AN ECONOMETRIC AND INSTITUTIONAL ECONOMIC ANALYSIS OF WATER USE IN THE CROCODILE RIVER CATCHMENT, MPUMALANGA PROVINCE, SOUTH AFRICA

by

R. Bate

R. Tren

L. Mooney

Report to the

WATER RESEARCH COMMISSION

by the

Cambridge Centre for the Study of Institutions

WRC Report No: 855/1/99

ISBN No: 1 86845 555 6

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Summary for Policymakers

This project has dealt with the subject of conflict in water use. It has explained one way that conflict could be reduced and water used more efficiently. The research concentrates on the Crocodile River Catchment in the Mpumalanga Province of South Africa. The primary user of water along the catchment is irrigated agriculture and therefore, this use is analysed in most detail, however, drawing on the work of Olbrich & Hassan ed. (1998), forestry's use is also briefly discussed.

To improve economic efficiency in the allocation of water it is essential to know the economic value that users place upon water. The usual method for achieving this is to base valuation on the unit market price, which is often absent from most water allocation frameworks. However, substantial trading of water use rights has occurred on the Crocodile River Catchment, hence the revealed preferences of many farmers as to the value they attribute to water is manifest. These trades are analysed in detail. It is found that the net present value of trades is approximately three to four fold greater than the price paid in water rates by farmers. It is demonstrated that trading has led to a significant increase in efficiency, with gains from trade being at least R 12m. Given that there has been only a marginal change in use of the water (from one irrigated activity in one part of the catchment to another irrigated activity in another part) it is assumed that there has been no increase in externalities.

Drawing on the figures from Olbrich & Hassan ed. (1998) for the value of water in various uses, gains from these trades are estimated. Given the evidence from other semi-arid regions

where trading has been discussed or enacted (such as Israel and Chile), a brief discussion is made of the possibility of extending the trading to include non-agricultural users. In this way, water conflict in South Africa could be turned into market competition, as it has been in Chile.

The second part of the study draws on the net back analysis of various crops use of water in the catchment. Various prices for water are compared with the estimates of an activity's economic revenue and cost data (i.e. net of subsidies - subsidies were ignored with the exception of intervention pricing for sugar, and water provision, which were assumed to be the greatest subsidies). We deduce whether irrigated crops can pay the full economic price and continue to make a profit.

Under most politically realistic water pricing scenarios, all crops make a profit, although not all crops do equally well. For example, avocados are far more profitable than sugar. Nevertheless, the net back study shows that investment in new water capacity is probably unwarranted, as many crops cannot pay for the full economic cost of water. This conclusion is very tentative as it is highly sensitive to assumed demand elasticities.

Provisional specific conclusions from the research are that water was misallocated (even within farming) on the Crocodile River Catchment, tariff prices would need to be much higher to recover the costs of water provision, water trading can improve allocative efficiency. The results of this research show that avocados and grapefruit are likely to be grown at the expense of other crops, such as sugar in the future if tariffs increase. If policymakers determine that total water use be the basis of water allocation then irrigated agriculture may provide a more profitable alternative use to forestry.

More general conclusions concern institutional structures. Changes proposed in the White Paper on National Water Policy (1997) and the National Water Act (1998) to scrap water rights and replace them with short-term licences will affect trading of water rights. This is because increased uncertainty over water rights and the length of time for which they will be valid will reduce the ability to trade. South Africa could be a major exporter of fruit to the Northern Hemisphere during their winter, however, it probably requires a more efficient use of water to achieve this end. Regardless of the method with which water is allocated in the future the institutions must be capable of quickly reallocating that water at low cost. A water market is probably the most efficient method to achieve this end.

While increasing water tariffs is necessary, it is not a sufficient condition to achieving efficient water use. Trading of water rights will increase efficiency, however removing security over water rights will decrease flexibility and the ability to trade and hence efficiency. Policymakers who contemplate any future changes should bare these points in mind.

ACKNOWLEDGEMENTS

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

Dr GR Backeberg	Water Research Commission (Chairperson)
Mr DJ Marais	Water Research Commission (Committee Secretary)
Mr H Maaren	Water Research Commission
Dr SH High	University of Cape Town
Dr B Olbrich	CSIR
Mr N van Wyk	Department of Water Affairs and Forestry
Dr DW van der Zel	Department of Water Affairs and Forestry
Prof LC Holtzhausen	Crocodile River Main Irrigation Board
Prof MF Viljoen	University of the Free State
Mr C Sellick	Department of Water Affairs and Forestry

The financing of this project by the Water Research Commission and the contributions of the members of the Steering Committee is acknowledged gratefully.

The project was only possible with the co-operation of many individuals and institutions. The authors therefore wish to record their sincere thanks to the following:

Mr Richard Dubourg, Centre for Social and Economic Research on the Global Environment (CSERGE), University College London and University of East Anglia.

Mr Hendrik van Dyk and Mrs Ronel Putter of the Crocodile River Main Irrigation Board, Malelane.

Chapter 1

Introduction

This project addresses the subject of conflicting water uses and will attempt to explain how that conflict could be reduced and/or turned into market competition, with water used more efficiently. The research concentrates on the Crocodile River Catchment in the Mpumalanga Province of South Africa. The study is split into two broad sections, with a conclusion drawing on both these sections.

The first section is an analysis of the existing institutions in the Crocodile River Catchment and the water use rights trading between farmers to analyse whether water is allocated efficiently in the catchment. It also discusses the potential gains from trade and the role that wider trading with other non-agricultural users could play.

The second section is a net back analysis of water use by farmers in several crops. It will demonstrate different scenarios, of water pricing and elasticities of production, and provides a new methodology for policy makers, which could be used to help analyse how to allocate water quotas in the future.

The conclusion will explain whether water is being allocated efficiently in the catchment, how trading could alter this allocation, and whether certain crops are likely to be grown in the future.

Further analytical detail and data are provided in the appendices:

Appendix B explains the theoretical basis of the economic approach.
Appendix C explains the mathematics behind water cost calculations for the net back study.
Appendix D gives data on the trades of water rights.
Appendix E gives the data and calculations for the net back analysis.
Appendix F gives the calculations of the full economic cost of water.

Chapter 2

Water use in the Crocodile River Catchment

Introduction

This chapter provides general information about the Crocodile River Catchment (CRC). It details water resources information, including demand, supply, costs and price information, and the various uses of water in the catchment .

Geographical data

The catchment of the Crocodile River covers an area of about 10,500km^2, and is located roughly 300km east of the city of Johannesburg in the Mpumalanga Province, formerly the Eastern Transvaal.

The Crocodile River is the largest tributary of the Komati River, which it joins shortly before the border with Mozambique. Approximately 20% (the north-eastern portion of the catchment) lies within the southern sector of the Kruger National Park.

The Crocodile River Catchment (CRC) has been divided into five tertiary sub-catchments, the general features of which are given in the following table.

Table 2.1: General physical characteristics of the five sub-catchments of the Crocodile River catchment

(MAP = mean annual precipitation, MAR = mean annual run-off).

Sub-Catchment Name	Area (km^2)	MAP (mm)	Total incoming precipitation in the Catchment (10^6 m^3)	Virgin MAR (10^6 m^3)	No. of Dams
Elands River	1 573	896	1 409	308	3
Upper Crocodile	1 518	825	1 253	226	3
Kaap River	1 640	901	1 477	206	6
Middle Crocodile	2 366	972	2 300	418	5
Lower Crocodile	3 349	650	2 176	105	4
Total # (or average*) for catchment	**10 446 #**	**865***	**8 614 #**	**1 263 #**	**21 #**

Source: Olbrich & Hassan ed. (1998)

The Catchment is characterised by a distinct pattern of warm to hot, wet summers, followed by warm to cool, dry winters. Climatic patterns within the CRC are largely influenced by the topography of the region (the Eastern Transvaal Highveld plateau, the Great Escarpment of the Transvaal Drakensburg range and the lowveld.) The climate varies from wet, humid areas in the northern and southern mountainous areas in the central portion of the Catchment, to hot, dry areas in the relatively flat plains zone in the east of the Catchment. The higher altitude, western portion of the Catchment is relatively dry and cool, and frost is often recorded during the winter months.

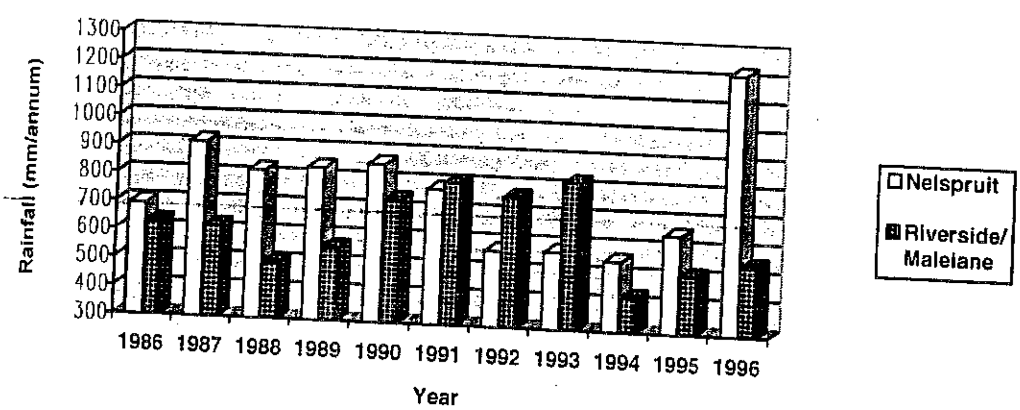
Moving from west to east across the Catchment, the values for both mean annual rainfall and mean monthly rainfall decrease. These changes are accompanied by an increase in mean monthly temperature and maximum annual temperature. These changes indicate the presence of a relatively steep gradient of increasing moisture stress from west to east. Any agricultural crops grown under irrigation along this gradient will require increasing quantities of water, particularly during the drier winter months when the moisture stresses are highest (Olbrich, & Hassan ed., 1998).

The CRC falls within the summer rainfall zone of Southern Africa and around 85% of the annual rainfall is received during the warm to hot summer months of November to March. The remaining 15% of the annual rainfall is received as isolated showers during the cooler winter months of April to October. Mean annual rainfall for the whole Catchment is approximately 880 mm, roughly 70% higher than the mean annual rainfall of 500 mm for South Africa.

Mean annual precipitation (MAP) varies gradually from approximately 500 mm in the lower (eastern) reaches of the Crocodile River, to above 1600 mm in the northern and central regions. Moving east to west, mean annual rainfall increases with altitude until the upper part of the escarpment zone is reached.

Figure 2.1 shows the variations in annual rainfall at the two main towns in the study area. Malelane is in the hotter and more prolific farming part of the Lower Crocodile, and Nelspruit is the largest town and nearer to the middle portion of the Catchment.

Figure 2.1: Annual rainfall, Nelspruit and Malelane, 1986 - 1996



source: Olbrich & Hassan ed. (1998)/ S.A. Meteorological Office

Mean annual temperature varies from about 23°C in the eastern Lowveld, through approximately 20°C in the Middleveld valleys, to about 12°C in the western Highveld areas. "Topography has a major influence on air temperatures in the CRC, resulting in a decrease of approximately 0.5°C for every 100 metres increase in altitude" (Olbrich & Hassan ed., 1998).

Table 2.2 shows selected summary statistics of the summer (January) and winter (July) temperature ranges, plus absolute maximum and minimum temperatures recorded and mean annual rainfall for representative weather stations in the three main topographical regions of the CRC area.

Table 2.2: Summary statistics of summer (January) and winter (July), plus absolute maximum and minimum temperatures recorded and mean annual rainfall for representative weather stations.

Sub-Region Locality and altitude (mamsl)	Temperature (°C)						Mean Annual Rainfall (mm)
	Mean Monthly Temperature		Mean Max.	Mean Min.	Absolute Values		
	Jan.	July	Jan.	July	Max.	Min.	
1. Lowveld							
Komatipoort (146m)	27.2	17.5	33.3	8.7	46.5	-1.9	683.3
Nelspruit (607m)	23.8	14.6	29.6	6.1	41.1	-0.8	734.1
2. Middleveld							
White River (900m)	22.5	13.9	27.8	6.5	39.4	-1.7	882.4
Barberton (880m)	23.3	15.6	28.5	9.3	41.1	1.7	766.6
3. Highveld							
Dullstroom (2,030m)	18.4	7.7	22.9	-2.1	32.8	-10.3	734.5

Source: Olbrich & Hassan ed. (1998)
mamsl: metres above mean sea level

As can be seen, the temperatures in the Lowveld are significantly higher than those in the Middleveld and the Highveld. Due in part to these climatic differences, the types of crops grown and the allocation of water rights in the Lowveld and those in the Middleveld and Highveld vary significantly. This is discussed in greater detail in the following sections.

Water Resources of the Crocodile River Catchment

Several water supply impoundments have been constructed on the Crocodile River and its tributaries. These have primarily been aimed at ensuring adequate water supplies for irrigation agriculture during the dry winter months. Flow gauging weirs constructed on shallow-gradient sections of the Crocodile River also hold back relatively large, still pools which are used as water abstraction points for canals and nearby irrigation. Details of each impoundment are shown in **Table 2.3**. Despite the relatively small extent of their combined surface areas, these dams command a large proportion of the CRC.

Table 2.3: Water impoundment in the Crocodile River catchment

Name of Dam	Catchment Area (km^2)	Surface Area (km^2)	Capacity ($10^6 m^3$)	Located on River
Kwena	947	12.60	161.00	Crocodile
Klipkoppie	78	2.34	12.09	White
Friedenheim	8	0.25	1.57	White
Longmere	104	0.94	4.24	White
Primkop	262	0.41	2.02	White
Spargo	18	0.25	4.44	Buffels Creek
Thankerton	8 625	0.80	0.85	Creek
Witklip	63	1.88	12.30	Sand
Ngodwana	N/A	N/A	N/A	Elands
Total for Catchment	**10303**	**19.47**	**198.51**	

Source: Olbrich & Hassan ed. (1998)

In addition to the dams, there are over 200 small farm dams within the CRC. In 1981, these farm dams were estimated to have a combined total surface area of some 12 to 15km^2 and a combined total volume estimated to be between 4 and 6 million/cubic metres. This area must have increased considerably since 1981, possibly by as much as 50-75%. As most of these dams are not deep, they are quite inefficient due to evaporation, however they do aid security of supply (Olbrich & Hassan ed., 1998)

In addition to the dams that have been constructed in the CRC, a small quantity of water is imported into the Kaap River sub-catchment. This water is brought by tunnel and canal from the Shiyalongubo Dam, which is located in the Komati River catchment to the south east of the town of Barberton. This water is supplied mainly to irrigation farmers and only a small amount reaches any of the tributaries of the Crocodile River.

According to Olbrich & Hassan (ed. 1998) the mean annual run-off varies widely with as much as a five-fold difference from year to year. Current land uses, especially irrigated agriculture and forestry have reduced run-off by at least 20% from that expected under virgin conditions. In 1996, the estimate virgin mean annual run-off for the catchment was 1,226.4 million cubic metres of water (p.14).

Land Uses and Water Requirements

Agriculture and forestry are the primary land uses in the CRC. The steeper slopes (over 15%) and higher rainfall of the escarpment region in the upper part of the river provide suitable conditions for the development of commercial forestry operations but are largely unsuitable for mechanised agriculture. Dryland and irrigation agriculture can only be normally safely practised where slopes average less than 8% along the valley bottoms (Hassan, 1995).

Agriculture

According to the National Department of Water Affairs and Forestry (DWAF, 1995), the Catchment supports some 79,000 hectares of irrigated agricultural crops[1], with a 20% increase in irrigated agriculture from 1987 to 1992. Most of the irrigated agriculture occurs in the Lower Crocodile, with water demand peaking in the summer months of December and January. There have been significant changes in crops grown recently, with declines in crops such as cotton, soya beans and guavas in favour of mainly citrus, macadamia nuts, avocados and bananas for example.

The areas covered by all these crops varies quite rapidly in response to climatic and market conditions. For some crops, however, like avocado and mango, trees can take seven years to reach maturity. Changing crops, therefore, in some cases has some time delay. Most farmers of tree crops, such as mangoes and citrus, do have a replacement policy whereby every year approximately 10% of the trees are replaced. This replacement policy allows farmers to gradually change to a different crop, while maintaining the cash flow of the existing crops. The key crops irrigated were tobacco, sugar cane, bananas, citrus, avocado, and mangoes. Total water use (rainfall - runoff - drainage + irrigation) by irrigated agriculture is approximately 570 million cubic metres of water a year.

Forestry

Forestry comprises the largest intensively managed land use in the Catchment. Very little (0.7%) indigenous forest remains, and only in the areas with the highest precipitation. Plantations covered 177 455 ha, or 17% of the Catchment in 1996, of which most is in the Middle Crocodile (Le Maitre, D.C., Scott, D.F. and Fairbanks, D.H. 1997). Exotic species such as pines and eucalyptus are the most prevalent in the Catchment, and have been planted because they produce up to ten times as much timber per hectare as indigenous and hardwood species. Softwood plantations take up 60% of the afforested area and produce veneer, sawtimber, pulpwood, mining timber, poles and droppers, and matchwood (DWAF, 1998). In 1972, when the afforested area was 144 360 ha (van der Zel, 1977), an Afforestation Permit System (APS) was introduced. Only limited expansion, not in all sub-catchments, was allowed with the last permits being granted in 1990. The reduction in runoff due to afforestation is approximately 207 million m^3 per year (Le Maitre, *et al.* 1997).

Other uses

The water use for domestic, municipal, industrial and mining purposes was calculated in 1987 to total 20 million cubic metres of water a year for the whole Catchment (Strydom *et al*, 1987). This use has increased to 42.3 million cubic metres in 1991 (JIBS, 1995) and is projected to rise to 78 million cubic metres by 2015. Water requirements have increased since the building of a sugar mill near Komatipoort, which has further

---

[1] The Joint Inkomati Basin Survey (JIBS) estimates the actual area irrigated (i.e. not fallow) as 37,780 hectares using applied water for irrigation of 281.9 million cubic metres a year.

encouraged irrigated sugar farming to ensure supply. Livestock and game consume about 2 million m^3 a year (JIBS, 1995); this figure is not expected to change.

The last major census of the area of the CRC was for the year 1991. During 1991, the population of the CRC was about 394,000 persons. It is projected to increase to 706,000 persons by 2015 (Sellick 1997:1). Couple the anticipated increase in population with increasing urbanisation and improving living standards and it is likely that the municipal demand for water will increase substantially over the coming years.

Demographic and Economic Data

The CRC is within the former South African Government's defined regional area F, now largely the province of Mpumalanga. The economy of this area has been growing at a rate of 7% a year for the past twenty years, double that of the next best region. Nelspruit, the municipal centre, is one of the fastest growing towns in South Africa. Most of this growth and contribution to GDP is in the manufacturing and electricity sectors. Agriculture accounts for only 7% of local GDP.

Table 2.4: The sectoral composition of Mpumalanga's economy (1994)

Sector	% of Economy
Mining	32.1
Electricity	22.2
Manufacturing	13.6
Community and Social Services	8.6
Agriculture	7.0
Commerce	6.1
Transport	4.0
Finance	3.4

(Source: Hassan et al 1995)

Tables 2.5 and 2.6 below show the increase in demand for water likely to be required by 2005. According to Olbrich & Hassan, ed. "No matter what scenario of daily water quantities is used, the daily requirements are destined to increase by at least 60% in the next 12 years". (Olbrich & Hassan, ed. 1998)

Table 2.5: Population numbers predicted until 2005.

	Population numbers predicted				
Region	**1980**	**1991**	**1995**	**2000**	**2005**
RSA	24 261 233	30 096 920	42 654 235	47 738 762	53 453 512
Region F	1 592 111	2 078 977	2 309 186	2 642 864	3 006 659
CRC	324 214	423 624	470 533	538 525	612 654

(Source: Hassan et al 1995)

Table 2.6: Predicted domestic water requirement increases of the population in the Crocodile River catchment from 1980 to 2005.

Water usage (litres/person/ day)	1980	1991	1995	2000	2005
10	0.32×10^7	0.42×10^7	0.47×10^7	0.53×10^7	0.67×10^7
20	0.64×10^7	0.84×10^7	0.84×10^7	1.06×10^7	1.2×10^7
50	1.6×10^7	2.1×10^7	2.4×10^7	2.7×10^7	3.1×10^7
80	2.7×10^7	3.4×10^7	3.8×10^7	4.3×10^7	49×10^7
350	11×10^7	15×10^7	16×10^7	19×10^7	21×10^7

(Source: Hassan et al 1995)

Where:

10 litres/day is average for isolated rural communities in southern Africa
20 litres /day is average for squatter camps and informal urban communities
50 litres /day is World Health Organisation minimum standard
80 litres /day is average for formal townships
350 litres /day is average for first world urban towns.

Competition for Water

The two major users of water in the CRC are irrigated agriculture and commercial forestry. Competition is indirect between the two, as forestry occurs in the Upper and Middle Catchment whereas most of the irrigated agriculture occurs in the Lower Catchment. Tree plantations reduce run-off and consequently river flows and water availability for irrigation at the lower parts of the Catchment. Hence a comparison is made of the implied water demands of forestry and irrigation.

It is significant that the water use rates for irrigation (of sugar) begin increasing in July and reach significant levels by September and October, which precedes the rainy season in this area (rain during the winter months is light and infrequent and cannot be usefully absorbed by the plants). In addition, most of the regions' export fruit require intensive irrigation between the months of August and November. This heightens shortages as this is also the time at which the water supply in the rivers is at its lowest. Although there is no direct confrontation between farming and forestry, indirectly a conflict exists at this time of year, to which there is no obvious extant political solution.

Demand for Irrigation Water

Of the 1 215 635 hectares of arable land in Mpumalanga Province, 154 296 ha are under irrigation as crops or orchards. Of that 46 740 ha (Olbrich 1997) of developed irrigated farmland lie within the CRC area. Rainfall, most of which occurs in the summer months, varies greatly along the river, with approximately 500 mm/year along the Lower Crocodile River and up to 1 600 mm/year in the higher mountainous area. With the unreliable amount of rainfall, irrigation is essential for most of the crops grown in the area.

