983) also considered the Santa Cruz case adding the use of game theory.
- Goeller et al. (1983) analysed alternative water management plans in the Netherlands.
- Mehrez & Sinuany-Stern (1983) considered water development options for Israel using MAUT.

Other areas of water resource planning in which MCDA has been applied include flood control, water allocation between users, water quality goals, reservoir system operation and cost sharing among users.

#### **3.2.3.1 Case study 1: Scenario-based policy planning in the Sabie river basin**

##### **Background**

In 1993, Stewart & Scott applied a framework called “scenario-based policy planning” for implementing MCDA tools to the hypothetical case of the future water resource planning needs of the Sabie river basin in Mpumalanga. The framework was developed in response to the following problems encountered in applying standard MCDA to this context:

1. Large discrepancies in the sophistication of the different affected parties, and an inability of many groups to express goals or trade-offs in terms of the natural system attributes;
2. Difficulties of establishing inter-group trade-offs; and
3. Poorly or imprecisely defined decision alternatives.

The exercise involved 11 representatives of the four main interest groups in the area, viz., the forestry industry, nature conservation, commercial irrigators and rural communities together with two representatives of the DWAF coming together in a workshop setting in order to determine the most suitable water supply planning policy scenarios for the region.<sup>31</sup> Stewart & Scott (1995) warn that the number of interest groups was relatively small, but point out that those involved were *truly* interested and affected.

### **Methodology and results**

“The process started with the workshops or group sessions aimed at establishing policy elements as well as the attributes needed to describe consequences. The process passed linearly through generation of the background set of 20 scenarios, the evaluation of the consequences for these scenarios, generation of the foreground set,<sup>32</sup> and the evaluation of these by the interested groups... As the results of individual group rankings are compared, some scenarios might immediately fall out, while certain variations of the remaining scenarios might equally evidently arise” (Stewart & Scott, 1995, p. 2840).

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<sup>31</sup> A policy scenario is defined as “a statement of a particular policy (for development of the catchment area) and its likely consequences, but described only to the level of detail necessary for different parties to express clear preferences between alternatives on the table at any one time” (Stewart & Scott, 1995, p. 2835).

<sup>32</sup> Using methods similar to those described earlier under the SMART procedure

Each stakeholder group evaluated the alternatives on their own and then came together to explore compromise alternatives. This step assisted the groups to formulate their own preferences while conveying these preferences to the other groups in a clearly understandable manner. When evaluating the alternatives on their own, each stakeholder group decided on its own set of criteria relevant to its interests. It then ranked each alternative from the point of view of each criterion. Direct comparison was possible between each group because they used the same scoring and weighting techniques. Scoring was done using a clearly defined interval scale from 0-100 which focused attention on the gaps between the scenarios under consideration in terms of the chosen criteria.<sup>33</sup> The first level of iteration came at the point when each interest group compared its ranking of the alternatives with those of other groups. This was done by comparing each group's thermometer scale which, again on a interval scale of 0-100, revealed the preferred alternatives of each group and the relative gaps between alternatives. Value paths were also generated from the thermometer scales to further illustrate the preferences of each group. These comparisons lead to the generation of the foreground set of 5 alternatives for further, more detailed, consideration. The study stopped at this point. It would, nonetheless, have been possible to carry the analysis further in order to determine the most favourable option using a similar analysis.

Once the results had been obtained, a questionnaire on the decision making process was administered to all of the interest group representatives. The following two sets of questions were asked (Stewart & Scott, 1995, p. 2842):

*Ease of understanding.* How easy (on a five point scale) are the following procedures to understand:

1. Use of "thermometer" scales for scoring.
2. Use of weights for measuring the importance of subcriteria and interests.
3. Method of combining weights and scores.

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<sup>33</sup>Although it was not necessary in this case study, Stewart & Scott (1995) warned that where a substantial degree of consensus is not achieved in evaluation, this points to the existence of sub-criteria within what may seem like single criteria.

**Confidence in procedures.** How satisfied or confident (on a five point scale) are you in the procedure as a method for exploring your needs:

1. Confidence in scores generated.
2. Confidence in weights generated.
3. Satisfaction with the way in which the issues were clarified by the procedure.
4. Confidence in the manner in which views could be expressed
5. Confidence that the procedure will lead to better balance between conflicting interests.

The results of the questionnaire showed that the representatives both understood the procedure and had confidence in its results.

The case study illustrated the successful use of relatively simple (yet rigorous) and understandable MCDA procedures in a South African context. The use of additive value scoring, interval scales, thermometer scales and value paths were successful and could find application in a WCSA decision making framework.

### **3.2.3.2 Case study 2: The Krishna river basin of South India**

#### **Background**

The Krishna river basin in South India is a large basin consisting of 8 reservoirs and a diversion works. In 1995, increasing water demand and changing land use patterns in the area necessitated a re-evaluation of water resource planning in the area. Raj (1995) contributed to this re-evaluation by attempting to identify which sets of three reservoirs should be operated in conjunction with each other and to rank the combinations in order of preference

## **Methodology and results<sup>34</sup>**

At the outset 27 options were identified, each consisting of the operation of three reservoirs in combination. The first step was to screen these options in order to generate a set of preferred alternatives which were preferred for most of the criteria and yet did not cause an unacceptable level of discontent for any one of the criterion. Each option was evaluated using ELECTRE 1 in terms of 6 criteria, viz., (1) irrigation benefits; (2) power production; (3) drinking water; (4) environmental quality; (5) flood containment; (6) cost of the project. Initially this was done using uniform weights and scales which resulted in the generation of a list of 4 preferred options. These options remained unchanged after a sensitivity analysis of the weights and scales (scores) applied to each criterion. The author notes that the sensitivity analysis performed on the scales affected the result less than the one performed on the weights. The 4 options were then further evaluated using ELECTRE 2 to establish the most preferred option. Once again the preferred options was able to stand up to sensitivity analysis. It was not possible to go beyond this and rank the other three options out of the four due to a lack of information.

The analysis was relatively straightforward due to the fact that clearly preferable options emerged through screening. The most preferred option among those screened also emerged without the need for extensive sensitivity analysis or debate.

### **3.2.3.3 Case study 3: Water provision options for Newport News, Virginia**

#### **Background**

In 1987 a freshwater crisis existed in Newport News as available supplies were dwindling. The city manager thus had to choose, in the face of uncertainty, from a number of alternatives including direct withdrawals, diversions, dams, groundwater usage, water conservation and desalination.

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<sup>34</sup>The combination of using ELECTRE 1 and 2 to determine the most preferred option was applied by Gershon et al. in 1982 for the Santa Cruz river, Arizona.

## **Methodology and results**

Anandalingham & Olsson (1989) started with 27 supply options and using multi-attribute value theory performed an analysis aimed at selecting a single most appropriate option. An initial screening eliminated 7 options due to unacceptable technical uncertainties and dominance on cost grounds (i.e. the same river could be tapped at a source which provided more water at a lower cost). Elimination by aspects (Tversky, 1972) was then applied which set up lower (or upper) bounds for the aspects under consideration and eliminated alternatives in which the probability of scoring below (or above) the bounds was statistically significant. This was done first for options that would be too expensive from the city's point of view, second for options that did not supply the required minimum level of supply and third for options that represented an unacceptable pollution risk. This resulted in there being only 3 options out of the original 27 with acceptable risks. These three were analysed comprehensively from the point of view of a single decision maker using the multi-attribute value technique. The criteria and the preference weights assigned to them were:

<u>Criteria</u>	<u>Weight</u>
1. Minimise initial investment	0.261
2. Minimise annual cost	0.131
3. Minimise adverse environmental impacts	0.087
4. Maximise contribution to future water supply	0.391
5. Minimise adverse social impact	0.043
6. Maximise reliability of source	0.087

The analysis yielded a single most preferred option which withstood a sensitivity analysis of the preference weights used and changes in the single cardinal value functions.

The elimination by aspects process was shown to be an effective way of handling initial screening formally, instead of just disregarding options based on discussion. It also made it

possible to perform a more in-depth analysis of the options remaining instead of having to analyse all the options, but in less detail.

Environmental and social considerations combined represented only 13% ( 0.087 + 0.043 as a percentage of 1) of the total preference weights used in the analysis - which seems rather low. This may, however, have been the case due to low environmental and social impacts of the options not being viewed as critical to decision making.

### **3.2.3.4 Case study 4: Development of the Tisza river basin, Hungary**

#### **Background**

In the mid 1970s five alternative water resource development system plans were proposed for the Tisza river basin. Fairly detailed plans and estimations of the alternatives were already available at the time for each system and the following objectives had been identified by the Hungarian National Water Authority: satisfaction of water needs, adequate flood protection, adequate drainage and used water disposal, efficient use of available resources, minimisation of environmental impacts, provision of flexible solutions. A decision was, however, needed as to which alternative to implement.

#### **Methodology and results**

Keeney & Wood (1977) applied compromise programming based on the utility function approach to the decision problem. Given the objectives, the following attributes were used in analysis:

1. Costs
2. Probability of a water shortage
3. Water quality
4. Energy efficiency

5. Recreational aspects
6. Flood protection
7. Land and forest used for each alternative
8. Social impact
9. Environmental impact
10. International co-operation
11. Development possibility
12. Flexibility

Each alternative was rated against the attributes using a scale of 1-100 for ease of understanding and to simplify quantifying the utility functions (Keeney & Wood, 1977). Recreational potential had previously been categorised as very good, good, fair, or bad. This categorisation was converted into a numerical scale by assigning a value of 100 to excellent, 80 to very good, 40 to fair, 20 to bad and 0 to no recreational potential. The five systems were assigned the following utility scores during the evaluation:

<u>System</u>	<u>Utility Value</u>
1	0.832
2	0.831
3	0.503
4	0.648
5	0.521

Two of the five alternatives were clearly more preferable at a preliminary stage and it was suggested that a more in-depth utility analysis be performed to determine which one alternative was most preferable.

Keeney & Wood (1977) mentioned the following lessons learnt from the analysis that could be useful in the Western Cape context:

1. Better articulation of the system objectives and better attributes for these objectives would have improved the analysis. In other words, the analysis could have benefited from improved structuring at the outset.
2. Formal inclusion of uncertainty in the analysis would have been an improvement. Keeney & Wood (1977) do not, however, specify how this could be done.
3. The inclusion of system flexibility as a consideration was important. It could even have been expanded on given the 55 year time span of the project during which possible changes (future water demands, developments in neighbouring countries, future navigation potential, etc.) would necessitate flexibility.

### **3.2.4 Discussion**

#### **3.2.4.1 Strengths**

MCDA allows a complex decision to be broken down into manageable components. One of its main advantages is that it defines separate objectives stemming from overall goals against which options can be evaluated. In this way complex decision problems can be treated as a series of separate smaller, more manageable, decision problems.

Using MCDA, it is possible to achieve a greater degree of representativeness in public sector decision making. The process can be opened up to allow for meaningful stakeholder participation in decision making as opposed to domination of the process by one decision maker or analyst. It thus has the potential to be a democratic and transparent methodology - a particularly important consideration given the current political trends in South Africa.

This representativeness also serves to lessen the income distributional problems inherent in SCBA. Joubert et al. (1997) point out that the Hicks/Kaldor approach is biased in favour of the

already affluent as they are more willing and able to compensate those that have experienced a decrease in utility. In addition, the bias can have particularly serious consequences when an environment is preserved purely because the rich use it as a recreational 'playground' while the needs of the poor to subsist from it are not given adequate consideration. "The potential pro-rich bias inherent in the Hicks/Kaldor compensation approach is avoided, as all stakeholders (rich and poor) are represented, the criteria chosen are those which reflect their values (in a non-monetary sense) and preferences are not governed by ability to pay" (Joubert et al., 1997, p. 127).

MCDA does not involve the use of monetary valuation techniques for intangibles. This allows the technique to avoid the associated ethical and practical problems discussed in section 3.1.4. At the same time the technique does not exclude the incorporation of results derived through the use of monetary valuation techniques. If credible valuations (which tend to be concerned with use values as they are easier to determine) are available, they can be used in an MCDA. In the controversial and difficult determination of non-use values such as existence and option value the avoidance of monetary valuation techniques is a definite advantage. As Joubert et al. (1997) point out, existence value can be operationalised in MCDA through the direct use of criteria such as uniqueness of environment or level of biodiversity.

#### **3.2.4.2 Weaknesses and criticisms**

MCDA has been criticised on the grounds that it is a way of justifying projects that do not make sense financially through the injudicious use of broader, imprecise criteria. MCDAs that use generalised judgements instead of more precise measures have been criticised for their lack of rigour as they have not included the precise measurement of aspects such as expected probability and attitude towards risk. This criticism is essentially methodological and thus falls away when the desired level of importance for each criterion is determined in a properly carried out, rigorous analysis.

