University of Cape Town

Economics Department

Water Supply in the Eastern Cape

An economic case study of land rehabilitation in the Kromme River Catchment

Masters of Commerce in Economics by dissertation only

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GLLKAT005

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Declaration

I, **Katie Gull**, hereby declare that the work on which the thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work or any part of it has been, is being, or is to be submitted for another degree in this or any university. I authorise the University to reproduce for the purpose of research either the whole or any portion of the contents in any matter whatsoever.

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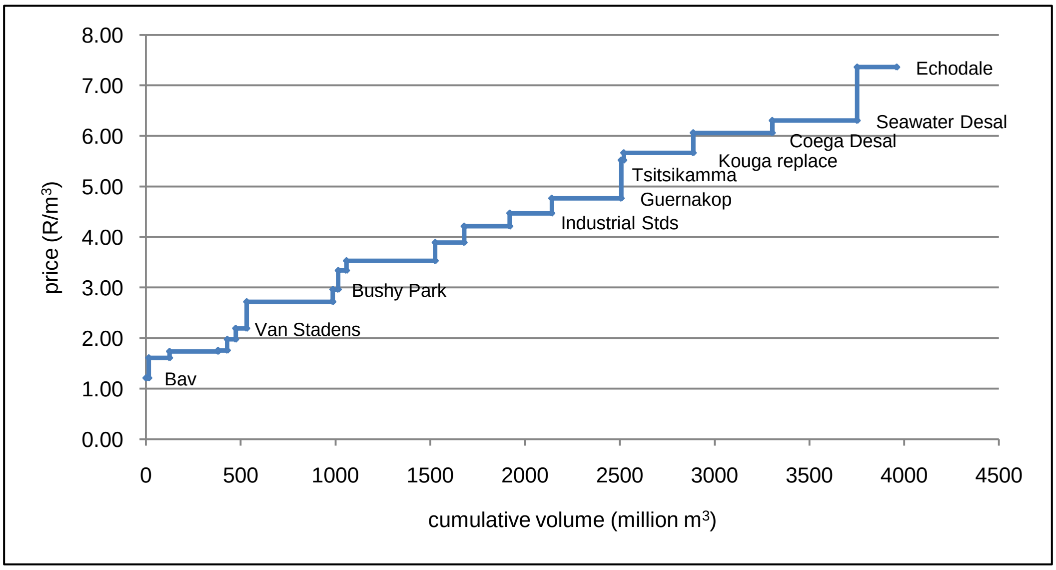
Executive Summary

South Africa is a water scarce country; with a mean annual precipitation of only 600 mm in 70% of the country and one of the lowest rain-runoff conversions in the world. South Africa consumes 31% of the available water resources, a high percentage by world's standards (National Planning Commission, 2011). Analysts predict that as South Africa approaches 40% consumption, South Africa will face a binding water constraint. Concern around future water supply is heightening due to increased demands from all sectors of the economy and growing awareness to protect our ecological reserves. Debates around future water supply are increasing; water reallocation in agriculture is being considered as a way to increase efficiencies and government is looking at capital intensive infrastructural developments to augment supply.

Nelson Mandela Bay Municipality (NMBM) faced severe water shortages in 2010 and projections estimated that future demand would outstrip future supply if no action was taken. NMBM receives 70% of its water supply from the Western system, a concentrated area with similar rainfall and weather patterns. As a result, the Department of Water Affairs and the NMBM are investigating possible supply schemes with the intention to maximise supply, minimise risk and minimise average costs.

Some of the proposed schemes include building a desalination plant, utilising groundwater from high-yielding boreholes, expanding existing dams and tapping into more of the Orange River water. An incremental cost curve, using the mean average cost of water, is created in this paper to compare the relative costs and supply of each proposed scheme. The comparison takes place over a 25 year timeframe and different methodologies are examined. The cost curve is a useful heuristic in understanding current and historic policy and assists the water manager in choosing the most secure cheap water at each step of the way.

Incremental Cost Curve of Water - using Levelised costs



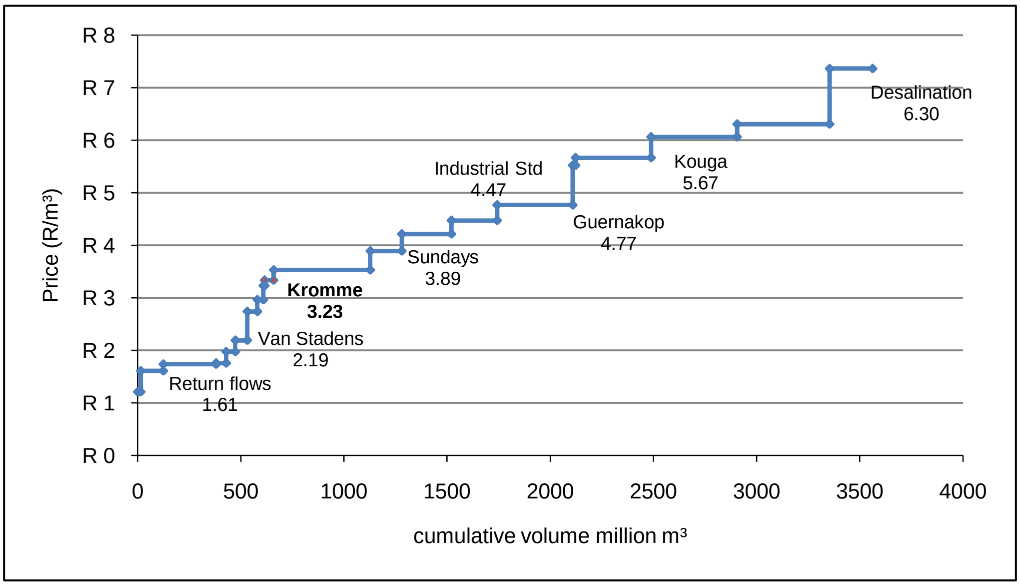
The analysis indicates that although the proposed desalination plant and the Nooitgedagt Low-Level schemes were expensive (averaging R6.18/m^3 and R3.52m^3 respectively), the schemes minimise risk by diversifying the current NMBM's bundle of water supply and provide the most water (432 million m^3 and 468 million m^3 respectively). The cheapest water included water trading and the reuse of agricultural return flow schemes, averaging R1.4/m^3. However, these schemes do not minimise risk and only augment water by an estimated 61 million m^3.

Catchment management is proposed as a possible augmentation scheme for the NMBM. The Kromme River, which supplies the Western system's dams, provides 40% of the NMBM's total water demand. However, the catchment is heavily degraded due to the invasion of alien invasive plants, the destruction of palmiet wetlands and poor farming practises. Not only do black wattles consume a lot of water, their roots are shallow which makes the river banks unstable, exacerbating erosion. Functioning wetlands usually provide water filtering and stabilising services and act as a buffer to floods. Ecological activists warn that the degradation of the catchment is compromising the NMBM's supply of water.

Using a cost-benefit analysis approach, the economical viability of restoration in the Upper Kromme Catchment over a 25 year period was examined. 'Working for Water', the main restoration intervention, has cost around R22 million. The expected and quantifiable benefits of restoration include improved land productivity for the private farmer and increased river yield, for the end-user, NMBM. The economic benefits amounted to R1.2 million in agricultural benefits and R8.5 million in hydrological benefits. The cost-benefit analysis showed that restoration is not an economically viable investment in Upper Kromme Catchment over both a 25 year and 50 year timeframe.

Using the incremental cost curve as the medium for comparison, it was investigated whether restoration in the Upper Kromme Catchment should be considered a possible augmentation scheme for the NMBM.

Incremental Cost Curve of Water – including the Upper Kromme Catchment



Additional water from the Upper Kromme costs R3.23/m^3 and thus falls within the cheaper group of schemes. Nevertheless, it only provides an additional 7.31million m^3 over 25 years and thus does not contribute significantly to the augmentation of NMBM's water supply sources and at the same time, does little to minimise the risk.

Nevertheless, one should not discard the importance of restoration as a means of catchment management. The delivery of the existing yield will be threatened if no action is taken and river flow losses are estimated at 0.115 million m^3/annum, costing the NMBM just under R20 000/annum.

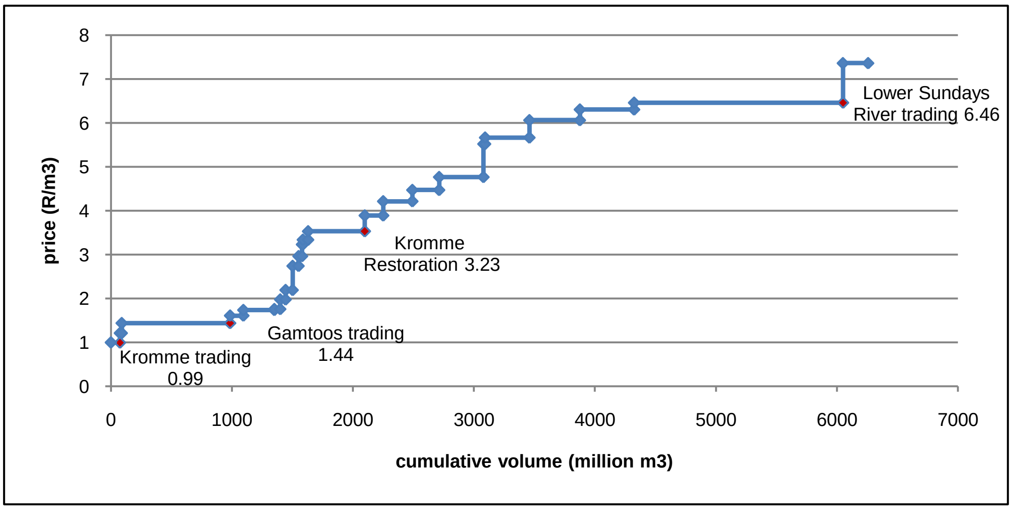
The possibility of water trading within the agricultural sector and across urban (NMBM) and agricultural sectors as a means of achieving allocative efficiency is explored in the final chapter. The opportunity cost of water, the foregone agricultural benefits, is used as a proxy for the economic value of water. Three agricultural areas which compete for water with the NMBM, the Gamtoos Valley, Lower Sundays River Valley and the Upper Kromme Catchment, were selected.

Comparing agricultural and urban value of water

Location	Total Yield (million m^3)	NMBM Opportunity Cost (R/m^3)	Agricultural Opportunity Cost (R/m^3)
Upper Kromme Catchment	74.58	1.61	0.99
Gamtoos Valley	896.00	3.53	1.44
Lower Sundays River Valley	1725.79	4.47	6.46

The economic value of water in the NMBM is greater than the agricultural value of water in both the Upper Kromme Catchment and Gamtoos Valley. It is suggested that water is transferred away from low-yielding agricultural uses towards high end urban uses to meet a Pareto efficiency condition. Alternatively, water should be transferred away from NMBM, towards agriculture in the Lower Sundays River Valley. Water trading in the Upper Kromme Catchment proves to be the cheapest water (R0.99/m^3).

Water trading as a possible scheme to augment NMBM

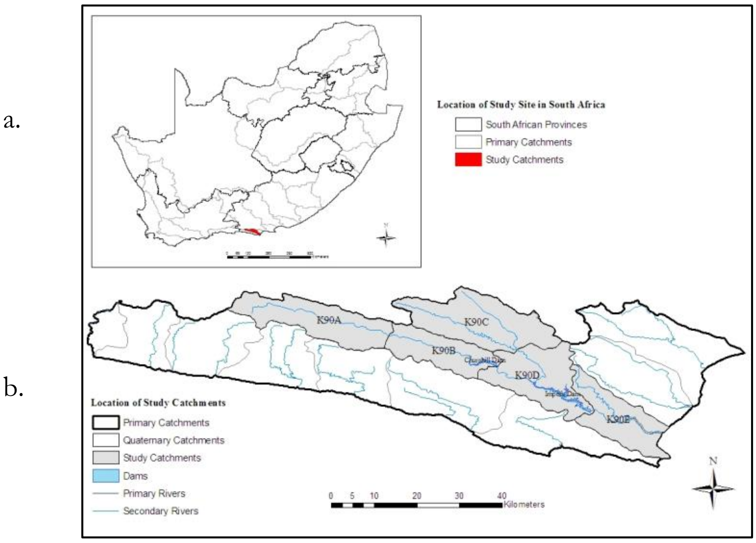


Preface

This thesis emerged from funded research by ASSET Research, contracted by Water Research Commission[1]. The project is co-funded by the 'Working for Water' programme. It forms part of a series of interdisciplinary studies focusing on the restoration of natural capital at nine sites throughout South Africa. The research stems from the hypothesis that restoring degrading landscapes has the potential to provide a quality flow of water, sequester carbon and improve land productivity. The studies will be merged in a meta-analysis using a systems model by a PhD student, drawing generic conclusions on restoration in South Africa.