The decision to invest in irrigation equipment is a function of the benefits and costs of irrigating. The benefits come in the form of increased yields, and the costs consist of capital outlays and operations and maintenance costs. The following section explains the significant cost to the farmer of irrigation, but also the insignificant costs to the farmer of water supply. Since most crops increase economic returns with more irrigation, the incentives to use large amounts of water once irrigation equipment has been purchased are significant. Furthermore, water tariffs are often insignificant. A detailed example from Viljoen (1996) will be drawn upon in Chapter 3.

Water Tariff Setting and the Allocation of Water Rights

Water Supply Pricing for the Current Allocation of Water Rights

The Department of Water Affairs and Forestry (DWAF) has legal responsibility for the setting of water tariffs together with the allocation of water rights[2]. Through general taxation DWAF have paid for the construction of most of the major facilities for water containment and distribution, and have explicitly attempted to recover operation and maintenance costs of these facilities from water users.

However, commercial forestry (like most rural users) does not pay any tariffs for the water that it uses, whereas domestic and industrial users pay approximately R1/m^3 of water. The administration for domestic users is undertaken by their local municipality (who pay DWAF 27c/m^3) and the industrial users pay DWAF directly.

In contrast, the administration of water for irrigation along the Crocodile River is undertaken by the Crocodile River Main Irrigation Board (CRMIB) which was set up under government direction and whose secretariat is based in Malelane. This Board is divided into three regions namely the Lower (Onderberg region), Middle (between Crocodile Gorge and Schagen); and Upper (between Schagen and the Kwena dam.) Each region elects two representatives who each sit on the board for a term of three years. The Board is made up exclusively of irrigation farmers, however the recently established Catchment Management Agency (CMA) is open to all water users, such as industrial and municipal users.

Farm enterprises are charged for water on a per hectare basis, with a volumetric water quota dictated by region. The basis of charging was set out by DWAF during the early 1980's after the completion of the Kwena dam in 1984. Land that was in production prior to the building of the Kwena dam is classified as low tariff land while any new land that was brought into production as a direct result of the Kwena dam is classified as high tariff land. Roughly, 60% of irrigation water demand has arisen since the dam was built and is hence high tariff (see **Table 2.7**).

The water charge for each farmer thus comprises the following:

$$\textbf{Charge} = \mathbf{W + A + R + P + vat}$$

where:

[2] Under the 1997 White Paper the pricing and allocation of water is undergoing a fundamental change in South Africa. Water rights may be abolished, to be replaced by non-proprietary licences.

W = water charge, A = Admin. fee, R = Research fee, P = Project fee

For the year beginning 1994, which is the primary year of interest in this study, these charges in South African Rand were:

W = 0.00154/cubic metre - low tariff (pre 1984 rights)
W = 0.0059/cubic metre - high tariff (post 1984 rights)
A = 14/hectare
R = 2.04/hectare
P = 4.00/hectare

There are two different allocations of water rights along the Crocodile River, and the rationale of this difference is discussed in the next section. Along the upper Crocodile the allocation is 8 000 m^3/ha/year and along the Lower Crocodile the allocation is 13 000 m^3/ha /year. Because of the difference in allocation, the high tariff along the Upper Crocodile (R47.23/ha/year) is lower than the high tariff along the Lower Crocodile (R77.24/ha/year). The low tariff of (R12.33/ha/year) is the same between the Upper and Lower Crocodile as is the administration fee of (R14/ha/year), the water research fee of (R2.04/ha/year) and the project research fee of (R4/ha/year). The Middle Crocodile and the Upper Crocodile face the same allocations and tariffs.

Table 2.7: Breakdown of low and high tariff hectares - Crocodile River

River Reach	Total: ha	Low Tariff: ha	High Tariff: ha	Water volume allocated (m^3)
Upper Crocodile	12 644.20	6 429.20	6 215.00	101 153 600
Lower Crocodile	16 136.18	5 508.45	10 627.73	209 770 340
TOTAL	**28 780.38**	**11 937.65**	**16 842.73**	**310 923 940**

source: Crocodile River Main Irrigation Board, 1997

Allocation of Water Rights

As can be seen from **Table 2.7**, approximately 44% of the farming enterprises scheduled (12,644 hectares) are in the Upper Crocodile and 56% (16,136ha) in the Lower. Although 12 644 hectares in the Upper Crocodile are scheduled, approximately half the number of hectares are utilised (pers. comm. Charles Sellick). The unutilised water along this section of the river could be due to a number of factors, such as changing farming practices and land uses. Of the water used by those farms in the Upper Crocodile 51% are at the lower tariff and 49% from the higher tariff, whereas in the Lower Crocodile the majority (66%) is high tariff. This implies that many more farms have either been established, or at least started irrigating, in the Lower Crocodile since the Kwena Dam was built in 1984.

The reason for the difference in quotas is due to the variations in climate, soil conditions and the crops grown, such as sugarcane, which are more water demanding[3]. Section 6.2 of the Water Act 1956 determines the water quotas, and the decisions on water allocation were made by DWAF during the 1960's.

Currently, farming enterprises pay only tariffs for water abstracted from the Crocodile River and not from groundwater sources.[4]

Most of the water used in agriculture in the CRC comes from surface supplies. According to farmers in the Catchment spoken to by the authors, boreholes are rarely used for irrigation. The main reason for this is that normally ground water supplies are insufficient for irrigation farming, although there are some farmers along the Lower Crocodile who do use ground water to a certain extent (pers. comm. Prof. Holtzhausen).

Non-farming users of water

The rights of non-farming users to water has changed since 1997. Before 1997, those villages on farms that bordered the river had preference to water and formal settlements had permits for water use. Since the publication of the White Paper on National Water Policy, a specific provision for basic human needs (25l/capita) and for instream flow requirements (IFR) for the ecological needs of the river was made.

Non-farming users of water have no *de jure* entitlement to water per se. They are entitled to keep any water that falls naturally upon their land, and they have the right to buy water from DWAF at a rate set by DWAF. However, they have no use right, other than riparian land owners 'reasonable use' and even riparian owners cannot trade with another user, without obtaining the necessary court orders.

The Costs of Water Supply

The DWAF, as already mentioned, have the responsibility for tariff setting in South Africa. South African Governments historically have not recovered the full costs of the provision of water to most agricultural users (Backeberg, 1994). Cost recovery is planned for future water provision. The Joint Inkomati Basin Study (JIBS, 1995) details extant and possible future water storage schemes (discussed in Chapter 3). The existing dams on the CRC are the Kwena, Ngodwana, Witklip and Klipkoppie. In addition to these there ~~are smaller farm dams all along the Catchment area, and~~ to account for these the JIBS has included dummy dams on the Upper Crocodile, the White and the Kaap rivers.

---

[3] Although the high tariff amount paid for the water in the lower Crocodile is, in principle, the same as in the upper crocodile (R0.0059/m^3), the average tariff paid for water per hectare is actually less, because the water use per hectare is 62.5% (13 000 vs. 8 000 cubic metres), higher in the lower crocodile, but the fixed charges (research, administration and project fee) are the same. The average price in the upper Crocodile is R0.0084/m3 (67.27/8 000), whereas in the lower it is R0.0075/m^3 (97.27/13 000).

[4] These is currently under review in the 1997 White Paper, see section 3.3.1.1 and has been implemented in the National Water Act (1998) which has now been implemented. One of the reasons this is important is to determine the possibility for farmers to switch to ground water if/when tariffs for surface water use increase significantly.

Table 2.8: Net capacities - existing dams

Dam Name	Capacity – mill. m^3
Upper Crocodile Dummy Dam (1)	3.80
Kwena	155.41
Ngodwana	8.80
White River Dummy Dam(2)	16.37
Witklip	11.93
Upper Kaap Dummy Dam (1)	9.28
Total	**205.59**

source: JIBS, 1995

(1) Tentative estimate based on typical farm dam capacities in other similar irrigation regions in South Africa.

(2) Includes net capacity of 12.21 mill. cubic metres for Klipkoppie Dam

The current system of charging for water provides no incentive for the water user to reduce consumption as charges are based on a per hectare basis. Incentives for reducing water consumption would exist if water use was measured and charges were based on the volume of water consumed. Currently very few meters are installed on irrigation pumps as they are costly to install and maintain. Consumption can however be monitored by the CRMIB by assessing the amount of electricity used by irrigation pumps. The future management of water resources along the CRC will in large part depend upon the ability of regulators to accurately assess the amount of water use by irrigation farmers.

Present Assurance of Water Supply[5]

Table 2.9 gives the annual assurance of supply for the CRC and shows the very high assurances of water supply under existing land uses. These target drafts should not be seen as water allocations, rather as derived water requirements. These assurances have been determined assuming full afforestation conditions.[6] These figures however do not differentiate between different uses for water, nor the fact that there are considerable areas of fallow land, for example along the White River. The data also make no allowance for releases into Mozambique, which would have very significant effects on assurances[7]. In order to allow for the amount of water stored in farm dams and small reservoirs, dummy dams are included for the various rivers.

[5] Assurance of supply is defined as the probability of supply - The average number of years within 100 years during which the full target draft (the volume of water that is aimed to be drawn from a system over a specified period, normally taken as one year.)

[6] This assumption is not unrealistic given the near full afforestation (85% in 1995) that already exists and the somewhat limited scope for further expansion.

[7] The international dispute over the instream flow of the Crocodile River as it enters Mozambique is an increasingly important issue. Any agreement would increase the required instream flow of the river as it leaves South Africa, hence reducing water supply assurance to the farmers.

Table 2.9: Target drafts and annual assurance of water - Crocodile River Catchment

Measurement Node	Target Draft (million m^3/a)	Annual Assurance (%)
Upper Croc. Dummy Dam 2	15.52	100
Schoemanskloof	4.81	100
Elands River	6.91	100
Ngodwana Dam	12.93	100
White River Dummy Dam 7	7.78	100
Crocodile Poort	102.97	100
Upper Kaap Dummy Dam 3	20.84	100
Lower Kaap River	20.99	94
Lower Crocodile Dummy Dam 4	118.08	100
TOTAL TARGET DRAFT	**310.83**	

source: JIBS, 1995

Estimated Costs of Past Water Supply

As dams world-wide are usually funded out of general revenues, and cost information is not often available, it is fortunate that the Chief Engineer at DWAF, Neil van Wyk (pers. comm.) was able to estimate the costs of the construction of the Kwena Dam. Given that this dam provides much of the water in this area it is a good indicator of the tariff that would have needed to be charged in order to recover the capital costs. Van Wyk's estimate of the capital costs of the Kwena Dam (in 1996 figures) was R 420m (electronic mail 26/6/97). Van Wyk's calculation ignored the financing cost of building the dam, which took nearly four years to complete, hence the derived unit cost is an underestimate of true cost.

Depending on the discount rate chosen and the lifetime of the dam, the cost-recovery price of building the Kwena Dam would be markedly different. Van Wyk suggested that the lifetime would be 30 years and that a discount rate of 7.34% (inflation was about 9%, so a nominal rate of 17% was used) would not be inappropriate. Using this rate an annual charge of R 0.463 /cubic metres would have recovered the costs of building the dam, and hence assuring the supply of the water.

The cost for capital recovery is calculated by using a formula for the 'textbook long run incremental cost' (TLRIC) (Bate & Dubourg 1997).

$$TLRIC_t = \frac{R_{t+1} - R_t}{Q_{t+1} - Q_t} + \frac{rI_k}{Q_{k+1} - Q_k}$$

Where R is the operating costs, Q is the water output, I is capital expenditures, t is the year for which the TLRIC is being calculated and k is the year in which the very next investment is expected to take place.

The discount factor *r* is given by the following expression:

$$r = \frac{I_i (1+i)^n}{(1+i)^n - 1}$$

where *I* is the investment cost, *i* is the appropriate interest rate and *n* is the useful life of the investment. In this analysis we have assumed an interest rate of 17%, which on a R1 loan over 30 years gives r = 0.1715.

The second term in the TLRIC relates to the marginal capacity cost and is akin to some contribution to the cost of future capacity expansion. This term produces a charge rate of R0.463/m^3/year assuming that the costs of the Kwena dam are R420m in 1996 prices and that the life of the dam is 30 years. With an interest rate of 15%, (a discount rate of only 5%) the cost recovery price would still be R0.41/m^3.

It is important to note the differences between full economic costing and financial costing. Full economic costing should take into account the financial cost of water supply, the external costs involved in water use and the opportunity cost of water use. Financial costing on the other hand takes into account only the full capital and operational and maintenance costs incurred in water supply. In the net back analysis (chapter 3), different scenarios are tested where these different forms of costing are used.

Cost Recovery

As can be seen from the previous section, the farming community barely pay for the costs of the operation and maintenance of the Kwena Dam (0.7c/m^3).[8] Therefore, their direct contribution to the capital costs of the dam is approximately zero (however on an incremental basis, the indirect contribution through taxes is higher.) The farmers would in fact have to have been paying not far short of 10-fold increase from their current level in order to have recovered the costs of the project.

It is interesting to note that domestic and industrial users pay substantially more for their use of water (at a cost of R1/m^3) than do farmers. The tariff they are paying is more than the capital costs of the Kwena Dam, and as such, costs are partially being recovered from the most heavily charged sector. It is important to note however, that the water supplied to industry and domestic users has been treated and therefore the additional treatment and infrastructure costs have to be recovered.

Since the Kwena Dam was built so that irrigated agriculture could expand, it is, therefore, not equitable to expect other sectors to repay the costs. However, non-farming use tariffs are mentioned to show the enormous discrepancy between pricing and costs, and hence the burden the taxpayer and urban user has paid for projects such as the Kwena Dam.

---

[8] The chief administrator to the CRMIB, Hendrik van Dyk, explained that he was unsure what the real costs were, implying they could be inflated, so he could not rule out the possibility that the farmers were in fact paying more than the operation and maintenance costs.

Industrial users pay R1.50/ m^3 for fully treated water and for half treated water pay R1.00/ m^3 (Nelspruit Municipality)

Table 2.15: Summary of unit prices for urban water users

Monthly use	Tariff (R/ m^3)
0 - 20 m^3	1.22
21 - 30 m^3	1.50
31 - 100 m^3	1.78
100 m^3 +	2.00

source: Nelspruit Municipality

In order to provide adequate potable and industrial water for the town of Nelspruit, the Nelspruit Municipality abstracts water from the Crocodile River and the White River. The Municipality pays 27c/m^3 to the DWAF for water abstracted from the Crocodile River and 54c/m^3 to the White River Conservation Board for water abstracted from the White River. The reason for the significant difference in prices is that a greater number of pumps and infrastructure is needed on the White River as compared to the Crocodile River.

Water that is supplied to the former homeland of KaNgwane is supplied free of charge from DWAF, however this is set to change and in the future DWAF will charge for water supplied to this area. (pers. comm. Frans Fourie, Town Treasurer, Nelspruit Municipality). Of all the water users along the CRC, consumers within the former homeland of KaNgwane face the lowest tariffs, the irrigation farmers pay the next lowest, and the domestic consumers in Nelspruit pay the highest.

The supply of water to KaNgwane was the responsibility of DWAF and no costs were recovered from this water supply. The old KaNgwane area has now been incorporated into the Nelspruit Transitional Local Council (TLC) which is now taking over water the water supply functions. Currently there are very low levels of cost recovery in these areas, such as Kanyamazane and Matsula A&C and a large number of unregistered and unauthorised water connections. Because of this water tends to be used very inefficiently and wastefully in these areas, however the Nelspruit TLC is striving to improve cost recovery and lower the number of unauthorised connections.

The Period for Optimal Increase in New Capacity

It appears that while the current dam building programme is based on the projected use for water in the future, little thought has been given to the tariffing of water and the full economic costs of supplying water, both now and in the future. The charging of water to irrigators that is predicted in Viljoen et al (1997) makes no reference to an explicit charge for water, charges are only based on recouping capital outlays, recouping research costs and covering operation and maintenance costs. It is on this basis of charging that the projected increases in hectares under production are made (to be discussed in Chapter 3).

If, as the White Paper (1997) suggests, sustainability of water use and the charging of full economic costs of water is a priority, consideration of the marginal benefits and marginal costs of new capacity must be considered.

As is explained in greater detail in Appendix C, expenditure on new water capacity results in losses in producer surplus due to excess capacity. This is because funds have been invested in increasing water capacity by a large amount, and water is available, that is not currently demanded. Authorities therefore have excess capacity from which they receive no income. At the same time, there are gains in consumer surplus, because consumers gain by having an increase in water availability, at a lower price (as the supply of water has increased and is now greater than demand.) Economic theory therefore indicates that investment in new water storage capacity should not be undertaken until the losses in producer surplus are matched by the gains in consumer surplus.

A number of new dams are under consideration for the Crocodile River Catchment, however at the time of initial research, investment in the Mountain View Dam was considered to be optimal. It is understood that the Mountain View Dam is no longer considered a suitable project, however for illustrative purposes, we continue to assume that this is the preferred choice for new water storage capacity.

The question arises as to the optimal time period for an increase in water storage capacity. Some economists have argued that the optimal time period for an increase in capacity is when the price of water equals the long term marginal cost of supply. However if one considers the fact that the supply of water cannot be increased by an incremental amount to meet the marginal increase in demand, this assumption is incorrect. Because the investment in dams are "lumpy", investment should only take place when the increase in consumer surplus as a result of the dam outweighs the loss of producer surplus as a result of the increased capacity, for which there is no immediate demand.

It emerges that calculating the optimal time for investment in new capacity is highly sensitive to the price elasticity of demand that is assumed. When a constant (e) of -0.1 is assumed, the optimal time to invest in the large Mountain View Dam is in the year 2012, which is when the gain in consumer surplus equals the loss in interest per incremental draft. At this time due to the capacity constraints the implicit abstraction tariff of water to irrigators is R2 976.12 /Ml/day or R1 086.18/m^3/year.

If the smaller Mountain View dam is chosen with a capital investment of R186 million and a local incremental target draft of 107 million cubic metres/year, the socially optimal time to invest in new capacity is brought forward by one time period. The optimal time paths for the large Mountain View Dam, assuming elasticities of -0.1, -0.3 and -1.0 and for the small Mountain View Dam assuming an elasticity of -0.1 are given in Appendix F.

Using the slightly higher price elasticity of demand of -0.3 results in a slower rise in the implicit abstraction price and lower gains in consumer surplus. Because of this it does not become feasible to construct new capacity during the time horizon used in this report. The same is true to a more marked extent when a price elasticity of demand of -1.0.

For a full discussion of optimal cost-recovery pricing, see Appendix D

Chapter 3

Water Use Rights Trading and Efficiency

Introduction

According to the World Bank (Brehm and Quiroz, 1995) "a private market for water rights could act as a substitute for costly new investments in water infrastructure. In this regard, instituting a market for tradable water rights is seen as a particularly attractive policy option for less developed countries" (p.1).

This chapter analyses water use efficiency in the Crocodile River Catchment. From the previous chapter, it is apparent that farmers have not directly paid the full cost of water in the past in the Crocodile River Catchment. However, even if the Crocodile River farmers (and other users) had paid the full price for the Kwena Dam and hence water storage guarantees, this does not imply that were they to have done so, efficiency would have resulted. Only where users' preferences for water, revealed through the exchange of rights, are available can a reasonably accurate analysis of efficiency result. Since 1994 water has been regularly traded on the Crocodile River Catchment, between certain farmers. This chapter analyses the impact on water uses and prices of those trades.

It should be noted that users other than farmers have no use rights (quotas) and hence cannot trade, therefore the following discussion refers to farmers only. Using data from Olbrich & Hassan ed. (1998) an estimate of gains from trade is made. This also enables a comparison with forestry.

Institutional Change: Why Did Trading Begin?

Small institutional changes can have significant long run consequences, - the changes in water law in Chile in 1981 (Hearne and Easter, 1997), directly caused Chile to have more users receiving adequate supply at efficient prices in comparison to anywhere else in the world. The lessons from Chile are instructive for South Africa's development, since both are semi-arid southern hemisphere relatively wealthy developing countries.

The following analysis will show how a simple change in administration has affected water use in this large geographic area of study.

Up until at least 1993 it was not accepted policy for farmers to trade the water use rights (quotas) to which they were entitled under the Water Act of 1956 (Backeberg 1995). Only with special ministerial approval or a court order could rights be transferred temporarily or permanently between users. Although it was not public policy, some water rights transfers were possible, however, the transaction costs involved in these transfers were very high.

Through Government Notice 966 dated 19 May 1989, the Minister of Water Affairs could delegate decisions allowing temporary quota trades, under certain circumstances[9], as far down the hierarchical chain as the Deputy Chief Engineer: Water Provision (Regions). This however, took four years before it could be implemented, as a DWAF internal memorandum was only published in 1993 and only after this was this policy accepted. Similarly, the Minister allowed permanent trades, under certain conditions, to be approved by the Manager of Water Resources. However, as far as can be determined no delegated decisions were actually made. On March 2nd 1993, a letter from the Director-General of the Department of Water Affairs and Forestry was sent out to all senior officials associated with water allocation in South Africa. The letter addressed a change in policy with regard to the transfer of water rights according to article 63(6) of the Water Act, 1956 (RSA, 1956).

The letter from the Director General of DWAF on 2nd March 1993 was to inform interested parties in the region of the institutional changes which had made trading easier. According to the Secretary to the Crocodile River Main Irrigation Board (CRMIB), and the man in charge of processing trades in the Crocodile region, most people were unaware that trading could legally take place until this letter was circulated[10].

Against a background of water shortage, the letter prompted trade. The Crocodile region was, in 1992-1994, experiencing a severe drought and according to the CRMIB secretary, farmers had already been attempting to ascertain their entitlements in anticipation of a shortfall. Their water quotas could not be fully met and were being proportionally reduced as allowed for in the regulations. The Kwena Dam that normally assures a flow of 7 cubic metres per second, was down to less than one cubic metre per second. Due to reductions in instream flows the farmers themselves were discussing the possibilities of trading rights, as some were not using any of their entitlement, whereas others were unable to irrigate all their crops (Van Dyk, 1997a).

According to the secretary of the CRMIB, (1997a) even before the letter ,"[i]t became evident that the Department of Water Affairs was quite willing to transfer water rights on a permanent basis", but this was not widely understood. The CRMIB advised their members that trades could take place, and started the process for registering such trades with the DWAF[11].