“Some efforts in multi-objective evaluation have suffered from inadequate care in specifying objectives, identifying trivial physical impacts as their objectives rather than employing measures representing legitimate public goals” (Young & Haveman, 1985, p. 493). MCDA thus has the disadvantage of being potentially open to manipulation particularly for political reasons (Thomas, 1979). This disadvantage will not however necessarily manifest itself unless the MCDA analysis is sub-standard.

The large number of MCDA methodologies available can be seen as a reflection of uncertainty in the field as to which MCDA methods are best. This is illustrated in the literature by the many articles comparing and contrasting different MCDA methods. On the other hand, the various MCDA methods allow for greater choice of methods ‘tailor made’ for specific problems. Hämäläinen (1992) advocates methodological flexibility and points out that decision analysts can miss opportunities for application by being too restrictive in their own choice of decision analysis methods.

The fact that MCDA methods often rely solely on value judgements can be seen as a potential disadvantage if this leads to the scrapping of important empirical research. ‘Hard’ facts are replaced by ‘softer’ opinions which are thought to have a greater chance of being incorrect. Once again this problem will not necessarily surface in a good MCDA, but should be guarded against.

### **3.3 ENVIRONMENTAL IMPACT ASSESSMENT (EIA) METHODS**

EIAs are not decision making techniques as they do not provide a way of getting to a decision on the desirability of a project. They are focused on highlighting and assessing environmental, social and economic impacts making them purely a *source* of primary data in decision making regardless of what decision making method is used. As all the decision making methods reviewed here (SCBA, MCDA, the Sondheim technique and the Delphi technique) depend on adequate primary data, EIAs are important to the successful application of these method.

Among the techniques used in EIAs are overlay maps (pioneered by McHarg), matrices (developed by Leopold) and 'scoring' techniques such as the Battelle-Columbus Environmental Evaluation System. Two early, and rather mechanical methods emerged from the EIA field that can be modified to include all the relevant aspects of a decision and thus represent forms of decision making methods with potential for application in water resource planning. They have thus been included in this survey for completeness albeit in far less detail than the other methods which have found more application in water resource planning. The first (the Sondheim technique) has a lot in common with multi-criteria methods while the second, the Delphi technique is a way of seeking expert consensus.

### **3.3.1 THE SONDHEIM TECHNIQUE**

#### **3.3.1.1 Theoretical background and historical development**

After the introduction of the National Environmental Policy Act (1969) in the United States, a number of EIAs were conducted using gross generalisations, minimal alternatives and public involvement that did not go beyond letting people have their say at public meetings and then proceeding to ignore their inputs (Sondheim, 1978). After surveying the existing techniques in EIAs at the time (mainly overlay mapping, matrix generation, index methods and modelling approaches), Sondheim came up with a method aimed at improving EIA practice with specific reference to the problems mentioned above.

#### **3.3.1.2 Methodology**

To start with a co-ordinating body is established. This body then has four main tasks:

1. List all realistic project alternatives and code them from 1 to "m"
2. Define 'environment' as a function of "n" independent or quasi-independent aspects or attributes which are relevant to the project alternatives. In order to make this method a holistic

decision method 'environment' can be expanded to include 'all relevant aspects' of the decision at hand.

3. Choose a rating panel of specialists whose collective knowledge will cover all the aspects mentioned in 2 so that they can rate each alternative against the aspect in their field of expertise
4. Choose a weighting panel to establish the weights to be attached to each aspect mentioned in 2. The members of the panel may include representatives of government, industry, public interest groups, community organisations and other potentially affected parties.

The weighting panel must be satisfied with the composition of the rating panel. In addition all the members of the rating and weighting panel must be satisfied with the listings in 1 and 2 above before the procedure can commence. Once this is established, the rating panel rates the alternatives against each aspect and the weighting panel attaches weights to the aspects using compatible scales. For each alternative the weighted rating values for each aspect is then simply summed and the alternative with the highest score is the preferred alternative.

### **3.3.1.3 Case studies**

#### **Case study 1: Shirley Lake, Ontario**

The Sondheim method was first used in a water resource planning setting in 1976 in order to establish the necessity of replacing an old dam in Ontario, Canada (Sondheim, 1978). A task-force established for the investigation served as a co-ordinating body, rating panel and weighting panel. The study went into considerable detail and identified 81 alternative courses of action. The following six environmental aspects were used: biophysical aspects, recreational values, policy effects, perception attributes (aesthetics), managerial considerations and economic factors

#### **3.3.1.4 Discussion**

The Sondheim method is similar to multi-criteria methods in that attributes are identified for alternatives which are then scored and weighted. Its strengths and weaknesses are thus similar to those of multi criteria analysis. It is appealing because it is a transparent approach with the potential for a broad representation of interests.

On the down side the Sondheim's success is highly dependent on a knowledgeable and impartial rating and particularly weighting panel for its success. Because the rating and weighting panels are made up of experts the method is biased in favour of experts at the expense of public opinion. The results of the method can also be dominated by emotive unsubstantiated judgements as it does not necessarily require proper research in order to substantiate judgements. The use of experts rather than interested and affected parties should, however, curtail unsubstantiated opinions.

### **3.3.2 THE DELPHI TECHNIQUE**

#### **3.3.2.1 Theoretical background and historical development**

The Delphi is a "systematic procedure for soliciting the advice of a number of experts, and forging a consensus from that advice" (Richey, 1985, p. 136). It originated in the field of technology forecasting as a communication and decision making method. Initially it was developed by Dalkey of the Rand Corporation and can used in various situations where judgmental information is needed (Dalky, 1967). Barkus et al. (1982) mention environmental management, socio-cultural issues and educational questions as fields in which the Delphi has been successfully applied.

### **3.3.2.2 Methodology**

“The Delphi process is essentially a combination and extension of a polling and conference procedure. In this technique, a small monitor team designs a questionnaire to address the range of decision issues to be considered by the Delphi process. The questionnaire is then sent to a larger group of expert respondents (the Delphi panel), each of whom submits answers to the monitor team. The monitor team reviews and summarises statistically the responses to this initial questionnaire. The monitor team then develops a second questionnaire, which typically includes both a reiteration of questions from the first questionnaire for which no clear consensus was evident, and new questions, which present new issues and options raised by the respondents during the first round. The expert respondents are given a chance to change their initial responses based upon the knowledge gained from the group consensus and the new options presented. the process of response and reiteration can be repeated as many times as needed” (Richey, 1985, p. 137).

### **3.3.2.3 Discussion**

The Delphi technique’s main strength is that it allows for an exploration of disagreements and the reasons for them. It also ensures a balanced representation of views which may not occur in a group meeting or conference setting due to varying degrees of ability or ‘personality’ among participants in promoting their views above those of others.

The most serious potential weakness of the method lies in its dependency on the ability of the monitor team to present views objectively in the iteration process. The team must be able to convey the developing consensus and points of disagreement to the group of experts effectively (Richey, 1985). The Delphi has the additional drawback of not providing an opportunity for the involvement of stakeholders as it uses only inputs from experts. Even if the experts involved were to take cognisance of the opinions of stakeholders in formulating their own opinions, there would still be no direct stakeholder participation.

The Delphi is more effective when conceptual or philosophical issues need to be considered and less so when issues requiring exact, quantitative answers (Richey, 1985). This lessens its applicability in development planning involving various technical components such as water resource planning. In water resource planning it has found application in the structuring of objectives before MCDA takes place, but not as a direct decision making tool (Khorramshahgol & Steiner, 1988).<sup>35</sup> Thus no case studies will be presented for the technique.

## **CONCLUDING REMARKS**

Of the methods surveyed, SCBA and MCDA have been applied most frequently in water resource planning. The Delphi and Sondheim have not been applied regularly and have revealed inadequacies. SCBA has been applied extensively in public investment decision making. Its main advantages are its use of a common yardstick and its handling of efficiency considerations. Its main disadvantages are its reliance on contentious valuation techniques, its lack of an avenue for public involvement and its relative inadequacy in dealing with multiple conflicting objectives. MCDA, on the other hand, is a 'young' method relative to SCBA which is increasingly being applied to decision situations involving multiple objectives and stakeholders - hence its frequent application to water resource planning problems. Its main advantages are in its involvement of stakeholders in a democratic decision making process, its avoidance of contentious valuation techniques and the relative ease with which it can be understood. On the down side, it relies heavily on value judgements and is not particularly well equipped in dealing with efficiency considerations.

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<sup>35</sup>See also Singg & Webb (1979) for a description of the use of the Delphi to assess the goals of the Cooper Dam and reservoir project in Texas.

## **CHAPTER 4**

### **THE CONTEXT AND CHARACTERISTICS OF DECISION MAKING**

#### **INTRODUCTION**

The previous chapter has outlined the decision making frameworks most commonly used in decision making between water supply options. Decision making requires the consideration of various contextual aspects which influence the choice of a framework, and its working once chosen . This chapter will attempt to place WCSA planning/decision making in the context of the conditions in the Western Cape and South Africa that are important to water resource planning. A brief outline of the salient characteristics of the decision making situation will also be included to compliment the context in guiding the choice of future decision making framework. This will be divided up as follows:

- Socio-economic context
- Environmental context(encompassing biophysical aspects),
- Regulatory context
- Political context
- The characteristics of the decision making problem

#### **4.1 THE SOCIO-ECONOMIC CONTEXT**

##### **4.1.1 Demography**

Demographic trends play the main role in determining projections for future water demand. In the GCTMA, the population was estimated at 2 930 000 people in mid-1996 (WESGRO, 1996). With a relatively high natural population growth rate and continued increases in in-

migration this figure should increase steadily. Estimated population growth trends will need to be continually monitored as more people will increase water needs.<sup>36</sup>

#### **4.1.2 Regional economic growth**

In the recent past, economic growth in the Western Cape has generally stayed above the national average. In 1996, the average was approximately 4 % while the national average was about 3 % (WESGRO, 1996). This relatively healthy growth trend seems likely to continue as the regional economy expands. Some of the sectors which have high demands on water that have shown particularly impressive growth are tourism, fruit production, wine production and heavy industry (notably Saldanha Steel and Namakwa Sands). Increased demands on water supply for commercial use from these and other sectors (industrial and agricultural) are thus to be expected as the economy continues to grow.

Economic growth can also be expected to make a positive contribution to the raising of average incomes.<sup>37</sup> As affluence increases, a rise in domestic water demand can be expected.

#### **4.1.3 Regional development planning**

Water resource planning needs to be as inclusive as possible in relation to broader economic and spatial development planning. A wide ranging reassessment of the development goals of Greater Metropolitan Cape Town (GMCT) has been taking place in conjunction with the profound political changes of the recent past. As early as June 1990, planners from a number of local authorities and the Cape Provincial Administration (CPA) met to discuss the need for appropriate planning for the Western Cape region to guide the rapid growth being experienced (CPA, 1993). Under the auspices of the Western Cape Economic Development Forum (WCEDF) work was started on a Metropolitan Development Framework (MDF) encompassing

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<sup>36</sup>This need has been recognised in the WCSA.

<sup>37</sup>Given the current income distribution, growth will not necessarily raise average incomes among the poor as much as it will raise them among the rich.

a Regional Growth Management Strategy. A WCEDF draft vision statement for the development of the Western Cape stated that:

*“We dedicate ourselves to the integration and sustainable development of the city and its rural hinterland, to the region as part of the South African nation and the African continent. Spatially and economically our region will be more efficient, better integrated, and able to meet the needs of its inhabitants, in a manner compatible with our unique and sensitive environment.”* (CPA, 1993, p. 2)

In early 1993 Cape Town City Council unveiled its “Vision 2000” discussion document which was focused on a collective development vision for Cape Town based on participative planning (one of the main aims of the document was to encourage debate). This was followed by “A Vision for the Future of Metropolitan Cape Town” compiled by the City Planners Department later that year. The main themes of this document were *equity, opportunity* and *sustainability* and how they could be operationalised and integrated to form “one of the world’s great cities.” In February 1995, the Metropolitan Spatial Development Framework was completed to form a synthesis of spatial development planning in the Western Cape.

At this point no economic development strategy exists for the Western Cape. The areas in which industrial, commercial and agricultural development is to be focused have not been identified. This creates uncertainty in planning water supply among other planning considerations. It has not, for example, been decided to focus industrial activity on the West coast near Saldanha although the approval of developments such as the Saldanha steel plant does seem to indicate that the area is likely to be developed industrially as per the plan of the previous government. Environmental objections to industrial development in the area have intensified though, making development more difficult to justify. The lack of a formal economic development plan constitutes a major constraint on future water supply planning. It is difficult to choose water supply options that complement future economic development without knowledge of the future location and projected phasing of economic development. In the

absence of this knowledge, water supply planning is forced to give inadequate consideration to economic development.

The provincial government has, however, been working on a economic development strategy to complement the spatially orientated development frameworks mentioned above. Furthermore, at a municipality level, the Green Paper on local government calls for Integrated Development Planning - a process through which municipalities can establish short, medium and long term development plans (Dept. of Constitutional Development, 1997). Water resource planning will have to be integrated into this process.