The prescribed site was the Upper Kromme Catchment in the Eastern Cape, focussing on quaternary catchments K90A and K90B.

Quaternary catchments which constitute the Kromme River on a) the map of South Africa and b) as part of tertiary catchment 'K90' which extends into the Eastern Cape



Source: Rebelo, A (MSc dissertation in prep)

I was one of two researchers on this site, working alongside Alanna Rebelo, an ecology master's student at the University of Stellenbosch. Alanna's research focused on the physical aspects of the Kromme and the change in the landscape and hydrology of the system over time, whilst I examined the economic consequences of these changes and restoration interventions. Our research was independent, yet in order to gain a holistic understanding of the study, my paper should be read in conjunction with this study.

Even though this study focuses on a small catchment in the Eastern Cape, with little significance to South Africa as a whole, these findings can be generalised across South Africa.

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[1] Funded and commissioned by the Water Research Commission, Key Strategic Area: Water Utilisation in Agriculture

Acknowledgments

Firstly I would like to thank my supervisor, Prof. Anthony Leiman, for all his time, effort and unceasing dedication to my thesis. His support, guidance and advice throughout this time are truly appreciated.

I would like to thank the core team at ASSET Research, and particularly Prof. James Blignaut and Prof. Martin de Wit for giving me the opportunity to take part in an interdisciplinary study. Thank you to Alanna Rebelo for being an enthusiastic and passionate team-mate.

The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to the NRF.

I was overwhelmed by the generosity of people, some of whom I never even met, always so willing to help and provide me with information. Special thanks must go to:

- All the Upper Kromme River farmers for welcoming me onto their farms and into their homes and for sharing their personal stories and disclosing personal information
- Pierre Joubert, from the Gamtoos Irrigation Board, for giving so much giving so much time to my research and for providing me with contacts; s special thanks for the helicopter flight over the Kromme River and Gamtoos Valley
- Japie Buckle, from Working for Wetlands, for sharing his passion and for teaching me so much about wetlands and the ecology of South Africa
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- Cobus Ferreira and Glen Daniel from the Department of Water Affairs
- Matthew McConnachie for sharing his research pertaining to the Kromme River
- Dave Gerber from the Lower Sundays River Valley

Finally I would like to dedicate my thesis to my beloved grandmother, Dawn MacFarlaine (10 Oct 1927 – 18 March 2011). Her love for the natural world and interest in my work right up until her last days will never be forgotten.

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Abbreviations

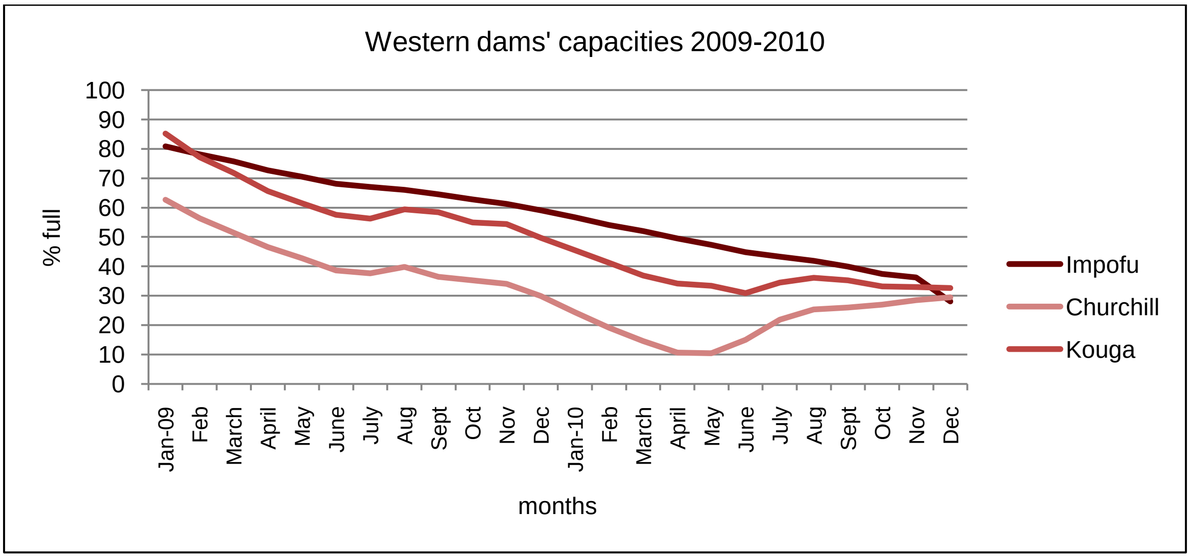
AIP	Alien Invasive Plant
BCR	Benefit Cost Ratio
CBA	Cost-Benefit Analysis
DWA	Department of Water Affairs
GIB	Gamtoos Irrigation Board
LM	Local Municipality
NMBM	Nelson Mandela Bay Municipality
PD	Person Days
PES	Payment for Ecosystem Services
PV	Present Value
TEV	Total Economic Value
WfW	Working for Water
WfWet	Working for Wetlands
WIMS	Working for Water Information Management System
WTA	Willingness to Accept
WTP	Willingness to Pay
WTW	Water Treatment Works

INTRODUCTION

South Africa is a water scarce country; with mean annual precipitation of only 600 mm in 70% of the country and experiences one of the lowest rain-runoff conversions in the world. South Africa consumes 31% of the available water resources, a high percentage by world's standards (National Planning Commission, 2011). Analysts predict that as South Africa approaches 40% consumption, South Africa will face a binding water constraint. Concern around future water supply is heightening due to increasing demands from all sectors of the economy and the need to protect our ecological reserves. Debates around future water supply are increasing; water reallocation in agriculture is considered as a way to increase efficiencies and government is looking at capital intensive infrastructural developments to augment supply.

The year 2010 has seen the Nelson Mandela Bay Municipality (NMBM) in the Eastern Cape, yet again experiencing severe water shortages. Flows in many nearby catchments reached critical levels and for the latter half of the year, the city's reservoirs were around 30% capacity. Figure 1 illustrates the change in capacities of NMBM's principal dams in the Western System, from 2009-2010.

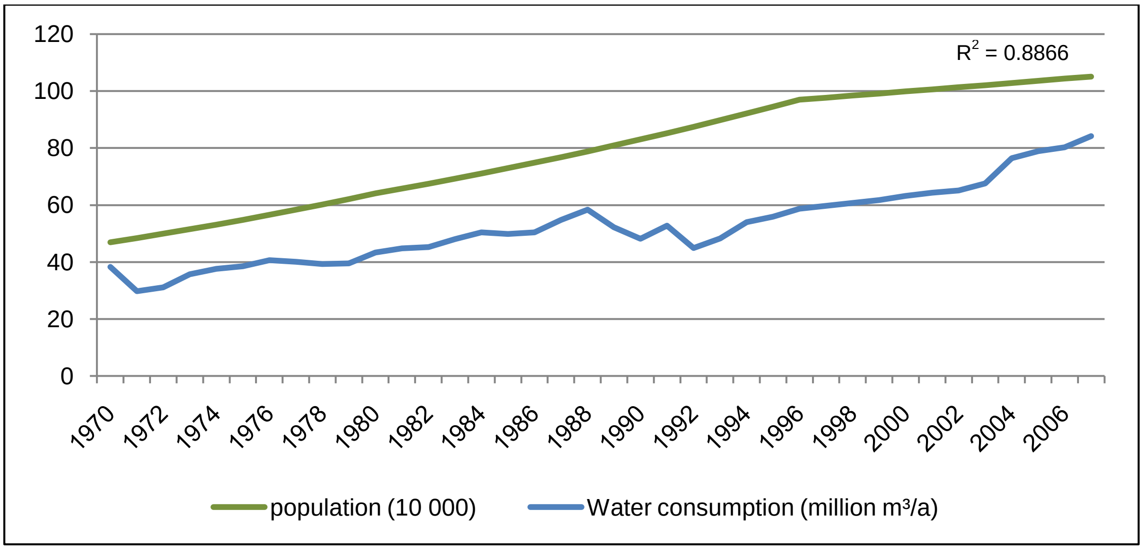
Figure 1: Western dam levels showing critical levels 2009-2010



Source: DWA, pers. comm. 2010

The region, being prone to both floods and droughts, has a history of water shortages. The NMBM has continually struggled to match the ever increasing water demand, whose increase is largely attributed to the ongoing influx of people to the area and rising economic activity (Raymer, 2008).

Figure 2: Historical Water Demand Trends 1970-2007



Source: Eberhard (2009)

The graph shows the correlation between historical population and water demand. As expected, a significant and positive correlation coefficient of 0.91 exists.

The water planners' problem has two major aspects, one concerning the mean water in storage, and the other risk at the lower tail of the storage distribution. The first means ensuring the volume of water ordinarily available is sufficient for normal needs; the second, involves ensuring that there is sufficient water in poor seasons to meet the city's minimum needs. The NMBM municipality is looking for ways to increase water volume and decrease risk by building new supply schemes, expanding existing sources and managing the municipality's demand. It is already clear that future water demand will outstrip current supply, and therefore efforts need to be undertaken to prevent this outcome (Eberhard, 2009). The *'Water Reconciliation Strategy Study for the Algoa Water Supply Area,'* commissioned by the Department of Water Affairs (DWA, 2010), will guide the NMBM on how to respond to the widening gap between water supply and water demand. Recommendations to augment water supply range from constructing desalination plants, to expanding existing infrastructure, to recycling and reusing water and exploiting productive boreholes.

The restoration of the Upper Kromme River Catchment is here being considered as a possible sustainable long-term means of augmenting NMBM's water supply. The Churchill Dam, which is supplied by the Kromme River, is a vital source of water for the NMBM, providing the municipality with a quarter of its water demand. The Churchill Scheme (which consists of Churchill Dam, Impofu Dam, Churchill and Elandsjacht Water Treatment Works) provides NMBM with an estimated 122Ml/d or roughly 36.5Mm^3 per annum (40% of its water demand).

Since 1950, the deterioration of the wetlands in the Kromme River has escalated. The invasion of alien invasive plants (AIPs), overgrazing and ploughing of the flood plains, the tarring and construction of roads and bridges and the channelling of the river have accelerated the degradation and compromised much of the catchment's health. Environmental activists have expressed fears that the Upper Kromme Catchment can no longer provide important ecosystem services and that this may threaten the future security of PE's water.

Should NMBM invest in catchment restoration in order to secure the expected benefits of improved water yield and water quality? This would involve the post-clearance follow-ups and the maintenance needed to control the further spread of AIPs, and rehabilitation of the wetlands. This improved catchment management option needs to be compared to alternative recommended water supply options in order to guide NMBM in its decision making.

This paper is divided into four chapters. Chapter One discusses the NMBM's existing water sources and future augmentation schemes. It establishes an average incremental cost supply curve, so that the cost of a cubic metre of water can be compared across proposed schemes and sources. An incremental (marginal) cost curve enables a value to be placed on the additional water expected from the Kromme River. This incremental cost curve also allows for the comparison of additional water coming to the NMBM from the Kromme, with additional water from elsewhere.

Chapter Two will focus on the restoration of the Kromme River Catchment. An overview of the site, restoration activities and background information commences the chapter. An in-depth investigation into the costs and benefits associated with the restoration activities follows so that a cost-benefit analysis can be performed to determine whether the restoration is economically justifiable. This chapter also establishes the cost of a cubic metre of water, so that restoration of the Kromme can be incorporated into the supply cost curve and be compared to other schemes.