---

[9] The provision of water from one location to another had to be technically viable, with the trading parties being willing to cover the costs for any construction needed to reallocate the water. The buyer had to possess adequate irrigable land on which he would use the water. The local government agency (for example, the CRMIB) had to consider the exchange to be viable, and support the exchange. And finally, there must have been no mortgage from the Land Bank on the sellers property, and if there was the Land Bank was willing to allow the exchange to take place.

[10] The letter stated explicitly that water could be traded only for agricultural activities. There is no record of non-agricultural businesses wishing to participate in the trade (however, since the CRMIB were unaware that they could trade before this letter, it is unlikely that non-agricultural businesses were aware either. Then, as now, they have to buy water from DWAF direct at non-agricultural tariffs.)

[11] It appears that self-reinforcement prompted trade: the farmers wanted to trade; the DWAF realised that water was not allocated efficiently,; the Minister faced pressure from the farmers. There were no obvious losers from the trades (as long as they were limited to the farming sector), so trading began. (It is

The importance of cultural norms

Although the legal rules allowing water exchanges were in place in 1989, and approval for those trades could be granted at the local administrative level, it is instructive to examine why trades did not occur immediately. One has to assume that, as the drought affected all of the farming regions of South Africa, most farmers would have been interested in exchanging water use rights, but most did not.

From our farm surveys, the reasons for this reticence seem to be chiefly that the water right holders believed water to be a fixed asset appurtenant to the land that they owned, and that any exchange of water quotas would have been informal and temporary. Some farmers believed that trades were not true alterations in property relations, but were more like exchanges of short term licenses. Secondly, even if farmers were aware in 1989 that a trade might be approved, they may have been deterred by the time and effort involved in persuading various levels of authority to allow the trade. Finally, trading partners were also hesitant about setting an appropriate price for water due to the absence of a reliable reference price.

North (1990) maintains that the constitution or other legal rules that make up the institutions which enable water allocation, are insufficient without cultural norms - what is and is not acceptable to the people involved in administering and taking part in the trades. The water trading literature is full of examples of the importance of water user associations in co-ordinating water exchange, which link the users (mainly farmers) with the central administrative body (in this case the DWAF). A clear point which arises from the literature is that unless the water using institutions are in favour of trade, it will not happen.

The CRMIB and its Secretary formed a vital role in initiating trade in the CRC. All but two of the farmers interviewed said that the CRMIB informed them about the possibility of trading. The Secretary of the Board also acts as lawyer for the trades and draws up the contracts. Most of the farmers regularly stay in contact with the Board about their needs and state that the Board keeps them informed about possible trades. The administrative and co-ordination work of the CRMIB, as well as its encouragement, seem essential to effective water rights markets.

Trade among farmers

From surveys of farmers in the CRC, the view was expressed that profitable farming would not be possible without irrigation, as precipitation alone is too infrequent and inadequate.

None of the farmers interviewed considered that either groundwater or water stored from private streams or springs was sufficient for irrigation. For this reason farmers who have sold water rights, either because they did not need their full quota or because they have

---

supposed that the bureaucracy, which might have been alarmed at its loss of responsibility in administering quotas, saw a new role in processing trades and did not argue against the move.)

temporarily ceased farming but intend to farm again, have traded on a temporary basis. Those farmers or property owners who have traded permanently have done so because they have ceased farming altogether and have no intention of starting again. Some that sold permanently were unable to use their quota as the nearest accessible water source was too far away and it was impractical to pump the water to where it was needed. Due to poor "grandfathering", a number of farmers were originally allocated more water than they required, and therefore were able to trade any surplus.

Anecdotal evidence suggests that those who did sell water rights permanently looked far less prosperous than those who sold their rights temporarily, most were leaving the farming business.

Reasons for Trading Water

Buyers

Buyers have cited three main reasons for making water trades. By far the most important was to ensure a steady flow of water in times of drought. Indeed, for many farmers, this was the only reason for trading. Secondly, some farmers bought water rights as a combination of insuring against drought and expanding production. A few only bought water rights solely to increase production.

For several of the traders, the proportion of total water used that came from trades was quite high, ranging from as much as 75% to around 50% and 25%. During times of drought one farmer's use of traded water increased to about 50%. Another farmer used no traded water in normal climatic conditions, using trades only for assurance.

Generally, buyers did not buy water rights for one specific crop, but used it equally on all their crops, although bought water quota was used overwhelmingly for sugar cane production. All those buying said that production had increased since they traded water, the main benefits being that in drought, output had not fallen dramatically and fewer citrus trees had been lost. As might be expected, whether or not water trading had been profitable depended in many cases on the general profitability and efficiency of the farm. Although it was certain that costs were reduced by saving trees in drought times, farmers were unable to say specifically whether or not water trades had been profitable.

Sellers

The sellers had, at some time previously, used the water they sold on a variety of crops such as vegetables, citrus and other tropical fruit. However, the majority of sellers had not used the water to which they had rights. One reason for this is because it is not practical for them to pump up the water. This was found along the upper reaches of the Crocodile, where the mountains sides are steep and the river runs far from the arable land, it is therefore expensive to set up pumps and pipes etc. to get the water to the necessary place. Perhaps irrigation had been practised here in the past in better (or more subsidised) times. Another reason given was that, where new crops were under development (e.g. the first years of citrus tree growth), less water was required but that the full quota would be required in the future. Others had stopped farming all together.

Sellers' costs have been reduced through not having to pay the CRMIB taxes and levies and sales revenue has proved to be an additional source of income. For those who have sold permanently, their property values have decreased, but they obviously have the revenue from the sale of water.

Trading Water Rights

According to local farmers, occasional trades of water had occurred before 1993/4 but they were rare , assumed to be illegal and therefore obviously undocumented. Since there was no regular market for water to be traded, and no method for registration of any trades that occurred, no trades are recorded for the year 1993[12]. Trades for the years 1996 and 1997 had not been registered when this research began. Therefore, the analysis that follows is of the trades that occurred, in the 1994/1995 season. The majority of data were collected by the CRMIB, and are analysed here for the first time. Further original data were collected from the farmers themselves.

Trades are either permanent or for a particular period of time, ranging (from the trades analysed) from one year to nine years. All changes in rights are registered at the CRMIB and the DWAF.

Trade data

The characteristics of the trading that took place in the CRC was similar to water trading regimes around the world - especially Chile.

There are only a handful of buyers (four of whom account for 90% of trade volume) but 45 sellers. There are some obvious economic issues associated with markets made up of few buyers which will be discussed later.

There were 23 permanent trades, 46 temporary trades, including one trade that involved temporary and permanent transfers. Half the temporary trades were traded at zero price and most were for just one year. A zero-price trade does not imply zero value, as with the trade went the responsibility for the buyer to pay the water rates, which, as explained above was as much as 0.84 cents/m^3. Several of the zero-priced trades were between the farms owned by the same man or company, but with farms in different parts of the Catchment[13]. All inter-farm trades were at a non-zero price. **Table 3.1** summarises the

[12] However, according to farmers many of them realised that gains could be had from exchange of water rights.

[13] The fact that many initial trades were zero-priced and intra-firm is typical of fledgling resource markets. According to Holden and Thobani (1996) this was the situation in Mexico's fledgling water market. This pattern is also echoed in other environmental markets. The majority of the initial trades in sulphur dioxide permits, under the US Clean Air Act (see Palmisano, 1996) were of this nature. However, once trading became accepted and was encouraged, much inter-firm trading began. In many ways the so-called SO_2 airshed bubble, is similar to intra-catchment water use rights trades.

trade data and gives the average net present values (NPV) of the trades, in other words, the future values of each trade discounted back to a present value.

Table 3.1 Trade data

General Trade Information		Permanent	Temporary
Number of Trades		23	46
Number of zero-priced trades		4	23
Area (ha) traded		563.3	2140.69
Volume of Water Traded (million m^3)		5.36	21.04
Total Value of all contracts (Rand)		529,450	405,309
Average of NPV of trade price (c/m^3)	r = 12%	2.25	3.05
	r = 16%	3.02	1.6
Average of NPV of non-zero trade price (c/m^3)	r = 12%	2.73	6.11
	r = 16%	3.65	5.49

Source: Crocodile River Main Irrigation Board

All of the water trades to date have taken place between farms or properties in the upper region of the river and those along the lower portion. The area along the upper portion of the river has higher rainfall and cooler climate than the Lower Crocodile region, therefore the properties and farms are entitled to a lower quota, (8,000 m^3/hectare/year compared to 13,000 m^3/hectare/year on the lower section) as discussed in Chapter 2.

The farms along the lower section downstream of Crocodile Gorge generally grow more water intensive crops such as citrus and sugarcane. Nuts and other fruit that are less water intensive are grown upstream. In addition the lower land is flatter, encouraging extensive arable farming. All these factors mean that demand for irrigation water on the lower sections of the Crocodile River is higher than demand along the upper sections. Most trades therefore (97% by volume and hectarage) are from a farmer in the upper/middle Crocodile selling to a farmer in the Lower Crocodile, although a few trades in the same part of the river have occurred, nonetheless all are downstream.

The direction of trade (upstream or downstream) is often important ecologically because one of the objections to water trading usually discussed (Preston, 1996), is the problem that in principle, can occur to instream flows. As Anderson and Snyder, (1997) explain "If a farmer downstream sold the rights to a farmer upstream, the users of water (including the ecosystem) in between may be deprived of the water needed (for non-consumptive uses such as power generation, or dilution of industrial effluent) even if the total quantity allocated and used along the river did not change." This potential externality problem is not an issue in this case as all trades are downstream. However, were future trades made upstream, analysis of instream flow requirements would have to be made[14].

[14] JIBS (1991) has calculated instream requirements for the Crocodile River, however, there is an international dispute between South Africa and Mozambique as to the latter's water requirements. The Crocodile River reaches the sea at the port of Maputo, the capital of Mozambique. If international agreement is reached the amount of water required by Mozambique, for instream flows will probably be higher than the existing level, reducing the quantity of South African quotas.

Who traded?

As explained above, several of the farms involved in trades are extremely large entities[15]. Farms such as the various Tenbosch estates are involved in many trades as the largest buyer. Unlike a mature market for other homogenous products (such as gold or oil), where price information about the good is detailed, ubiquitous and prices are rarely volatile, there is a wide range of trade prices for water, from zero to 6cents/m^3, with a modal value of about 2.5 cents /m^3. There is almost certainly an asymmetry of information between a buyer like Tenbosch and some of the smaller farms (with Tenbosch paying significantly different prices for water from different sellers).

Table 3.2: Low Tariff Trades[16]

	Permanent	Temporary
Area Traded (hectares)	191.8	272.27
Volume of Water Traded (million cubic metres)	1.78	2.17

Source: Crocodile River Main Irrigation Board

Although 40% of all quotas on the CRC are low tariff (i.e. existing quotas in 1984), as a percentage of total trades they make up a much smaller fraction (15%). The farmers themselves put forward several reasons for this, all of which seem plausible. Farmers who have been in the Catchment for a long time are probably more adept at knowing what their water requirements will be and hence will have adequate water supplies and not need to trade. However, it is also plausible that they are less flexible and or less willing to part with their rights given political uncertainty. One point was ventured by several farmers as to why newer farmers traded. Financial difficulties (due to droughts and the political changes) of many sellers and larger expansion by a few relatively successful farm companies meant that the market was volatile, encouraging trading between new farmers, those who were unsuccessful and had to close and the more successful ones who needed water to expand their enterprises.

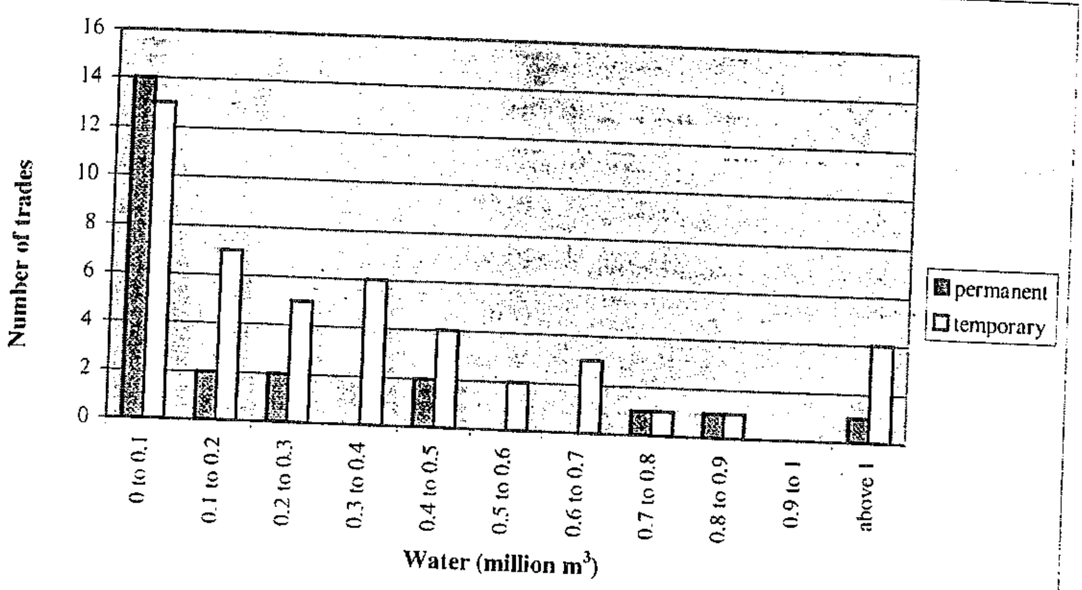
How much was traded?

About 8% of the total amount of water available for farming was traded, roughly representing just under 10% of the total scheduled agricultural area in the Crocodile River Catchment. As can be seen from the following charts, the majority (over 90%) of water trades were for less than one million cubic metres of water, (there was one major temporary trade for nearly six million cubic metres, not shown).

[15] The Secretary of the CRMIB was largely responsible for instigating the trading of water rights and acted on behalf of the seller and the buyer of the water rights. It is not however accepted legal practice for one party to act on behalf of both seller and buyer because, among other concerns, of asymmetry of information. Under these conditions, it is less likely that a full market price for the water rights would be reached.

[16] It is worth noting that three of the temporary and two of the permanent trades had some low tariff component, which was not defined in the contract information available and for the sake of the analysis was assumed to be zero. These part low tariff trades raises the amount of low tariff trade volume, but the figures in the attached table would have only been slightly larger given the size of the trades in question.

Figure 3.1: Volumes of water traded – 1994 and 1995. Permanent and Temporary Transfers



What price did they pay?

The prices paid for water rights ranged quite widely with the prices paid for permanent trades being less variable than for temporary trades. [17] The net present value (NPV) of the revenue raised from trades was equivalent to approximately 50% of the total amount paid to the CRMIB in water rates in any year.

As shown in **Table 3.1** the NPV of the permanent and temporary trades were 2.25 and 3.05 c/m^3 respectively, with a nominal discount rate of 12%. And 3.02 and 1.6 c/m^3 respectively, with a more appropriate nominal rate of discount of 16%. The temporary trade NPVs were lower, with the greater discount rate, as payments made in future years will be of less value in present times.

Efficiency and the price mechanism

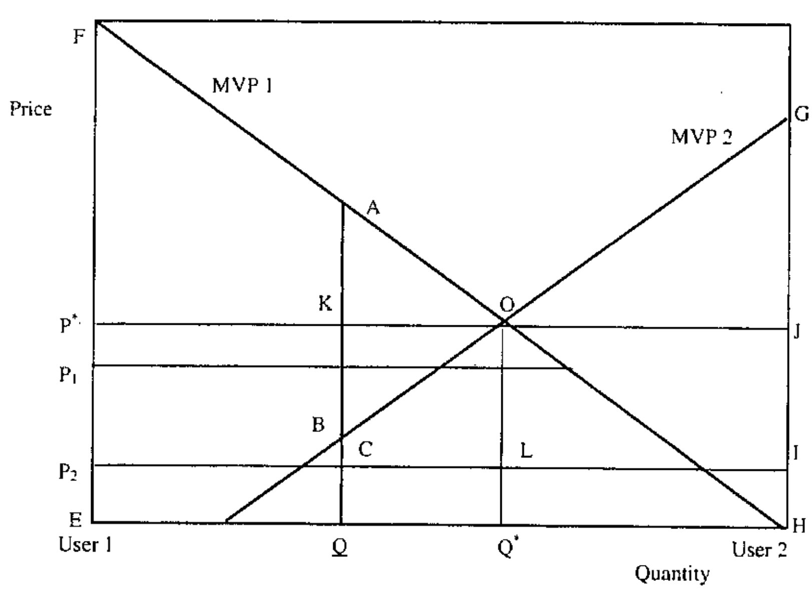
The role of prices in any economic system, including the water sector, should bring about several conditions that guarantee efficiency of production and consumption. At any given efficient price there will be water withdrawals, such that the marginal cost is less than or equal to price. Only users for whom the value of water is greater than or equal to price will then consume this amount of water. Finally, an equilibrium condition is required. That is, the price at which the quantity demanded is equal to the quantity

[17] It would be interesting to follow up this data analysis with a time series study to see whether prices converge to one market going rate for water, as information about the market spreads; whether the local circumstances surrounding each sale makes the rate variable, and the impact of escalating water rates on trade prices.

supplied. These conditions are efficient in the sense that they maximise the social value of water.

To illustrate this suppose that due to a failure of the price system to equate demand to supply, water is allocated by historical quotas. In the figure below there are two individual Marginal Value Product (MVP) curves - representing the value produced from one additional unit (cubic metre) of water to two users, 1 and 2. Suppose that over the long run it is impossible to use more water than is presently available (an assumption that is rapidly becoming plausible in many semi-arid regions), but that quotas cannot be transferred. It is well known that optimality is achieved when both MVPs are equal that is, at (Q*, P*). The initial allocation is, however, at Q. That is, user 1 receives Q and user 2 receives the rest (H-Q). This initial allocation is not optimal, of course, as it fails the MVP equality condition. User 1 uses less water than optimal. The dead weight loss is given by the triangle OAB. The efficient water price would be P* with an open market for the quotas. If the administered price should be set at P_1 there will be an excess demand for individual 1, while if the price is set lower at P_2, there will be an excess demand for both individuals[18].

Figure 3.2: Two individual MVP curves when water quotas cannot be transferred.



Empirical Example

The above theoretical discussion can be applied to water allocation in South Africa and specifically to the trade data in the Crocodile River Catchment, as explained earlier. Let user 1 represent the buyers of water (those in the Lower Crocodile) and let user 2 be the sellers of water (those in the Upper Crocodile) in the Catchment. Given that trading will lead to equilibrium of the marginal value products we can further assume that it is

[18] This analysis can be extended beyond the individual and be applied to industries or regions. So that users 1 and 2 could refer to the agricultural sector and the mining sector, or indeed groups of farmers, user 1 representing the Lower Crocodile users and user 2 representing the Upper Crocodile users.

reasonable to use the mean (weighted by temporary and permanent trades) trade price of 2.07 c/cubic metres as the optimal price P*. We could designate the price paid in CRMIB water rates as either P_1 or P_2, however, let us assume P_2, as the water rates (about 0.7 c/cubic metres) is a considerably lower price than the aggregate trade price - as reflected in the diagram. Prior to the institutional change which allowed trading, dead weight losses, such as the area OAB, would have occurred, whereas now that trading has been allowed that dead weight loss is eliminated. Of course, the size of the dead-weight loss can only be determined by the marginal value that water contributes to the production process, which is discussed later. However, there is no doubt, assuming no increase in external effects like pollution, that there has been an increase in efficiency from these trades.

External Effects?

If all water sold in trades was being used prior to the trade then there will be only minor changes in use of that water after trading and probably no increase in externality, as there will be no reduction in instream flows. However, anecdotal evidence shows, much of the water sold was not being used prior to trading. Hence trade may result in a reduction in flow for dilution of industrial, sewage and farming effluent. An increased use of 12 million cubic metres of water may have arisen from trades. However, several farmers only sought extra water as an assurance against drought, so not all supplies will have been used. Our evidence is that an additional 8 million cubic metres was used. Since measurement of the cost of negative externalities has not been undertaken to any significant degree in the Catchment, it will be assumed in the following analysis that external effects are negligible. This is a considerable assumption and one that further research should investigate.

Why was there institutional inertia?

South Africa gradually moved from a situation where water rights were centrally administrated and planned, to one where administration was devolved to a provincial level and then finally decentralised completely to a local level. Institutional inertia could therefore have emanated from central authorities that are, in general, slower to initiate change or promote innovation.

Given the benefits of trading, it is worth considering why it had not occurred before. Following Becker (1995), it could be argued that if the price set by the South African DWAF for water rates implemented by CRMIB had been equal to P*, that the efficiency condition could be met, as equilibrium is reached when the MVPs for each farmer or group of farmers are equated in both regions. Hence pricing at P* would undoubtedly lead to a statically efficient outcome. Of course, with the bounded knowledge of the administrator, they are unlikely to know what an efficient outcome would be over time, even if the assumption is made that P* was the known static equilibrium price, whereas the benefits of the market (with its dispersed inherent knowledge) obviously provide more flexibility in use and pricing as preferences change over time.

Consider that when 'user 1' is an aggregate, such as the farmer groups in the Lower Crocodile, this analysis no longer holds. The problem lies with the fact that a cost-benefit analysis would reveal that at least some of the users have become worse off by moving from P_2 to P* . The net benefit for farmer group 1 (total value of the water, less payment for that water) when it uses Q at the price of P_2 is given by $FACP_2$, while the net benefit when it uses Q* at the real price of P* is given by FOP*. For group 2, the net benefit is altered from GBCI before the price change, to a net benefit of OGJ, after the water price is raised to P*.

It then becomes obvious that while group 2 is worse off, the change in the situation of group 1 is uncertain without an empirical investigation. All in all, the situation of the two users is worse off by comparing net total benefit before the change (FACP2+GBCI) to the net benefit after the change (FOGJP*). Therefore, while there is an undoubted improvement in efficiency from the higher priced water (P*), the farmers themselves, as a group, are worse off. This economic analysis explains a key reason why farmers the world over have consistently demanded subsidised and low priced water, and hence the opposition of the farming community to increased water tariffs. In the absence of markets, rent seeking is likely to occur in the political arena. This rent seeking analysis is further explored in Appendix B.

It can be argued that the first approach, of quota price increases to P*, worsened the farmers' situation because there is a shift of revenues from the agricultural sector into the national budget. However, if the extra revenues raised by the relevant authority were to be distributed back to the farmers as a transfer payment, then the results of the two approaches (market and administered) would be similar. However, making transfers is fraught with problems in reality (in terms of bureaucratic inefficiencies, including distributional costs and rent seeking[19]) and here lies another advantage of the markets. There is no need for the government to enter the market once it operates. All it has to do is decide the initial allocation of rights.