#### **4.1.4 National economic objectives**

National economic objectives have an 'indirect' influence on regional water resource planning that is worth considering. The government's Growth, Employment and Redistribution (GEAR) strategy identifies public infrastructure spending on projects such as improved water supplies as an important priority which will "... add to the quality of life in communities, while simultaneously building productive capacity" (Dept. of Finance, 1996, p. 15). At the same time, however, the GEAR strategy calls for tighter fiscal discipline. Infrastructural developments such as new water supply projects will thus have to be justified in the presence of other high priority infrastructural needs.<sup>38</sup> Demand management strategies, on the other hand, will not face similar budget constraints.

The White Paper on a National Water Policy for South Africa brings attention to GEAR's recommendation that the economy cannot grow merely through the exploitation of crude natural resources (DWAf, 1996). This should apply as much to water as to the more traditional area of minerals.

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<sup>38</sup>The National Infrastructure Investment Report indicated that South Africa faces a infrastructure backlog of R 170 billion (Dept. of Finance, 1996).

There is a recognised need for growth with equity in the South African economy (see for example Nomvete et al., 1997). In terms of more equitable water resource planning, the need for affordable water supply for basic needs will have to be addressed. It is envisioned that this will happen mainly through the extension of supply infrastructure (for domestic and commercial supply) to poorer communities and subsidised life-line tariffs. Water resource planning aimed exclusively at economic growth will, on the other hand, include projects such as increased supplies to industry and agriculture. This tension between water resource planning for growth as opposed to planning for equity will continue to present difficult trade-offs that will have to be dealt with in decision making.<sup>39</sup>

## **4.2 THE ENVIRONMENTAL CONTEXT**

### **4.2.1 Land use**

Land in the Western Cape faces competing demands for its use. It can be divided into:

- Natural areas
- Agricultural and commercial forest lands
- Built up areas (residential and industrial areas)

The natural areas of the Western Cape, home to the fynbos floral kingdom, are under continuous development pressure as the population of the area expands. Due to their uniqueness, high levels of biodiversity and recreation value, these areas are a valuable resource. Their value is also likely to increase as their scarcity increases. Mountain fynbos has tended to be under less pressure than lowland varieties mainly because there are less competing land uses in mountainous areas. Dam construction is, however, a potential competing use in mountainous as well as lowland areas.

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<sup>39</sup>Van Rooyen (1995) presented a rural water supply policy framework designed to reconcile this conflict through the use of a set of policy criteria supporting both efficiency and equity objectives. The framework could be used to evaluate programmes/projects from the point of view of the trade-offs that they represent.

The irreversible nature of dam construction in natural areas makes it important to consider future trends for preservation and development benefits. Fisher et al. (1972) point out that the benefits from the preservation (the marginal opportunity costs of development) of a natural site will increase over time for two reasons. Firstly, they argue that this will occur because the demand for wilderness recreation increases over time given population growth and growth in average income levels.<sup>40</sup> Secondly, they argue that the 'quasi-option value' of a preservation worthy dam site, containing for example rare species and/or high levels of biodiversity, will also increase over time.<sup>41</sup> On the other hand, the benefits from dam development (measured as the difference between the costs of the present option and the next best option) will decrease over time as new technology becomes available leading to cheaper ways of accessing water (Fisher et al., 1972). In other words, preservation benefits are likely to increase over time while development benefits decrease.

Changes in land use which occur when natural areas are disturbed can impact negatively on water availability. This is because fynbos is a very sparing user of water in comparison with other vegetation types. Invasive alien vegetation and forest plantations, in particular, have high rates of water absorption and transpiration decreasing run-off significantly. This prompted the Minister of Water Affairs and Forestry to launch a project in 1995 which employs people to eradicate alien vegetation.

#### **4.2.2 Rainfall**

The Western Cape is characterised by heavy winter rainfall with minimal rain in the summer months. The growing season for many important irrigated crops does not coincide with the rainy season as it does elsewhere in South Africa which puts extra pressure on stored water resources during this period. The warm summer climate also contributes to the problem of relative water scarcity in summer through evaporation.

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<sup>40</sup>Wilderness recreation is assumed to be a higher income or 'luxury' activity.

<sup>41</sup>This argument is also contained in Arrow & Fisher, 1974.

## **4.3 REGULATORY CONTEXT**

### **4.3.1 Changing water law**

Beginning in 1995, a comprehensive review of South Africa's water laws was initiated by the DWAF. The process involved extensive public participation and culminated in a new set of water law principles. An integral part of water resource planning, its legal framework, is thus undergoing change. The main changes are aimed at enforcing water's status as a national asset for all South Africans by attempting to improve equity, increasing efficiency of use and improving environmental considerations. The following principles taken from the white paper on an national water policy for South Africa (DWAF, 1997) impact directly or offer guidance in water resource decision making:

2. All water, wherever it occurs in the water cycle, is a resource common to all, the use of which should be subject to national control. All water should have a consistent status in law, irrespective of where it occurs.
  
3. There shall be no ownership of water but only a right (for environmental and basic human needs) or an authorisation for its use. Any authorisation to use water in terms of the water law shall not be in perpetuity.
  
5. In a relatively arid country such as South Africa, it is necessary to recognise the unity of the water cycle and the interdependence of its elements, where evaporation, clouds and rainfall are linked to underground water, rivers, lakes, wetlands, estuaries and the sea.
  
6. The variable, uneven and unpredictable distribution of water in the water cycle should be acknowledged.

7. The objective of managing the quantity, quality and reliability of the nation's water resources is to achieve optimum, long term, environmentally sustainable social and economic benefit for society from their use.

9. The quantity, quality and reliability of water required to maintain the ecological functions on which humans depend should be reserved so that human use of water does not individually or cumulatively compromise the long term sustainability of aquatic and associated ecosystems.

13. As custodian of the nation's water resources, the National Government shall ensure that the development, apportionment and management of water resources should be carried out using the criteria of public interest, sustainability, equity and efficiency of use in a manner which reflects its public trust obligations and the value of water to society while ensuring that basic domestic needs, the requirements of the environment and international obligations are met.

14. Water resources should be developed, apportioned and managed in a such a manner as to enable all user sectors to gain equitable access to the desired quantity, quality and reliability of water. Conservation and other measures to manage demand shall be actively promoted as a preferred option to achieve these objectives.

17. Water resource development and supply activities should be managed in a manner which is consistent with broader environmental management approaches.

#### **4.3.2 Changing water tariffs**

The formulation of a new resource pricing policy for South African water has been undertaken by the Department of Water Affairs and Forestry (DWAF). This process has reached the final draft stage before a white paper will be drafted (DWAF, 1997a). It has sought to identify the shortcomings of the present bulk water tariff structure and make suggestions for future tariff policy. The pricing policy review has occurred alongside the water law review and has served as

a point of reference for the water law review committee. Three main goals have been identified for the new pricing policy:

1. The optimisation of economic efficiency,
2. the achievement of social development, and
3. the enhancement of ecological quality.

These goals can be likened to the efficiency, equity and sustainability criteria used by the DWAF in water supply decision making. The policy is based on an economic approach that is intended to promote the efficient allocation of water - an increasingly scarce resource. It has been suggested that the overall costs of abstracting water be considered in determining appropriate pricing. Overall costs have been divided into three categories - the infrastructure costs of abstraction, the necessary catchment management costs and the economic costs associated with using a scarce resource. The approach differs markedly from the existing approach which does not consider resource scarcity and often does not reflect the full costs associated with abstraction. Over a period of time, the policy suggestions put forward are bound to have a profound effect on raising bulk water prices. This, in turn, will determine the price of water sold to the public thereby influencing economic demand management strategies. Appendix 2 discusses the role of pricing/tariffs and other economic instruments in water demand management and makes some predictions on the expected efficacy of tariffs in demand management..

#### **4.4 POLITICAL CONTEXT**

Since the beginning of a new political era in South Africa in 1994, profound political changes have occurred and continue to occur nationally and in the Western Cape. A far more participatory approach to decision making has entrenched itself along with this political change. Population groups as well as interest groups that were marginalised in the past now have a greater say in matters of public interest. Transparency and accountability in government workings have also improved and are being encouraged to a greater degree particularly at a

local level. One of the objectives of local government contained in the Constitution of the Republic of South Africa is "...to encourage the involvement of communities and community organisations in the matters of local government" (Constitution of the Republic of South Africa, 1996. p. 81). The Green Paper on Local Government contains a recognition that the local sphere is critical for enhancing participative democracy in government because citizens may have greater incentives to participate at local levels. "The local sphere is an arena where citizens can participate in decision-making to shape their own living environments, and exercise and extend their democratic (social, economic and political) rights" (Dept. of Constitutional Development, 1997, Section D, p. 9)

The allocation of infrastructural development funds between ministries is a politically charged issue. Backeberg (1996, p.161) recommends that, "Post-constitutional policy making and application of policy instruments must adhere to the rules of simple majority decision but subject to passing the test of generating net economic benefits. Only pure public goods and services can be financed totally with taxes. Expenditure of public funds for any other capital investment must be justified by a social benefit-cost study." At this point, infrastructure investment decisions are still made independently by the ministries involved. If inter-sectoral comparisons are carried out in the future, however, water supply projects will have to compete directly with other infrastructural projects. The maintenance of objectivity in comparisons will be difficult unless they are carried out by a neutral party not involved with any of the ministries that stand to benefit.

#### **4.5 THE CHARACTERISTICS OF THE DECISION MAKING PROBLEM**

Chapter 1 provided an overview of the WCSA which showed many of the main characteristics of the decision making problem (i.e. deciding between options). These characteristics indicate the nature of the decision problem and offer guidance for the choice and possible workings of a future decision making framework. The main characteristics of the decision making problem that need consideration are thus listed below before continuing with recommendations for the future.

- Multiple, often conflicting objectives need to be considered together. These include maximising water yield, ensuring engineering feasibility, minimising costs, minimising negative environmental impacts, minimising negative social impacts.
- Multiple stakeholders with different values need to be satisfied with decisions. Some of the needs of the stakeholder groups are in actual conflict - for example, agricultural and urban users in greater Cape Town.<sup>42</sup>
- The need for water supply is a given for the continued functioning of society. The decision is thus not whether to provide water supply, but how best to do it.
- The vitally important nature of water as a societal resource necessitates public consensus on its management.
- Budgetary constraints do not allow for highly elaborate and expensive forms of analysis to aid decision making.
- Relatively high degrees of uncertainty with regard to some of the factors being considered in decision making, for example social impacts of dam construction activity. Some uncertainties are due to a lack of complete information and can be addressed given time and money. Due to their nature, other uncertainties may never be resolved.

## **CONCLUDING REMARKS**

The context of water resource planning in Greater Cape Town has various facets that make for a complex decision making setting. The socio-economic environment is characterised by rapid change and the continued need for equity with growth. The increasingly pressurised biophysical

environment is unique with a high degree of species diversity and endemism. Changing water laws and tariff structures are emphasising water's status as a national asset and aiming for full cost recovery in the future. In the political arena, a far more transparent and participatory approach to decision making is entrenching itself. The decision making setting is also characterised by multiple conflicting objectives and stakeholders that need to be accommodated.

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<sup>42</sup>The new water law will reduce farmers' legal rights to water. Their de facto rights to water have been eroded over time. This is illustrated by the fact that Theewaterskloof dam water originally meant for their use is being used for other purposes.

## **CHAPTER 5**

# **RECOMMENDATIONS FOR FUTURE DECISION MAKING BETWEEN WATER SUPPLY OPTIONS**

## **INTRODUCTION**

As has been shown, in the preceding chapter, the context and characteristics of the decision making problem with regard to water supply is highly complex and can be expected to increase in complexity. Given this, it is hard to ignore the potential benefits of using a formal decision making framework to improve future decision making. Chapter 3 reviewed the main formal decision frameworks/methods used in water resource planning from which a choice can be made for a framework appropriate to the unique requirements of the Western Cape. This chapter will attempt to provide and justify a framework for future decision making between water supply options. The choice of an appropriate new framework will be discussed followed by its suggested operational features and possible constraints. A brief simulation of its application to the problem of deciding on the next water supply option to follow Skuifraam dam and water demand management is also presented for illustrative purposes.

### **5.1 THE CHOICE OF A DECISION MAKING FRAMEWORK**

Chapter 3 concluded that the choice of a future decision making framework for deciding between water supply options in Greater Cape Town should be between social cost-benefit analysis and multiple criteria decision analysis. The Delphi and Sondheim methods were shown to have major shortcomings in terms of encouraging stakeholder participation as well as limited practical application in water resource planning.

This section will consider how the following factors affect the choice between the SCBA and MCDA frameworks:

- Methodological considerations - given the context and characteristics of the decision making situation.
- Lessons from the decision making process used thus far in the WCSA.
- Case studies on the application of decision making frameworks in deciding between water supply options.