A discussion around the opportunity cost of water in agriculture is contained in Chapter Three. Competition between agriculture and urban demands are increasing and water trading is continually raised as an option for securing future water supplies. Chapter Three investigates the opportunity cost of water in three agricultural areas in the Algoa Region where the water being used in agriculture, could be supplying the NMBM. The average opportunity cost of agricultural water is calculated and compared to the cost of securing water from the proposed schemes.

The dissertation concludes in Chapter Four with a summary of the key findings. It highlights the limitations of the study and provides recommendations for further research.

CHAPTER ONE

THE ECONOMICS OF NELSON MANDELA BAY'S WATER SUPPLY

A rational water manager faces a bounded rationality problem. He needs an array of water supplies that will maximise supply, minimise risk and minimize average costs. Since all three desires cannot be achieved simultaneously, the manager must take it step by step, choosing the most secure cheap water at each stage (Leiman and van Zyl, 2000).

This chapter is divided into two sections. The first section examines NMBM's current water sources, investigates the correlation and covariance among existing sources and determines the cost of current water supply. Section two describes the future augmentation schemes, analyzes the costs and ascertains the average cost of producing a cubic metre of water from each proposed scheme thereby enabling a marginal average cost curve for water as a whole to be created.

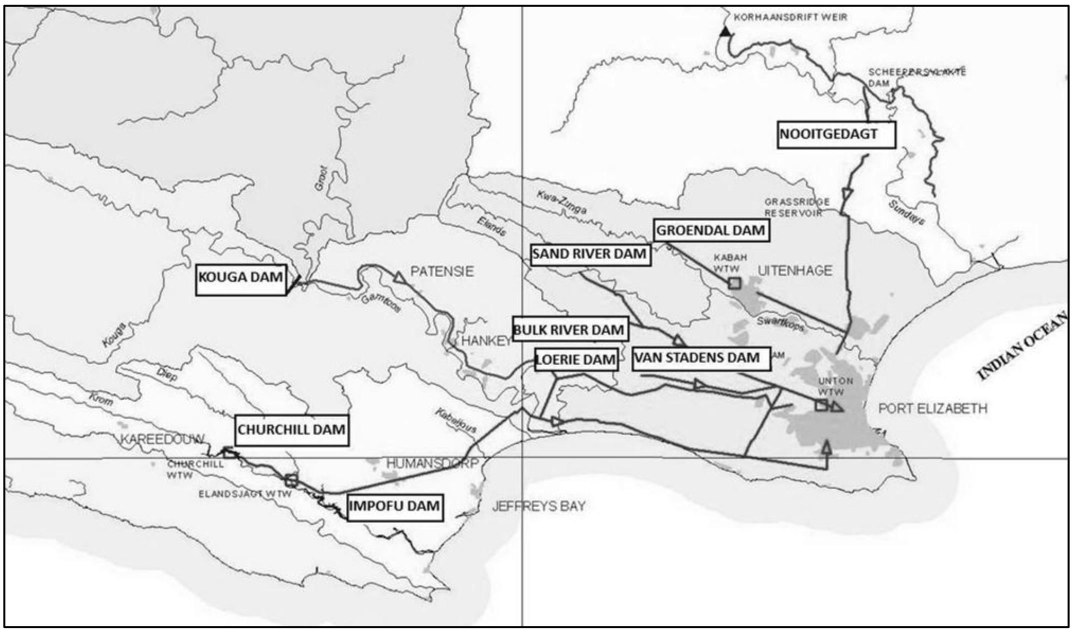
1 Nelson Mandela Bay Municipality's current water supply

1.1 Current Water Sources

Given the capacities of the present dams and water schemes, the total available water for urban use in the NMBM is 99 million m^3 per annum and irrigation use is set at 48.5million m^3/annum (DWA, 2010).

Figure 3 describes the NMBM's water sources and shows the locations each source.

Figure 3: Overview of NMBM's water sources



Source: Raymer (2008)

The supply sources can be divided into three systems, namely the Western, Eastern and Secondary Systems. The Churchill Dam, Impofu Dam, Kouga Dam and the Loerie Balancing Dam make up the Western System, and together provide the bulk of supply to the NMBM, roughly supplying 66% of all water to the municipality as shown in Figure 4 (DWA, 2010). Figure 5 illustrates the proportion of water flowing to NMBM from each water source over time.

Figure 4: NMBM's water sources

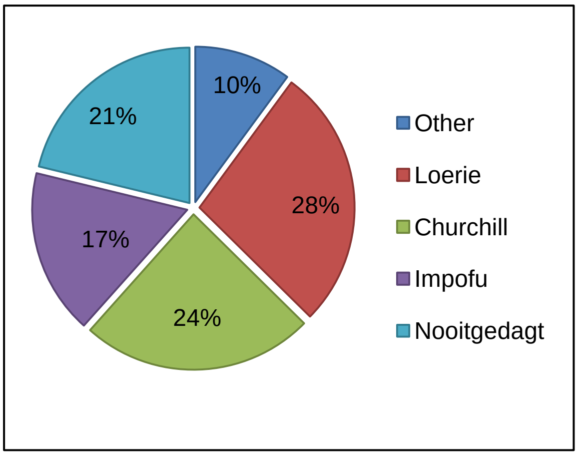
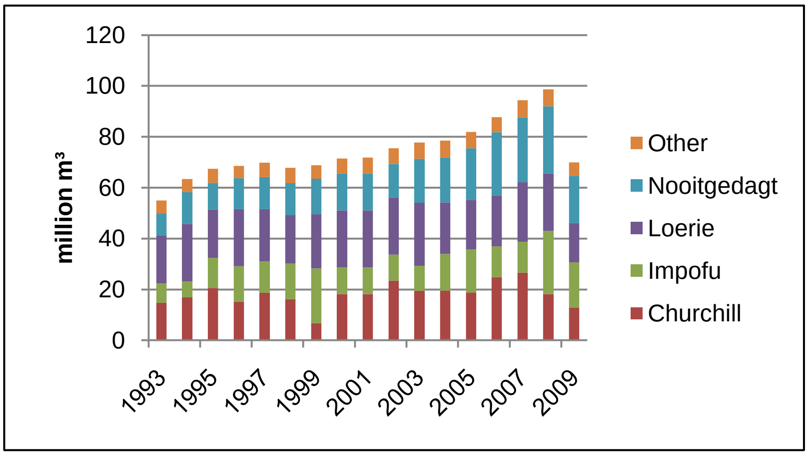


Figure 5: NMBM water consumption from water sources



Source: Raymer, D., pers. comm. 2010. 25 May

There are agricultural activities above the Churchill Dam, and the extent to which these compete with municipal demands are an issue of interest. There is also competition for the water in the Kouga Dam, which not only supplies the NMBM with water, but also the towns of Hankey and Patensie and the farmers in the Gamtoos Valley. Around 28% of the allocated water flows from the Kouga Dam, via canals, into the Loerie Balancing Dam. Water from the Loerie catchment also flows into this balancing dam, which then supplies NMBM.

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depicts characteristics of the Western Supply System[2]. It is interesting to note that Churchill Dam imparts the highest proportion of its water to the NMBM. Irrigation-intensive agriculture in the Gamtoos

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[2] The average volumes and the change in net capacity have been calculated over the life of the respective dams and therefore differ according to each dam. The information pertaining to the NMBM is based on a 20 year average.

Valley, situated below the Kouga Dam competes for water, and limits the share accessible by the NMBM. The ecological reserve requirements demand releases from the Impofu Dam to protect the 14km long Kromme estuary. The amount made available to NMBM is further restricted by the demands of the coastal towns and an estimated 650 hectares of irrigation which depend on the Impofu Dam for water (Mallory, van Vuuren and Pashkin, 2008; Weitz, F., 2011 pers. comm., 9 March).

Table 1: Characteristics of the Western Supply System

Characteristics	Unit of measurement	Churchill	Impofu	Kouga	Loerie
dam's maximum capacity	million m^3	35.69	105.84	129.58	3.33
mean annual volume	million m^3	26.06	74.98	85.70	2.97
mean % full	%	73	71	66	89
change in net capacity	%	3.18	-1.40	-3.03	-10.89
mean annual supply to NMBM	million m^3	18.19	13.32	Flows via canal to Loerie Balancing Dam	21.02
% total NMBM consumption	%	23.7	17.29	/	28
20 year average rainfall	mm	642	706	580	723

Source: DWA unpublished (2010), NMBM unpublished (2010)

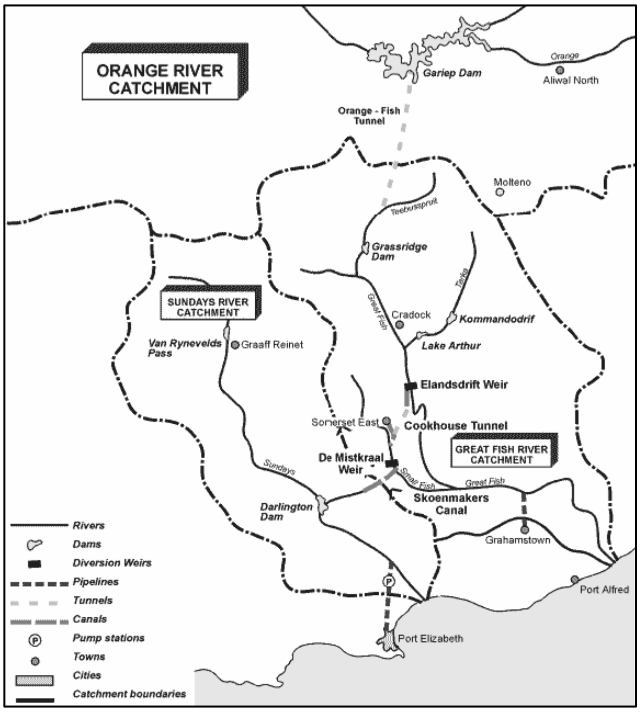
The Secondary system only provides NMBM with an average of 10 million m^3/annum (around 10% of NMBM's water demand) and consists of the Sand Dam, Bulk Dam, Van Stadens Dam, Kwa Zunga Dam, Uitenhage Springs and Groendal Dam. The Groendal Dam also provides irrigation farmers with 2.4 million m^3/annum (DWA, 2009).

The transferred water, which flows from the Gariep Dam, via the Orange-Fish tunnel, along the Fish-Sundays canal into the Darlington Dam, makes up the Eastern System and supplies the NMBM with 26million m^3/annum (see Figure 6). This water diversifies NMBM's water supply, by having a low negative covariance with the other sources it decreases the risk of water shortages in the city's overall water supply portfolio. The covariance between the Western supply system and the Eastern system is -0.004. This Orange River water provides the NMBM with some insurance against water shortages. During the 2009/10 drought in the Eastern Cape, the Gariep Dam was 80-90% full, a stark contrast from the capacities seen in Figure 1.

Irrigation farmers, within the Lower Sundays River Water User Association, obtain water from the same system and are allocated 99 million m^3/annum. This allocation is expected to increase to 155 million

m^3/annum as part of an irrigation expansion project, which aims to serve poor farmers (DWA, 2010). The Department of Agriculture, Forestry and Fisheries' draft irrigation strategy targets to increase irrigated land in South Africa by 50%. Revitalisation, re-development and water allocation reforms fall part of the strategy (DAFF, 2010).

Figure 4: Orange River Project



Source: Raymer (2008)

1.2 Current Water Supply Costs

In 1881, South Africa saw its first significant interbasin transfer, the Van Stadens River Waterworks Scheme. The Sand River Dam (1905) and the Bulk River Dam (1907) were constructed to meet the growing demand for water. Unfortunately no cost data is readily accessible for these dams.