Market pricing is part of a feedback mechanism that informs traders about the relative value of water in their location. But of course, price information is not only available to traders but to government officials as well (as in South Africa, where all trades are lodged with the DWAF and CRMIB). It is possible that farmers had not previously supported trading (or at least the centralised holding of price exchange information) because this might signal a tolerance for water price rises. On the other hand government-sponsored, tax-funded water provision (dams etc.) would leave them better off as a group, even though this ensured very low efficiency.

Nevertheless, as explained above, under drought conditions and with water quotas scaled down, a critical mass of farmers wanted to trade. Of course, water trading did increase the price paid for water but these were offset by avoiding the loss of citrus trees, and by irrigated crops producing higher yields than expected. Numerous authors

---

[19] Political solutions of this type are prevalent in agriculture the world over. A policy of compensation for not using the water may be found cheaper than subsidising the water. However, ideological considerations and other social reasons may prevent such a transfer. Also, the massive inefficiencies of this system employed in the European Common Agricultural Policy and elsewhere, should act as a warning to choosing this path (Pennington, 1997).

have discussed the benefits of trading (see Vaux and Howitt, 1984; Saliba and Bush, 1987; Randall, 1981; Anderson, 1983 etc.).

Worldwide systems of centralised water allocation have created economic inefficiencies that have been documented by economists elsewhere (Anderson 1983, Becker, 1995, etc.). As discussed, the former rigidity in the quota allocation in South Africa, which prevented water from being sold or bought at a given market price caused some farmers to use more water than they would have required, while others who would have been willing to buy the water were not able to do so. As Becker explains from his analysis of a similar water allocation system in Israel, "the consequence of this policy is demand for water that is not based on price signals but rather on the domestic political situation of the different sectors, which of course does not have anything to do with efficiency at all" (Becker, 1995: 13).

If we look back at the figure, we can see what will happen to our two water users who decide to trade. The first pays an extra KOQ*Q for the water, but receives the larger amount of AOQ*Q in increased revenue. Therefore, their situation has been improved by area KOA. User 2 has sold (Q*- Q) units of water at the equilibrium price of P* and received KOQ*Q in exchange. BOQ*Q is what he would have gained from using that water to irrigate his crops. KOB is their gain from the trade. Both users, therefore, have an interest in entering the market because they both gain by doing so. Using this type of analysis at the regional level Becker (1995: 20) estimates that allowing trades of water between agricultural users in Israel, a country often thought to have sound water management, would bring efficiency gains of US $64m.

Furthermore, the alteration of institutions in the Israeli water sector was calculated to be cheaper than investment in 'hardware' components of the water system, such as developing new water resources, water importing, or water desalinisation (Becker, 1995). It is possible that a situation similar to this exists in South Africa.

Gains from Trade

As demonstrated diagrammatically above there was an increase in efficiency from the water trading in the Crocodile River Catchment. However, the value of that efficiency improvement can only be calculated by knowing water use values. The marginal value of water is not identifiable for each trade, nor in aggregate, however, an estimated value of water in various uses can be estimated from calculations made by Hassan et al (1995), and Olbrich & Hassan ed. (1998) for the Crocodile River Catchment.

Both Hassan et al (1995) and Olbrich & Hassan ed. (1998) tacitly assume that farmers have little control over the prices they can charge for their produce, as many prices will be subject to international competition. For sugar there is still price intervention by the South African Sugar Association. In this instance the price is determined by political negotiation, which the farmers may be able to influence. This price-taking assumption means that gains from trade in water rights can be more easily estimated, as crop prices are assumed to be fixed.

Hassan et al (1995) analysed the Nkomazi district, which accounts for a significant amount of all economic activity in the Catchment, whereas in 1997 (Olbrich & Hassan ed. 1998) estimated economic values of water for the whole of the Catchment. The figures are not dissimilar and, as they are more representative of the farming interests analysed in the earlier discussion, the figures in Olbrich & Hassan's 1998 studies are used in calculating any efficiency gains from trade in water. A discount rate of 20% is used in his calculation which is similar to the 16% rate used in our analysis.

Table 3.3 provides annualised net returns in Rand per cubic metre of water for plantations and irrigated crops in the Catchment. The first column shows the average productive value of water, the second shows best performance value of water to each use. For example, best performance will be at a high rainfall level (>1000 mm) for eucalyptus and a low rainfall (400-600 mm), warmer location, lower in the Catchment for sugar cane. Comparisons are made difficult since water use calculations for plantations is total whereas for irrigated crops is applied (i.e. irrigation water only). It is important to note that these figures were obtained during research trials and that different data sets were used. Because of this, some inconsistencies may appear, such as the low value given to avocados in the best practice (1994 prices) column.

Nevertheless, there is no doubt that pine and eucalyptus trees grown in the upper part of the Catchment fair reasonably well with sugar cane grown in the Lower Catchment. The remaining crops provide excellent returns at average and best yields.

Table 3.3 Average value of water in various uses.

Crop	Value of water for various crops per m^3 in Rand	
	Average practice (1994 prices)	**Research trial data for the best practice (1994 prices)**
Eucalyptus	0.16	0.31
Pinus elliottii	0.2	0.21
Pinus patula	0.2	0.22
Sugar cane	0.62	0.66
Orange	3.39	4.1
Grapefruit	4.16	6.8
Mango	7.15	11.7
Banana	2.7	3.49
Avocado	3.1	1.77

Source: Olbrich & Hassan ed. 1998.

Aggregate values of water

Of course to be able to calculate gains from the traded water, we would have to know exactly which crops were grown by the sellers (if any) and which crops are now grown by the buyers, and the exact profitability of each crop to each farmer. This information is not available, as the CRMIB did not collect it when they collected the trade data[20].

[20] To follow up their original survey would have been difficult in many cases, as the farmers are now out of business, extremely expensive, and it is uncertain whether the individual farmers would have divulged the financial information required.

Several farmers who bought water in trades indicated that of the irrigated crops they were producing, they were producing proportionally more mangoes and bananas than the average farmer (as **table 3.3** shows above these crops have the highest values from applied water). However, from our survey it appears that sugar cane (and some citrus) was overwhelmingly the crop grown with the traded water. Our estimate is that 80% of water that was used was scheduled for sugar cane, 10% for grapefruit and 10% for valencias.

Table 3.3 suggests that agriculture is a far more efficient water user than agriculture. The table shows that of all the crops examined, forestry has consistently the lowest value of water per m^3. The highest values are found in tropical fruits, such as mangoes, citrus and avocados. Of the agricultural crops, sugar cane, which is a large consumer of water along the Lower Crocodile, exhibits the lowest value of water.

If we assume that the buyers were above average farmers, requiring more water as they wanted to expand their scheduled land, it makes sense using the best practice figures from **table 3.3** in calculating gains from trade. The aggregate value of the water used after trading would then be calculated by multiplying the percentage of water used for each crop by the best practice values. This value would then be multiplied by 8 million cubic metres of water, the amount of water we estimate was additionally used after trading.

Sum of (Percentage of each crop * best practice price for that crop) * 8 million cubic metres of water

= (80% of sugar cane (0.659) + 10% of valencias (4.1) + 10% of grapefruit (6.8)) 8m
= (0.51+0.41+0.68) 8m
=1.6*8m
=R12.8m

The additional water used after trading is estimated to be worth R 12.8m.

Since all farmers who bought water were probably more efficient than the sellers, the value of trading is likely to be higher than this figure as the water used before trading will probably be used more efficiently afterwards. However, we cannot calculate this improvement as there are no details of what the sellers were growing before.

Even assuming that the gains estimated above are correct, this does not mean that an efficient allocation of resources has been achieved. For example, the value of the water used in irrigating the most prevalent crop, sugar cane, is not a great deal more than the (total) cost of provision of that water. Nevertheless, assuming no increase in externalities, an efficiency improvement has been made.

According to Olbrich & Hassan ed. (1998) eucalyptus forestry has a strong competitive advantage in using water resources in the high rainfall zone, but that at all other zones irrigated agriculture provides greater returns per cubic metre of water consumed.

Olbrich's & Hassan's own analysis leads him to conclude that "The opportunity costs (net returns foregone) per unit of water reduction runoff caused by forest plantations can be as high as R 10.9 net terminal value (NTV)[21] achieved with mangoes under current average practice (at 4% social discount rate)...If one considers only 50% of the returns realised with irrigation agriculture to be profits (after accounting for land rents) this suggests that the economic value of water (per cubic metre) in the Crocodile River Catchment was about 5.05R/m3 in 1994 (e.g. residual returns to water." (1998, p.67). It must be noted that these figures are likely to be overestimates of the actual situation as Olbrich & Hassan use gross margins in calculating the returns to irrigated agriculture.

Using Olbrich's figures, the value of water traded in the CRC is about R130m (26m*5.05). Of the R26m, R18m is estimated to be water that was in use before, therefore the gains from trade are likely to be below that stated here. It is however impossible to make the calculation more accurately without more information on the crops on which the traded water was used. These figures ignore potential uses other than forestry and agriculture.

Olbrich goes on to stress that his analysis does not allow for indirect employment effects (food preparation industry being reliant on agriculture and mining requiring timber etc.) or indeed for any externalities associated with the two key options. For example, on balance irrigated agriculture causes more environmental problems than does plantation forestry (see table and discussion in the next section on inter-industry trades).

Institutional Improvements to Increase Efficiency

Some institutional changes could make water use even more efficient. Firstly, there is the possibility of trading water rights between industries. Secondly, there is the possibility of trading between rivers in the Inkomati Basin. There is also the possibility of strengthening the roles of the organisations involved in trades.

Inter-Industry trades?

There has been tacit or indirect trade in water between industries for decades. Mining companies, such as De Beers, have bought farms for their water rights. For example, De Beers diamond mine at Messina in the Northern Province bought a farm at Schroda nearby. This farm used 3million m^3 per annum. This irrigation stopped after the purchase and the water was hence used in the mine. It now accounts for 75% of the water demand for the mine (ETG, 1995, p. 88).

The water fee to farmers on this water was only R1,800 ($0.1c/m^3$). The value of the crops produced was a maximum of R2.9m per annum. The value of the water in the mine was over R20m with increased employment (p.123). The water was hence put to an economically more productive use. Nevertheless, it would have made more sense for De Beers to have bought the water and not the farm if they had been allowed, this would have been cheaper and may have enabled the farmer to grow dryland crops.

[21] Net Terminal Value measures the present worth at the end of a crop cycle, of the stream of net benefits generated in previous years Olbrich & Hassan ed. (1998).

The following table shows the economic returns, the profitability of water use in other sectors.

Table 3.4: Inter-user profitability

	Average profitability of enterprise per unit of water (Rand/m^3)	Price paid for water (Rand/m^3)	Level and spread of pollution
Forestry	0.104	0	low - wide
Irrigated agriculture	0.358	0.007	high - wide
Mining	19.28	0.69	v. high - point
Industry	10.73	1.1 - 1.66	v. high - point
Domestic urban		1.5	med. - point

Source: Hassan et al. (1995)

Pollution caused by forestry is likely to be of a low level and spread over a wide area while pollution from the mining or industrial sectors could be of a very high level and restricted to a particular area (point source). These externalities will have varying economic and social effects depending on their level and spread.

Calculations by Hassan et al (1995), show how profitable mining and industry are compared with forestry and agriculture per unit of water used. Calculations of the costs of pollution and other environmental degradation of the various activities have not been made yet in this region. These calculations would probably show that mining and industry were in fact, less profitable when all the social costs were calculated.

Restricting inter-industry trades is the norm internationally. However, some countries, such as Chile, Mexico and Australia have allowed such trades.

International examples

Lessons from Chile (Hearne and Easter, 1997) show that enormous (tens of millions of dollars) gains from trading occurred when trades were made between farmers (mainly sellers) and municipalities (mainly buyers) and industries (mainly buyers). If trades were allowed between sectors in the Crocodile River Catchment then efficiency gains could be considerable. The price paid in the CRC for water by industry and urban domestic users ranged from about 30 to 60-fold greater than the farmers' trade price, and 100 to 150-fold higher than the farmers water rates. There is, therefore, considerable scope for inter-industry trades as the price discrepancy is significant. For Chile, the municipalities purchased over a third of the water sold by farmers. Similarly, as was shown in Chapter 2, Nelspruit is one of the fastest growing towns in South Africa, and as its water demand is set to increase, it would probably be a significant purchaser of water rights. The sugar mill at Komartipoort would also be a substantial buyer. There are however, likely to be institutional problems with such transfers. At the moment water use by farmers is estimated by the pumps that transfer the water from the river or canals onto the land. There is no metering of quota limits as such, just general assumptions about rates of pumpage, and critically, self-monitoring and enforcement of each other's water use by the farmers themselves. If water was transferred to a municipality, the users in the town could not (easily) monitor the use of water by farmers (the use of water meters for agricultural consumption has so far been rejected, party due to cost.) And the incentives of the farmers would be to sell water to the towns and then continue to use water to irrigate their crops. Nevertheless a condition of expansion of the market could be that metering of irrigation water would be mandatory. Even so, monitoring and enforcement are major problems for any expansion of trade.

Transfers of water to other sectors and within the farming community might also negate the alleged (van Dyk, 1998) need to build new dams and further water provision. This was certainly the case in Chile. The proposed Puclaro Dam project, on the Elqui River upstream of La Serena is "an example of how the presence of a market alternative to water allocation may reduce political pressure to invest in large water-storage projects. The project has been proposed in different forms since 1956. As recently as 1989, potable water was considered to be the most important benefit of the dam. But when ESSCO [the water supply company] did not agree to collaborate with the Directorate of Irrigation in paying for part of the construction costs, the political importance of the dam declined" (Hearne and Easter, 1997:198). As will be seen in the next section, the proposed Mountain View Dam on the Crocodile River, may not be necessary if trading increases the availability of water resources.

Also, other advantages to increasing the number of buyers exists. Since complaints have been made against the buying power of the four major farm buyers, widening the market to include industrial and municipal users would reduce the buying power of these farmers.

A small number of farmers who had traded in the past were interviewed and the responses of this sample was unexpected. The sellers thought that water should be used primarily for agricultural uses, two farmers felt very strongly that "they would not be prepared to sell water to non agricultural users". Even though more competition amongst buyers would likely drive up the price the sellers would receive. Whereas, the buyers of water considered that as long as industry paid the going rate, they could see no reason why water should not be sold to them. This seems paradoxical, as the buyers would be opening themselves up to greater competition from industrial users, (who as it stands pay over thirty times as much for water and would undoubtedly drive the price paid for water upwards). A possible interpretation for this is that the buying farmers are ignorant of the prices paid by industry for water.

Inter catchment trades within the Inkomati Basin?

The likelihood of such trades is very slight. Many of the farmers themselves thought it completely impractical and unworkable, although others thought it possible, but that there were possible harms to the environment that would need to be overcome. And therefore there would need to be strict regulation of such activity.

Anderson (1994) and Preston (1995) explain how massive water transfers between catchments and even water basins have occurred in USA and South Africa respectively. According to Anderson governmental "grandiose schemes capture the public's attention and invoke incorrect perceptions of what water transactions would be like under a free trade regime that included water." (1994, p.4). It is likely that inter-basin transfers in a market system would be much smaller in size and more frequent in number.

A mixture of public concern and loss of political power seem to be the chief political reasons large water market transfers are vetoed (Leal and Anderson 1991). At an economic level the reasons are even simpler, because most water storage and diversion schemes (like the Kwena Dam) involve Government subsidies, the costs and benefits are not internalised by those who supply and demand water. As Anderson explains: "On the supply side, the citizens of the 'selling' region gain little or nothing as individuals if exports are allowed. Hence it is costless to 'just say no' to water exports. On the demand side, the 'buying' [region] has an insatiable thirst because the real cost of water consumption is hidden in taxes or other fiscal illusion" (1994, p.4). Trade therefore rarely occurs, whether it be from one region to another or from one water basin to another in the same country. This has been described as 'hydrological nationalism' (Salinas-Leon quoted in Anderson 1994, p.2).

While there could be institutional obstacles to inter-catchment trading of water rights, essentially it is a technical impossibility in the area as the Crocodile, Komati and Lomati rivers are too isolated to accommodate such transfers.

Strengthening the roles of DWAF and CRMIB

Although the DWAF and CRMIB have contributed significantly to the trading environment, it is possible that their role could be strengthened. The farmers considered that DWAF had no business encouraging trades directly, but should make sure that the institutional framework (especially the rights) were defined properly.
The CRMIB as already mentioned was responsible for making most farmers aware that they could trade. As in many small organisations, an individual, secretary is largely responsible for this considerable benefit. However, as the Secretary of the CRMIB draws up the contracts for the trades and acts for many of the buyers, there has been unease expressed by at least one farmer, at the fact that there is a potential conflict of interest in his work. A more efficient system should be implemented where the roles of the administrator of the CRMIB and that of legal representative for the buyers of water rights are separated.[22]

Broadening trade amongst farmers would assuredly need better institutions. For example, in the fully developed water trading in Chile's Limari Basin accounting for 89% of the water, 300,000 rights holders are involved.

The formation of Catchment Management Agencies (CMA) and also the Water Use Associations (WUA) are already providing effective and useful vehicles for the management of water use in catchments. These bodies should play a greater role in fostering and encouraging the trading of water rights and the greater role of market mechanisms in resource allocation.

[22] There is obviously a serious issue here and it highlights the importance of the strict delineation of roles of individuals. It is a corollary to the strict delineation for rules/rights, mis-specified rights leads to conflict and abuse.

Conclusion

This chapter has shown that the trading has been an efficient way of re-allocating water rights that in the past were essentially mis-allocated. Trading has undoubtedly been a success with efficiency gains - perhaps in the tens of millions of Rands - occurring. It was largely down to individuals within the CRMIB that facilitated and allowed trading to take place. There is scope to strengthen the capacity of the water institutions in the Crocodile River Catchment and in other catchments so that efficient trading of water rights can occur.

The analysis has not addressed the issue of externalities that may arise as a result of water rights trading. Externalities could occur because of higher amounts of water being extracted from the source as a direct result of trading. If there has not been a significant increase in negative externalities, trading should be further encouraged, perhaps even between sectors and regions. And even if pollution has increased this is no reason to stop trading, since it is manifestly increasing efficiency. Proportional lowering of quotas and allowing trading would be a preferable solution.

Chapter 4

Netback Study of Water Use in Selected Crops

Introduction

If sustainable water use is to be achieved at the minimum cost to society, resources must be allocated to those who value them the most thus ensuring efficient resource use. With only limited water markets in the agricultural water sector, net back analysis can provide important insights into the highest value users, which will be essential, if an efficient sustainable path of water use is to be achieved.

The following net back analysis is based on 1994 agricultural data and 1994 prices. The net back methodology is explained in detail below, however it is worth stating that this section draws from a narrow base of information and relies on a small number of studies. Much of the agricultural data comes from the Department of Agriculture's Enterprise Budgets, COMBUD and from a case study of agriculture in the Crocodile River Catchment by Viljoen et al. (1996). It is important to bear in mind that this net back analysis examines only six crops and compares the efficiency of water use of these crops relative to each other, not in absolute terms.

Investing in new water storage capacity is often welcomed by farming and urban users alike, however frequently the decision process on when to invest does not take into account the net benefits of the investment to society. This analysis will examine the socially optimal time to invest in new capacity and will determine a socially optimal price path of irrigation water.

As water policy changes net back analysis can not only predict which crops would no longer be economically viable in the face of full economic costs, but also highlights which crops have been over using water in the past.

Costs of Irrigation Equipment

A recent study by Viljoen et al (1996) estimate that on the Crocodile River and its smaller tributary the Kaap River, farming enterprises have invested on average R 617 989 and R 509 500 respectively in irrigation equipment. It must be noted that this is a case study and although it is not fully representative of the entire Crocodile River Catchment, it is the only available study which gives information on the fixed costs and capital expenditures of the farmers in the area.

Their study shows that irrigation equipment can form a substantial part of the entire assets of the farming enterprise. **Tables 4.1** and **4.2** show a summary of farming enterprises asset structures for the Crocodile and Kaap Rivers respectively. As has been explained, this study was essentially a case study with only twenty-five farmers surveyed along the Crocodile River, and four farmers surveyed along the Kaap River.

Of long term assets along the Crocodile River, land and buildings make up the largest component with a mean value of R 7 687 240. Of the farmers surveyed along the Crocodile River, the total long term assets came to R 216 522 231 with a mean value of R8 660 889. Of this mean value, investment in irrigation equipment comprised approximately 7% (or R 617 989).

Irrigation equipment is divided into storage facilities, permanent irrigation, main lines and pumphouses and pumps. Not all farmers have invested in all these items (for example, only 15 farmers had storage facilities on their properties) and the number of farmers that had invested is given in the second column of **table 4.1**. Medium term and short term assets are also shown in **table 4.1**. Medium term assets are made up of vehicles, machinery and farm implements and short term assets are made up of cash, stock, livestock and savings.

In order to arrive at net margins for farming enterprises, fixed costs and some allowance for return to capital must be made. The data contained in **table 4.1** is therefore used to determine a suitable return to capital for farming enterprises as explained in more detail below.

Table 4.1: Asset Structure - Crocodile River (1994)

Description	No. of Farmers	Total (R)	Mean (R)/Farmer	Smallest non zero Value (R)	Largest Value (R)
Long Term Assets					
Land and Buildings		192180 993	7 687 240	658 143	26 875 750
Water Storage	15	500 857	20 034	2 000	182 000
Permanent Irrigation	19	3 323 984	132 959	5 000	1 168 500
Main Lines	21	9 922 396	396 896	50 000	2 000 000
Pumphouses & Pumps	21	1702 509	68 100	1 200	445 000
Total Long Term Assets	25	216 522 231	8 660 889	750 000	28 817 000
of which, Total Irrig.			617 989		
Total Medium Term Assets	25	35 558 448	1 422 338	271 000	7 854 425
Total Short Term Assets	22	13 577 899	543 116	1 000	6 494 898
Total Assets	25	265 658 578	10 626 343	1 212 070	36 502 700
Total No. of Hectares	20 417				
Total Assets/Ha		12 979		1 225	188 721
% Irrig of Long Term Assets			7.14%		

source: Viljoen et al. (1996)

It is estimated (BDT Janse van Rensburg 1997) that the establishment costs of irrigation for sugarcane vary from R10 500 to R12 850 per hectare of which pumphouses and main lines makes up R3 000 - R4 000 per hectare and surface sprays R3 000 - R4 000 per hectare. Investment in irrigation equipment makes up between 50% and 60% of total costs for establishing irrigated sugarcane.