### **5.1.1 Methodological considerations - given the context and characteristics of the decision making situation**

In Chapter 3, the strengths and weaknesses of SCBA and MCDA were discussed. Any future decision making framework will have to be compatible with the context and characteristics of the decision making situation. It would be rather futile to suggest a method that has theoretical merit, but would be inadequate in dealing with the realities of the decision situation. This section debates the influence of these realities (the context and characteristics of the decision making situation/problem) on the choice between SCBA and MCDA. Some of the methodological strengths and weaknesses of SCBA and MCDA dealt with in Chapter 3 are referred to, or briefly revisited, as part of this discussion

#### ***The environment***

Environmental issues enjoy high priority in Greater Cape Town and can be expected to grow in importance. A decision making framework suited to dealing with environmental issues as a major influence on decisions would be ideal. It has been shown in Chapter 3 that MCDA is generally better suited to dealing with environmental considerations than SCBA. Indeed, MCDA emerged partly in response to the need for adequate consideration of difficult or controversially quantifiable aspects such as the environment in decision making. Section 3.1.4.2 discusses the weaknesses of SCBA in dealing with the environment including inadequacies in

terms of environmental valuation and income distributional considerations. Section 3.2.4.1 discusses the strengths of MCDA in dealing with the environment including its avoidance of environmental valuation and incorporation of income distributional concerns.

### ***Social impacts***

Social impacts associated with certain water supply options such as displacement of local inhabitants from dam sites, impacts of imported workers and in-migration into areas by job seekers need to be considered in decision making. These issues featured prominently in the case of the proposed Skuifraam dam (see Appendix 1) as well as in workshops held to discuss the development of the Palmiet river (NSI, 1992). Issues of this nature have been difficult to deal with within the SCBA framework. For example, in the case of displacement, Meier & Munasinghe (1994) cite a case in Sri Lanka, where the compensation offered to local inhabitants (derived through valuation) for moving away from a proposed dam site did not do much to dampen their opposition to the dam. The sums offered as compensation thus did not capture the full willingness to accept compensation of the locals who would have had to undergo major disruption and stood to lose ancestral lands.

SCBA can also be considered inadequate in evaluating and comparing the intangible societal benefits projects may have, such as skills enhancement and technological knowledge transfer. These are a form of positive externality which should be considered a benefit, however, there are no techniques for their valuation in SCBA, causing them to be merely mentioned or ignored. MCDA, on the other hand, can incorporate these considerations directly through the use of the appropriate criteria. This would allow for comparisons between options in terms of intangible societal benefits.

Meier & Munasinghe (1994, p. 75) summarise their experience with SCBA in these types of situations as follows:

“In short, whatever the theoretical promise of being able to internalise all of the significant externalities into a single benefit-cost criterion, in practice there are well defined limits to what can be done. It is this limitation that points to the use of multi-attribute decision analysis methods.”

Mirrilees et al. (1994, p. C.1-9) reinforce this assertion concluding that:

“CBA is a good and valuable technique with which to determine, from a set of feasible decisions, the one that is most economically efficient. But it is not a sound basis on which to decide which decision is optimal from the viewpoint of non-economic criteria. For this latter purpose, other techniques (multiple criteria decision making or MCDM techniques) have been developed, and for a comprehensive analysis of a decision CBA should be treated as one input into these MCDM methods.”

### *Democratic process*

Any decision making framework would have to be compatible with consultative, democratic decision making. It would also be ideal if it was transparent, and thus rendered decision makers accountable for their actions. One of the main strengths of MCDA is that it can use a participatory approach which allows direct public input in decision making. SCBA, on the other hand, places the power to influence decisions in the hands of the expert/s conducting the SCBA. It is also not particularly transparent as society's values are assumed to be reflected in the monetary estimates derived in valuations that form part of SCBA. Members of society are not directly asked to openly articulate their values. This makes it difficult to see the trade-offs that are involved in decision making impacting negatively on transparency.

### ***The lack of an economic development plan***

Economic development planning is in a state of flux in the Western Cape - the region lacks a comprehensive economic plan to complement the current spatial plan as discussed in section 4.1. The region is also undergoing healthy growth which can be expected to continue. This lack of a fixed plan together with fast growth necessitates a decision making framework that would be flexible and could incorporate economic development considerations as a clearer vision for the future of the area emerges. An MCDA framework would allow for the comparison of options with regard to their contribution to, and compatibility with, economic development planning through the use of appropriate attribute/s. It would be difficult to include economic development considerations directly into a SCBA because of the difficulty that would be experienced in placing a value on economic development. It would be possible to qualitatively discuss the economic development implications of options as part of a SCBA. This would, however, increase the probability of economic development being viewed as a low priority in the analysis due to its lack of a quantifiable value.

### ***Multiple objectives and stakeholders***

The decision making situation is characterised by multiple objectives and multiple stakeholders. MCDA was specifically designed for this kind of problem as it breaks down complex problems into manageable objectives and can accommodate multiple stakeholders. SCBA tends to focus on a single objective and makes market-based value judgements for stakeholders. For example, the environment is valued without environmental groups being able to debate their standpoint and reach compromises with other stakeholders.

The fact that MCDA promotes compromise and eventual consensus among stakeholders as part of the MCDA process is a further advantage of the method. In situations where decisions are made without this taking place it is often necessary to embark on a time consuming and expensive campaign aimed at justifying decisions to stakeholders and the general public after they have been made. This can happen when SCBA decisions have to be 'defended'. Also in the

case of environmental impact assessments, stakeholder inputs have the potential to be ignored in making a decision, necessitating post decision justification and attempts at building consensus around what has already been decided

### ***Uncertainties and risks***

“Development decision making is the art of making good decisions on the basis of uncertain knowledge” (Goulet, 1986, p. 301). Water supply decision making has to take numerous uncertainties into account. Although it handles risk better than MCDA, SCBA has the disadvantage of not dealing with uncertainty particularly well (Maguire & Boiney, 1994). This is mainly because SCBA tends to ‘hide’ uncertainties in a way similar to its ‘hiding’ of trade-offs. MCDA should fare slightly better in this respect due the fact that uncertainties can be made more explicit and dealt with through negotiation between stakeholders if necessary. Raiffa (1986) recommends that in cases of uncertainty, subjective probability distributions need to be elicited from decision makers or those with expert knowledge. These kinds of judgements can be incorporated in MCDA, although the level of complexity introduced by them may be a disadvantage in some instances.

In terms of risk, SCBA usually handles risk through the use of normative scientific probability theory. This is a more precise approach than the one used in MCDA based on the use of human reasoning and judgement which introduces fuzziness or imprecision into the analysis. Both these approaches have their shortcomings. Normative scientific probability theory relies on adequate statistical evidence while the human reasoning approach relies on human comprehension of the nature and seriousness of risks. Lein (1992) argued the need for an more formal approach to risk assessment (in this case, environmental risk) which could bridge the gap between the scientific and qualitative approaches and lead to a more precise representation of human judgements on risks. The approach uses fuzzy sets to model inexactness so that human judgements on the determinants of risk which defy precise definition or measurement (i.e. normative probabilities cannot be attached to them) can be incorporated in a formal analysis. It

uses fuzzy reasonings' "...ability to quantify the qualitative, while preserving and expressing in an explicit way the imprecision inherent to its definition" (Lein, 1992, p. 260).

### ***Budget constraints***

Decision making analysis occurs under budgetary constraints. The analysis that would be required in order to do a SCBA which would be able to compare the water supply options would be extensive and costly particularly if valuation following the National Oceanic and Atmospheric Administration (NOAA) guidelines is attempted. MCDA type analysis is not cheap, but because it avoids the intricacies of SCBA, it tends to be less costly if there are significant environmental and social impacts which would otherwise have to be quantified..

### ***Skills requirements***

High levels of skill are required to perform SCBAs. These skills are relatively scarce in South Africa making the SCBA methodology relatively inaccessible. South Africa does not have a history of SCBAs being performed as in the United States and England where specific guidelines for their performance are in place. Central Economic Advisory Services used to have guidelines for SCBA in South Africa, but these have not been approved by the present government. Due to the lack of guidelines and sporadic application of the method, a skills base and familiarity with the method has thus yet to be properly developed in South Africa.

MCDA in its simpler forms is within the conceptual grasp of the average person. This does not, however, make the analysis "easier". In order to perform a good MCDA, a lot of input and commitment is necessary from both the analyst/s and stakeholders involved. In term of institutional support, the Western Cape has a strong MCDA research team at the University of Cape Town that enhances local accessibility.

### ***Compatibility with existing decision aides***

The Integrated Environmental Management (IEM) process is presently entrenched as the way environmental impact assessments (EIAs) are conducted in South Africa. Any future framework will have to be compatible with this process if it is to be accepted. Fortunately neither SCBA nor MCDA is at odds with the IEM process. Indeed, they both rely on the incorporation of the results of the IEM process as discussed in section 3.3. Furthermore, they would help to focus impact assessments on assessing considerations which are most pertinent to the decision at hand. This would eliminate some of the unnecessary information gathering that can occur in EIAs.

#### **5.1.2 Lessons from the decision making process used thus far in the WCSA**

Section 1.6 outlined the decision process used thus far by the DWAF in deciding among water supply options. This section will attempt to draw some lessons from this process for future decision making. This will be done by highlighting some of the positive aspects of the process, and the areas in which improvements could be made, followed by a discussion.

##### **5.1.2.1 Positive aspects**

- The DWAF process was in line with the 'democratisation' of decision processes in the South African government. This represents a break with past, more autocratic, procedures in which the public were not given a chance to participate in joint problem solving or in which participation occurred along racial lines.
- A high degree of representativeness was achieved. The approximately 100 groups represented covered all the major interests affected by water resource decisions.
- The participation process added legitimacy to the decisions reached in the public's view by making them part of it.

- As part of the process, values were elicited from the public in the form of principles and criteria for evaluation. These values were not only useful in the specific evaluation exercise for which they were elicited, but should also be useful guides for water authorities in the future when considering actions that will affect the public.
- The decision variables considered included engineering and financial considerations as well as environmental and social ones. This made the process more holistic.
- The profile of the water supply question in the Western Cape was raised through the public participation process. This should lead to a greater awareness of water related issues and support other initiatives such as the alien vegetation clearance programme and water conservation programs.
- Valuable information was gathered as part of the process which may be useful in other ways for future water resource planning.

#### **4.1.2.2 Possible areas of improvement**

The following improvements to the decision making process could make a positive contribution to future decision making:

- The public participation process could be seen as a 'first stab' at crude multi-criteria decision making as it did make use of multiple criteria. However, the evaluation process lacked formality and therefore could have been more accurate.
- A more direct link between criteria and the options chosen would lead to a more explicit process that makes it clear how certain options fared when evaluated against criterion. This would mean that all the options could be directly comparable in how they fared with respect to each individual criterion.

- Many of the criteria chosen for evaluation were not very useful in aiding decision making as they were vague and did not allow for a comparison of how each option would fare when evaluated against each criterion.<sup>43</sup>
- Some of the criteria overlapped unnecessarily adding to the complexity of the analysis.
- The process did not lend itself to sensitivity analysis as there was no scoring of options or the use of any other evaluation technique that would have made a sensitivity analysis possible.
- If the criteria had been chosen more carefully and at an earlier stage, they could have been used to direct information gathering towards information that would have been directly useful in assessing the options in relation to the criteria. "Because data are useful to the extent that they are able to lead to clearer distinctions among alternatives (options), some information on impacts will be identified as not worthwhile to collect (and therefore not worth spending money on) because it could not alter the decisions made" (Gregory et al., 1992, p. 72).

### **5.1.2.3 Discussion**

The process has introduced the representatives of the public and the water resource planning authorities to basic MCDA concepts. They are thus somewhat familiar with what MCDA is about and it should be possible to build on this through the introduction of more formal, proper MCDA analysis. Although the DWAF process had many positive aspects, lessons for the future can be learnt from the negative aspects of the process. The improvements suggested above could be used to bring future decision making more in line with formal multiple criteria decision analysis methods.

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<sup>43</sup>This assertion was backed up by personal communications with Professor Raimo Hämmäläinen, a decision analysis expert based at the Helsinki University Systems Analysis Laboratory.

### **5.1.3 Case studies on the application of decision making frameworks in deciding between water supply options**

The investigation into the application of SCBA in water resource planning presented in section 3.1 revealed that SCBA has been used extensively, particularly in the United States, when evaluating single water supply projects such as dams. Although some SCBAs have included a comparison of different dam sites, the method has not found as much application in the simultaneous consideration and comparison of numerous different types of water supply options.

The only case study that could be found in the literature, where different types of options were compared and jointly evaluated using SCBA, was a rather simple analysis that focused on comparing engineering feasibility and financial costs of municipal water supply options in Jamaica (TAMS, 1977). The analysis ignored environmental and social considerations. Numerous other SCBAs to be found in the literature dealing only with the evaluation of single water supply options also tended to concentrate on financial considerations.