Raymer's *Streams of Life* (2008) reveals the historical construction costs of NMBM's dams. The Groendal Dam was constructed in 1934, costing £310 000. The Churchill Dam, which took 11 years to build, opened in 1943 and the Churchill Water Scheme, which was finalised five years later, cost the city £2 250 000. Due to a rising population and increased water demands, the city constructed a second pipeline from Churchill Dam, which passed 11 major river crossings, 30 kloof crossings, and was effective by 1962. 1970 saw the completion of the Kouga Dam and Loerie Balancing Dam, costing R9.6 million. The Impofu Dam, built twelve years later, totalled R17.4 million. The continued rising water demand put pressure on the city to build a canal to tap into the Sundays/Orange-Fish river water and in 1992, the extension was finished, amounting to R93.6 million (Raymer, 2008). Correcting these costs for subsequent inflation one obtains the following:

Table 2: Current Water Schemes

Date	Scheme	Cost in 2009 Rand (R million)	Mean volume (million m^3)	Ave cost (R/m^3)
1943	Groendal Dam	101.97	9.690	10.52
1948	Churchill Dam	969.39	26.06	37.20
1970	Kouga Dam	680.99	85.7	7.95
1982	Elandsjacht (Impofu Dam)	279.92	74.98	3.73
1993	Sundays River transfer scheme	316.26	25.55	12.38

Source: Raymer (2008)

The dams owned by the municipality also have annual expenses for their maintenance and upkeep. Catchment management has been incorporated into the dam maintenance budget since 2009 and constitutes a significant proportion of the annual costs. Alien clearing forms the basis of the catchment management expense.

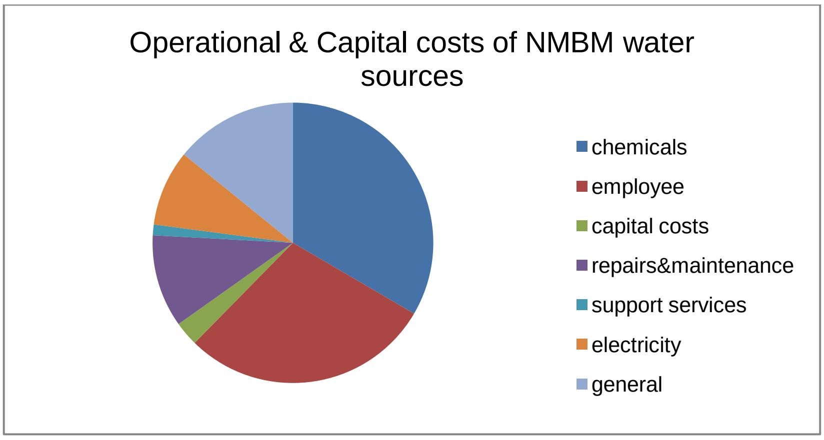
Table 3: Catchment Management Budget (2009 Rand)

Scheme	Catchment Management
Bulk	R 148 916
Sand	R 301 283
Van Stadens	R 321 379
Loerie	R 17 581
Churchill	R 859 142

Source: unpublished NMBM (2011) du Plessis, P, 2011, pers. comm., 8 August

One of the arguments for catchment management is that it reduces sediment loads and cuts the risk of poor water quality. This might manifest itself as a saving in water treatment costs. Before pronouncing on this, however, one needs to know the nature and relative magnitude of these costs. Using annual budgets from the six Water Treatment Works (WTW), ten years of expense data was collated from 2001-2011. The cost data does not include the NMBM distributional costs or pump station costs, but merely the costs relating to treatment of the water itself. The operating and annual depreciation of the WTW are divided into seven major cost categories, as seen in Figure 5.

Figure 5: Distribution of operational and capital costs of the WTW



Source: NMBM raw data (du Plessis, P, 2011, pers. comm., 30 June)

The chemical and labour costs, the largest expenditures, each constitute 30% of the total water treatment costs. The support services, which form the lowest costs, represent the specialised scientific services required at each treatment works. The electricity costs are fairly low at all the treatment works, except at Loerie (which is a balancing dam), where they make up 40% of the total costs. The repairs and maintenance costs are equivalent across all the sites and contribute 11% to the total costs. A breakdown of the average costs, adjusted for inflation and assuming a base year of 2009, for the major WTWs is shown in Table 4. This is of interest as it shows the cost variation across the three main water supply sources.

Table 4: Breakdown of the average costs per cubic metre of water at the main WTW (new 2009 prices)

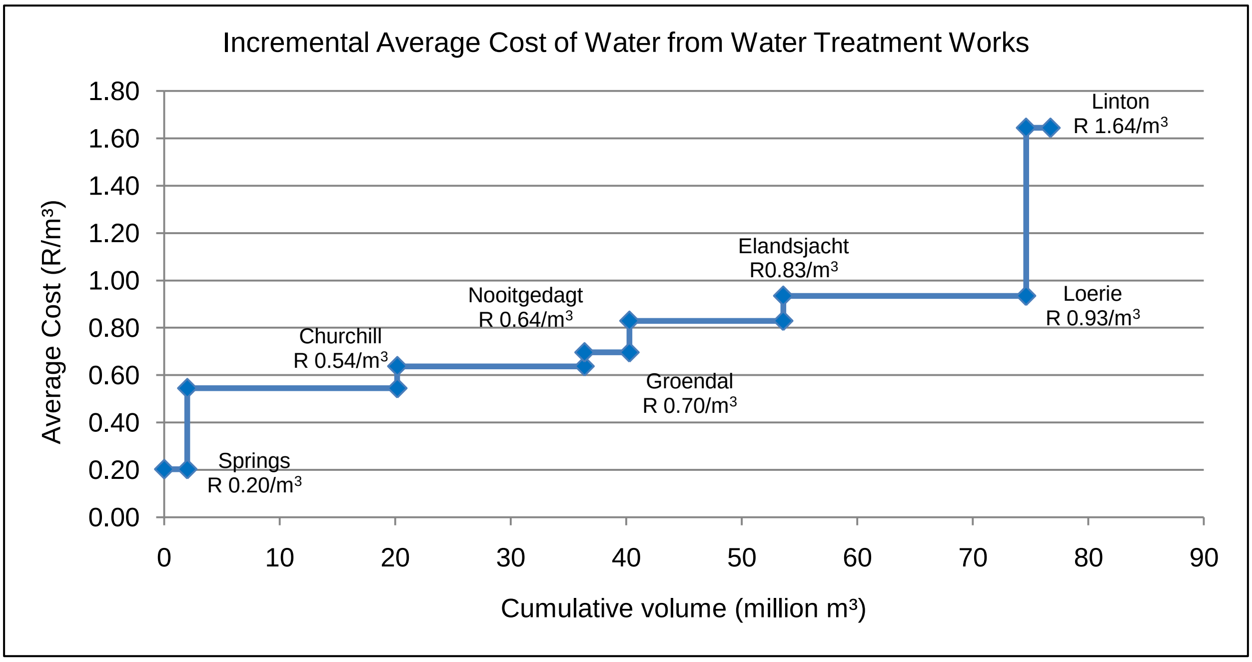
	Chemicals	**Labour**	**R&M**	**Electricity**
Churchill	R 0.26/m^3	R 0.16/m^3	R 0.06/m^3	R 0.00/m^3
Loerie	R 0.31/m^3	R 0.10/m^3	R 0.08/m^3	R 0.37/m^3
Nooitgedagt	R 0.19/m^3	R 0.11/m^3	R 0.07/m^3	R 0.03/m^3

The average cost of treating water at each site was determined by dividing the total annual costs by the Water Works' output. An average cost per cubic metre of treated water per scheme and the relative output of water supplied to NMBM is displayed in Table 5.

Table 5: The average cost per cubic metre of water at each WTW (new 2009 prices)

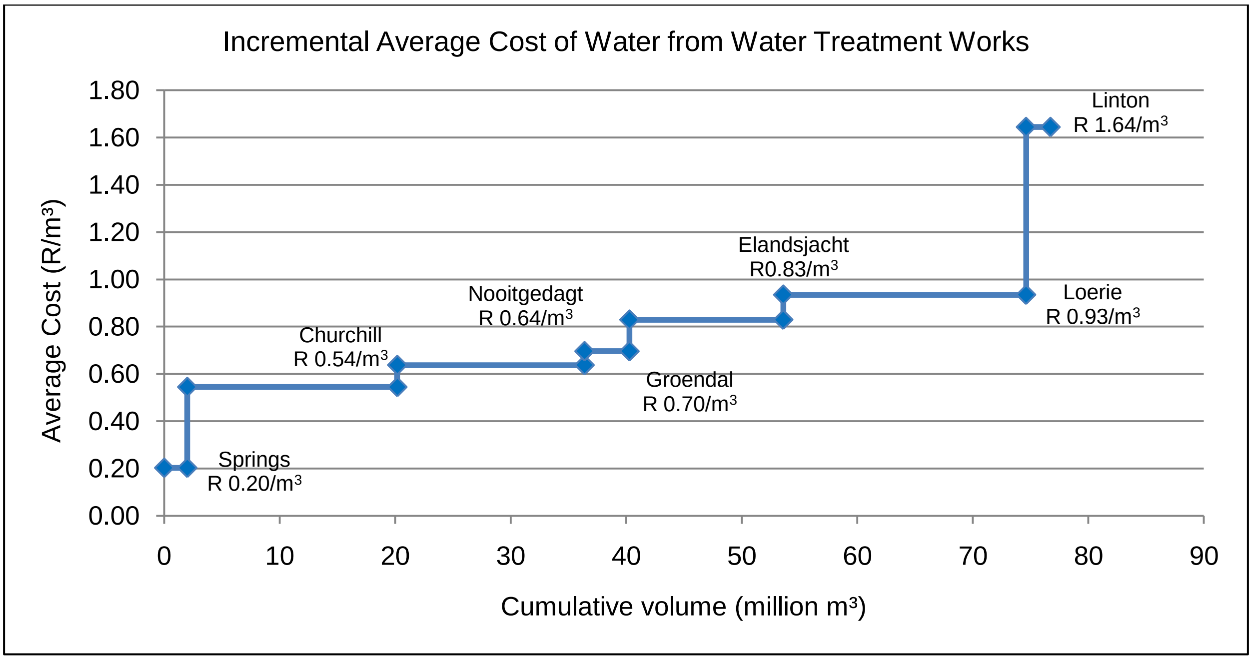
	Springs	**Churchill**	**Nooitgedagt**	**Groendal**	**Elandsjacht**	**Loerie**	**Linton**
Average Cost (R/m^3)	0.20	0.54	0.64	0.70	0.83	0.93	1.64
Average annual output (million m^3)	2.00	18.18	16.21	3.89	13.32	21.02	2.12

Using the relative average costs from each scheme, an incremental average operating cost curve is created for the NMBM.



represents the increasing cost of water per cumulative output.

Figure 6: NMBM's Incremental Average Operating Cost of Water from the WTWs



The Springs WTW supplies the cheapest, and one could argue, the cleanest cubic metre of water, costing the municipality R 0.20/m³. Nevertheless, it plays an insignificant role in NMBM's water supply portfolio, providing less than 5% of the municipality's total water. Churchill water, followed by the Orange-Fish-Sundays water at Nooitgedagt is the next cheapest source of water. Together these sources supply almost half of all NMBM's water and are substantially cheaper and cleaner than water from the Loerie Dam. The water from the Sand, Bulk and van Stadens dams, which is treated at Linton WTW, is the most expensive water, at R1.64/m³, but it makes-up less than 3% of the NMBM's total water supply.

It is necessary to look at NMBM's water costs as a whole and data was sourced from the municipality water budgets (2002-2011). The municipality pays the Department of Water Affairs (DWA) a consumptive charge for water from DWA-owned dams. Additionally, the municipality pays a compulsory Water Research Management (WRM) and Water Research Levy (WRL) fee for water from all dams. These costs, as well as any purchases of water from Irrigation Boards or Water User Associations, make up the Water Purchases entry in Table 6.

Table 6: Distribution of NMBM's water supply costs

Break-down of Water Costs NMBM	**%**
Employee Costs	23
General Expenses	14
Bad debts	8
Repairs & Maintenance	26
Purchase of water	14

Chemicals	7
Electricity	5
Internal Costs	3

Source: NMBM (du Plessis, P, 2011, pers. comm., 1 July)

According to the municipality tariff budgeting, the bulk water costs makes up 57% of all water expenses and the supply/distribution costs make up the remaining 43% (Groenewald, S, 2011, pers. comm., 14 April). The distribution, bad debts and chemical costs are excluded in the calculation of the current average water costs. This is justified on the grounds that the augmentation schemes analyzed in this study compare water at source-value and do not include the relative distribution or treatment costs.