For bananas it is estimated (BDT Janse van Rensburg 1997) that investment in irrigation equipment is as much as R8 000 per hectare, a major part of the R15 000 to R18 000 per hectare establishment costs.

Data on the operational and maintenance costs of irrigation, which includes the cost of upkeep of irrigation equipment, are derived from COMBUD (1994). Certain items that are listed as costs for some crops are not given for others. This is so for the water tariffs for sugar, avocados and bananas, however one could assume that they are not dissimilar to those of mangoes and citrus.

The opération and maintenance costs for irrigation are detailed in **Table 4.2**. These costs vary widely between different crops as clearly some are more water intensive than others. Water charges form a very small component (often less than 5%) of total irrigation costs, with the largest component being power used for pumps and motors. The inconsequentially priced water rates is a crucial factor in determining water use, as will be discussed later.

Table 4.2: Per hectare Operation and Maintenance costs of irrigation

Item	Sugar[1]	Mangoes[2]	Grapefruit[3]	Citrus[4]	Avocados[5]	Bananas[6]
Water Charge		50.00	70.00	88.00		
Repairs to Equipment	2.35					0.97
Power	758.50	573.50	431.67	616.67	592.00	1,154.40
Repairs to Motors	40.09	30.31	22.82	32.59	31.29	61.01
Labour	168.48	48.96	120.96	172.8	34.56	161.28
TOTAL	**969.42**	**702.77**	**646.45**	**910.06**	**658.85**	**1,377.66**

Units = Rands

1 Malelane, drag line irrigation, years 2 - 6
2 Hoedspruit, micro irrigation, years 5 – 20
3 Letsitele, micro irrigation, years 7 - 12
4 Valencias, Malelane, micro irrigation, years 4 - 10
5 Levubu, micro irrigation, years 7 - 20
6 Malelane, micro irrigation, years 2 - 10

source: COMBUD 1994

The per hectare operating and maintenance costs of irrigation vary quite significantly between the various crops. These costs come directly from COMBUD 1994 and wherever possible, data is used that resembles the Crocodile River Catchment most closely. In some cases, such as with grapefruit, the cost data has been gathered from Lesitele and therefore is different to the citrus cost data which is based on valencia oranges in Malelane.

Non Irrigation Fixed Costs of Farming Enterprises

Annual fixed costs for farms along the Crocodile River are estimated by Viljoen et al. (1996) to be on average R1 753 054 per farm. This figure however included fixed labour and water charges and fuels and oils which are already taken account of in the agricultural figures provided by the Department of Agriculture (COMBUD) therefore they are excluded from **Table 4.3**. When these items are excluded the total annual fixed expenditure is R29 205 782 for the farms surveyed. This translates to an average annual fixed cost of R1 168 232 per farm or an annual average per hectare fixed cost of R1 426 based on an average of 819 hectares per farmer along the Crocodile River.

Table 4.3: Farmers annual fixed farm expenditure (R) - Crocodile River, 1994

Description	Total R	Mean per farm	Smallest non zero number	Largest Value	R/Ha
O & M costs	4 820 122	192 805	18 116	881 000	2 392
Insurance & Licenses	1 191 373	47 655	2 500	226 533	921
Electricity	5 158 588	206 344	4 440	907 534	2 544
RSC*	116 983	4 679	260	24 091	300
Work Injuries**	71 524	2 861	1 000	24 000	37
Other expenses	17 847 192	713 888	3 000	8 747 709	8 972
TOTAL	**29 205 782**	**1 168 232**			15 166
Mean per hectare		**1 426**			

* Regional Services Council

** Paid to the Commissioner of Work Injuries (a payment to cover injuries to employees)

source: Viljoen et al. (1996)

The Relationship between Irrigation and Yields

The following data are based upon studies performed by the Institute for Tropical and Subtropical Crops (Olbrich 1997) and gives details on the crop responsiveness to irrigation. In the study area, all crops, with the exception of valencia oranges exhibited a positive relationship between irrigation and crop yields.

Sugar: This crop is grown extensively in the Onderberg region of the Crocodile River and covers a greater area than any other irrigated crop. Olbrich (1997) quotes a study of water use and sugar yield in the Lower CRC using the CANEGRO simulation model developed by Inman-Bamber. The model simulates the amount of water added by irrigation and the sugar yield to define curves relating sugar yield to irrigation. Six different irrigation regimes were simulated with regime 1 using only rainwater and regimes 2 to 6 representing successively greater amounts of irrigation.

As would be expected the lowest cane and sucrose yields were obtained from the poorest soil types and lowest irrigation. The simulations show that sucrose yields peak at total water applications in excess of approximately 1500 mm a year. When considering irrigation alone (rainfall was subtracted) dryland cultivation would yield between 2.5 and 4 tonnes/hectare/year. The sucrose yield peaks at 19.1 tonnes/hectare /year which corresponds to an annual irrigation of 900 mm/year. (The fact that yield increases even with substantial irrigation provides a powerful incentive to maintain high levels of irrigation).

It is important to note that seasonal use of water varies significantly with sugar cane, and that during winter irrigation falls to 2.3 mm/day compared to the peak of 5.8 mm/day during mid summer.

Farmers questioned by the authors stated that sugar was a favoured crop in the area because of its stable price, consistent profitability and because of the presence of a large sugar mill in the region.

Citrus: Studies were performed at Nelspruit on valencias and at Malelane on grapefruit. Nelspruit is cooler, has higher rainfall (850 mm/year) and lower evaporation than Malelane which has an annual rainfall of 493.7 mm/year.

Water use for valencia oranges peaks during mid summer at approximately 4.8 mm/day and during June and July the figure falls to 1.5 mm/day. Results from tests show that there was no positive correlation between the quantity of water used and total yield. This could however be down to over-irrigation which caused negative effects such as phytophthora root disease.

On average water use for grapefruit is higher than for valencia oranges, with a peak of 4.5 mm/day during January and a minimum of 2.3 mm/day during July. Unlike valencias, grapefruit produce a greater quantity of larger fruit the wetter the soil. For the same total water applied, small frequent applications produce better yields than fewer, larger applications.

A view expressed by local farmers is that citrus fruit in general is considered to be a risky crop to grow because of short term fluctuations in the product price, however it has considerable profit potential, especially for export quality fruit.[23]

Mangoes: Tests were conducted on mangoes in Nelspruit and commenced in 1988 on 12 year old mango trees and continued for 6 years. Unlike the other fruits discussed here, mangoes are harvested in the summer (usually during January). One farmer questioned by the authors stated that one reason for growing mangoes was that he could make better use of farm labour and equipment while they would otherwise have been unoccupied.

Water use on mangoes peaks at 4.2 mm/day during November and reaches a minimum of 0.5 mm/day during May and June. The study shows that the total yield of mangoes increased significantly in response to increased water use. Fruit size was however not significantly affected by any of the treatments.

Avocados: Irrigation trials were conducted at Burgershall, which although not in the CRC area has a climate that is typical of the important avocado growing areas along the Catchment area. Two types of avocado were studied, Fuerte and Hass and the latter showed better responses to irrigation with a strong positive relationship between

[23] Based on conversations held by the authors with various farmers along the Crocodile River

irrigation and yield. Fuerte produced low yields and there appeared not to be any difference in yields according to different irrigation treatments.

Bananas: Experiments were conducted in the Levubu district in the North Eastern Lowveld of the Northern Province. A crop factor of 1.0 (equivalent to total consumptive water use of 1489 mm/year) gave the best banana yields, while a crop factor of 0.6 (equivalent to 991 mm/year) produced 20% less crop. Water stress (days without water) was recorded in all irrigation treatments except that with a crop factor of 1.0.

Water Use Efficiency

The table below shows the total water use, fruit yields and water use efficiency (WUE) for the major fruit crops grown along the Crocodile River. Although many factors influence fruit yields, such as the frequency of irrigation, the phenological stage at which water stress occurs, the figures give a general idea of the more water demanding crops and the those that are most efficient at using water. Although the key issue is whether economic efficiency is achieved, water use efficiency is of interest if the institutions over water use, and/or the price of water is increased, as it may indicate which crops are likely to be grown in the future.

Table 4.4: Water use efficiencies of various crops determined for best treatments on the irrigation trials.

Crop	Treatment	Nett irrigation applied (mm/yr)	Fruit yield (kg/ha/yr.)	WUE (kg fruit/mm water)
Grapefruit	Tensiometers (-55kPa)	818	95,300	81.4
Valencias	Tensiometers (-30kPa)	627	52,040	46.5
Mangoes	Tensiometers (-30kPa)	463	29,000	30.3
Avocados	Tensiometers (-30kPa)	634	8,170	7.3
Bananas	Crop factor = 1.0	1,156	32,700	23.3
Sugar Cane		900	19,100	11.57

Source: Olbrich & Hassan ed. (1998)

Forestry

Approximately 11.2% of the total Catchment area is planted with pines and 5.8% with Eucalyptus. It is difficult to measure exact water use by plantation forestry, however, the reduction in run-off can be estimated (Le Maitre et al 1997). Simulations accurately predict what the run-off would be without afforestation and hence water use can be calculated simply by subtracting actual run-off from estimations of virgin run-off.

Although the rate of tree growth is determined by many factors, it is known to be slower in lower rainfall areas, however, in lower rainfall areas forests will usually absorb a greater proportion of the rain than in higher rainfall areas. Within the bounds of CRC, there is undoubtedly a positive relationship between rainfall and tree yield. (Olbrich & Hassan. ed., 1998). The ratios are important because they allow measurement of water use by forests.

Because of the conflict between agricultural and forestry for water the afforestation permit system (APS) was introduced in 1972 in South Africa by DWAF (van der Zel, 1995). The APS places restrictions on expansions in commercial plantations and is currently under review to encourage more efficient water management. One of the permit conditions is maintenance of a 20 to 50 metre wide (on both sides) open strip in riparian zones (where the highest water reduction would occur). Large forest companies have, since 1972, voluntarily cleared riparian zones in plantations plated before the APS system came into being. It is foreseen that this will improve streamflow and restore biodiversity of natural fauna and flora in these ecologically sensitive zones (Environmentek, 1998).

Netback Analysis

In this analysis, the net present values over the lifecycles of six crops are presented and the detailed figures are given in Appendix E. Ignoring the expansion of water trading, as discussed in the previous chapter, the option for an increase in capacity is either the building of the large Mountain View Dam which has a local increment in target draft of 138 million cubic metres/year at a capital cost of R262 million, or the smaller Mountain View Dam with local incremental target draft and capital cost of 107 million cubic metres/year and R186 million respectively.

Another option for increasing water supplies would be to reduce the amount of afforestation along the upper reaches of the Crocodile River, which would increase the mean annual runoff. Insufficient data and the uncertainties as to the quality of water that runs off newly deforested areas prevents this being analysed any further within this project.

The agricultural data that is used in this analysis is derived from the COMBUD enterprise budgets (1994). This information was compiled by the Department of Agriculture, which undertook a lengthy consultation process with a panel of farmers in the study area. The panel collectively determine the per hectare and per tonne variable costs for a range of different crops and the appropriate yields over the lifecycle of the crops. These figures are then analysed by local researchers and are discussed again with the panel of farmers. Inevitably the figures presented in COMBUD are likely to be a compromise acceptable to all the interests represented, and it is likely that there are farmers who can achieve higher yields at lower costs. However, given the lengthy and detailed analysis that the gross margins for different crops in COMBUD are subjected to, the authors feel that the data is acceptable for this study.

COMBUD calculates gross margins (per hectare and per tonne) for a range of crops, however, in order to arrive at a true picture for farming enterprises, net margins would need to be calculated. In order to arrive at the net margins, the authors rely on a report by Viljoen et al, already mentioned above, which gives the asset structures and fixed costs of a sample of farming enterprises along the Crocodile and Kaap rivers. The authors acknowledge that this report should be seen as a case study, rather than providing definitive data for the Crocodile River Catchment. However, in the absence of any other reliable data, the authors are forced to use this information and apply it to the net-back analysis.

In order to arrive at net margins, allowances are made for a return on capital and for fixed costs. In order to arrive at an appropriate figure for a return on capital, a real percentage of 6% is deducted from the gross margin. Assuming an inflation figure of 9% per annum, a nominal percentage of 16% is deducted from the average per hectare assets of farming enterprises along the cubic metres/year. Figures from Viljoen et al suggest that the mean value for long and medium term assets for farming enterprises along the cubic metres/year is R10 083 227. This translates to mean per hectare figure of R12 311 (Viljoen et al. p. 14). A real return of approximately R1 969 should therefore be deducted from net margins to account for this.

Based on the figures presented in Viljoen et al. mean fixed costs of R1 426 should also be deducted from the COMBUD gross margins to arrive at net margins (see **Table 4.3**). There is no single and accepted way of allocating fixed costs, and therefore two different scenarios for the allocation of these fixed costs and the return on capital are presented. In the first scenario, it is assumed that there is a relationship between contributions to gross revenue and fixed costs. Data from COMBUD 1994 are used in order to arrive at a weighted average of fixed costs and return on capital for the various crops.

Under the second fixed cost and return on capital scenario, it is assumed that there is a relationship between fixed costs and per hectare crop coverage. The fixed costs are therefore allocated to each crop on a pro- rata basis according to the number of hectares under cultivation. Data on the number of hectares under cultivation is taken from Olbrich & Hassan ed. 1998.[24]

Two important considerations for a farming enterprise are ensuring that labour (which constitutes a major proportion of costs) is utilised fully, and that the cash flow of the enterprise is smooth and stable. In order to achieve this, a farmer will choose to cultivate crops that utilise labour throughout the year, and ripen and can be harvested at different times of the year. Based on discussions with farmers in the area, the authors estimate that on average each farmer grows three crops, and for the purposes of allocating fixed costs, it is assumed that sugar, mangoes and bananas are grown together and that valencia oranges, avocados and grapefruit are grown together.

Table 4.5 details the allocation of fixed costs and the return on capital under each scenario. It is recognised by the authors that there are other ways of allocating fixed

---

[24] Data on irrigated crop areas is also contained in JIBS, 1994, however the data is too aggregated to be of use in this study.

costs, such as relating fixed costs to variable costs, and while these two methods may seem subjective, some estimate of fixed costs and return on capital has to be made.

The net-back analysis is therefore divided into two broad groups based on the allocation of fixed costs. In each group, different assumptions are made as to the tariffs that should be paid for water, however the method of calculation in each case is the same.

The purpose of the analysis is to determine the maximum willingness of a farming enterprise to pay for water and compare this with the different levels of water supply tariffs. Comparisons are made between tariffs based purely on the operational and maintenance costs of water supply, with the full financial costs of water supply and with the market price for water rights based on the trade data. In addition, the opportunity costs of water is calculated and used as the full economic costs of water and is incorporated into the analysis.

Table 4.5: Weighted Average of Fixed Costs

Scenario 1 – Allocating fixed costs according to contribution to gross income				
Crops	Gross Income/ha R/ha	Proportion of Costs	Fixed Costs (R)	Return on Capital (R)
			R 1 426	R 1 696
Sugar	8 595	0.25	357	493
Mangoes	13 707	0.39	569	786
Bananas	12 034	0.35	500	690
Valencias	25 514	0.32	455	628
Avocados	20 095	0.26	373	515
Grapefruit	32 168	0.42	597	825
Scenario 2 – Allocating fixed costs according to per hectare crop coverage				
Crops	Hectares [25]	Proportion of Costs	Fixed Costs (R)	Return on Capital (R)
			R 1 426	R 1 969
Sugar	12 500	0.21	313	433
Mangoes	7 913	0.14	198	273
Bananas	4 500	0.07	112	155
Valencias	10 000	0.18	263	364
Avocados	2 132	0.04	56	78
Grapefruit	10 000	0.18	263	363

Source: COMBUD, Olbrich & Hassan ed. 1998.

The analysis is approached as an investment problem for the farming enterprise, where a farmer faces a decision of whether or not to invest in a certain crop. Theoretically, the crop that offers the highest net present value (NPV) should be considered as the most

[25] Source: Olbrich & Hassan ed. 1998. Total area covered by crops in 1991/92 is estimated to be 79 033 ha. Costs are allocated as a proportion of this total. Although 1994 data is available in the JIBS 1994 report, this data is too aggregated to be useful for this study.

profitable while those with negative net present values are not worthy of investment. In each of the scenarios that are presented below, the per hectare non water costs are subtracted from the per hectare revenues for each crop to obtain a maximum willingness to pay for water. The non water costs include all variable cost, such as seed and tree costs, fertilisers, pesticides and fuel as well as allowances for fixed costs and a return on capital. This is calculated for each year in the crop cycle based on COMBUD figures and the annual figures are discounted to obtain the NPV for each crop. Then at each time period in the crop lifecycle, the water costs are added in order to arrive at the true net present value (TNPV) for the different crops. A negative TNPV would suggest that, on aggregate, the crop in question is not sustainable and were water to be priced at its opportunity cost, production would no longer be feasible[26].

All prices and data for the net back analysis are based on 1994 figures, including the discount and inflation rates. Based on information supplied by the Land Bank (Mr. Roussoux, pers. comm.) and the South African Reserve Bank (Anna-Marié Jones, pers. comm.), a bank lending rate of 16% and an inflation rate of 9% are used giving a real discount rate of 6.42%[27]. While this discount rate appears fairly high, the authors feel that it accurately reflects the uncertain economic, agricultural and political situation faced by irrigation farmers. In order to test the sensitivity of the analysis to the discount rate, the analysis is performed in addition using a bank lending rate of 18% above and 14%.

Various scenarios for the net-back analysis are given below. Under each scenario, two different methods for allocating fixed costs are used. The first method allocates according to the contribution that that crop makes to gross revenues, the second method allocates fixed costs according to per hectare crop coverage.

Different assumptions are made for the tariff that a farming enterprise has to pay for water. The first scenario is one in which a farming enterprise is only required to pay the operational and management (O&M) costs of supplying water. For the year 1994/95, which corresponds to same time period the farming data are based on, the per unit O & M costs of the Kwena dam is 0.63c/m^3. (Pers. Comm. Mollie Wilkinson, DWAF). Government policy at the time was that irrigation farmers should only pay the O & M costs of water supply, so this case should reflect the financial conditions under which farming enterprises would base decisions at that time.

The second scenario is one where the farming enterprises are required to pay the full financial costs of water supply, in other words the capital costs in addition to the O & M costs. This was not government policy at the time, however, since the enactment of the National Water Act, irrigation farmers are required to pay the full financial costs of water supply. Although the Kwena dam was built in 1984 and theoretically the capital costs for this dam would have been written off by today. The capital costs are however included here for illustrative purposes. According to DWAF, the per unit capital costs

[26] This does not mean that the crop could not be grown by the most efficient farmers, just that it is unlikely to be grown by most farmers.

[27] Where real interest rate = $\frac{(1 + \text{nominal})}{(1 + \text{inflation})} - 1$

for the years 1994/95 for the Kwena dam stand at 6.91c/m^3. Thus the capital and O & M costs would be 7.54c/m^3.

A third scenario is explored where the traded price for water rights is used as the price for water. Given that this price was established through a relatively free market, it should reflect the value that irrigation farmers attach to water rights. The trade data upon which the market price for water rights is based, is 1994 and 1995 data.

The final scenario uses estimates of the full economic cost of water, based on calculations in Appendix F. Here the opportunity cost of water is calculated in order to calculate the optimal time period for investment in new water storage capacity. While this does not necessarily reflect the actual water supply tariff that irrigation farmers would face, it is indicative of the full economic cost of water use and given the scarcity of water in the region gives important insights into the sustainability of water use.

Scenario 1 - Operational and Maintenance Costs only

Table 4.6 shows a summary of the net-back analysis calculations that are contained within Appendix E. In this scenario, the farming enterprise is required to pay on the operational and maintenance costs of water supply. This according to DWAF in 1994 was 0.63c/m^3.

The table below and all those presented in the subsequent scenarios follow the same format. The lifecycle of the crop is shown in the first row and the average yield for that crop is given in the second row. Although the average yield is given in this table for illustrative purposes, in the actual net back calculations, the anticipated yield for each crop in each year was used, not an average yield. The price per tonne that could be expected from the crops in the year in question is then given and is calculated in Rand per tonne.

The NPV per hectare of each crop is then given and is calculated by subtracting the per hectare non-water costs in each year of production from the per hectare revenues and then discounted to an NPV. The water requirement, according to Olbrich et al. for each crop is then given, and this is multiplied by the appropriate figure for the cost of water supply, or water rights (in this case only the O&M costs) to give the cost of irrigation water per hectare. This is added to the running costs of irrigation equipment, such as electricity and irrigation labour to give the full costs of irrigation water. The summary table shows the total per hectare full costs of irrigation, however the net-back calculations subtract the appropriate amount at each year of cultivation. The result is the true net present value (TNPV) for each crop. Depending on the scenario and the figure used for the cost of water, this value should give a more accurate picture of an investment decision based on full economic costs, rather than the costs faced by farming enterprises that are distorted by subsidies.

Table 4.6 Summary of Present Value Willingness to Pay for Water and the True Net Present Values for Various Crops Scenario 1.1. Fixed costs allocated according to gross revenues.