MCDA on the other hand has been applied extensively to the problem of choosing between different types of water supply options - case studies of which have been documented in the literature as illustrated in section 3.2 Four case studies were presented and a further six have been referenced which have used a variety of MCDA methods. One of the case studies was of particular interest as it dealt with the application of a MCDA methodology in a South Africa water resource planning setting (Stewart, 1993). These case studies contain many valuable practical lessons on the application of MCDA to the specific problem of choosing from among water supply options which can be applied to the Greater Cape Town situation.

Looking purely at the frequency of application of SCBA and MCDA in choosing between water supply options, the literature seems to indicate that MCDA is gaining ground. This is a point in

favour of MCDA as it indicates a general trend in favour of using MCDA in decision problems of this nature.

## **5.2 A SUGGESTED DECISION MAKING FRAMEWORK**

The previous section on the choice of a decision making framework argued that a MCDA based framework would be most appropriate for decision making between water supply options in Greater Cape Town. This final section will conclude with some suggestions on how such a framework could work with a brief simulation of its application to the decision problem of which water supply option to choose after Skuifraam dam and water demand management. The possible constraints that the framework may face are also briefly outlined.

### **5.2.1 Which MCDA framework ?**

Numerous authors have convincingly argued that simpler MCDA methods such as the simple multi-attribute rating technique (SMART) are to be preferred to complex ones in water resource planning. Snell (1994) points out that one could argue in favour of one of the more obtuse decision aids such as outranking or compromise programming, but gains in theoretical vigour would not outweigh losses in transparency and ease of understanding. Stewart et al. (1993) echoed this point for the Sabie River basin MCDA, emphasising the advantages of simplicity and ease of use. Marttunen & Hämäläinen (1995) found that the analytical hierarchy process method was too cumbersome in water resource planning in Finland opting for the simple multi-attribute rating technique. Henig & Buchanan (1996, p. 11) conclude that, "...solution methods should not operate like a 'black box' with incomprehensible workings."

In addition, research on the cognitive limits of humans when making choices (see Frank, 1991 for a review of this topic) tends to favour simple procedures. It is therefore suggested that the SMART framework be adopted in the case of Greater Cape Town. It is also suggested that the framework be applied interactively as there are numerous benefits (mentioned by Belton (1997)

and Hämäläinen & Pöyhönen (1996) among others) such as the visual representation of ideas, quicker results and easier sensitivity analysis.

### **5.2.2 The workings of the framework**

In order to achieve success, it would be imperative that any MCDA process be organised and executed in accordance with professional standards. This becomes particularly important in terms of dealing with ill-considered or vague stakeholder inputs that may arise when members of the public have to make judgements as opposed to analysts trained in decision making practice. Keeping the analysis as rigorous as possible must be a high priority. The following process, based on the SMART, is suggested for decision making between water supply options in Greater Cape Town (see section 3.2 taken from Goodwin & Wright, 1992 for a more detailed description of the nine stages):<sup>44</sup>

#### **Stage 1: Identify the decision maker.**

The DWAF, lead by the Minister of Water Affairs and Forestry, is the decision maker that recommends which water supply option is favoured and then accesses funding for its implementation from the Department of Finance. The degree to which the DWAF allows the public to influence this decision directly is crucial here. International trends seem to be moving towards more direct participation - "Water planning and decision making will be democratic, ensuring representation of all affected parties and fostering direct participation of affected interests" - California Water 2020: A Sustainable Vision (Gleick et al., 1995, p. 1). Public participation has been actively encouraged by the DWAF, yet the public have not had a direct stake in decision creating the potential for their inputs to be ignored. It is thus suggested that public stakeholders become part of decision making process alongside the DWAF as joint decision makers in the SMART framework. This would empower the public as they would

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<sup>44</sup>The workings of the framework have not been spelt out in great detail as this would only be possible once the framework is adopted.

'own' the decision and have a direct influence on public policy which should after all be aimed for in a democratic society.

The top-down approach to decision making relies on public representatives at the higher levels of government being able to decide on the needs of their constituents. This is a process fraught with the danger of misrepresentation as public representatives may not be interested or able to reflect public needs correctly. For example, public representatives may act as 'vote maximisers' lead by self-interest and not the public interest. Public representatives may also act according to the 'political business cycle' making decisions in order to maximise votes in the next elections (Downs, 1957).<sup>45</sup> MCDA offers a way of taking this decision making power away from high level public representatives and putting it in the hands of genuine stakeholders thus significantly reducing the chances of misrepresentation occurring.

In suggesting stakeholder groups that would become joint decision makers, the groups below represented on the Task Group appointed to evaluate the WCSA options would be ideal:

- The DWAF
- Environmental groups
- Emerging farmers
- Irrigation farmers
- Labour
- Commerce and industry
- Breede River area<sup>46</sup>
- Local authorities
- Rural Community Based Organisations (This group consisted of one representative from each of the following organisations: The Kogelberg Biosphere Organisation, Rivieronderend Youth League, Velddrift RDP Forum, Friends of Hangklip.)

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<sup>45</sup>The public choice literature deals with the problems of reaching collective choices in detail.

<sup>46</sup>This stakeholder groups was invited to participate in the Task Group in order to help to ensure that cognisance was taken of the needs of the river basin adjacent to the study area.

- **Urban Community Based Organisations** (This group consisted of one representative from each of the following organisations: Stellenbosch RDP, Cape Metro Region Interim Services Council, Wolfgat Interim Management Committee, Observatory CA.)

### **Stage 2: Identifying the alternatives under consideration.**

This has already been done as the alternative supply options have already been identified as part of the WCSA. The evaluation of options carried out by the Task Group (described in section 1.6) produced a list of 12 options from an initial set of 24 for further study, thus a screening exercise has already been performed and any future decisions between options could focus on the 12 screened options. The early elimination of options can be a bad idea if relatively little is known about the options. However, the relatively large number of options left after the Task Group's screening indicates that only options with major drawbacks were eliminated. In any event, it would be possible to add other options to the existing list if they emerge in the future. Ideally, options should also come from stakeholders other than the DWAF. The technical nature of options does tend to preclude this from happening though.

### **Stage 3: Identify the attributes (also know as criteria) and associated sub-attributes.**

The determination of a single set of attributes and sub-attributes to measure the performance of alternatives in relation to objectives is recommended as it allows for direct comparisons between the views of different stakeholder groups. The main stakeholder groups have shown themselves capable of jointly determining a set of criteria at the Goudini conference. It would be possible to allow each stakeholder group to use its own set of objectives and attributes. However, this does not allow for direct comparisons. In order to determine a suitable set of attributes and sub-attributes there are a number of theoretical considerations that should govern their choice:

1. **Attributes need to be clearly defined and the reasons for their choice carefully considered.** It is pointless to choose attributes that will not affect the decision at hand because they are not relevant or important enough.

2. Double counting should be avoided, i.e. attributes should not capture the same impacts or considerations.
3. Attributes should be conceptually distinct to ensure that they are preference independent<sup>47</sup> (Meier & Munasinghe, 1994).
4. The use of too many attributes tends to complicate analysis and draws attention away from what is really important. A proliferation of attributes can make weighting more difficult (and may introduce a bias simply because one is reluctant to weight any particular attribute as near zero) as well as introduce too many trade-offs making their comprehension more difficult for decision makers (Meier & Munasinghe, 1994). Meier & Munasinghe (1994) recommend assigning one attribute to each of the most important impact issues.
5. Attributes that can be measured or predicted within time and budget constraints are preferable.
6. The splitting of attributes into sub-attributes needs to be handled carefully as research has suggested that when attributes are divided into many sub-attributes they tend to be over-weighted in relation to other attributes (Weber et al., 1988).
7. Keeping a balance between simplicity and completeness of detail throughout the process of selecting attributes is recommended (Marttunen & Hämäläinen, 1995).

The set of evaluation criteria chosen at the 'Evaluation of the Options' conference held at Goudini provides a good starting point in choosing suitable attributes. The conference could be likened to a type of value forum in which the values of the stakeholder groups were expressed

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<sup>47</sup>A set of attributes is preference independent of its complement (i.e. the other attributes) if the trade-offs a decision maker is willing to make among the set do not depend upon the levels of its complement (Meier & Munasinghe, 1994).

as principles and criteria. The criteria as they stand are not, however, adequate for the reasons argued in section 5.1.2 and upon consideration of the above theoretical guidelines.

Upon review of (1) the DWAF values used to draw up a short list of options prior to the public involvement process initiated at Goudini, (2) the Goudini conference principles and criteria, (3) the criteria used in the case studies outlined in section 3.2.3 and (4) taking into account the above theoretical considerations for optimal attribute choice, the following list of attributes and sub-attributes is suggested:<sup>48</sup>

<b>Attributes</b>	<b>Sub-attributes</b>
Cost efficiency	<ul style="list-style-type: none"> <li>• Overall cost per unit of water considering:               <ol style="list-style-type: none"> <li>1. Capital costs</li> <li>2. Operation and maintenance costs</li> </ol> </li> </ul>
Environmental impacts	<ul style="list-style-type: none"> <li>• Impact on ecological functioning of source</li> <li>• Impact on conservation status of areas affected</li> <li>• Impact on biodiversity and rare species</li> <li>• Aesthetic impacts</li> </ul>
Social impacts	<ul style="list-style-type: none"> <li>• Displacement of local inhabitants</li> <li>• Social disruptions (for e.g. from in-migration)</li> <li>• Recreational and tourism impacts</li> </ul>
Economic impacts	<ul style="list-style-type: none"> <li>• Contribution to equity and/or economic growth</li> <li>• Positive and negative externalities not covered by other attributes</li> <li>• Employment creation impacts</li> <li>• Contribution to the economic and spatial development plan of the region</li> </ul>
Flexibility and longevity	<ul style="list-style-type: none"> <li>• Impact on further development of the source and other sources</li> <li>• Maintenance of adequate supply to the donor basin</li> <li>• Expected lifetime of the option</li> </ul>

<sup>48</sup>It is important to bear in mind that ideally attributes should be chosen by the stakeholder groups and that this list is merely a suggested list.

The establishment of an overall objective such as, "Improving overall welfare through efficient<sup>49</sup>, equitable and sustainable choice of water supply development", could also help in further focusing participants on the aim of the task at hand.

**Stage 4: For each attribute, assign values to measure the performance of the option on that attribute.**

In terms of this process two courses of action are possible due to the group nature of the decision. Either, (1) each individual stakeholder group evaluates the options against the attributes on their own and then come together to explore compromise solutions to the choice between options or (2) all the stakeholders perform the evaluation together. Performing the analysis on their own first would give each group a chance to clarify their own preferences before attempting to reach compromise solutions. On the other hand, the various stakeholder groups have shown through the Task Group evaluation process that they are capable of reaching agreement as a unified decision group.

At this stage of the process it would be important to ensure that all the stakeholders involved have access to all the information relevant to decision making. It must be possible for the stakeholders to assign values to all the attributes based on reliable information. EIAs, feasibility studies and other studies should provide the bulk of this information. Where other information is required it may be necessary to seek out other sources. For example, before assigning values to the economic impacts attribute, it may be useful to consider the results of selected economic models. Input-output models, social accounting matrices and linear programming models would be worth considering.<sup>50</sup>

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<sup>49</sup> From an engineering and financial perspective.

<sup>50</sup> Louw & Van Zyl (1997) have developed a multi level linear programming model to support agricultural decision making in the Western Cape and have used it to simulate the effects of water tariff changes on agriculture. It should be possible to model water supply source effects using this model. Eckert et al. (1997) have also compiled an agricultural social accounting matrix for the Western Cape.

In the case of the cost efficiency attribute, comparisons between options could be based on a cost effectiveness analysis that would essentially use the cost per yield of water for each option already calculated in the WCSA.

The information necessary to consider the environmental, social and economic impact attribute could be accessed from impact assessments and feasibility studies.

The flexibility and longevity attribute could be assessed by looking at engineering aspects of options and through systems analysis of how new options would affect the operation of the current water supply infrastructure.

**Stage 5: Determine a weight for each attribute.**

Once again, due to the group nature of the decision, this can be done using the same courses of action as in stage 4 (i.e. each stakeholder group determines its own weights and then negotiates with the other stakeholder groups in order to determine the most preferred option, or the stakeholder groups act as one unified group in determining weights and determining the most preferred option).

**Stage 6: For each alternative, take a weighted average of the values assigned to that alternative.**

This involves a straight forward calculation.

**Stage 7: Make a provisional decision.**

This should be based on a discussion of the scores achieved in stage 6. If each stakeholder group evaluated the options against the attributes on their own, this stage would involve negotiation and consensus seeking among groups. If the evaluation was performed by all of the stakeholder groups together, negotiation and consensus seeking would not be necessary.

### **Stage 8: Perform sensitivity analysis.**

This would involve assessing the effects of changing the scores and weights used on the attributes. Further negotiation and consensus seeking among stakeholder groups may be necessary at this stage depending on whether a clear consensus emerges.