For the purposes of this study, the average water cost divided by the mean water supply (over the past nine years) will be used to represent the current water supply costs. The average cost of water in the NMBM is R1.43/m^3 (new 2009 prices).

Water budgets fail to reflect the scarcity value of water as they only consider the abstraction, distribution, treatment and storage costs of water. The opportunity cost of using water for any one purpose needs to be accounted for in order to determine the true economic cost of a resource. (Marais *et al*, 2001). For example, the foregone benefits of using the water for agricultural activities, instead of urban consumption, are not included in these budgets. These budgets only deal with the financial transactions and fail to reflect the true economic cost of water. Chapter 3 delves further into the issues surrounding the opportunity cost of water.

2 Nelson Mandela Bay Municipality's Proposed Augmentation Schemes

Population growth and immigration lead to increased water demand. Faced with this, a rational water manager has two basic responses to the problem of securing adequate future water supplies. He can increase supply and provide more water or he can manage demand and try to shift the per capita demand curve backwards through the use of water tariffs.

The '*Water Reconciliation Strategy Study for the Algoa Water Supply Area*', undertaken by the DWA to secure future water supply for the NMBM and surrounding towns, responds with the first two choices. Nevertheless, the NMBM has been using prices as a means to change residents' behaviour, and it increased water tariffs steeply during the drought (Groenewald, S, 2010, pers. comm., 28 July). Another potential reason for increasing water tariffs is because the municipality was selling less water during the drought and thus need to charge more per unit of water to maintain their revenues.

The constitutional imperative that the public has a right to clean safe water, makes pricing problematic as a means of regulating the water demands of the urban poor. Nonetheless, the NMBM used water tariffs to manage water demand during the drought and thus this section begins with a theoretical review of using prices for residential demand management. Following the literature review, the supply-side schemes and WCDM proposed in the Algoa Reconciliation Strategy will be discussed. The analysis of residential demand for water in NMBM is not within the scope of this paper.

2.1 Using Prices in Demand Management

There is a trend towards demand management in dealing with the growing scarcity of potable water and thus the importance of price efficiency has gained recognition (Jones and Morris, 1984, Arbués, Garcıa-Valiñas and Martınez-Espiñeira, 2003). Economists suggest price as a means to achieve allocative efficiency and it is also the medium through which governments endeavour to reach social objectives, such as equity and redistribution. Methods such as water tariffs, metering or charges are used to control demand and achieve a balance between supply and demand (Stephenson, 1999:115). Before prices are utilized in policies or as a demand management tool, it is imperative to appreciate the impact that changes in price have on consumers' demand for water. This is dictated by the price elasticity of demand $\varepsilon_d = \frac{\partial x}{P_x} . \frac{P_x}{x}$.

Consumer demand functions, grounded in utility theory, are derived by maximising utility subject to a budget constraint (Espey, Espey and Shaw, 1997:1369). Residential water, the only category whereby water is consumed directly and therefore classified as a final consumption good, competes with other items in the household budget (Nieuwoudt, Backeberg and Du Plessis, 2004). The price elasticity and consequently, the value of water can be determined from the demand schedule. The total value of water is the consumer surplus, while marginal value (or scarcity value) is given by the price level

(Williams, Veck and Bill, 2008:15). Economists assume that it behaves like any other good, insinuating that consumers change their water consumption in response to changes in price (Young, 2005:248). For most residential uses, it is assumed that water is a normal good, displaying positive income elasticity and negative own-price elasticity of water demand (Hanemann, 1998). Water demand is generally rather inelastic, due to the fact that water has no close subsitutes. In addition, it forms a small proportion of income and hence, consumers are not sensitive to the tariff structure. However, as long as price elasticity is different from zero, prices can still play a role in demand management (Arbué *et al*, 2003:84).

Inductive methods (using econometric models) are the most common form of evaluating residential demand for water and these usually employ secondary data to evaluate at-site water values (Young, 2005:248). Like other goods, the price of water (P_W), the price of other goods (P_a), consumer income (Y) and a host of factors (Z), such as consumer tastes and preferences, seasons and policies, influence the demand for water: $Q_w = Q_w\ (P_w, P_a, Y, Z)$ (Renzetti, 1992:153).

Demand often fluctuates and it is important to delve a bit further into the explanatory variables which influence water demand. There has been much debate around specifying the price variable (P_W) – should one use marginal or average prices? Foster and Beattie (1979) determined the urban residential demand for the United States of America using the average price of water and they justify this by stating in (1981) that average price is "more likely to motivate consumer response" as perfect information, necessary for marginal pricing, is not plausible. Foster and Beattie (1979) represented urban demand as a function of average price, median family income, precipitation and average number of residents per square meter. An exponential form of the function was used to allow for the variation in price elasticity. Price elasticities varied across cities from -0.27 in Calumet City to -0.76 in Colorado Springs, indicating that water demand differs across sub regions in the United States.

Table 5 Price Elasticities of South African residential demand for different income groups

Study Area	Source	High income price elasticity	Middle income price elasticity	Low income price elasticity
Greater Letaba River Catchment	Williams *et al*, 2008	-0.29	-0.250	-0.397
Vaal River Catchment	Greengrowth Strategies cc, 2003		-0.35	-1.12

Billings and Agthe (1980:73) introduce the issue of block rates in the tariff schedule and argue average prices overestimate price elasticities when block rates are in use. Rates that do not correspond to consumption levels are called intramarginal rates and under block rate tariffs it is difficult to analyze the effect a change in intramarginal rates has on demand (Arbués *et al*, 2003:84). A solution to this dilemma, which was suggested by Taylor (1975) and updated by Nordin (1976), advocates the use of a two-variable representation of water price (Young, 2005:252). This features both the marginal price and a "difference" variable, which is the difference between the actual total water fee and the water fee if all the units were taken at marginal price (Billings and Agthe, 1980:74). The "difference" variable was expected to represent the income effect of changes in intramarginal rates; however empirically it has been without much success.

Weather variations have a strong seasonal impact on water consumption. Wong (1972) discovered in his time-series analysis, that average summer temperature has a significant impact on water demand for communities in and around Chicago. Foster and Beattie (1979:50) used a precipitation variable to take into account the impact of weather and found that it was significantly and negatively related to water demand.

The independent variable income (Y) is a significant determinant of residential water demand. Usually average income is used, such as in Wong (1972:38), where average household income was used. Foster and Beattie (1979:47) refrained from using variables such as value of homes, lawn area or household characteristics or preferences instead of, or in addition to income, for fear that these variables were interrelated and correlated with income. Jones and Morris (1984:198) created a comprehensive replacement for household income using property value, age of residence, education level of head of house and car ownership in order to bypass autocorrelation.

Some studies have estimated different demand functions for different income levels so that the income effect can be analyzed. It has been hypothesized that wealthier consumers are less sensitive to water prices as the total water fee embodies a lower proportion of their income (Arbués *et al*, 2003:85). Williams *et al* (2008) derived municipal water demand for low, middle and high-income groups in the Greater Letaba River Catchment Area in Limpopo using contingent valuation techniques.

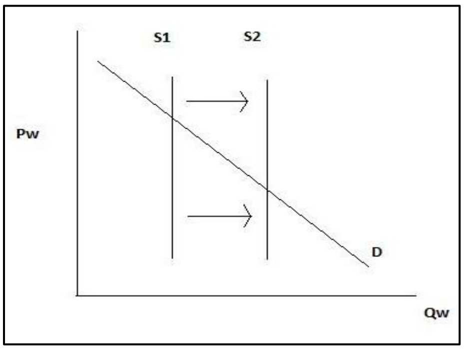
Greengrowth Strategies cc (2003), commissioned by the Water Research Commission, undertook a study of the economic value of water in the Vaal River Catchment. The study investigated the price elasticities of municipal demand for different income groups, namely the Upper Middle (above R26 900, 1998 price levels) and Lower (below R26 900, 1998 prices) and noticed that the price elasticities varied substantially. The study divided residential water demand into two components, indoor and outdoor use. In accordance with other literature it was found that outdoor water demand was more elastic than indoor for both income groups (Greengrowth cc, 2003).

Conradie (2002) found that the price elasticity of municipal water demand in the Fish-Sundays River transfer scheme was -0.47, and was the same across different income groups. Van Schalkwyk (1996 cited in Conradie, 2002) carried out a study which looked at the water demand of low-income groups situated in informal settlements in the Northern Transvaal. It was found that people living in informal settlements obey the same laws of demand as those who live in formal settlements and that water demand was a function of "income, water price, presence of gardens, awareness of scarcity, time of day, season, number of household members and number of visitors" (Conradie, 2002). Jansen and Schulz (2006) argue that pricing is an effective tool to manage water demand among the rich, yet ineffective among the poor.

2.2 Proposed schemes

There are several supply augmentation options that the NMBM is considering. These range from desalination plants, tapping into ground water supplies, advancing the infrastructure of surface water schemes, and water trading with irrigation farmers. All these options look at increasing the stock of water available to the NMBM and keep the water demand function constant. The simple neoclassical representation in Figure 9 illustrates the shift of the supply curve from S1 to S2.

Figure 7: Increase Supply Side



Source: Leiman and van Zyl (2000)

New dams built in the NMBM area would increase the stock of water available, as seen in Figure 9, but do little more. Raising the Kouga Dam or building the new Guernakop Dam, would not make the water supply more reliable to NMBM as neither reduces the risk of drought, leaving the entities in the water supply portfolio with the same naturally positive covariance. Municipalities need to look at ways to increase the reliability of water supply, allowing water managers to exploit more fully the reserve supply of water, currently kept for drought-situations. NMBM needs to look at interventions that simultaneously reduce the risk within the water supply portfolio while increasing supply. The Nooitgedagt Scheme and the Swartkops desalination plants, at which the salt and minerals from seawater are removed to make it suitable for human consumption, are such supply programmes.

The NMBM currently receives most of its water from a concentrated area, whose catchments have similar rainfall and weather patterns. This increases drought risk. Thus, when a drought hit this area in 2009/2010, 70% of NMBM's water supply was under threat. A positive covariance between supplies has implications for water-resource management. Although the inflows in the Western System's dams are closely correlated, the city manager does not deplete the dams evenly. The result is that 'percentage full' shows a positive but low covariance across the Western System dams of 0.03. The Orange River Project Nooitgedagt Low-Level Scheme's tender process is being fast-tracked and the design modified, in order to secure water delivery by December 2011 (DWA, 2010). This intervention is considered crucial for development at the Coega IDZ. The Low-Level Scheme will increase the capacity, of the existing works so that they can treat the additional water. There are many competing water users for the Orange River water and most of the water has been fully allocated. However, according to the DWA Internal Strategic Perspective, there is yet another 41.3Mm^3/a available for the NMBM, for which the municipality have submitted an application (DWA, 2009). The Orange River water is expected to increase to a total of 58.3M m^3/a when the Nooitgedagt Low-Level Scheme is complete.

Another supply-side scheme that forms part of the Emergency Intervention is the Swartkops Desalination Plant. The brine from the desalination plant will combine with the water from the Fishwater Flats Water Treatment Works and be discharged via the existing sea outlet (DWA, 2010). The water is to be distributed to the Western areas of the city (those which are served by the Churchill pipeline), and will therefore help insure the Western System against localised droughts (DWA, 2010). Progress on this development has been delayed whilst larger sites are being investigated (DWA, 2011).