	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
Lifecycle (years)	7	12	25	21	20	12
Yield t/ha (average)	112.6	22.50	15.9	39.03	10.69	55.95
Price R/tonne	80.22	535	1,930	682.4	1,358	574.95
NPV R/hectare	**25 365**	**44 801**	**131 158**	**41 226**	**49 533**	**57 076**
Water Req. m^3/annum	9 000	11 560	6 340	6 270	4 630	8 180
Full Cost of Water R/hectare	397	873.6	997.5	829.5	584	618
Irrig. Running Costs R/hectare	6 786	16 531	16 471	17 263	13 055	9 865
TNPV R/hectare	**19 359**	**32 153**	**122 021**	**30 812**	**41 486**	**49 459**

NPV	net present value
Water Req.	annual water requirement measured in m^3/annum per crop
Full Water Costs	sum of appropriate cost of water multiplied by water requirement over lifecycle of crop
Irrig. Running Costs	annual variable costs of running and maintaining irrigation equipment for each crop
TNPV	true net present value = present value of maximum willingness to pay for water minus opportunity cost of water

Table 4.7 Summary of Present Value Willingness to Pay for Water and the True Net Present Values for Various Crops Scenario 1.4. –Fixed costs allocated according to per hectare crop coverage

	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
Lifecycle (years)	7	12	25	21	20	12
Yield t/ha (average)	112.6	22.50	15.9	39.03	10.69	55.95
Price R/tonne	80.22	535	1,930	682.4	1,358	574.95
NPV R/hectare	**25 974**	**52 835**	**141 028**	**46 746**	**59 953**	**64 009**
Water Req. m^3/annum	9 000	11 560	6 340	6 270	4 630	8 180
Full Cost of Water R/hectare	397	873.6	997.5	829.5	584	618
Irrig. Running Costs R/hectare	6 786	16 531	16 471	17 263	13 055	9 865
TNPV R/hectare	**19 968**	**40 187**	**131 891**	**36 332**	**51 907**	**56 392**

NPV	net present value
Water Req.	annual water requirement measured in m^3/annum per crop
Full Water Costs	sum of appropriate cost of water multiplied by water requirement over lifecycle of crop
Irrig. Running Costs	annual variable costs of running and maintaining irrigation equipment for each crop
TNPV	true net present value = present value of maximum willingness to pay for water minus opportunity cost of water

According to the net back analysis for this scenario, the crop with the highest TNPV is avocados, followed by grapefruit, mangoes, bananas, valencias and sugar. Avocados are known to attract a high export price, use relatively little water and according to the COMBUD figures have amongst the lowest non-water costs.

As would be expected, when farming enterprises are required to pay only the O & M costs for water supply, the cost of water forms a very minor part of the investment decision. In fact the irrigation costs themselves, which are made up of electricity costs and labour costs, form the bulk of the costs of water use.

When fixed costs are allocated according to per hectare crop coverage, the results of the net back analysis are largely unchanged. Avocados still have the highest TNPV and sugar cane the lowest. This method of allocating fixed costs favours those crops that have relatively lower per hectare coverages, such as mangoes and bananas. Sugar cane on the other hand covers a relatively large area and therefore a higher proportion of fixed costs would be allocated to it.

Clearly, changing the discount rate will have an effect on the TNPV, however the relative sizes of the TNPVs do not change to any significant degree. **Tables 4.8** and **4.9** give the results of the analysis using the different discount rates, for each of the fixed costs allocation cases.

Table 4.8 Comparison of True Net Present Values using different discount rates - fixed cost allocated according to contribution to gross revenue.

Scenario	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
1.1 (real r = 6.42%)	19 359	32 153	122 021	30 812	41 486	49 459
1.2 (real r = 8.26%)	17 991	28 745	91 910	18 608	30 881	42 929
1.3 (real r = 4.59%)	20 856	36 021	162 244	46 991	55 204	57 023

Table 4.9 Comparison of True Net Present Values using different discount rates - fixed costs allocated according to per hectare crop coverage.

Scenario	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
1.4 (real r = 6.42%)	19 968	40 187	131 891	36 332	51 907	56 392
1.5 (real r = 8.26%)	18 573	36 163	100 445	23 464	40 091	49 331
1.6 (real r = 4.59%)	21 495	44 764	173 846	53 344	67 128	64 568

Scenario 2 - Operational and Maintenance Costs and Capital Costs

This analysis assumes that farming enterprises are expected to pay the full financial costs of water supply, i.e. O & M costs and capital costs. According to DWAF in 1994 this should amount to a sum of 7.54c/m^3.

Although the Kwena dam was built 14 years ago, and therefore the capital costs would have been written off by this time, they are included in this analysis for illustrative purposes. The capital costs are included here to show what the crop patterns would have been if irrigation farmers had been required to pay the full financial costs.

As before, the results of the net back analysis are presented in a summarised format in **table 4.10** below.

Table 4.10 Summary of Present Value Willingness to Pay for Water and the True Net Present Values for Various Crops Scenario 2.1. –Fixed costs allocated according to contribution to gross revenue.

	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
Lifecycle (years)	7	12	25	21	20	12
Yield t/ha (average)	112.6	22.50	15.9	39.03	10.69	55.95
Price R/tonne	80.22	535	1,930	682.4	1,358	574.95
NPV R/hectare	**25 365**	**44 801**	**131 158**	**41 226**	**49 533**	**57 076**
Water Req. m^3/annum	9 000	11 560	6 340	6 270	4 630	8 180
Full Cost of Water R/hectare	4 750	10 459	11 951	9 928	6 982	7 401
Irrig. Running Costs R/hectare	6 786	16 531	16 471	17 263	13 055	9 865
TNPV R/hectare	**15 719**	**25 188**	**116 292**	**25 575**	**37 711**	**44 531**

NPV	net present value
Water Req.	annual water requirement measured in m^3/annum per crop
Full Water Costs	sum of appropriate cost of water multiplied by water requirement over lifecycle of crop
Irrig. Running Costs	annual variable costs of running and maintaining irrigation equipment for each crop
TNPV	true net present value = present value of maximum willingness to pay for water minus opportunity cost of water

With farming enterprises required to pay the O & M costs and capital costs of water supply, the TNPVs of all crops are significantly reduced. The most profitable crop however remains avocados, and in fact the order of the crops in terms of TNPVs between this scenario and the previous scenario where only O & M costs are charged, is virtually the same. Valencia oranges and sugar cane remain among the least profitable crops according to this analysis.

When fixed costs are allocated according to per hectare crop coverage, the results of the analysis, in terms of the order of crops in terms of TNPV is unchanged.

Table 4.11 Summary of Present Value Willingness to Pay for Water and the True Net Present Values for Various Crops Scenario 2.4 - Fixed costs allocated according to per hectare crop coverage.

	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
Lifecycle (years)	7	12	25	21	20	12
Yield t/ha (average)	112.6	22.50	15.9	39.03	10.69	55.95
Price R/tonne	80.22	535	1,930	682.4	1,358	574.95
NPV R/hectare	**25 974**	**52 835**	**141 028**	**46 746**	**59 953**	**64 009**
Water Req. m^3/annum	9 000	11 560	6 340	6 270	4 630	8 180
Full Cost of Water R/hectare	4 750	10 459	11 951	9 928	6 982	7 401
Irrig. Running Costs R/hectare	6 786	16 531	16 471	17 263	13 055	9 865
TNPV R/hectare	**16 328**	**33 222**	**126 162**	**31 095**	**48 132**	**51 464**

NPV — net present value
Water Req. — annual water requirement measured in m^3/annum per crop
Full Water Costs — sum of appropriate cost of water multiplied by water requirement over lifecycle of crop
Irrig. Running Costs — annual variable costs of running and maintaining irrigation equipment for each crop
TNPV — true net present value = present value of maximum willingness to pay for water minus opportunity cost of water

Table 4.12 shows the TNPVs under the same assumptions (i.e. O & M costs and capital costs charged for water supply) with different discount rates used to calculate the TNPVs.

Table 4.12 Comparison of True Net Present Values using different discount rates – Fixed costs allocated according to contribution to gross revenues

Scenario	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
2.1 (real r = 6.42%)	15 719	25 188	116 292	25 575	37 711	44 531
2.2 (real r = 8.26%)	14 517	22 314	86 957	14 001	27 545	38 379
2.3 (real r = 4.59%)	17 036	28 441	155 511	40 965	50 884	51 659

Table 4.13 Comparison of True Net Present Values using different discount rates - Fixed costs allocated according to per hectare crop coverage

Scenario	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
2.4 (real r = 6.42%)	16 328	33 222	126 162	31 095	48 132	51 464
2.5 (real r = 8.26%)	15 098	29 732	95 492	18 857	36 755	44 780
2.6 (real r = 4.59%)	17 675	37 184	167 113	47 317	62 809	59 205

As before, changing the discount rate does have a significant impact on the TNPVs. Using the lower discount rate changes the ranking of the crops slightly, with valencia oranges having a higher TNPV than banana and mangoes have the second highest

TNPV, ahead of grapefruit. Although mangoes will not produce fruit until the fourth year of cultivation, they have relatively low establishment and non water running costs which makes them an attractive crop for farming enterprises.

Scenario 3 - Net Back Analysis using the Traded Price of Water Rights as the Water Cost

Chapter 2 examines and describes the trading of water rights along the Crocodile River. Given that to a certain extent the free market mechanisms have operated in the determination of the price at which water rights have traded, it would seem appropriate to perform the net back analysis using this market price for water rights.

In the analysis, the weighted average of the permanent and temporary traded prices for water rights, of 2.07 c/m^3 is taken as the price paid by farming enterprises for water rights.

Table 4.14 below shows the results of the analysis using a discount rate of 6.42%.

Table 4.14 Summary of Present Value Willingness to Pay for Water and the True Net Present Values for Various Crops Scenario 3.1. Fixed costs allocated according to contribution to gross revenues

	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
Lifecycle (years)	7	12	25	21	20	12
Yield t/ha (average)	112.6	22.50	15.9	39.03	10.69	55.95
Price R/tonne	80.22	535	1.930	682.4	1,358	574.95
NPV R/hectare	**25 365**	**44 801**	**131 158**	**41 226**	**49 533**	**57 076**
Water Req. m^3/annum	9 000	11 560	6 340	6 270	4 630	8 180
Full Cost of Water R/hectare	2 009	4 425	5 056	4 200	2 953	3 131
Irrig. Running Costs R/hectare	6 786	16 531	16 471	17 263	13 055	9 865
TNPV R/hectare	**18 601**	**30 702**	**120 827**	**29 721**	**40 700**	**48 432**

NPV — net present value
Water Req. — annual water requirement measured in m^3/annum per crop
Full Water Costs — sum of appropriate cost of water multiplied by water requirement over lifecycle of crop
Irrig. Running Costs — annual variable costs of running and maintaining irrigation equipment for each crop
TNPV — true net present value = present value of maximum willingness to pay for water minus opportunity cost of water

Again the crop with the highest TNPV using the traded price for water as the price for water rights is avocados. The crops with the lowest TNPV are valencia oranges and sugar cane, as above. When the analysis is performed for crops, with fixed costs allocated according to per hectare crop coverage, the results are very similar.

Table 4.15 Summary of Present Value Willingness to Pay for Water and the True Net Present Values for Various Crops Scenario 3.4. – Fixed costs allocated according to per hectare crop coverage

	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
Lifecycle (years)	7	12	25	21	20	12
Yield t/ha (average)	112.6	22.50	15.9	39.03	10.69	55.95
Price R/tonne	80.22	535	1,930	682.4	1,358	574.95
NPV R/hectare	**25 974**	**52 835**	**141 028**	**46 746**	**59 953**	**64 009**
Water Req. m³/annum	9 000	11 560	6 340	6 270	4 630	8 180
Full Cost of Water R/hectare	2 009	4 425	5 056	4 200	2 953	3 131
Irrig. Running Costs R/hectare	6 786	16 531	16 471	17 263	13 055	9 865
TNPV R/hectare	**19 210**	**38 736**	**130 697**	**35 241**	**51 120**	**55 365**

NPV	net present value
Water Req.	annual water requirement measured in m³/annum per crop
Full Water Costs	sum of appropriate cost of water multiplied by water requirement over lifecycle of crop
Irrig. Running Costs	annual variable costs of running and maintaining irrigation equipment for each crop
TNPV	true net present value = present value of maximum willingness to pay for water minus opportunity cost of water

When the analysis is performed using different discount rates, the results are again broadly similar.

Table 4.16 Comparison of True Net Present Values using different discount rates – Fixed costs allocated according to contribution to gross revenue.

Scenario	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
3.1 (real r = 6.42%)	18 601	30 702	120 827	29 721	40 700	48 432
3.2 (real r = 8.26%)	17 267	27 405	90 878	17 648	30 186	41 981
3.3 (real r = 4.59%)	20 066	34 452	160 851	45 744	54 310	55 913

Table 4.17 Comparison of True Net Present Values using different discount rates - Fixed costs allocated according to per hectare crop coverage.

Scenario	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
3.4 (real r = 6.42%)	19 210	38 736	130 697	35 241	51 120	55 365
3.5 (real r = 8.26%)	17 848	34 823	99 413	22 504	39 396	48 383
3.6 (real r = 4.59%)	20 699	43 185	172 443	52 088	66 228	63 451

<u>Scenario 4 - Net Back Analysis using the Opportunity Cost of Water as the Water Cost</u>

The following set of scenarios relies on calculations derived in Appendix E of the opportunity cost of water. Given that water is a scarce resource and that economic theory tells us that efficiency requires that resources are allocated to those who attach the highest value to them, it would seem appropriate to perform the net back analysis based on the full economic cost of water.

It is acknowledged that the method of arriving at the price path for water across time is stylised, however it should give an indication of the full economic cost of water use. As demand for water rises, however the supply remains fixed due to supply constraints, the price rises. The way in which the water price rises across time will depend on the price elasticity of demand for water. In other words, the sensitivity of water demand to an increase in the price for water will determine how rapidly the water price rises. Because of this, different scenarios are calculated in which varying price elasticities are used. No studies have been undertaken to determine the price elasticity of demand for the various users in this region. However given that irrigation farmers are heavily reliant on irrigation water and that changes to cropping patterns would take place over a long period, the price elasticity of demand for water is likely to be fairly inelastic.

The price path is calculated on the basis of the next investment in water storage capacity being the Mountain View Dam. It is understood that this is no longer the case, however for illustrative purposes, it is assumed that the Mountain View Dam will be the next investment in water storage capacity.

Scenario 4.1.1

Price Elasticity of Demand of -0.1

The trend seen above is largely mirrored in this scenario. **Table 4.18** shows that the crop with the highest TNPV is once again avocados, followed by grapefruit. Grapefruit and sugar cane are the only other crops which has a positive TNPV, while mangoes, which showed relatively high TNPVs in the previous examples, now has a negative TNPV, as do bananas and valencia oranges with the lowest TNPV.

This analysis suggests that amongst these crops, avocados make the most efficient use of water. Should farmers face the full economic costs of water rights, it is likely that a change in crop patterns would arise with a greater concentration in avocados, grapefruit and sugar cane and a move away from mangoes, bananas and valencias. The authors acknowledge that this analysis is based on crop prices in 1994 and that since then there have been fluctuations in crop prices. The model also does not take account of any improvements in efficiency that farming enterprises could make, for which there is probably considerable scope.

Table 4.18 Summary of Present Value Willingness to Pay for Water and the True Net Present Values for Various Crops Scenario 4.1.1 - Fixed costs allocated according to contribution to gross income.

	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
Lifecycle (years)	7	12	25	21	20	12
Yield t/ha (average)	112.6	22.50	15.9	39.03	10.69	12
Price R/tonne	80.22	535	1,930	682.4	1,358	55.95
NPV R/hectare	**25 365**	**44 801**	**131 158**	**41 226**	**49 533**	574.95
Water Req. Ml/day	9 000	11 560	6 340	6 270	4 630	**57 076**
Full Cost of Water R/hectare	17 395	76 561	176 038	155 171	101 804	8 180
Irrig. Running Costs R/hectare	6 786	16 531	16 471	17 263	13 055	54 175
TNPV R/hectare	**6 397**	**-14 845**	**49 803**	**-35 534**	**-3 834**	9 865
						16 202

NPV net present value
Water Req. annual water requirement
Full Water Costs sum of opportunity cost of water multiplied by water requirement over lifecycle of crop
Irrig. Running Costs annual variable costs of running and maintaining irrigation equipment for each crop
TNPV true net present value = present value of maximum willingness to pay for water minus opportunity cost of water

Table 4.19 shows that summary of the net back analysis when allocating fixed costs according to per hectare crop coverage. As before, the crop with the highest TNPV is avocados, followed by grapefruit. Under this system of allocating fixed costs, the TNPV for sugar cane rises slightly and remains positive. Mangoes are the only other crops which has a positive TNPV.

Table 4.19 Summary of Present Value Willingness to Pay for Water and the True Net Present Values for Various Crops Scenario 4.1.4 – Fixed costs allocated according to per hectare crop coverage.

	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
Lifecycle (years)	7	12	25	21	20	12
Yield t/ha (average)	112.6	22.50	15.9	39.03	10.69	55.95
Price R/tonne	80.22	535	1,930	682.4	1,358	574.95
NPV R/hectare	**25 974**	**52 835**	**141 028**	**46 746**	**59 953**	**64 009**
Water Req. Ml/day	9 000	11 560	6 340	6 270	4 630	8 180
Full Cost of Water R/hectare	17 395	76 561	176 038	155 171	101 804	54 175
Irrig. Running Costs R/hectare	6 786	16 531	16 471	17 263	13 055	9 865
TNPV R/hectare	**7 006**	**-6 811**	**59 672**	**-30 014**	**6 586**	**23 135**

NPV net present value
Water Req. annual water requirement
Full Water Costs sum of opportunity cost of water multiplied by water requirement over lifecycle of crop
Irrig. Running Costs annual variable costs of running and maintaining irrigation equipment for each crop
TNPV true net present value = present value of maximum willingness to pay for water minus opportunity cost of water

Varying the discount rate, when fixed costs are allocated according to the contribution to gross income, the TNPVs are accordingly higher or lower, however the order in which the crops fare is not changed.

Table 4.20 Comparison of True Net Present Values using different discount rates – Fixed costs allocated according to per hectare crop coverage

Scenario	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
4.1.1 (real r = 6.42%)	6 397	-14 845	49 803	-35 534	-3 834	16 202
4.1.2 (real r = 8.26%)	5 942	-12 694	34 244	-34 879	-6 006	13 606
4.1.3 (real r = 4.59%)	6 886	-17 520	70 692	-36 237	-1 056	19 136

Varying the discount rate, when fixed costs are allocated according to per hectare crop coverage, does have a slight effect on the order in which crops are placed in terms of TNPV. Importantly, the TNPV for mangoes is more than halved when discounted at the higher real discount rate of 8.26% (nominal 18%). Valencias and bananas all consistently show negative TNPVs.

Table 4.21 Comparison of True Net Present Values using different discount rates

Scenario	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
4.1.4 (real r = 6.42%)	7 006	-6 811	59 672	-30 014	6 586	23 135
4.1.5 (real r = 8.26%)	6 523	-5 276	42 779	-30 023	3 203	20 008
4.1.6 (real r = 4.59%)	7 525	-8 777	82 294	-29 885	10 868	26 681

Scenario 4.2.

Price Elasticity of Demand of -1.0

Here the scenario is changed and it is assumed that the price elasticity of demand is more elastic at -1.0. This means that for a certain percentage increase in the price of water rights, ~~the reduction in demand would be far more pronounced.~~ The effect of this is that the price path rises far less steeply and subsequently, the TNPVs of the various crops that are examined here are all positive and are shown in **Table 4.22**

Table 4.22 Summary of Present Value Willingness to Pay for Water and the True Net Present Values for Various Crops Scenario 4.2.1 – Fixed Costs allocated according to contribution to fixed costs.

	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
Lifecycle (years)	7	12	25	21	20	12
Yield t/ha (average)	112.6	22.50	15.9	39.03	10.69	55.95
Price R/tonne	80.22	535	1,930	682.4	1,358	574.95
NPV R/hectare	**25 365**	**44 801**	**131 158**	**41 226**	**49 533**	**57 076**
Water Req. Ml/day	9 000	11 560	6 340	6 270	4 630	8 180
Full Cost of Water R/hectare	1 559	6 296	15 698	10 865	7 259	4 455
Irrig. Running Costs R/hectare	6 786	16 531	16 471	17 263	13 055	9 865
TNPV R/hectare	**18 495**	**28 825**	**116 463**	**26 424**	**38 457**	**47 104**

NPV	net present value
Water Req.	annual water requirement
Full Water Costs	sum of opportunity cost of water multiplied by water requirement over lifecycle of crop
Irrig. Running Costs	annual variable costs of running and maintaining irrigation equipment for each crop
TNPV	true net present value = present value of maximum willingness to pay for water minus opportunity cost of water

In this scenario, the patterns that were seen above in terms of the ranking of the crops' TNPVs are very similar. As none of the crops exhibit negative TNPVs it suggest that they all have sufficiently high abilities to pay for water to render them economically efficient with in this scenario. As before however, the analysis suggests that a move away from the crops with particularly low TNPVs and towards those with higher TNPVs would improve economic efficiency. Allocating fixed costs according to per hectare crop coverage produces broadly similar results.

Table 4.23 Summary of Present Value Willingness to Pay for Water and the True Net PresentValues for Various Crops Scenario 4.2.4 - Fixed Costs allocated according to per hectare crop coverage.

	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
Lifecycle (years)	7	12	25	21	20	12
Yield t/ha (average)	112.6	22.50	15.9	39.03	10.69	55.95
Price R/tonne	80.22	535	1,930	682.4	1,358	574.95
NPV R/hectare	**25 974**	**52 835**	**141 028**	**46 746**	**59 953**	**64 009**
Water Req. Ml/day	9 000	11 560	6 340	6 270	4 630	8 180
Full Cost of Water R/hectare	1 559	6 296	15 698	10 865	7 259	4 455
Irrig. Running Costs R/hectare	6 786	16 531	16 471	17 263	13 055	9 865
TNPV R/hectare	**19 104**	**36 859**	**126 333**	**31 944**	**48 878**	**54 037**

NPV	net present value
Water Req.	annual water requirement
Full Water Costs	sum of opportunity cost of water multiplied by water requirement over lifecycle of crop
Irrig. Running Costs	annual variable costs of running and maintaining irrigation equipment for each crop
TNPV	true net present value = present value of maximum willingness to pay for water minus opportunity cost of water

When the analysis under this scenario is performed using different discount rates, the results are broadly similar and again the order of the crops in terms of TNPV is the same.

Table 4.24 Comparison of True Net Present Values using different discount rates – Fixed Costs allocated according to contribution to gross income

Scenario	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
4.2.1 (real r = 6.42%)	18 495	28 825	116 463	26 424	38 457	47 104
4.2.2 (real r = 8.26%)	17 194	25 823	87 557	15 057	28 409	40 862
4.2.3 (real r = 4.59%)	19 918	32 215	155 045	41 510	51 456	54 330

Table 4.25 Comparison of True Net Present Values using different discount rates – Fixed Costs allocated according to per hectare crop coverage.