### **Stage 9: Make a final decision.**

At this stage all joint decision makers should be satisfied with the decision reached even if it was not necessarily their first choice.

### **5.2.3 A simulation of the framework**

In order to illustrate the workings of the suggested framework a simulation of its use where each individual stakeholder group evaluates the options against the attributes on their own and then come together to explore compromise solutions to the choice between options is presented here. The chosen decision problem is that of deciding on the next water supply option which would follow the Skuifraam dam and ongoing water demand management. The simulation is based on the authors perceptions of the possible ranking of options from the perspective of one stakeholder group - the DWAF. These perceptions are based on the views expressed by DWAF and reports prepared for the evaluation of the options process followed by the author and outlined in section 1.6. They do not necessarily reflect the views of the DWAF and are for illustrative purposes only.

In a proper application of the framework, the other stakeholder groups would follow the same process as that followed by DWAF (simulated here). After this had been done by all groups consensus seeking would take place between groups in order to reach a final decision.

The list of options, taken from the Task Team evaluation process in section 1.6, from which to choose the next option is as follows:

1. Voëlvlei/Lorelei 1
2. Eerste River diversion
3. Alien vegetation clearance
4. Lourens River diversion
5. Cape Flats aquifer
6. Re-use of sewage effluent
7. Desalination of sea water
8. Skuifraam supplement
9. Michell's Pass
10. Sewage effluent exchange

Using the attributes outlined above the following possible values on an interval scale of 1 to 100 can be assigned to each option.<sup>51</sup>

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<sup>51</sup>Cost effectiveness values are based on the relative costs of the options in ZSA, 1996. Environmental values are based on the predicted environmental impacts of the options in Brown & Ratcliffe, 1996. Social and economic values are based on the predicted socio-economic impacts of the options in Tapscott, 1996. Flexibility and longevity values are based on information relating to these aspects in ZSA, 1996.

**Table 5.2.3.1: Possible attribute values for the water supply options**

<b>Option</b>	<i>Cost effectiveness</i>	<i>Environmental impacts</i>	<i>Social impacts</i>	<i>Economic impacts</i>	<i>Flexibility &amp; longevity</i>
Voëlvei / Lorelei 1	95	20	75	30	0
Eerste River diversion	97	40	50	20	55
Alien vegetation clearance	90	95	100	100	90
Lourens River diversion	90	30	70	40	50
Cape Flats aquifer	88	45	80	25	60
Re-use of sewage effluent	50	80	0	80	80
Desalination of sea water	0	100	90	65	100
Skuifraam supplement	80	50	65	0	40
Michell's Pass	100	0	80	50	70
Sewage effluent exchange	60	80	10	70	80

The following possible swing weights and importance rankings can be assigned to the attributes from DWAF's perspective:

**Table 5.2.3.2: Possible attribute importance rankings and weights**

<b>Attribute</b>	<b>Swing weight of attribute</b>	<b>Importance ranking of attribute</b>	<b>Normalised weights<sup>52</sup> (adding up to 100)</b>
Cost effectiveness	100	1	37
Environmental impact	65	3	24
Social impact	20	4	7
Economic impact	15	5	6
Flexibility & longevity	70	2	26

<sup>52</sup>Rounded off to the nearest whole number.

The weighted average of the values assigned to each option can now be calculated by multiplying the above weights (Table 5.2.3.2) with the above values (Table 5.2.3.1).

**Table 5.2.3.3: Possible weighted averages for the water supply options**

<b>Option</b>	<i>Cost effectiveness</i>	<i>Environmental impacts</i>	<i>Social impacts</i>	<i>Economic impacts</i>	<i>Flexibility &amp; longevity</i>	<i>Total</i>
Voëlvlei / Lorelei 1	3515	480	525	180	0	4700
Eerste River diversion	3589	960	350	120	1430	6446
Alien vegetation clearance	3330	2280	700	600	2340	9250
Lourens River diversion	3330	720	490	240	1300	6080
Cape Flats aquifer	3256	1080	560	150	1560	6606
Re-use of sewage effluent	1850	1920	0	480	2080	6330
Desalination of sea water	0	2400	630	390	2600	6020
Skuifraam supplement	2950	1200	455	0	1040	5645
Michell's Pass	3700	0	560	300	1820	6380
Sewage effluent exchange	1560	1920	70	420	2080	6050

Alien vegetation clearance scores the highest weighted average by far and should be seen as a high priority for the DWAF. It is also likely that environmental groups would support this option as it is to the benefit of indigenous vegetation growth. Community based organisations seeking to increase local employment opportunities should also be supportive of this option. The Cape Flats Aquifer and the Eerste River Diversion have the second and third highest weighted averages. This indicates that the DWAF should favour these two options above the others. The values assigned to each of the options could now be used by the DWAF in seeking consensus with the other stakeholder groups. These groups would use their own weighted averages revealing their preferred options for the same purpose.

#### **5.2.4 Possible constraints**

The framework suggested here would almost certainly face constraints and difficulties in its implementation. This section briefly discusses some of the main constraints to be expected.

##### ***Institutional adaptability***

The suggestions would require a change in current DWAF procedures that may be difficult to accept. The DWAF is used to public participation, but not this form of direct involvement at a high level. The public participation procedure initiated by the DWAF does, however, give an indication that they should be open to suggestions that further enhance the incorporation of public inputs in decision making. Stakeholder participation in the evaluation of the options thus far also tends to indicate that all stakeholders would be willing to continue their participation in decision making under the suggested future framework.

##### ***Political manipulation***

Decisions reached may not suit certain public representatives' political agendas and this may result in attempts to influence decisions. This would, however, not be a constraint unique to MCDA as political manipulation can occur in any decision making process.

##### ***The maintenance of representativeness***

It would be vital to maintain true representativeness in the decision making group and domination by any individual stakeholder group must be guarded against. This could be assisted through monitoring the composition of the stakeholders involved to ensure that representativeness is maintained. Process facilitation would also minimise domination and help to keep the process on track.

##### ***Lack of adequate data.***

It can be particularly difficult to get accurate data on environmental and social effects. Often studies on such effects need to take place over a long time span when adaptations to environmental effects are gradual in nature.

***Lack of a common data base.***

All decision makers need to have access to the same data base. This may not occur if stakeholders withhold information from each other.

***Uncertainty.***

Uncertainty may introduce difficulties particularly in terms of environmental and social impacts. For example, uncertainty remains in the prediction of social impacts on nearby small communities associated with in-migration during dam construction. In cases of uncertainty, it would be vital to explore all information sources and place an emphasis on sensitivity analysis which highlights the effects of uncertainties.

***Inconsistent preferences.***

It sometimes occurs that decision makers reveal inconsistent preferences usually because they do not understand them or have not considered them adequately. Keeney (1992) and Henig & Buchanan (1996) recommend that in this kind of situation, the inconsistent decision maker needs to be (graciously) confronted and helped to develop a better understanding of his or her preferences.

***Uncompromising stakeholders.***

The MCDA process relies on stakeholder parties being willing to compromise which may not always be the case. There may be a need for the application of conflict resolution techniques in this eventuality.

***Inadequate process facilitation.***

Successful MCDA is a human centred process which relies on the proper management of the social interactions among participants through facilitation. If facilitation is inadequate, participants are likely to be dissatisfied with the decision exercise and even the result.

## **CONCLUDING REMARKS**

The decision making framework suggested here was decided on considering lessons from the literature on water supply decision making, the context and characteristics of decision making, the evaluation of the options process used by DWAF and case studies of water supply decision making. It would allow for the consideration of multiple conflicting objectives while directly involving the relevant stakeholders thereby turning them into 'co-decision makers'. Its workings are relatively straightforward making them easy to understand and accept. Although constraints such as inflexible institutions and the possibility of misrepresentation are present, they are not insurmountable.

## **CONCLUSIONS**

The WCSA generated a list of feasible water supply options from which future supply choices can be made. The list is not final making it possible to consider other options such as the use of tradable water rights in future demand management.

Consideration of the assessment of individual supply options is important as an input into decision making between options. The Skuifraam dam feasibility study illustrated the use of the integrated environmental management procedure in assessing a supply augmentation option and highlighted some of the issues commonly encountered in such cases. Water demand management as an option is interesting from an economic perspective because of the potential incentive effects of changing tariffs which can be predicted by looking at price elasticities. It is also an option finding increasing support locally and internationally as available water supplies continue to decline along with tolerance for the negative impacts of dams.

The DWAF decision making process for deciding which supply options to put on a short list for further study included an extensive public participation process which added to the credibility of the process while paving the way for formal joint decision making in the future. As part of the process, an evaluation Task Group consisting of representatives from the DWAF, environmental groups, emerging farmers, irrigation farmers, labour, commerce and industry, the Breede river area, local authorities, rural community based organisations and urban community based organisations was appointed to represent the wider group of stakeholders. This Task Group then used a set of guiding principles and comparative criteria agreed on by all stakeholders to compile a short list.

After reviewing the literature on formal decision making frameworks applied to the problem of choosing between water supply options, it was found that social cost-benefit analysis and multiple criteria decision analysis have been applied most frequently. Both these methods have their own strengths and weaknesses and areas of most appropriate application that need to be considered in choosing where to apply them.

The context of the decision making situation for deciding between future options is one of:

- Rapid socio-economic growth and the lack of an economic development plan.
- Conflicting land uses and diminishing rare natural areas.
- Water laws and tariffs under review aimed at improving the efficiency, equity and sustainability of water use.
- Decision making becoming more democratic, transparent and inclusive of public stakeholders.

The situation is also one of multiple conflicting objectives and stakeholders which is bound to increase in complexity. Given this, the use of a formal decision making framework should lead to improved future decision making.

After reviewing, (1)methodological considerations including the context and characteristics of the decision making situation, (2)the decision making process for deciding between the options carried out thus far as part of the WCSA and (3)case studies on the application of decision making frameworks in deciding between water supply options, it was decided that a framework based on multiple criteria decision making would be most appropriate for future decision making.

The suggested decision making framework would be based on the simple multiple attribute rating technique (SMART) mainly because of its simplicity and ease of understanding. The framework would offer the opportunity to build on and use elements of existing DWAF evaluation procedures by involving similar stakeholder groups and using the evaluative criteria already generated to guide the choice of attributes. It would lead to the direct involvement of stakeholders in formally structured joint decision making.

Finally, some of the possible constraints to the successful application of the suggested framework include:

- The lack of institutional adaptability to a new procedure

- **The maintenance of representativeness among stakeholder groups involved in decision making.**
- **Inadequate data and the lack of a common data base.**
- **Inconsistent preferences and unwillingness to compromise among stakeholders.**
- **Inadequate process facilitation.**

**Hopefully, the suggestions made here will make a contribution to the ongoing improvement of water resource decision making.**

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## **APPENDICES**

### **APPENDIX 1:**

#### **Case study 1: The Skuifraam Dam feasibility study<sup>53</sup>**

##### **1.1 Background**

The Skuifraam Dam was identified in the WCSA as a supply option which showed promise at a preliminary stage from an engineering, financial, ecological and socio-economic standpoint. The DWAF appointed Ninham Shand Engineers in 1995 to complete a full feasibility study as the planning of the project would have to start well in advance due to its size. The summary of this study is outlined below as an illustration of the evaluation process for a single water supply option.

##### **1.2 The process**

In accordance with the integrated environmental management (IEM) process developed by the Department of Environmental Affairs, bio-physical and socio-economic impacts were also considered alongside detailed engineering and financial considerations. A public participation process involving extensive consultation was carried out by Zille, Shandler and Associates as part of the IEM process. The first stage of this process involved identifying the issues that needed to be investigated in consultation with interested and affected parties. Studies were then commissioned to investigate the following issues: social aspects, fluvial geomorphology, economics, tourism, vegetation, archaeology and forestry. Comments were invited on the findings of these studies by mail and in public meetings. Two draft impact assessments were presented after which a final environmental impact assessment (EIA) was compiled for consideration by the Minister of Water Affairs and Forestry just over one year after the process

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<sup>53</sup>This section was sourced from The Skuifraam Dam Feasibility Study: Environmental Impact Assessment Summary Report, NSI, 1996 to which I contributed the Economic Impacts specialist report.

started. The decision to go ahead with the dam was made in September 1997 by the Minister of Water and Forestry. Approval was however contingent on the Cape Town City Council showing a greater degree of commitment to curtailing water demand.

### **1.3 The proposal**

The proposed dam will be built on the Upper Berg River in the La Motte forest, about 5 km west of Franschhoek. The Western half of the dam wall, including the spillway (the lower part of the dam wall which carries overflow water) will be made of concrete, and the rest will be an earth and rock wall. The dam wall will be about 950m long and 55m high the resulting lake having a surface area of 488 hectares. Construction on the dam will take about four years at an approximate cost of R490 million (in 1997 Rands).