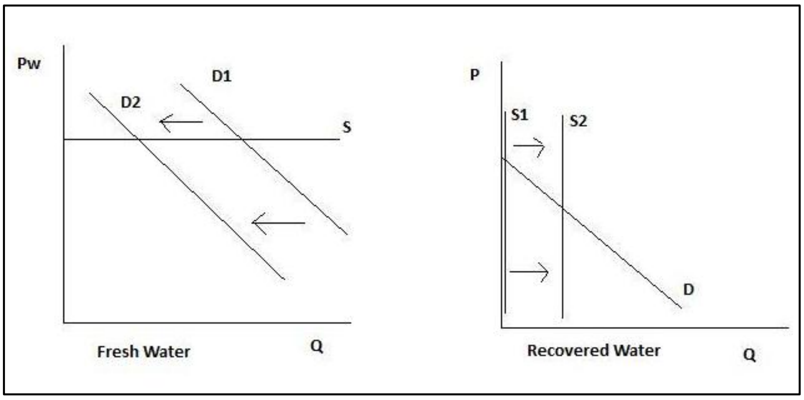
Although the initial capital costs and the annual running costs of a desalination plant are expected to be high, in terms of local rainfall the plant is risk-free. This means that the size of buffer stocks in city dams, which water managers usually keep against the possibility of future drought, can be reduced. It also means that even when it is not running, the desalination scheme can generate revenue.

Water trading is also considered as a form of supply augmentation. It typically involves the selling of agricultural water rights to the NMBM and thus a transfer of water away from agriculture towards urban use.

The NMBM is also exploring water recycling through the treatment of effluent. Proposed schemes consider treating effluent, subjected to flocculation, rough screening and a compulsory ‘treatment train’, in order to reach industrial (non-potable) standards (DWA, 2009).

Although water recycling is normally viewed as a supply-side scheme, the demand for fresh water from the municipality is met in part by supplies of the substitute. Figure 10 indicates the shift in the demand of fresh water D1 to D2, and the second diagram denotes the increase in the supply of recovered water S1 to S2.

Figure 8: Recycling Water

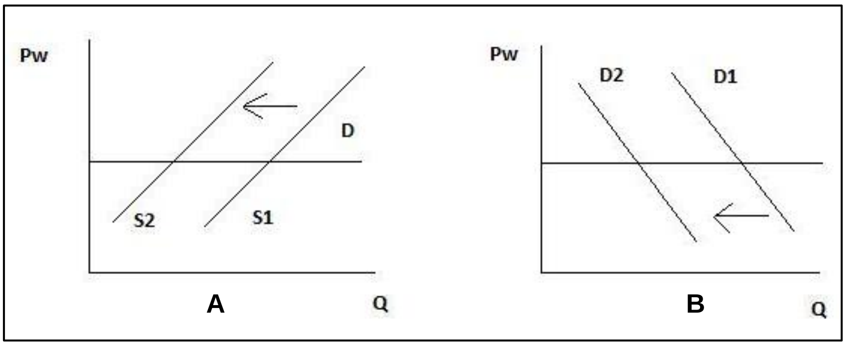


Source: Leiman and van Zyl (2000)

The final intervention focuses on the conservation of water and demand management. The intervention is a response to the excessive wastage of water in the system, estimated to be a third of all water supplied (DWAF, 2008). The investment involves leakage repairs, tariff adjustments, adopting water efficient technologies and public awareness programmes. A change in the by-laws has been instigated by the NMBM to allow for the harvesting of rainwater (DWA, 2011).

The diagrams in Figure 11 illustrate the implication of non-price based demand side options. These diagrams represent the introduction of water efficient technologies, improved metering and leakage controls, repair and awareness programmes. Each can be interpreted as in A, as a reduction in the flow of supply, or as in B, as a reduction in household demand.

Figure 9: Demand side options



Source: Leiman and van Zyl (2000)

Table 7 below lists all the options considered by the NMBM. The report, *'Water Reconciliation Strategy Study for the Algoa Water Supply Area'* commissioned the DWA, incorporates all the capital and running costs of the schemes, along with the associated yields. The study was compiled and prepared by Aurecon South Africa (Pty) Ltd, although much of the engineering costing was undertaken by Afri-Coast Engineers SA (Pty) Ltd.

Table 7: Compilation of all augmentation options considered by NMBM

Supply Augmentation	
Desalination	Swartkops Desalination
	Coega Desalination
	Seawater Desalination
	Desalination of Sundays River Return Flows
Surface water schemes	Nooitgedagt Low-Level
	Gamtoos river irrigation return flows
	Tsitsikamma River diversion
	Guernakop Dam
	Kouga replacement Dam
Groundwater	Bushy Park
	Jeffrey's Arch
	Coega fault
	Van Stadens
Water Trading	Baviaanskloof
	Upper Fish River
Recycling	
Re-use of water	Industrial standards Fishwater Flats WWTW
	Treated effluent from Coega
	Echodale: potable standards
Demand Management	
Water Conservation & Demand Management	Upstream of meters
	Downstream of meters

Source: DWA (2010)

2.3 Proposed schemes' costs of water

2.3.1 Review of methodology

This section develops a cost curve for NMBM's water supply, illustrating the relative costs of the proposed schemes and their associated yields. Literature differs on which indicators best assess the costs of water development schemes. The Unit Reference Value (URV) has become a common indicator in South Africa, used to evaluate projects in the water services sector, while scholars elsewhere often advocate the use of levelised costs (LCs) or average incremental costs (AICs). A short review of each methodology will be discussed, followed by an explanation of the methodology chosen for this paper, and how it deviates from the others.

The URV has a become a popular cost reference in South Africa, due to the fact that the Department of Water Affairs and Environment's water engineers use this term to evaluate water augmentation schemes (Blignaut *et al*, 2010). The URV, found in engineering computations, is calculated as the ratio between the present value of the costs over the lifespan of the project and the present value of the total yield over the same time (Africoast, 2010 and Aurecon, 2010). It is site and time specific and is not documented to be a representative for the unit cost. It assumes that a scheme's total yield is equal to the shortage that would occur should the scheme not be implemented and no explanation is given as to why the yields are discounted (Hoffman & du Plessis, 2008). There is no typical guideline for URVs which indicate whether the scheme is favourable or not; however it is suggested that a URV between 2 and 4 is standard for a development project (Blignaut *et al*, 2010; Marais & Wannenburgh, 2008).

Blignaut *et al* (2010) and Marais and Wannenburgh (2008) use the URV ratio as a means of determining the economic feasibility of respective water augmentation schemes. The restoration in the Maloti–Drakensberg mountain range is considered in Blignaut *et al* (2010) and the economic impact of clearing alien invasive plants is analysed in Marais and Wannenburgh (2008). The URV was used because it is directly comparable to the Department of Water Affairs and Environment's calculations of future augmentation schemes. However, the URV described in these papers differs as it was calculated as:

URV=

$$\frac{PV\ of\ total\ costs\ over\ lifespan\ of\ project}{PV\ of\ total\ benefits\ over\ lifespan\ of\ \ project}$$

(Marais and Wannenburgh, 2008).

This is not a URV calculation, but an economic Cost-Benefit Ratio (CBR), which divides the discounted costs of the scheme by the discounted benefits of the scheme over the same timeframe. If the ratio is greater than one, the costs outweigh the benefits and vice versa. This cost-benefit ratio is broader than the URV they claim to be calculating and therefore these calculations are not strictly comparable to URVs.

Levelised Costs (LC), based on the methodology of least-cost planning, is an economic approach that measures the cost-effectiveness of the water supply schemes and is used to compare supply and conservation options. The use of LC was developed in the 1980's by the electricity industry in the United States of America and is determined as:

$$\frac{PV\ (costs)}{PV\ (\ water\ demand\ conserved\ or\ supplied)}$$

(Fane, Robertson and White , 2003).

Levelised costs is a simplified version of Average Incremental Costs (AIC), which is defined as the discounted value of all incremental future supply costs divided by the discounted physical volume of additional water (Warford, 1994:6). This means that the incremental costs of each projected are taken and discounted back. While AIC is dependent on future demand and future prices, LCs assume that future water demand is independent of marginal costs (Fane *et al*, 2003).

The issue of capital indivisibility makes the implementation of strict marginal cost pricing problematic. Since supply schemes are meant to meet demand for numerous years, the problem involves the spreading the capital costs over time (Warford, 1994:6). Due to the initial large capital expenditure common to many supply-side schemes, marginal cost pricing causes significant price fluctuations and uncertainty among consumers and investors. Warford (1994:6) suggests using average incremental costs because it smoothes out prices and provides a reasonable price approximation for long term water supply costs.

All the mentioned methodologies agree that the denominator (water conserved, water supplied or incremental water supplied) should be discounted and this is to account for the time preference of consumption. A more basic reason given is that discounting the physical volume allows one to work out a cost per unit volume that is not skewed over time. If the costs are discounted, but the volumes are not, future water appears unduly cheap.

Discounting the denominator is also justified mathematically by implying that yield is a function of future demand met, and not just a volumetric term. Fane *et al* (2003) explain that the LC can be viewed as the price per unit of water needed to break even in Present Value terms and therefore needs to be discounted.

Average Incremental Costs (AIC) will be used to explain the mathematical analysis, although this term is interchangeable with Levelised Costs (LC). AIC is the average cost of water and is constant over time, WS represents water supply and ES is expenditure stream or cost of the scheme (World Bank, n.d).

$$PV(WS * AIC) = PV(ES)$$

$$AIC * PV(WS) = PV(ES)$$

$$AIC = \frac{PV(ES)}{PV(WS)}$$

This mathematical formula is validated by the fact that the AIC is constant in real terms over time and can therefore be taken outside of the bracket.

Although this paper accepts LC and AIC methodologies and the rationalisation for discounting water yields, it questions whether there is still a need to discount water yields. It also argues that, when building an incremental cost function, in which the next 25 years of operation are taken as a common unit, there is no need to discount water yields.

2.3.1.1 Is the time-preference of consumption applicable in water supply scheme?

The positive discount rate and the theory of time preference of consumption are based on the premise that 'consumption today is preferred to consumption tomorrow.' Intertemporal choice, which reflects society's desire for consumption at different points in time, is not necessary when establishing the relative costs of the water augmentation schemes:

- *Water supply is not a choice or a preference, but a fixed allocation*

The expected annual yields estimated for each scheme form part of the NMBM water allocation. Each year there is a fixed allocation of water, which is distributed accordingly. Although individual consumers may choose not to consume their full allocation, this analysis is taken from a macro governmental perspective and therefore intertemporal choice is not relevant.

- *If water is not consumed it today, the commodity will not be saved for tomorrow*

If the water is not utilised 'today,' it will not necessarily be saved for 'tomorrow,' but rather reallocated, evaporated or lost out to sea.

2.3.1.2 Is future water disproportionately cheap?

When yields are not discounted, there is an inherent bias in favour of water schemes with initial high capital costs, such as the construction of a dam. However, this can be interpreted as a true reflection of water costs, because future water will become increasingly cheaper, as the dam is amortized. In the future, when the dams' costs are fully amortized, the cost of this water will be cheap because the annual operating and maintenance costs are low. Society views the initial capital costs of the present dams as sunk costs; hence the cost of water at any point in time is calculated as the present running costs.

2.3.2 Methodology

The water scheme costs will be analysed using two different methods to account for the above arguments. Seeing that one cannot discard the accepted and well-documented methodology, the levelised costs (LC) of water will be used to compare the cost of water from different schemes over 25 years. This method will show how discounting yields influences the attractiveness of large scale schemes.

The formula used is shown below:

$$\boldsymbol{LC} = \frac{\sum PV(K_t + M_t + E_t + W_t) \Big/ (1+r)^t}{\sum \frac{Y}{(1+r)^t}}$$

K: Capital Costs

***M*:** Maintenance costs

E: Electricity usage

W: Water purchases

Y: Water yield

The annual costs are discounted using a real interest rate of 4%, based on the current opportunity cost of riskless government bonds and the yields are discounted at the same rate. The denominator becomes a function of demand and it is assumed that the expected yield of the scheme is equal to water demand.

The Present Value of the stream of costs generated by the scheme is divided by the total expected yield of the scheme, to give the average cost of water over a 25 year timeframe. The annual costs are discounted using a real rate of 4%, but the volumetric yield is not discounted.

$$\boldsymbol{Average\ Cost} = \frac{\sum PV(K_t + M_t + E_t + W_t) \big/ (1+r)^t}{\sum Y}$$

It will be interesting to compare these methodologies and evaluate whether there are substantial differences in the results. In order to compare the costs of the schemes a marginal supply curve will be created.