Scenario	Sugar	Bananas	Avocados	Valencias	Mangoes	Grapefruit
4.2.4 (real r = 6.42%)	19 104	36 859	126 333	31 944	48 878	54 037
4.2.5 (real r = 8.26%)	17 775	33 241	96 092	19 913	37 620	47 263
4.2.6 (real r = 4.59%)	20 557	40 958	166 647	47 862	63 381	61 875

Projected Changes in Agriculture

Scenarios for increased agriculture after the Mountain View Dam

In the feasibility study of the Mountain View Dam project (Viljoen et al.), farmers were questioned as to whether they would increase their areas under agriculture if the Mountain View Dam was built. This study was undertaken in 1994 and many of the predicted changes have already taken place. The question farmers were asked was:

"How would you expand if the Mountain View Dam is built and you have to pay a water tax of approximately R4,500 per hectare" (pers. comm. Prof. M.F. Viljoen)

The water charge was calculated so as to cover the capital costs, and research costs of building the dam and the operation and maintenance costs of supplying water. A number of financing scenarios were tested, one of which assumed that tariffs for the new dam would only be applied to new land brought into production as a direct result of the dam. It emerged that this would not be financially feasible and charges would have to be based on existing agricultural land as well. This would seem to make sense, as one of the main purposes of the dam would have been to stabilise water supply.

Of the four farmers questioned along the Kaap River, two said that they could not expand as they had no scope to do so and two stated that they would only expand the area under production if the large dam was built. Along the Crocodile River, twenty-five farmers were questioned. Of these seven stated that they would not expand and saw the dam as a stabiliser of water resources. Eight farmers would expand if a medium or large size dam was built and nine would expand under all dam size scenarios. This appears to be a high proportion of farmers who are planning to expand, especially as the dam is essentially designed to stabilise supplies and not to stimulate increases in demand.

Farmers' attitudes towards water

The authors surveyed nine farmers along the Crocodile River. While this is not a significant number of farmers, those that were surveyed represented small medium and large farms, the latter accounting for a major proportion of farming land in the area.

While most farmers considered long term sustainable supplies of water to be one of the most, if not the most important issue facing them, only one considered the pricing of water to be a tool in achieving this goal. Most farmers favoured the construction of more water storage and better management of existing capacity as ways of securing long term supplies.

When asked whether they would change the crops grown if faced with significantly higher water charges, only one farmer stated that the crops grown would change and this would be to move the land out of agriculture and into industrial or urban land.[28] The existing 'portfolio' of crops has on the whole been chosen to reflect the farmer's preferred risk exposure. The decision of which crop to grow will have more to do with projections of future crop prices than the price they are charged for water.

A widely held view is that water can be used more efficiently by farmers by changing to more advanced irrigation equipment (this will however involve considerable investment.) It was also expressed that in the face of higher water charges, farming enterprises would be forced to lay off labour and to increase mechanisation (for which there is considerable scope). The longer the crop lifecycle, the less likely the scope for change in the short term. The fact that sugar has the shortest lifecycle of the crops studied here, and also has amongst the lowest true net present values makes it a prime candidate for change in the medium and long term. This prospect is however dampened by the fact that one of the country's largest sugar mills, which also own large tracts of sugar plantations, is located in the area.

While most farmers recognised the need for a review of water policy, and were in favour of greater access to water resources for the disadvantaged, they all deeply resented the proposed changes to water rights. It was stated more than once to the authors, that when buying a farm in South Africa, one is not buying the land, but the water rights. Uncertainty as to whether or not farmers will have access to water will restrict prospects for investment in new crops or irrigation technology.

[28] the farmer in question was located close to Nelspruit, and so the potential to develop the land for urban or industrial use would be significant.

Greater trading of water rights was favoured by all farmers as an efficient way of allocating water. Of those farmers that had traded water rights, all had leased the rights for a certain period of time as farmers were reluctant to part with water rights on a permanent basis.

All farmers favoured the management of local water resources by local organisations and were very sceptical of the ability of central government to manage local water resources. According to the majority of farmers questioned these local councils should be made up of all water use groups, and not just agricultural users as was previously the case.

Conclusions

Water is greatly under charged in the study region and the existing allocation and use of water resources is economically inefficient. The net- back analysis suggests that under the scenarios where farming enterprises are required to pay tariffs for water rights that approach economic prices, certain crops are no longer economically viable. Valencia oranges and sugar cane have amongst the lowest TNPVs of the crops analysed while avocados, grapefruit and mangoes have amongst the highest, suggesting that sugar may became a less suitable crop in future.

It is important to note that sugar cane production has increased in the area, despite the findings of the net-back analysis. This is likely to be because sugar cane is seen as a stable and low risk crop and the fixed domestic price for sugar cane would encourage farmers into this crop. Water traded on short term leases is likely to be used on sugar cane because it is a shorter term crop and unlike orchard crops, can be changed relatively quickly.

There are of course many different factors that should be taken into account when determining the suitability of a crop. This model cannot allow for improvements in efficiency of water usage, or for the reduction of non water costs, however as a tool for comparing the six crops under the assumptions of the model, it can indicate relative suitability.

There is significant scope for farmers to use water more efficiently and to make cost savings in other areas. While many farmers have stated that there is no scope for them to change ~~the crops that are grown, this should be seen in light of~~ the fact that in the past many changes in the agricultural sector have taken place. These changes have in part been due to government incentives, but have also been instigated by market signals.

Economic incentives can have significant impacts and so while the net back analysis suggest that certain crops are unsustainable, allowance should be made for farmers to change practices and water use so as to put these crops on a more sustainable path. Although many farmers stated to the authors that it would not be feasible for them to change the crops that are grown, the reality is that over the last 10 years many farmers have been changing the crops that are grown, such as increasing the amount of land under citrus and moving into macadamia nut farming. It should therefore be recognised that there are alternative crops that can be grown in the area and that it is feasible for farmers to change their combination of crops.

The changes to water policy emphasise the fact that water should be put its highest value use. The type of analysis presented in this project should indicate which uses are consistent with this concept and which are not. The analysis also provides a framework for estimating the socially optimal time to invest in new water storage capacity.

As water pricing policy changes in South Africa to fully reflect the economic costs of supplying water, this analysis predicts that irrigated agriculture will be forced to undergo significant changes. The extent to which water demand will change will however depend upon the price elasticity of demand and the extent to which farmers are able to reduce expenditure on other inputs. Scope for short and medium term change is reduced by the significant investments that farming enterprises have made that are specific to their crop and the economic infrastructure that is geared to certain crops.[29]

[29] Such as packing houses that are specific to mangoes, and the location of the sugar mill at Malelane

Chapter 5

Conclusion

As has been stressed by numerous authors before, irrigated agriculture uses the majority of water in the Crocodile River Catchment. As Olbrich & Hassan ed. 1998 have shown water is worth up to R5.05 per cubic metre for use in agriculture in the Catchment. As we demonstrate in chapter 1, the full economic cost (excluding financing costs) of provision of the Kwena Dam is over 46 cents per cubic metre of water. Farmers pay only a tiny fraction of this cost, yet industry and urban users pay approximately double. These users with taxpayers have been heavily subsidising farm water supply.

From a policy perspective, there is a strong need to increase the efficiency of water use and to implement policies that can effect this. Increasing water tariff levels is one way to achieve this, however to which tariffs should be increased is not clear as it is difficult to estimate the opportunity cost of water use. An efficient way of exposing water users to the opportunity cost of water is through the market and by encouraging the trading of water rights.

Significant, although not precisely quantifiable, efficiency gains have been made from water use rights trading between farmers in the Catchment. Although we estimate that gains of about R 12.8m have been made from water used after trading that was not used before. Efficiency gains could perhaps be enhanced by greater definition of the amounts of water used through metering, and in principle by extending trading to include other water users such as the Nelspruit municipality and the various mills in the area. Several, technical and institutional barriers would have to be overcome for this to be achieved, especially analysis of potential external pollution costs would have to be undertaken. As water becomes relatively scarcer, and governmental priorities may also shift, water will have to go to its highest economic use if conflict is to be avoided. Farming will have to demonstrate that high value crops deserve water, and changes in the crops grown will probably have to occur. Farming does, however, compare favourably with forestry in economic terms.

If evidence drawn from other semi-arid regions, such as Chile, is used it is also possible that water trading could negate the requirement for further water supply impoundment (the Mountain View Dam), making future water rate increases less excessive.

The net back analysis demonstrates that under certain circumstances, in aggregate, some crops become uneconomic as the full economic cost of water is used to calculate the true net present value of crops. However, any conclusions drawn from this analysis are tentative because, it is very sensitive to changes in fixed cost allocations to crops grown, and assumed demand elasticities.

It is interesting to note that in the net back study (farm data largely drawn from Viljoen et al. 1996) mangoes are relatively uneconomic, however, in Olbrich & Hassan ed. (1998) they provide some of the best returns, with high net present values. This could be because Olbrich & Hassan use gross margins, whereas this study uses net margins.

The efficiency gains that have been shown in this study should drive policy makers to encourage and promote the trading of water rights in other areas of South Africa and to extend trading between different economic sectors (such as between agriculture and industry.) Catchment Management Agencies (CMAs) and other water institutions that are being established in line with the new National Water Act, 1998, can play an important role in advocating and facilitating the trading of water rights.

There is a need for further research to determine more accurately the benefits of water trading and to determine the institutional requirements for trading to take place on a wider basis. Policy makers and water users need to understand the benefits of trading and the role of market mechanisms and research that achieves this should be encouraged.

Bibliography

de Alessi, L. (1981) "The Economics of Property Rights: A Review of the Evidence", Research in Law and Economics, Vol. 2, pp. 1-47.

Allan, T. (1995) Water deficit regions: economic and political issues and policy options, SOAS working paper

Anderson, T. L (ed.) (1983) Water Rights: Scarce Resource Allocation, Bureaucracy and the Environment, San Francisco: Pacific Institute for Public Policy Research

Anderson, T (ed.) (1994) Continental Water Marketing, Montana: Political Economy Research Center

——— & Snyder, P. (1997) Water Markets, Washington D.C. Cato Institute

Anglo American (1995) Optima, September

Armitrage, R (1997), "Farmer Questionnaire: A", University of Natal, *Water Research Commission report K5/870*, Pretoria.

Asmal, K. (1995) The National Water Conservation Campaign, Balancing supply and demand. Department of Water Affairs and Forestry, Pretoria.

Asmal, K. (1997) Speech and the news conference on water tariffs, 3 March, Johannesburg.

Ault, D. E. and Rutman, G. L. (1979) "The Development of Individual Rights to Property in Tribal Africa," Journal of Law and Economics, vol. 22, pp. 163-82.

Backeberg, G. R. (1995) Towards a Market in Water Rights: A pragmatic institutional Economic Approach, Discussion paper.

——— (1996a) The Challenge of Irrigation Policy Reform in the Mature Water Economy of South Africa. In: Pigram, J. J. (1996) Security and Sustainability in a Mature Water Economy. Armidale NSW: Centre of Water Policy Research, University of New England.

——— (1996b), "Policy Proposal for Irrigated Agriculture in South Africa". *Water Research Commission* report KV96/96, Pretoria.

Barzel, Y. (1989) Economic Analysis of Property Rights. Cambridge: Cambridge University Press.

Bate, R. and R. Dubourg (1997) A Netback Analysis of Irrigation Water Demand in East Anglia, Journal of Environmental Management, 49, 311-322.

Bates, R. H. (1981) Markets and States in Tropical Africa: The Political Basis of Agricultural Policies, Berkeley and Los Angeles: University of California Press.

——— (1983) Essays on the Political Economy of Rural Africa, Cambridge: Cambridge University Press

——— (1989) Beyond the Miracle of the Market: The Political Economy of Agrarian Development in Kenya, Cambridge: Cambridge University Press.

Baumol, W. J. and Oates, W .E. (1988) 1975 The Theory of Environmental Policy, Cambridge: Cambridge University Press.

Becker, N. (1995) Value of moving from central planning to a market system: lessons from the Israeli water system. *Agricultural Economics*, **12**:11–21.

Brehm, M. and Quiroz, J. (1995) The Market for Water Rights in Chile: the major issues, World Bank Technical Paper number 285, Washington, D.C

Briscoe, J. (1996), "Water as an Economic Good: The idea and what it means in practice", *World Bank*, Washington DC.

Bromley, D. (1991) Environment and Economy, Oxford: Basil Blackwell.

_____ and Cernea (1989) The Management of Common Property Natural Resources and Some Conceptual and Operational Fallacies, Washington D. C.: The World Bank, Discussion Paper No. 57.

Brubaker, E. (1995) Property Rights in the Defence of Nature, Earthscan Publications Ltd.

Bullock, J and Darwish, A. (1993) Water Wars: Coming Conflicts in the Middle East, London: Victor Gollancz

Buchanan, J. M. and Tullock, G. (1962) The Calculus of Consent, Michigan: Ann Arbor.

Carruthers, I and Stoner, R. (1981) Economic Aspects and Policy Issues in Groundwater Development, World Bank Staff Working Paper No. 496, Washington DC: The World Bank.

Coase, R. H. (1984) "The New Institutional Economics," Journal of Institutional and Theoretical Economics, Vol. 14, pp. 229-31.

COMBUD (1994) "Enterprise Budgets," *Directorate of Agricultural Economics*, Department of Agriculture (RSA), Pretoria.

Conley, A. H. (1994) The Water Resources of South Africa In: Large Dams and Water Systems in South Africa.

Department of Agriculture (1996), "Report on the Role of Agriculture in the South African Economy", *National Department of Agriculture*, Pretoria.

DWAF (Department of Water Affairs and Forestry) (RSA) (1995) Discussion Document on Future of Irrigation in South Africa, Pretoria

DWAF (1995) Discussion document on future irrigation in South Africa, Pretoria.

DWAF (Department of Water Affairs and Forestry) (1996), "White Paper on National Water Policy for South Africa", *Department of Water Affairs (RSA)*, Pretoria.

DWAF (1996) Water Law Principles, Document for discussion, Pretoria.

DWAF (1997) A Resource Pricing Policy for South African Water, 13 May, Pretoria.

DWAF (Department of Water Affairs and Forestry) (1997), "A Resource Pricing Policy for South African Water", *DWAF*, Pretoria.

Directorate Agricultural Statistics and Management (1997), "Abstract of Agricultural Statistics, *National Department of Agriculture*, Pretoria.

Demsetz, H. (1967) "Toward a Theory of Property Rights," American Economic Review, Vol. 57, pp. 347-59.

Deininger K. and H. P. Binswanger (1995) Rent Seeking and the Development of Large-Scale Agriculture in Kenya, South Africa, and Zimbabwe, Economic Development and Cultural Change, 493-522

Dubourg, W.R "The Sustainable Management of the Water Cycle - Economics and Policy", CSERGE, *National Rivers Authority*, Bristol

Economist, (1996) Water in the Middle East: As Thick as Blood, January 5th.

Ensminger, J. (1992) Making a Market: The Institutional Transformation of an African Society, Cambridge: Cambridge University Press.

ETG (1995) Limpopo Government Water Scheme, Environmnetal Impact Report

Hall, C. G. (1939) The Origin and Development of Water Rights in South Africa, Oxford: University Press.

Hassan, R. et al. (1995) Economic Policies and the Environment in South Africa: the case of water resources in Mpumulanga. Pretoria: Forestek.

Hearn, R. R. and Easter, W. K. (1995) Water Allocation and Water Markets: An Analysis of Gains-from-Trade in Chile, World Bank Technical Paper number 315. Washington, D.C.

Hearne, R. R. and Easter, K. W. (1997) The economic and financial gains form water markets in Chile. *Agricultural Economics*, **15**, 187–199.

Holden, P. and Thobani, M. (1996) Tradable Water Rights: a property rights approach to resolving water shortages and promoting investment. World Bank Policy Research Working Paper 1627, Washington, D.C.

Howe, G. and le Roux, P. (Eds.) (1992) Transforming the Economy: policy options for South Africa, Indicator Project South Africa, University of Natal and the Institute for Social Development, University of the Western Cape.

Joint Inkomati Basin Study (JIBS), Department of Water Affairs and Forestry (RSA), Pretoria Chunnet, Fourie and Partners (RSA)

Johnson, R. N., Gisser, M. and Werner, M. (1981) The Definition of a Surface Water Right and Transferability. *Journal of Law and Economics* **24**:273–288.

Krueger, A. O. (1974) "The Political Economy of the Rent-Seeking Society," American Economic Review, Vol. 64, pp. 291-303.

LAPC (Land and Agriculture Policy Centre of South Africa) (1995) Position Paper on the Trading of Usage Rights to Water

Leal D and Anderson, T (1991) Free Market Environmentalism, San Francisco: Pacific Research Center

Libecap, G. D. (1990) Contracting for Property Rights, Cambridge: Cambridge University Press.

Livingstone, M. L. (1995) Designing Water Institutions: Market Failures and Institutional Response. *Water Resources Management*, **9**:203–220.

Lowi, M. R. (1993) Water and Power: The Politics of a Scarce Resource in the Jordan River Basin, Cambridge: Cambridge University Press

Mbaku, J. (1991) "Property Rights and Rent Seeking in South Africa," Cato Journal, Vol. 11, pp. 135-50.

Mbaku, J. and C Paul (1989) Political Instability in Africa: A Rent-Seeking Approach, Public Choice 63:63-72

McCormick, Z. (1994) Institutional Barriers to Water Marketing in the West. *Water Resources Bulletin*, **30(6)**:953–961.

McLaren, J. P. S. (1972) The Common Law Nuisance Actions and the Environmental Battle – Well-tempered swords or broken reeds? *Osgoode Hall Law Journal* **10**; 3:505 – 561.

Mirrilees, R.L. Forster, S.F. & Williams, C.J. (1994), "The Application of Economics to Water Management in South Africa", Institute of Natural Resources, University of Natal - *Water Research Commission* report 415/1/94, Pretoria.

Mpumalanga Department of Agriculture (1996) Proposed construction of a new dam in the Crocodile River Catchment to improve water supplies in the Crocodile River. Executive Council Memorandum.

NDA (National Department of Agriculture) (1995) Trends in The Agricultural Sector No. 56, Pretoria

Nell, C (1989) Water Outside Control Areas, South African Farmer's Weekly

North, D. (1981) Structure and Change in Economic History, New York: Norton.

______ (1990) Institutions, Institutional Change and Economic Performance, Cambridge: Cambridge University Press.

Olbrich, B and AM van Tienhoven (1995) Characteristics of the Crocodile River Catchment, Mpumalanga, Pretoria: Forestek, CSIR, Working Paper.

Olbrich, B. ed. (1997) A comparison of the economic efficiency of forest plantations and irrigated agricultural crops. WRC Progress Report.

Olson, M. (1967) The Logic of Collective Action, Cambridge, Mass: Harvard University Press.

Ostrom, E. (1986) "An Agenda for the Study of Institutions," Public Choice, vol. 48, pp. 3-25.

_____ (1990) Managing the Commons, Cambridge: Cambridge University Press.

_____ et al. (1994) Institutions for Sustainable Development, Boulder: Westview

Ostrom, V., Feeny, D. and Picht, H. (ed.) (1988) Rethinking Institutional Analysis and Development: Issues, Alternative and Choices, San Francisco: ICS Press.

Palmisano, J (1996) A Market in Emission Credits, London: Institute of Economic Affairs

Pearce, F (1992) The Dammed: Rivers, Dams, And The Coming World Water Crisis, London: The Bodley Head

Penningtom, M (1997) Conservation and the Countryside: By Quango or Market, London: Institute of Economic Affairs

Pigram, J. J. (1993) Property Rights and Water Markets in Australia: An Evolutionary Process Toward Institutional Reform. *Water Resources Research* **29(4)**: 1313–1319.

Preston, G. (1995) The National Water Conservation Campaign, Pretoria.

RSA (1995) Abstract of Agricultural Statistics

Randall, A (1981) Resource Economics: An Economic Approach to Natural Resource and Environmental Policy, Columbus:Grid Publishing

Robbins, D. (1995) Thirsty Land: South Africa's water resources into the 21st Century, Optima, September.

Rosegrant, M. W. and Schleyer, R. G. (1994) Reforming Water Allocation Policy Through Markets in Tradable Water Rights: Lessons from Chile, Mexico, and California. Washington DC: International Food and Production Technology Division, EPTD Discussion Paper No. 6.

_____ (1996) Establishing tradable water rights: implementation of the Mexican water law. *Irrigation and Drainage Systems* **00:** 263–279.

Saliba, B and Bush, D (1987) Water Markets in Theory and Practice: Market Transfers, Water Values and Public Policy, London: Westview Press

Sandler, T. and Tschirhart, J. T. (1980) The Economic Theory of Clubs: An Evaluative Survey. *Journal of Economic Literature*, **XVIII**: 1481 – 1521.

Schlager, E. and Ostrom, E. (1992) Property-Rights Regimes and Natural Resources: A Conceptual Analysis. *Land Economics* **68(3)**: 249 – 262.

Schlager, E., Blomquist, W. and Yan Tang, Shui. (1994) Mobile Flows, Storage, and Self-Organized Institutions for Governing Common-Pool Resources. *Land Economics,* **70(3)** 294-317.

Schleyer R. G. (1992) Chile's Market-Oriented Water Policy: Institutional Aspects and Achievements, in World Bank (1995)

Sellick, C. (1997) Crocodile River Catchment: Guide Water Plan Part One – Situation Assessment, Pretoria

Simon, H. (1961) Administrative Behaviour (2nd Ed.), New York: Macmillan.

_____ (1978) "Rationality as a Process and as Product of Thought," American Economic Review, 68, pp. 1-16.

Smith, R. J. (1981) "Resolving the Tragedy of the Commons by Creating Private Property Rights in Wildlife," Cato Journal, Vol. 1, pp. 439-68.

Stall, M. (1993) "Land Degradation in East Africa," Ambio, Vol. 22, pp. 505-8.

Stigler, G. J. (1974) "Free Riders and Collective Action: an Appendix to Theories of Economic Regulation," Bell Journal of Economics, pp. 359-365.

Sturgess, G. L. and M. Wright (1993) Water Rights In Rural New South Wales: The Evolution of a Property Rights System, St. Leonards, Australia: The Centre For Independent Studies

Sugden, R. (1986) The Economics of Rights, Co-operation and Welfare, Oxford: Blackwell.