The dam will supply about 70 million cubic metres of water per year meeting the growth in water demand in Greater Cape Town for four to five years. This amount will be enough to irrigate 10 000 ha of land or supply water to 640 000 people. The proposed uses of the water are to help farmers irrigate their lands during summer months and augment urban supplies.

### **1.4 The existing situation**

#### ***The dam site***

Most of the land on which the dam will be built is a state-owned pine plantation. The 38 hectare Dew Dale trout and fruit farm makes up the remainder of the land to be inundated. The farm is under private ownership and was recently purchased at a time when the Skuifraam dam proposal was already public knowledge. Apart from Dew Dale farm, no-one lives in the dam basin, nor is it much used for recreation. As the area is under commercial use, there is very little natural vegetation.

## ***The Berg River***

The foothill zone of the Berg River (from upstream of the dam to Paarl) contains some rare and endangered fish and is in relatively good condition making it worth conserving. The river downstream of the dam, however, has been damaged by releases of water from the Theewaterskloof Dam for summer irrigation, by the invasion of exotic vegetation, the planting of pine plantations and the regular bulldozing of its banks.

The middle stretch of the river is degraded and suffers from high levels of nutrients and salts, as well as water loss due to irrigation. The river floodplain/estuary supports a large variety of bird life and is regarded as a site of international importance.

## ***The neighbouring areas***

The Franschhoek Valley is home to some 8000 people. There is a severe housing shortage and approximately 1500 people are unemployed.

The Franschhoek area is famous for its cultural heritage, beauty, restaurants, wine and unique atmosphere. The town is currently visited by between 150 000 and 200 000 tourists per year. Tourism and agriculture are the two most important economic activities.

## **1.5 Significant biophysical and socio-economic impacts**

### **Biophysical impacts**

#### **a) Significant negative biophysical impacts include:**

- Less frequent flooding of the land next to the river is likely to encourage urban and agricultural development in the area. This will increase the amount of damage caused by naturally-occurring large floods (which are not affected by the dam).

- The loss of habitat for river invertebrates due to the flooding of 6 km of the ecologically important foothill area.
- The effect on the river ecosystem of increased sedimentation during construction.
- Potential damage to the natural environment and downstream agricultural and urban areas in the extremely unlikely event that the dam breaks.
- Possible damage to the ecologically important Berg River floodplain and estuary as a result of a reduction in floods. Although this impact is unlikely to occur as dam operation would adhere to the instream flow requirements (an indicator of how much water is needed for the river to function normally) of the river below the dam, if it did occur, the implications would be significant.

**b) Significant positive biophysical impacts include:**

- A decrease in small and moderate floods. This is likely to benefit downstream landowners whose land would be flooded less frequently.

**Socio-economic impacts**

**a) Significant negative socio-economic impacts include:**

- The economic effects on SAFCOL caused by a reduction in wood produced by the La Motte plantation along with the reduction in timber processed at the Wemmershoek sawmill. This may however be mitigated if alternative forest land are given to SAFCOL as compensation
- The loss of about 20 jobs over about 10 years as a result of the reduction in size of the La Motte plantation.
- The possible loss of approximately 25 jobs due to the inundation of Dew Dale farm.
- The possibility of a surplus labour pool forming when the approximately 150 construction jobs come to an end and there are few other employment opportunities in the area.

- Possible social conflict as a result of workers permanently employed by the DWAF receiving housing in an area where there is a great shortage.
- Possible social tensions and increased pressure on employment due to in-migration of unemployed people looking for jobs during the construction of the dam.
- The possible negative consequences on the character and atmosphere of Franschhoek during construction. These include an increase in numbers of people in the area, traffic congestion, noise, safety, crime and pollution. This could affect tourism and the quality of life of Franschhoek residents.

**b) Significant positive socio-economic impacts include:**

- The provision of about 70 million cubic metres of water every year for urban use and agriculture.
- The creation of about 150 temporary jobs for the local community during the construction phase. This will result in a temporary reduction in unemployment and upliftment of the local community.
- Training and skills made available to the local community.
- Accommodation built for managerial, technical and core labour (currently employed by DWAF) may result in the availability of residential land and infrastructure after the construction period.
- A positive effect on the local and regional economy during the construction phase through economic multiplier effects.
- Potential recreation and tourist opportunities associated with the dam.

## **1.6 Discussion**

The environmental impact assessment (EIA) report did not identify any impacts associated with the dam that were significant enough to rule out the building of the dam. This was however subject to the adoption of the mitigatory measures contained in the EIA and the implementation of the suggested environmental management plan. On the whole, the proposed dam will provide

a high yield of water at a relatively low cost in comparison to the other options. This will be achieved with the minimum of environmental damage at the site of the dam as it does not contain natural vegetation.<sup>54</sup> Negative downstream environmental impacts will also be minimal and acceptable under correct management adhering to the recommended instream flow requirements.

The main socio-economic mitigation necessary will be finding alternatives for those that will lose their jobs at Dew Dale farm and in the plantation. The potential social disruption caused by the influx of workers and work seekers will also need to be mitigated against. The DWAF have pledged that they will negotiate with the town council to assist in paying for extra services (sewerage, electricity, clean-up, etc.) that will be necessary during construction.

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<sup>54</sup>It has even been argued (mainly by environmentalists) that the inundation of a pine plantation would not be such a bad thing as plantations are highly water absorbent and contain invasive species.

## **APPENDIX 2:**

### **Case study 2: Water demand management**

#### **2.1 Background**

Water demand management has been assigned a high priority by the DWAF and is the only option which enjoys practically unanimous support among stakeholders. On a world-wide scale, demand management is being viewed as an increasingly important option for water supply management. Winpenny (1994) attributes this to (1) new supplies reaching their physical limits, (2) environmental costs of new schemes becoming less acceptable and (3) increasing financial costs of new supply infrastructure such as dams.

The classical argument against demand management is that it reduces flexibility when droughts occur. If water use has already been significantly reduced, there is generally little room for further reduction without substantial cost to the economy. In the case of Cape Town one could, however, argue that it should be possible to avoid these negative consequences because (1) there is relatively little variation in annual rainfall aiding predictability (2) if need be household use can be dropped dramatically allowing commercially important use to continue (3) in a drastic situation desalination will be possible.

In the context of the WCSA, demand management consists of a set of measures, described below, which can be used to curb water demand.

**Table 2.1.1: Typical long-term water conservation measures (NSI, 1994a)**

<b>STRATEGY TYPE</b>	<b>AREA OF APPLICATION</b>	<b>MEASURES</b>
<b>Economic</b>	<b>Regional</b>	<b>Inclining tariff structure</b> <b>Seasonal rates</b> <b>Excess use surcharge</b> <b>Sewer surcharge</b>
<b>Managerial</b>	<b>Regional</b>	<b>Pre-payment meters</b> <b>Universal metering</b> <b>Meter repair programme</b> <b>Distribution network leak detection and repair programme</b> <b>Limiting distribution pressure</b> <b>system rehabilitation</b>
<b>Technological</b>	<b>Interior residential</b>	<b>Lower flow shower heads</b> <b>Shower flow restrictors</b> <b>Toilet tank displacement bottles</b> <b>Dual flush toilets</b> <b>Lower flow toilet flushes</b> <b>Tap aerators</b> <b>Water efficient appliances</b> <b>Insulate hot water pipes</b>

<b>STRATEGY TYPE</b>	<b>AREA OF APPLICATION</b>	<b>MEASURES</b>
Technological	Landscape irrigation (residential and agricultural)	Efficient landscape design Low water use vegetation Scheduled irrigation Efficient irrigation systems Tensiometers
Technological	New construction	Low-flush/dual flush toilets Low-flow shower heads Insulate hot water pipes Tap aerators Water efficient appliances
Technological	Industrial	Recirculation of cooling water Re-use of process water Re-use of treated waste water Process modification Low water-using fixtures Efficient landscape irrigation
Behavioural	General	Public information - water bill pamphlets - meetings/seminars - media information - in-school - education/competitions - water facility tours Water audits

## **2.2 Economic options for water demand management**

“Managing demand entails taking into account the value of water in relation to its cost of provision, and introducing measures which require consumers to relate their usage more closely to those costs. It entails treating water more like a commodity, as opposed to an automatic public service” (Winpenny, 1994, p. 15). In this section the economic options already identified as part of the WCSA (see NSI, 1994a) will be elaborated on and the tradable water use rights option will be introduced. Following this, the price and income elasticity of demand for water will be discussed as they affect the success of tariff policy in demand management. Estimates of elasticities drawn from the literature will then be used to effect policy inferences

### **2.2.1 Options already identified**

*Inclining tariff structures* are based on increasing water prices linked to increased usage. Under this system tariffs are usually levied on ‘blocks’ of water with successive blocks increasing in price. It is widely recognised in the theoretical literature that inclining tariffs are more effective than flat rates at encouraging conservation (see Briscoe, 1993). NSI (1994a) showed that while most local authorities in Cape Town use inclining rates structures there remained room for their introduction or improvement among the others.

*Seasonal rates* can be used to discourage higher summer usage. These rates could be particularly beneficial in Cape Town with its distinct seasons and highly seasonal rainfall.

*Excess use surcharges* are a variation of the seasonal rate concept whereby base demand is measured in winter according to actual readings and a surcharge applied during summer for consumption in excess of the winter base demand (NSI, 1994a). This measure is particularly effective in targeting summer use for gardening - an area in which substantial reductions are achievable.

*Sewer surcharges* are mentioned in NSI (1994a). It is argued that these measures would indirectly encourage conservation as less consumption would mean less chance of a surcharge being levied. Their focus is however primarily on water quality and not quantity and their advantages relative to charging for water use instead are unclear.

### **2.2.2 Transferable water use rights**

*Transferable or tradable water use rights* are a measure not mentioned in the demand management documentation of the WCSA (NSI, 1994a). A strong case can, however, be made for their consideration and further investigated as part of an economic demand management strategy. Tradable rights have been most appropriate for dealing with direct abstractions as they occur in agriculture and in the allocation of water between local authorities (Mirrilees et al., 1994). They do not have as much scope for application among individual urban users due to the complexity of the system required for their successful implementation. Under a transferable rights system, efficient allocation of water is promoted by the emergence of a market in use rights. The potential for efficiency gains from water markets are well developed in the literature (see for example: Burness & Quirk, 1979 and Rosegrant & Binswanger, 1994). “Water users for whom water has low use-value will have an incentive to use water economically and to sell or lease their rights for spare water. Water users for whom water has high use-value will have an incentive to lease or buy water rights in order to expand their activities” (Mirrilees et al., 1994, p. A.3-1).

The first step in the process of introducing tradable rights is to establish the amount of water available for extraction. Water use rights adding up to this desired level are then allocated to users in a given area/catchment. Allocation can be handled through:

- **Selling/auctioning use rights.** This has a revenue raising effect, but runs the risk of resulting in inequitable allocations.
- **Giving use rights to users based on their current use levels, production levels (in the case of agriculture), historical and potential beneficial use of the water.**

Once use rights are allocated, holders are allowed to trade them freely at market-determined prices creating the incentive for efficient allocation and use. There is thus no need for authorities to calculate and administer tariffs. Rosegrant & Binswanger (1994) identify the following potential advantages of tradable use rights over alternative allocative mechanisms:

- Markets may economise on transactions costs, reducing the information costs of a centralised managing institution, with the market generating the necessary information and market users bearing the information costs.
- Markets in tradable rights induce water users to consider the full opportunity cost of water, including its value in alternative uses, thereby increasing efficiency.
- Tradable water rights provide incentives for irrigators to internalise many of the externalities inherent in irrigation.
- Tradable rights increase the flexibility of resource allocation.

The main caution in the use of these systems is that market failures may occur. Mirrilees et al (1994) point out that monopoly/monopsony situations might occur if there is a dominant buyer or seller as well as externalities due to “public good” or “third party” effects. They suggest that the monopoly/monopsony power situations can be limited if regions in which trading takes place consist of large numbers of users. In regions where this is not feasible, legal and/or institutional measures need to be introduced that will limit inequitable allocations. The OECD (1989) offer three possible solutions to the “public good” effect - (1) the potentially damaged party having recourse to administrative or court action, (2) a water authority being responsible for monitoring and perhaps amending potential transfers, and (3) strict geographical specification of areas within which transfers will be allowed.

Examples in the literature of transferable water use rights have been identified in California, Arizona, Mexico and Chile by Rosegrant & Binswanger (1994) as well as in Colorado, South Australia and Victoria by the OECD (1989).<sup>55</sup>

### 2.2.3 The price elasticity of water

Although not relevant to tradable use rights, the efficacy of water tariffs as a demand management tools is highly dependant on the price elasticity of water defined as:

$$\begin{aligned} \text{Price elasticity} &= \frac{\% \text{ change in quantity demand (water)}}{\% \text{ change in price (water)}} \\ &= \frac{\Delta Q_w}{\Delta P_w} \times \frac{P_w}{Q_w} \end{aligned}$$

Price elasticity can be used as a way of predicting the consumption response that changes in tariffs will most likely induce. Some of the main factors influencing price elasticity outlined by Eberhard (1995) are:

- *Nature of use.* Different uses of water have different price elasticities, discretionary use (for example, gardening) has a much greater price elasticity than non-discretionary use (for example, cooking).
- *Current consumption levels.* Consumers using only a basic amount of water will have much lower price elasticities than consumers using large amounts.
- *Water bill as a proportion of income.* Higher price elasticities for consumers which have a water bills that represent higher proportions of their incomes.