The average costs from each scheme are ranked, along with their volumes, from cheapest to most expensive. The series gives the incremental or marginal average cost curve for water as a whole. This is useful in comparing the relative schemes' costs and the relative output each scheme can produce.

The graph will assist in guiding public decision making on how best to expand the supply of water, minimise the risk of drought, while at the same time minimising the average cost of water. It is also useful in comparing new recommendations, such as investment in restoration activities to enhance better catchment management.

A sensitivity analysis is performed, to test the receptiveness of the assumptions and the robustness of the results. A change in the discount rates and the time horizon is tested to see whether the results differ substantially and whether the ranking of the schemes is significantly altered. Furthermore, the importance of the initial capital costs is investigated by assuming the capital costs sunk and by only comparing the annual operations and maintenance costs. The impact these changes have on the rank of the schemes is examined.

2.3.3 Data

Raw data for all the engineering supply augmentation, recycling and demand management schemes was sourced from Aurecon South Africa (Pty) Ltd and Afri-Coast Engineers SA (Pty) Ltd (van Reenen, D. 2011, 6 May; Versfeld, K. 2011, 12 May). The data contains the details of estimated costs and expected yields over a 25 year projection level. 2009 prices are used for all the schemes. A 3.5% linear growth in potable water requirements was assumed by the Department of Water Affairs (2010) and this is based on the estimated future economic and population growth rates. It is anticipated that the Coega Industrial Development Zone will not only increase economic productivity for the region, but also increase the demand for water.

2.3.3.1 Desalination, Surface Water Schemes, Ground Water and Re-use of Water

It is assumed that the initial capital costs of these schemes are incurred over the first two years. Capital costs also encompasses the cost of reservoirs, dams, pipelines and pump stations, each apportioned into electrical, mechanical and civil engineering costs. Annual maintenance costs comprise 0.25% of total civil costs, 4% of total mechanical and electrical costs and between 0.35% and 0.5% of total pipeline costs. The labour costs are included in all the above costs (Dr M. Shand, 2011 pers. comm.7 July).

Water purchases and electricity costs form part of the annual costs. The impending electricity hikes were taken into consideration by assigning a R0.50/KWh tariff to electricity, double the average 2009 electricity tariff. Many of these schemes have significant electricity requirements: the desalination plants demand between 18-92 million KWh/annum; the recycling schemes require between 7-28 million KWh/annum, and the groundwater schemes need between 1-3 million KWh/annum. Further electricity increases will have a severe impact on the costs of these schemes.

The Swartkops Desalination plant was placed on NMBM's Emergency Intervention list, but unfortunately there is no available cost data relating to this scheme. Preliminary reports exclude details of the Swartkops site and therefore raw data referring to other desalination plants will be used as a proxy for the Swartkops Plant.

2.3.3.2 Demand Management

The water conservation and water demand management scheme (WC/WDM), calculated by Afri-Coast Engineers SA (Pty) Ltd, involves a different cost formulation. The demand management scheme is already part of the municipality's annual budget and a fixed figure of R5 million/annum and R7.7 million/annum has been dedicated to the respective schemes. The water conserved by the WC/WDM is expressed as additional water supplied.

2.3.3.3 Water Trading

Secondary data was used in calculating cost of the water trading in the Baviaanskloof and Upper Fish River. Information was sourced from the report, *'Water Reconciliation Strategy Study for the Algoa Water Supply Area'* commissioned the DWA (2010), and from the various preliminary documents (DWA, 2009; DWA, 2010). Details of the capital and annual costs and the exact incremental annual expected yields are therefore not available.

The costs were based on the purchase price of irrigation rights on approximately 500ha and 1500-2000ha of land within the Baviaanskloof Valley and Upper Great Fish River Valley respectively. Costs were based on historical transactions and varied between R25 000/ha and R68 000/ha for undeveloped and developed entitlements in the Baviaanskloof Valley and R35 000/ha and R88 000/ha in the Great Fish Valley.

The impact of water trading on agriculture and secondary businesses has not been included. Only the direct financial implications of the scheme have been assessed and therefore these prices do not reflect the total economic cost.

2.3.3.4 Existing Water Schemes

The cost of water from the existing schemes is included for interest of comparing the water prices across old and new schemes. It merely acts as a ball-mark figure. For the purposes of comparing like with like, it is assumed that the historical capital costs are incurring now. The costs and yields are thus projected over the same 25years time-frame as the other proposed schemes. In order to determine the average cost of water, the yields are taken as the average volume over the life of the dam thus far. This does not equate to NMBM's water demand, because not all the water from these dams is distributed to the NMBM. The maximum capacity was neither chosen, because the dam is rarely at full capacity.

The capital costs are taken from Raymer's *Streams of Life* (2008). For the most part, the expansions of the dams, such as Churchill's second pipeline and the additions made to Impofu Dam, have been accounted for. However, there is no cost data for the second stage of the Kouga Dam and this water will therefore appear unduly cheap. The schemes built before 1943 cannot be incorporated due to unavailable cost data.

The average annual maintenance costs are taken from 7 years of annual budgets. These include the maintenance and upkeep of the dam and nearby facilities, but do not include the operations and running costs. For this reason, the estimates used for the proposed schemes by Aurecon and Afri-Coast have been included.

3 Results

This presents the results of the analysis in table and graph format. It compares the results of both methodologies mentioned. Table 8 and Figure 12 represent the schemes' average cost of water by means of average costing. On the other hand, Figure 13 and Table 9 use the Levelised Cost approach, whereby both the yields and costs are discounted.

The *x*-axis depicts the cumulative yield supplied by the schemes and the *y*-axis is the average cost of a cubic metre of water. In terms of the existing schemes' yields, only the yield allocated to NMBM is illustrated on the graph. Not all the labels depicting the schemes are shown in Figure 12, however all the data can be found in Table 8. The labels indicated in bold represent the cost of water from existing schemes. The stepped-graph can be interpreted as an incremental average cost curve for supplying additional water to the NMBM over 25 years.

Figure 10: Incremental Cost of Water by Scheme – using Average Costs

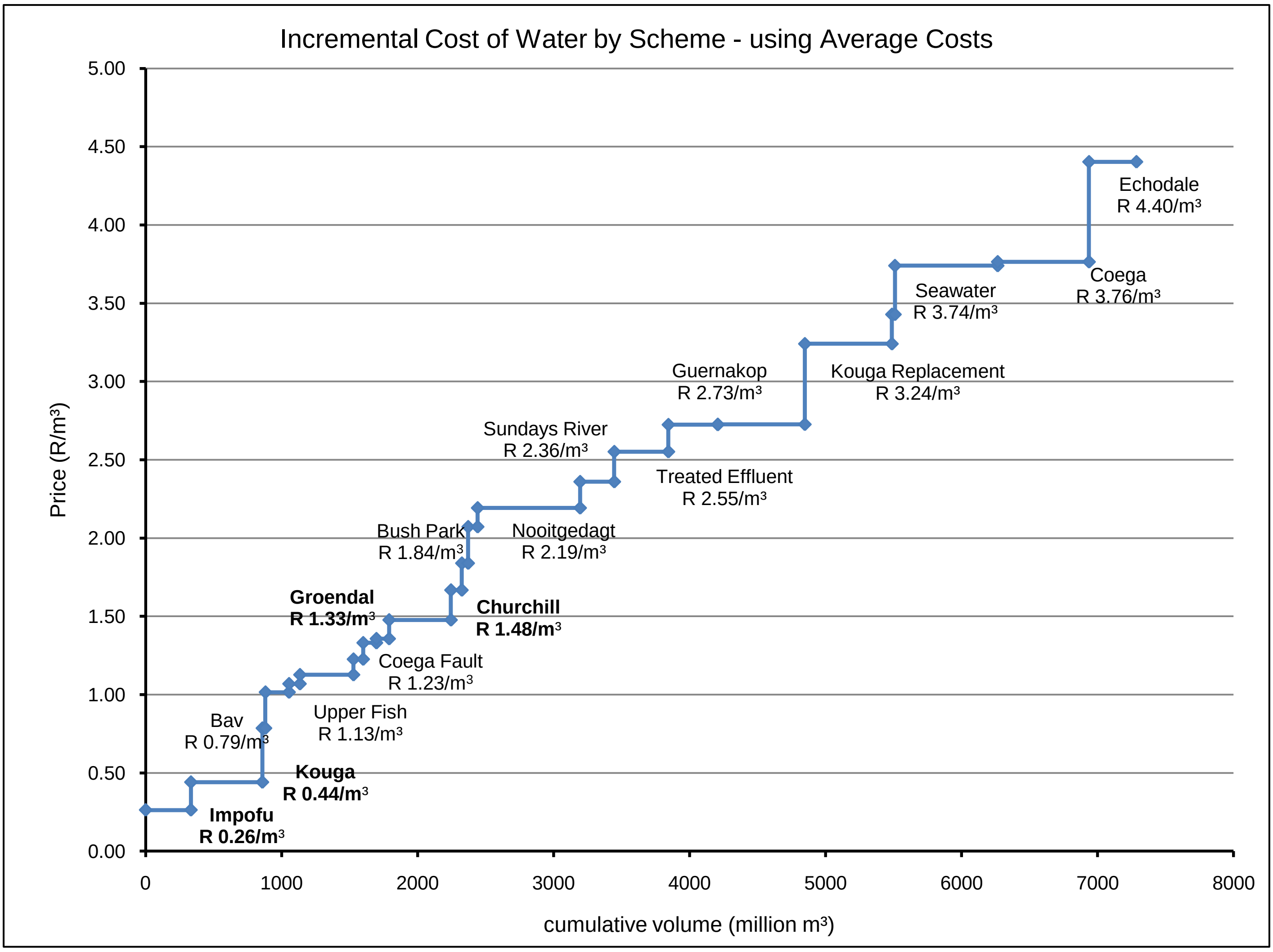


Table 8: Discounted Costs and associated Yields of proposed schemes over 25 years – using average costs

SCHEME		Present Value Total Cost	Total Water	Average Cost per cubic metre
Supply augmentation		R million	million m3	R/m^3
Desalination	Coega desalination	2 528.40	671.60	3.76
	Seawater	2 825.95	755.55	3.74
	Sundays River	592.64	251.12	2.36
Surface water schemes	Nooitgedagt Low-Level	1 652.46	753.73	2.19
	Gamtoos river irrigation return flows	176.03	173.38	1.02
	Tsitsikamma River diversion	75.71	22.08	3.43
	Guernakop Dam	1 745.45	640.25	2.73
	Kouga replacement	2 075.04	640.25	3.24
Groundwater	Bushy Park	84.92	46.17	1.84
	Jeffrey's Arch	144.37	69.68	2.07
	Coega fault	87.48	71.36	1.23
	Van Stadens	126.98	93.59	1.36
Water Trading	Baviaanskloof	17.67	22.50	0.79
	Upper Fish River	443.59	393.75	1.13
Recycling				
Re-use of water	Industrial standards FWF WWTW	989.39	363.18	2.72
	Treated effluent from Coega	1 015.20	397.85	2.55
	Echodale: potable standards	1 535.47	348.67	4.40
Demand Management				
Water Conservation & Demand Management	Upstream of meters	85.83	80.30	1.07
	Downstream of meters	133.90	80.30	1.67
Existing Sources				
Dams	Groendal	322.37	242.25	1.33
	Churchill	962.14	651.50	1.48
	Impofu	493.00	1874.50	0.26
	Kouga/Loerie	976.66	2216.80	0.44

The *x*-axis in Figure 13 portrays the discounted cumulative yield of water generated over 25 years by the respective schemes. The existing schemes' yields represent NMBM's water allocation discounted at 4%. The *y*-axis depicts the mean cost per cubic metre of water. As a whole, the graph can be interpreted as the marginal incremental average cost curve for supplying water to the NMBM over 25 years. The existing schemes are once again highlighted in bold and are depicted merely to provide a ball-mark figure.