Tang, S. Y. (1992) Institutions and Collective Action: Self-Governance in Irrigation, San Francisco: ICS Press.

Thorsen, J. E. (1989) Water Marketing in Big Sky Country: An Interim Assessment. *National Resources Journal,* **29**:479–488.

Tullock, G. (1967) "The Welfare Costs of Tariffs, Monopolies and Theft," Western Economic Journal, Vol. 5, pp. 224-32.

_____ (1993) Rent Seeking, Aldershot: Edward Elgar.

Umbeck, J. (1981) Might makes Rights: A theory of the formation and initial distribution of property rights. *Economic Inquiry* **XIX**:38 – 59.

USAID (1993) Water Resources Action Plan for Water, Uys, M (1992) Statutory protection for the water requirements of natural ecosystems, Koedoe, 35,1,101-118.

Van Dyk, H. (1998a) Crocodile River Main Irrigation Board: Analysis of Current Pricing. Pretoria.

van Rooyen, C. J. and Nene, S. (1996) What can we learn from previous small farmer development strategies in South Africa? *Agrekon* **35**;4.

van Rensburg, J. (1997), " The Economics of Sugar and Banana Farming", *BDT Janse van Rensburg - Agricultural Economist*, Standard Bank, Mpumalanga Provincial Office.

Vaux H and Howitt R (1984) "Managing Water Scarcity: An Evaluation of Interregional Transfers", *Water Resources Research*, 20:785-792)

Viljoen, M.F, Potgieter, P.J, du Plessis, L.A, van der Ryst, C. (1996), "Feasibility Study of the Mountain View Dam Project - interim report 2, part 1", *University of the Orange Free State.*[30]

Vos, W. J. (1978) Principles of South African Water Law (2nd ed.). Cape Town: Juta and Co.

WRC (forthcoming) A Holistic, Catchment Scale, Comparison of Water-Use Efficiency of Crops, focusing on the Comparison between Forest Plantations and Key Irrigated Agricultural Crops (#666) Division of Forest Technology, Council for Scientific and Industrial Research

WRC (1995) The Alternative of Property Rights to Water and the Market in Water rights: A Response to the Invitation for Comment by the Minister of Water Affairs and Forestry, Proceedings of a Workshop, 22 June 1995, Pretoria

Williamson, O.E (1966), "Peak-Load Pricing and Optimal Capacity Under Indivisibilty Constraints", *The American Economic Review*, Vol. 57: pp 810-827.

______ (1985) The Economic Institutions of Capitalism, New York: The Free Press

______ (1991) "Economic Institutions: Spontaneous and Intentional Governance," Journal of Law, Economics and Organization, vol. 7(Special Issue), pp. 159-87.

Williamson O. E. (1991) Economic Institutions: Spontaneous and Intentional Governance. *The Journal of Law, Economics and Organization* **V7 Sp**: 159 –187.

World Bank (1995a) Water Policy and Water Markets, Selected Papers and Proceedings for the World Bank's Ninth Annual Irrigation and Drainage Seminar, Annapolis, Maryland, December 8-10, 1992.

World Bank (1995b) Water Pricing and Management, South African Water Conservation Conference, World Bank Presentation, October 2nd.

Yin, R. K. (1994) Case Study Research, London: Sage.

[30] Published in Afrikaans

Appendix A

TECHNOLOGY TRANSFER ACTIONS THAT EMANATED FROM THE RESEARCH PROJECT:

1 Post-graduate studies

TREN, R.J. 1997 A net back analysis of irrigation water demand along the Crocodile River – South Africa. MSc Dissertation, University College London

2 Papers presented at conferences

TREN, R.J. 1998 Net back analysis – An indicator of sustainability and efficiency of water use. IAIA South Africa Congress, October 1998

Appendix B

According to Feeny, (1994) institutional arrangements inform decision makers about their standing and about the consequences of their behaviour. Mainstream economics does not provide a basis for analysing institutions, assuming them to be fixed and determining efficiency within that context. The understanding of institutions is therefore implicit in economics but is not made explicitly in the mainstream literature. Explicit discussion would highlight the importance of rules for policy advice (Everest, 1995).

North (1981, 203) distinguishes among constitutional rules, operating rules and normal behavioural codes. Constitutional rules are "for making other rules" (Davis and North, 1971, 6). Operating rules are derived from them for the functioning of economic activities and behavioural codes are those which are less explicit, cultural endowments.

This research uses the framework of the new institutional economics (NIE) (see North 1990 and Ostrom 1986) as its theoretical basis. The NIE fills the void left by neo-classical economics.

The NIE literature suggests that decentralisation of decision making to localised groups and individuals, with minimal centralisation, leads to more efficient and equitable management of resources (Bromley and Cernea, 1989; Bromley, 1991; E. Ostrom 1994). This hypothesis has been confirmed by several empirical studies (inter alia Anderson 1983, E. Ostrom 1990; Tang, 1992).

The NIE is founded on the premise that individuals are the primary unit of analysis, and it makes certain assumptions about the individual's decision-making processes. Two assumptions often made are that individuals act rationally, subject to certain limitations (for a description of "bounded rationality" see e.g. Simon, 1961) and, second, individuals behave opportunistically (see e.g. Williamson, 1985).

The NIE analysis draws *inter alia* from the property rights literature (see e.g. Demsetz, 1967; Barzel 1989), from the rent-seeking literature (see e.g. Tullock, 1967; Krueger, 1974), from the transaction-cost economics literature (see e.g. Williamson, 1985, 1991) and from the social choice literature (see e.g. Olson, 1967; Sugden, 1986).

The property rights literature stresses the efficiency of private ownership. In particular, it has been suggested that private property will emerge when the losses from open access exceed the costs of monitoring and enforcing these new private boundaries (Demsetz, 1967)[31]. Anderson and Hill (1975) concur and explain that as a resource becomes scarcer due to greater demand, its value increases to such an extent that ownership of the resource becomes more important. The "privatisation" of water has occurred in locations where demand has been high relative to supply.

The rent-seeking literature suggests that communal management (and, even more so, state management) of resources may suffer from inefficient bureaucratic involvement, with rents being extracted by managers rather than being disbursed to members of the community (Tullock, 1993) - reducing the incentive for opportunistic individuals to conserve natural resources.

The transaction-cost economics literature emphasises the problem of asset specificity. Asset specificity is a problem for those seeking to alter the institutional arrangements governing resource use because changes in these institutional arrangements may well result in irreversible changes to the pattern of resource use[32]. As a result, those who believe the new pattern of resource use will not be in their favour are likely to object to the change. Clearly, asset specificity is fundamental to the problem of collective action for institutional change and the greater the expected asset specificity of the institutional change, the greater the problem of collective action. In a broad sense, path dependence is often caused by asset specificity.

The social choice literature explains why communal self-regulating management becomes unworkable if the "commune" increases in size and scope because of free riding (see e.g. Olson, 1967). However, size can be large before a failure of self-regulation occurs (see e.g. Ostrom, 1990).

---

[31] Whether private, communal or public property has emerged will be a function of the available economic benefits to cover differential costs.

[32] For example, land which has been intensively farmed in monoculture is a specific asset. Farmers have invested time and money in special equipment to develop that land, often based on cheap/free water. They will therefore oppose any change in water access/rights as it is likely to make redundant all of their "specific" investments.

This analytical synthesis shows that misuse and misallocation of resources can mainly be attributed to the absence of required institutions. It also avoids the simplistic, empirically flawed and culturally specific prescriptions for sustainable resource use that until recently pervaded much of the literature (see e.g. Carruthers and Stoner, 1981, who favour the Leviathan approach above all else, and Smith, 1981, who favours the privatisation approach above all else.

Appendix C

Efficient Water Pricing

Marginal Cost Pricing

Marginal cost pricing lies behind many of the economic solutions to resource allocation. We assume that the objective of the resource price setter is to maximise social welfare by maximising the net benefits from an economic activity. We can represent net benefits as follows:

$$NB = \int_0^q P(Q)dQ - C(q)$$

Where P(Q) is the demand curve for the product or resource Q. C(q) represents the costs of supplying amount q. In maximising the net benefits, the standard result produces:

$$P - \frac{\partial C}{\partial Q} = 0$$

rearranging we get:

$$P = \frac{\partial C}{\partial Q}$$

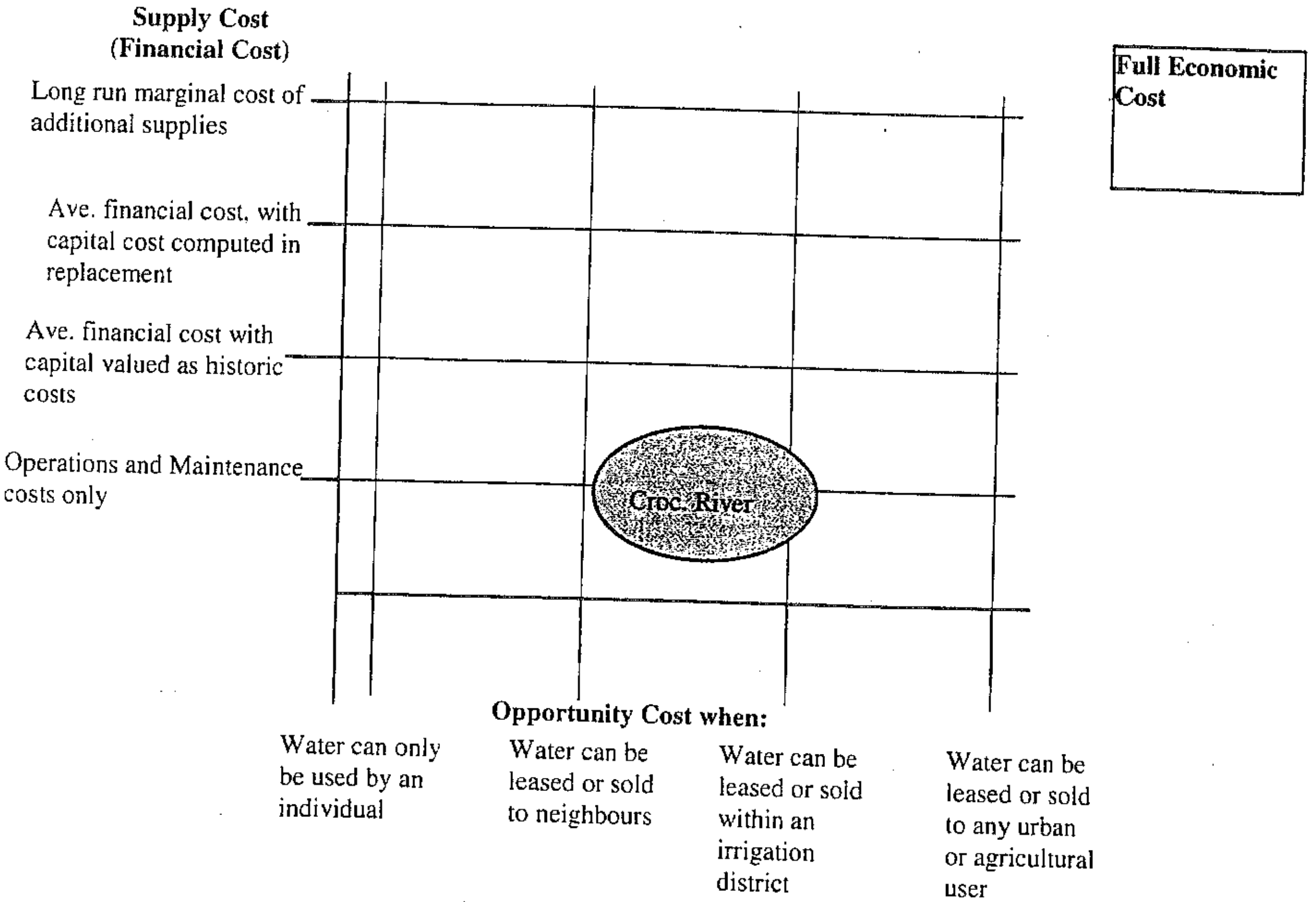
This states that if policy is to maximise net benefits from an economic activity, the marginal benefits from the activity should equal marginal costs.

Full Economic Costs of Water

Two costs are identified in the use of water. The first is known as the supply or use costs which are made up of all the costs of building and maintaining the infrastructure that transports the water to the user. The other cost which has been referred to above is the opportunity cost, which again, is the cost imposed on an alternative user by not having the resource for his own use. The size of the opportunity cost depends on the value of water in its highest value alternative use. The template below (Briscoe 1996) shows the interaction between these two costs, and that only when both are fully accounted for is water at its full economic cost. With only operations and maintenance costs being covered by water charges, the cost of water is at the bottom left hand corner. If full trading of water were permitted, water would be sold to the highest value user, and thus full opportunity costs would be accounted for. In such a situation the cost of water would be at the bottom right hand corner. It is only once the full financial or supply costs of water are accounted for in addition, that water is at its full economic cost, i.e. at the top right hand corner of the template.

Currently there is a certain amount of trading of water rights between farming enterprises along the Crocodile River, but no trading has taken place between irrigators and non-irrigation users.

Figure 1 Schematic representation of supply cost and opportunity cost (Briscoe 1996)



The area along the Crocodile River, particularly near the town of Nelspruit is said to be the fastest growing area in South Africa in terms of population and industrial development. The opening up of the border between South Africa and Mozambique and the increased use of Maputo as the nearest port for regionally produced goods can only ensure the sustained long term urban growth in the area. The demand for non irrigation water is likely to grow significantly well into the next century.

The right to clean water that is enshrined in the constitution and the focus of the White Paper 1997 to providing drinking water to those that were previously excluded will require a large increase in the supply of urban and industrial water. As it is generally accepted that the highest value of water is in urban and industrial use (Briscoe, J.) and there is a commitment to move away from subsidised water, the opportunity cost of water is set to rise.

Optimal Pricing with Indivisible Plant - 'Lumpy' Investments

Above the concept of marginal cost pricing was introduced. Economic theory tells us that the optimal time to invest in new capacity (in this case new dams or reservoirs) is when the price of the resource equals long run marginal cost (LRMC). This however assumes that the marginal cost function is continuous and smooth and that additional investment in capacity can be made in infinitely small increments. This is an unrealistic assumption when dealing with water where the next investment is likely to be a new dam and where the investment is not divisible but comes in one 'lump'.

One implication of this is on the optimal time to invest in new plant. There are likely to be capacity constraints in water supply and as demand rises, the capacity constraints will be met. Once at a capacity constraint, price rises to reflect scarcity and traditionally once the price equals LRMC, investment in new plant is economically justified.

In the case of lumpy investments however, new capacity cannot be increased just to satisfy the marginal increase in demand. The investments are large and once made there will be excess capacity. Once the new capacity is completed, capital costs are written off, and the price of the resource falls to the new short run marginal cost (SRMC). The excess capacity and price at SRMC implies losses in producer surplus and from a social point of view, the investment should only be justified if the loss in producer surplus is matched by a gain in consumer surplus. In order to offset the loss in producer surplus therefore the price should rise to a level higher than LRMC. Figure 2 (adapted from Williamson 1966), shows that price should rise to $P_{(t)}$, above LRMC, so that the gain in consumer surplus is equal to the loss in producer surplus.

The socially optimal time to invest in new plant is when the present value of net benefits is maximised. The benefits from investment are the sum of producer and consumer surplus and the costs are represented by the lost interest on investment capital.

The net benefits are a function of the demand curve D(P,t) where P is the price of the resource and t is the time period.

$$D(P,t) = Min\left[\overline{Q}, D(c,t)\right]$$

where $\overline{Q}$ is the capacity constraint, and c is the short run marginal cost. The correct time to invest in new capacity is when the present value of net benefits is maximised. The present value of net benefits can be represented as follows:

$$\int_0^{t_1} NB(t)e^{-rt}dt + \int_{t_1}^{t(I)} NB(Q,t)e^{-rt(I)}dt + \int_{t(I)}^{t_2} NB(t)e^{-rt}dt - Ie^{-rt(I)}$$

Where t_1 represents the time period when the capacity constraint is met, t(I) represents the time period in which the investment in new capacity takes place and t_2 is the time period when the next capacity constraint is met.

Maximising the above expression yields:

$$NB(Q,t(I))e^{-rt(I)} - NB(t(I))e^{-rt(I)} + rIe^{-rt(I)} \geq 0$$

Solving this implies that an increase in capacity is justified when

$$NB(Q,t(I)) - NB(t(I)) = rI$$

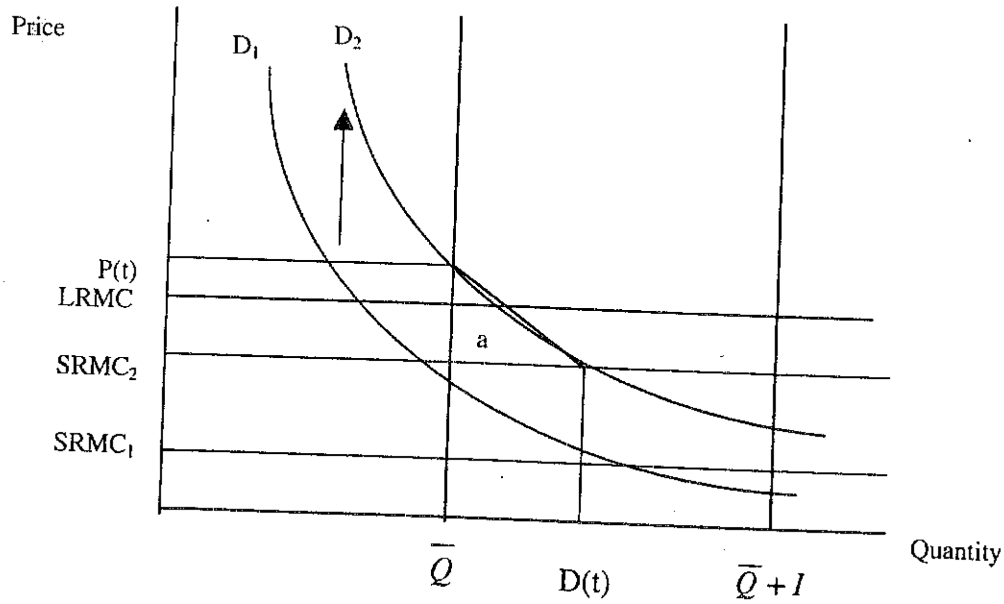
In other words, investment in new capacity is justified when the marginal benefits from expanding capacity are equal to the lost interest caused by the investment.

Figure 2 below shows the demand curve at capacity and the gain in consumer surplus that would come about if capacity were to be increased and the implicit abstraction price were to fall to $SRMC_2$. The gain in consumer surplus, area a, can be approximated as:

$$\frac{[P(t) - SRMC_2][Q(t) - \overline{Q}]}{2} = rI$$

The expansion in capacity is justified when the above expression is satisfied. By modelling demand the optimal time period, and hence the optimal abstraction price, for an increase in capacity can be found.

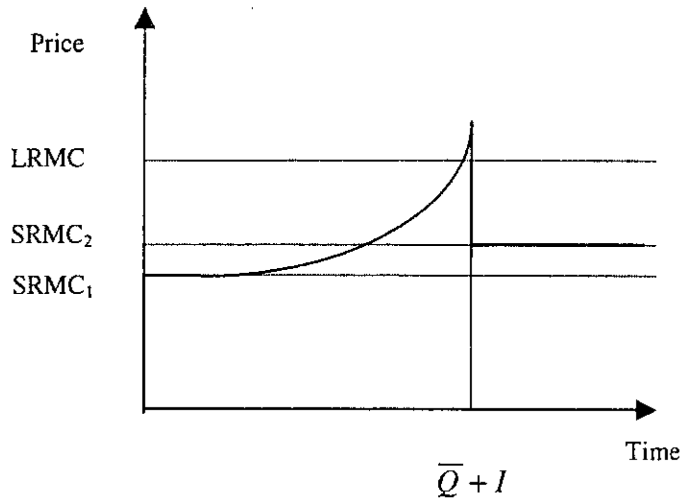
Figure 2 Demand for water with capacity constraints



For the purposes of this study, demand will be modelled based on existing demand and projections of future demand. The size of the next proposed investment in new capacity is known as is the current price paid by irrigators, urban users and industrial users. With this information a simple demand curve can be modelled and the price that signals the socially optimal time for investment in new capacity can be derived. The baseline price upon which demand is modelled will be the price paid by urban and industrial users. As demand increases, but supply is limited by the capacity constraint, the implicit abstraction price rises. This implicit abstraction price less the baseline price will give the opportunity cost of water use. This opportunity cost at each time can then be compared to the farmers maximum willingness to pay for water at every period and from this conclusions can be drawn as to the suitability of crops.

The optimal price path should approach the function shown in figure 3. In calculating the optimal price path, it is assumed that currently demand is at the target draft of 310.83 million m^3/annum. Urban use is scaled down to accommodate this assumption. The demand curve is modelled using a baseline price of R1.50/Kl or R1,500/Ml/day (detailed below). Price rises reflecting the increasing opportunity costs, and once the marginal benefits are sufficient to offset the marginal costs of increasing capacity, the dam is built and the efficient price of water is the new short run marginal cost, $SRMC_2$, as capital costs are sunk.

Figure 3 Optimal price path of irrigation water



Assume a demand function for water of

$$D = AP^e$$

where P = price, A = constant, e = price elasticity of demand

alternatively:

$$\ln D = k + e \ln P$$

Different assumptions are made as the size of the price elasticity of demand. Demand curves are calculated with a constant price elasticity (e) of -0.1, and -0.3 which are both inelastic and a more elastic demand is also modelled with an (e) of -1.0. While it is acknowledged that "..the price elasticity of demand for water is significantly negative, meaning that users react to price increases by reducing demand." (Briscoe,J. p8) the fact that the region's agriculture is heavily reliant on irrigation and that it is classified as a semiarid climate justifies an inelastic price elasticity of demand. Briscoe estimates that the price elasticity of demand for water in the United States ranges from between -0.1 and -1.0. For residential outdoor demand in a wet climate the price elasticity of demand can range from between -1.3 and -1.6.

The assumption of a highly inelastic demand is supported by anecdotal evidence collected by the authors through conversations with farmers in the area where many stated that the demand for water and the crops grown would not change if the price of water were to rise significantly.