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<sup>55</sup> Active markets in water rights occur on the Orange River which could help inform the Western Cape on the appropriate institutional arrangements needed to make them work.

- *Rainfall and season.* Price elasticities are typically higher in the summer. This is because summer use includes a larger proportion of outdoor water use (discretionary use) which is more elastic thus making overall use more elastic than in the winter.

Unfortunately, price elasticities for water in Cape Town have not been measured. Döckel (1973) estimated elasticities using data from 27 municipalities in the Gauteng area. He found the following elasticities:

- Domestic use in white areas - 0.695,
- Industrial use - 0.623,
- Commercial use - 0.835,
- Combined domestic, industrial and commercial use in white areas - 0.629

There is also a substantial literature of other international estimates which can be instructive. Spies & Barriage (1991), the WCSA report dealing with water demand projections, presented the findings of an American Public Works Association (1981) study which found the median of a wide range of price elasticity data from US studies between 1952 and 1972 to be -0.26 for indoor residential use and -0.40 for outdoor residential use. This information can be expanded on using the more recent literature. Estimates can be divided into *urban* (in some cases separate figures for indoor and outdoor use as well as summer and winter use), *agricultural* and *industrial* use. It must be stressed that the elasticity estimates to be found in the literature were arrived at using different techniques (log linear vs. linear demand curves, regression vs. discrete/continuous choice models) and different types (average prices vs. marginal prices, time series vs. cross-sectional) and amounts of data. The debate on the optimal technique and data usage continues. The following table summarises the price elasticity estimates to be found in the literature.

**Table 2.2.3.1<sup>56</sup>: Urban water use price elasticities**

USE CATEGORY STUDY, YEAR	LOCATION/COMMENTS ON ANALYSIS	AVERAGE PRICE ELASTICITY <sup>57</sup>	USE CATEGORY AVERAGE
<b>Residential water demand</b>			
<b>In-house use</b>			
Thomas et al, 1983	Perth households	-0.04	-0.136
Danielson, 1979		-0.27	
Boland, 1991		-0.1	
City of Perth, 1985		-0.05	
Spies, 1991	American Public Works	-0.26	
<b>Outdoor use</b>			
Thomas et al, 1983	Perth	-0.31	-0.865
Danielson, 1979	Raleigh, NC	-1.38	
Schaefer, 1979	US cities	-0.85	
Boland, 1991	Western US	-0.8	
Spies, 1991	Eastern US American Public Works	-1.45 -0.4	
<b>Summer use</b>			
Grima, 1972	Eastern Canada	-1.07	-0.568
Sewell & Rouche, 1974	Victoria, Canada	0	
Howwe et al, 1967 & 1982	US East <i>using average prices</i>	-0.72	
	US West <i>using marginal prices</i>	-0.48	
<b>Winter use</b>			
Gallagher & Robinson, 1977	Australia	-0.36	-0.458
Grima, 1972	Eastern Canada	-0.74	
Sewell & Rouche, 1974	Victoria, Canada	-0.58	
Howe et al, 1967 & 1982	US Cities	-0.15	

<sup>56</sup> The format of this table is based on the one found in Barrett (1996) with the figures taken from the studies mentioned at the end of the table.

<sup>57</sup> sr = short run, lr = long run.

USE CATEGORY STUDY, YEAR	LOCATION/COMMENTS ON ANALYSIS	AVERAGE PRICE ELASTICITY <sup>58</sup>	USE CATEGORY AVERAGE
<b>Warmer summer climates</b>			
Grunewald et al, 1979	Kentucky, rural	-0.92	
Walters & Young, 1993	Colorado	-0.40 (sr)	
Cochran et al, 1977	Las Vegas	-0.34 (sr)	
Palencia, 1988	Manila	-0.29 (lr)	
Danielson, 1979	Raleigh, NC	-0.27 (lr)	
Martin et al, 1983	Tucson	-0.26 (sr)	
Thomas et al, 1983	Perth	-0.18 (sr)	-0.429
Metro water authority, 1985	Perth	-0.11 (sr)	-0.24 (sr)
Carver, 1980	Washington, DC	-0.10 (sr)	-0.45 (lr)
Moncur, 1987	Honolulu	-0.345	
Billings & Day, 1989	Tucson	-0.27 (sr)	
	Tucson	-0.49 (lr)	
Gallagher et al, 1981	Toowoomba	-0.26 (sr)	
	Toowoomba	-0.75 (lr)	
Nieswiadomy & Molina, 1989 <sup>59</sup>	Denton, Texas	-0.55	
Dandy et al., 1997	Adelaide, Australia	-0.70	
<b>Cooler summer climates</b>			
Sewell & Rouche, 1974	Victoria, Canada	-0.40 (lr)	
Hanke & de Mare, 1982	Malmö, Sweden	-0.14 (lr)	
Braden & Martin, 1993	Illinois	-0.12	-0.18
Laukkanen, 1981	Finland	-0.11 (lr)	
Schneider & Whitlatch, 1991	Columbus, Ohio	-0.262	
Hansen, 1994	Copenhagen	-0.05	

<sup>58</sup>sr = short run, lr = long run.

<sup>59</sup> Hewitt & Hanneman (1995) found an elasticity of -1.6 using discrete/continuous analysis on the same data

USE CATEGORY STUDY, YEAR	LOCATION/COMMENTS ON ANALYSIS	AVERAGE PRICE ELASTICITY <sup>60</sup>	USE CATEGORY AVERAGE
<b>Overall use</b>			
Schaefer, 1979	US cities	-0.3	-0.369
Foster & Beattie, 1979	General urban demand model, US cities	-0.52	
Sawchuck, 1981	US cities	-0.23	
Martin & Wilder, 1992	Columbia, SC <i>using average prices</i>	-0.60	
	Columbia SC <i>using marginal prices</i>	-0.46	
Green, 1992	US cities survey	-0.31	
Nieswiadomy & Cobb, 1993	US water utilities <i>using average prices</i>	-0.54	
	US water utilities <i>using marginal prices</i>	-0.22	
Whitcomb et al, 1993	SW Florida	0	
	SW Florida	-0.51	
<b>Industrial water demand</b>			
Thackery & Archibald, 1981	Severntrent firms	-0.30	-0.431
Jones & Morris, 1986	British Columbia, petrochemicals	-0.12	
	Firms in 81 light industries	-0.54	
Williams & Suh, 1986	Industry using average costs	-0.438	
Herrington, 1982	Industrial consumpt in England and Wales	-0.30	
	Aggregate categories, industry	-0.65	
Boland, 1991	Canadian manufacturing	-0.33	
Renzetti, 1992	Aggregate categories, 7 studies	-0.77	
World Bank, 1995			

Sources: Foster & Beattie (1979), Hanke & de Mare (1982), Jones & Morris (1984), Nieswiadomy & Molina (1989), Schneider & Whitlatch (1991), Spies & Barriage (1991), Renzetti (1992), Hewitt & Hanneman (1995), Eberhard (1995), Mirrilees et al (1994), Barrett (1996), Hansen (1996)

<sup>60</sup>sr = short run, lr = long run.

**Table 2.2.3.2: Irrigation water price elasticities**

<b>AUTHOR/ SEASON</b>	<b>'AVERAGE' ELASTICITY</b>	<b>'LOW-PRICE' ELASTICITY</b>	<b>'HIGH-PRICE' ELASTICITY</b>	<b>AREA STUDIED</b>
Anderson, 1983	-0.65	-0.14	-1.58	San Joaquin, Calif.
	-0.65	-0.19	-0.70	San Joaquin, Calif
	-0.64	-	-	34 Calif. Water dists
	-0.37	-0.17	-0.56	17 US Western states
	-	-0.56	-2.32	California
	-	-0.48	-2.03	California
	-0.97	-	-	California
	-1.50	-	-	California
Finn, 1964				
Seasonal demand	-0.46	-0.09/-0.25	-0.91/-1.73	5 representative farms in the Yanco irrigation area, Australia
Spring only	-0.70	-0.09/-0.26	-1.61	
Summer only	-0.06	-0.01/-0.03	-0.09	
Autumn only	-0.68	-0.09/-0.25	-1.56	

(Source: Mirrilees et al, 1994)

Unfortunately few studies have investigated the effects of income levels on price elasticity. Barrett (1996) refers to the results of a study by Whitcomb et al (1993) which shows that wealthier households have more price elastic demand as follows<sup>61</sup>:

	<b>Low property value (\$50 000)</b>	<b>High property value (\$150 000)</b>
High marginal price (\$6/1000 gallons)	-0.01	-0.09
Low marginal price (\$1/1000 gallons)	-0.55	-0.74

<sup>61</sup> Cairncross & Kinnear (1992) found a price and income elasticity of 0% in impoverished squatter areas in Khartoum, Sudan. The water people used was for basic needs thus rising prices did not cause consumption cuts.

It should be borne in mind that this may not only reflect income levels, but also the effect of high current consumption.

The following trends and lessons identified by Barrett (1996) are present in the data presented above:

- Indoor use reveals a lower average elasticity than outdoor use (-0.136 vs. -0.865). Thus a reduction in outdoor use should be easier to achieve than a reduction in indoor use.
- Summer use has a higher average elasticity than winter use (-0.568 vs. -0.458). This supports the argument for seasonal tariffs.
- Climates with warmer summers reveal higher elasticities than cooler climates (-0.429 vs. -0.18).
- Elasticities measured over a longer period of time tend to be higher than those measured over shorter periods (-0.45 vs. -0.24). Longer adjustment periods are thus necessary for consumers' responses to price changes.<sup>62</sup>
- Wealthier households generally have higher price elasticities

#### 2.2.4 The income elasticity of water

Income elasticity of demand for water is defined as:

$$\text{Income elasticity} = \frac{\% \text{ change in demand (water)}}{\% \text{ change in income}}$$

Income elasticity gives an indication of the changes in demand that can be expected to occur when income levels change. The estimates for income elasticities to be found in the literature (summarised below in Table 2.2.4.1) are all below one which means that as incomes rise, the

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<sup>62</sup> Schneider & Whitlatch (1991) suggest that the time to reach 90% of the long-run response varies from three to eight years

proportion of spending on water in total spending will fall. This implies that poorer people will be impacted more by water price increases as spending on water represents a higher proportion of their total spending. This lends support to the argument for a low “life-line” tariff on water for basic needs.

**Table 2.2.4.1 : Income elasticities for water**

<b>STUDY, YEAR</b>	<b>LOCATION</b>	<b>INCOME ELASTICITY</b>
Palencia, 1988	Metro Manilla	0.54
Martin & Wilder, 1992	Columbia, SC	0.04 - 0.27
Nieswiadomy & Cobb, 1993	USA water utilities	-0.06 - 0.67
Bryant & Tillman, 1988	Hays, Kansas	0.76
Jones & Morris, 1984	Denver, Colorado	0.40 - 0.55
Braden & Martin, 1993	Central Illinois	0.08 - 0.32
Davies, 1995	Adelaide	0.33 - 0.55

Source: Barrett (1996)

### **2.2.5 Discussion**

To illustrate the projected effects on demand of different price changes under different elasticity assumptions, Eberhard (1995) performed a modelling exercise for the Cape Town Metropolitan area. His results show that annual real increases in the average water tariff of between 6% and 11% per annum over 5 years could result in overall water savings of between 8% and 17% (based on average price elasticities of between -0.24 and -0.35). It could also generate tariff income between 18% and 38% higher for the CTWU compared to the situation in which prices remain constant in real terms. Saunders & Singles (1991) suggest that savings of between 5 and 10 % could be achieved for the GCTMA. Preston & Davies (1996) go further and claim that 19% savings could be achieved under more stringent conditions. A pilot water saving scheme in Hermanus which used stringent tariffs was able to cut urban consumption by 20 % (The Argus, 16th August 1997).

**It should be noted, however, that none of these projections or the pilot scheme deal adequately with the risk implications that arise when consumption is reduced substantially. In situations of relative water shortage these can become significant - particularly if consumption is already at a bare minimum due to existing demand management.**

**The variability of price elasticities to be found in the literature lends support to the need for elasticity estimates for water demand in Cape Town. This could be a vital first step in being able to make more confident predictions of what the likely consequences of tariff increases would be on demand. Elasticities could also be estimated for the different water use sectors which would help in formulating sector specific demand management policies. The importance of elasticity data and the potential for the use of economic instrument such as tradable use rights should be fully recognised in deciding on future demand management strategies.**