Figure 11: Incremental Cost of Water by Scheme – using Levelised Costs

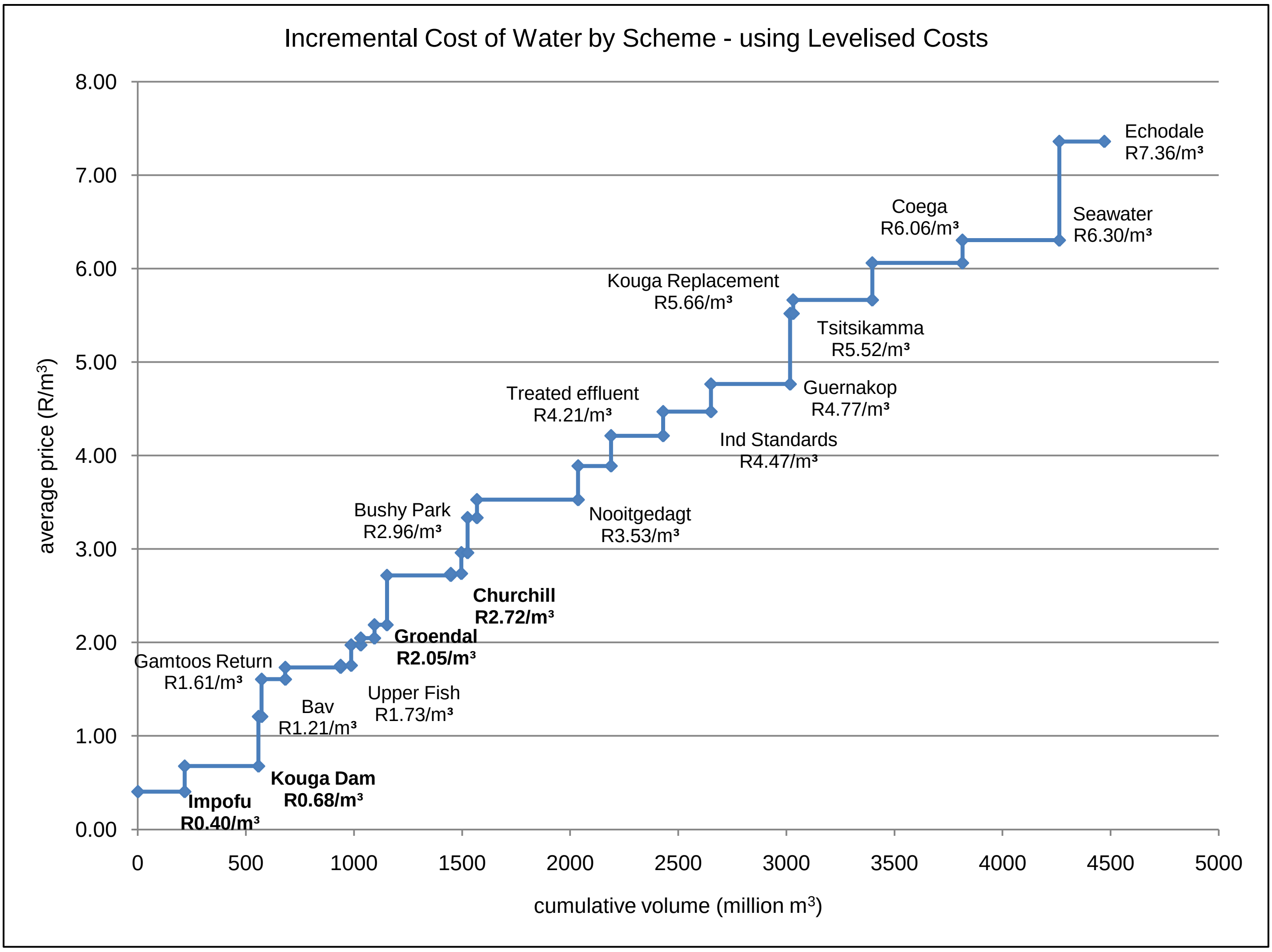


Table 9: Discounted Costs and Yields for proposed schemes over 25 years using Levelised Costs

SCHEME		Present Value Total Cost	Present Value Total Water	Average Cost
Supply augmentation		R million	million m³	R/m³
Desalination	Coega desalination	2 528.40	417.13	6.06
	Seawater	2 825.95	448.24	6.30
	Sundays River	592.64	152.37	3.89
Surface water schemes	Nooitgedagt Low-Level	1 652.46	468.32	3.53
	Gamtoos river irrigation return flows	176.03	109.55	1.61
	Tsitsikamma River diversion	75.71	13.71	5.52
	Guernakop Dam	1 745.45	366.29	4.77
	Kouga replacement	2 075.04	366.29	5.66
Groundwater	Bushy Park	84.92	28.68	2.96
	Jeffrey's Arch	144.37	43.28	3.34
	Coega fault	87.48	44.32	1.97
	Van Stadens	126.98	57.99	2.19
Water Trading	Baviaanskloof	17.67	14.62	1.21
	Upper Fish River	443.59	255.89	1.73
Re-use of water	Industrial standards FWF WWTW	989.39	221.33	4.47
	Treated effluent from Coega	1 015.20	240.98	4.21
	Echodale: potable standards	1 535.47	208.59	7.36
Demand Management				
Water Conservation & Demand Management	Upstream of meters	85.83	48.90	1.76
	Downstream of meters	133.90	48.90	2.74
Existing Sources				
Dams	Groendal	322.37	157.43	2.05
	Churchill	962.14	423.40	2.27
	Impofu	493.00	1218.20	0.40
	Kouga/Loerie	976.66	1440.65	0.68

Excluding the existing schemes, a comparison in the cost of water as estimated with the two methodologies is compared in Table 10 and Figure 14. The difference in the ranking of the schemes is considered more important than the actual price differences.

Figure 12: Incremental Cost of Water by Scheme - a comparison of methodologies

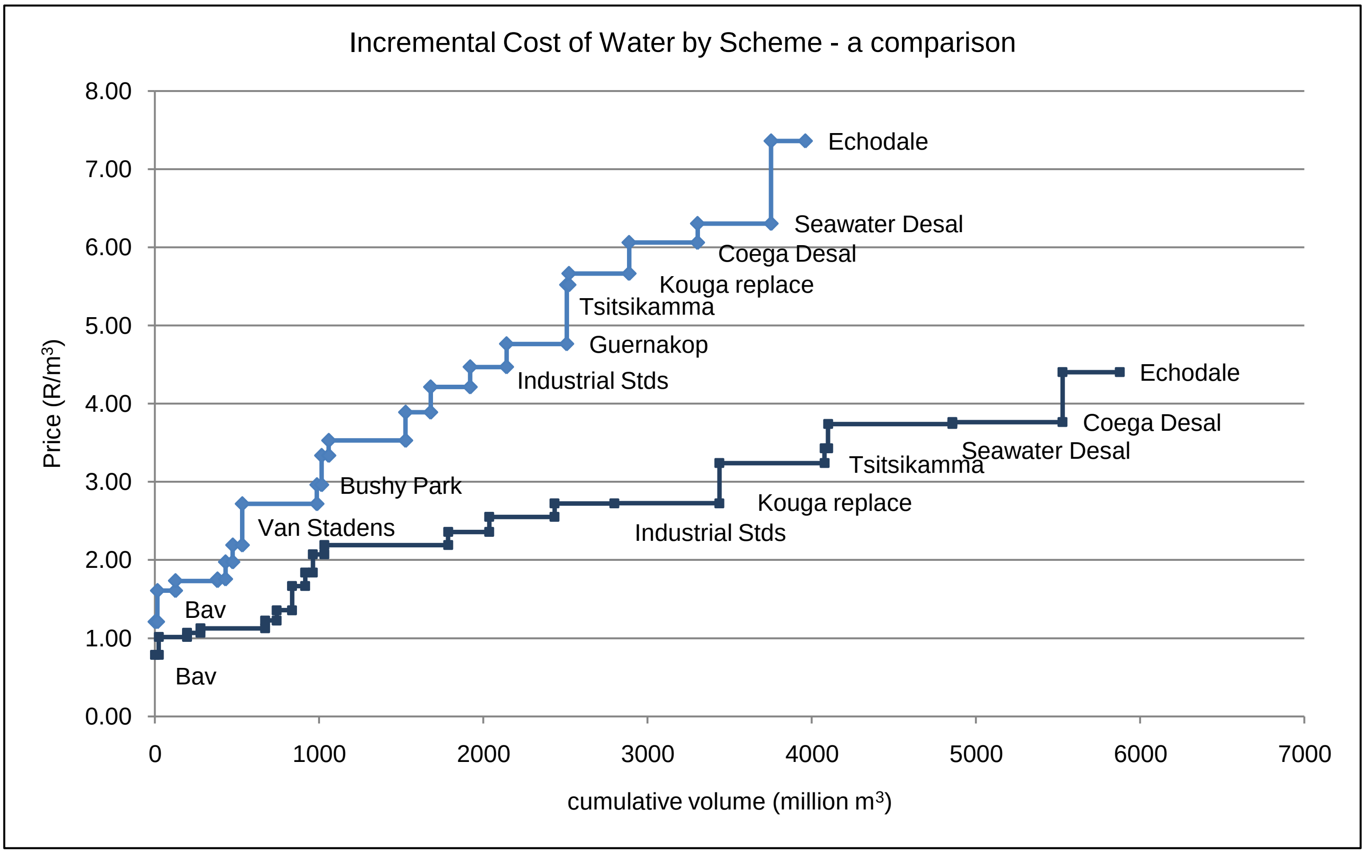


Table 10: A comparison of the ranking of schemes according to each methodology

R/m³	**SCHEMES -** no discounting of yields	**SCHEMES -** 4% discounting of yields	R/m³
R 0.7854	Baviaanskloof	Baviaanskloof	R 1.2085
R 1.0153	Gamtoos river irrigation return flows	Gamtoos river irrigation return flows	R 1.6069
R 1.0689	Upstream of meters	Upper Fish River	R 1.7335
R 1.1266	Upper Fish River	Upstream of meters	R 1.7554
R 1.2260	Coega fault	Coega fault	R 1.9739
R 1.3569	Van Stadens	Van Stadens	R 2.1896
R 1.6675	Downstream of meters	Downstream of meters	R 2.7384
R 1.8392	Bushy Park	Bushy Park	R 2.9612
R 2.0719	Jeffrey's Arch	Jeffrey's Arch	R 3.3359
R 2.1924	Nooitgedagt Low-Level	Nooitgedagt Low-Level	R 3.5285
R 2.3600	Sundays River	Sundays River	R 3.8895
R 2.5517	Treated effluent from Coega	Treated effluent from Coega	R 4.2129
R 2.7243	Industrial standards FWF WWTW	Industrial standards FWF WWTW	R 4.4701
R 2.7262	Guernakop Dam	Guernakop Dam	R 4.7652
R 3.2410	Kouga replacement	Tsitsikamma River diversion	R 5.5203
R 3.4287	Tsitsikamma River diversion	Kouga replacement	R 5.6650
R 3.7403	Seawater	Coega desalination	R 6.0614
R 3.7647	Coega desalination	Seawater	R 6.3046
R 4.4038	Echodale: potable standards	Echodale: potable standards	R 7.3612

3.1 Discussion

3.1.1.1 Methodologies – question of discounting

The most apparent difference between the schemes is that the LC curve is much steeper and is spread over a shorter range. The LC approach yields higher costs per unit volume because it discounts future physical yields.

It is of further interest that the ranking of the schemes is very similar. This means that the policy implications will be almost identical and thus the debate over the methodologies can be deemed redundant. It is recognised that schemes with higher capital costs are identified as less favourable, and hence the Seawater Desalination and the Kouga Dam Replacement have higher average costs when calculated using the LC approach.

A change in the discount rate also has little effect on the ranking of the schemes. When the discount rate changes to 10%, the ranking is almost unchanged, the exception is the Kouga Dam Replacement which, having a very high initial capital outlay is rendered even less favourable.

3.1.1.2 Existing schemes

Although crude data and assumptions were used to calculate the cost of water from existing dams, it is interesting to note how much cheaper the water is compared to the new proposed dams. For example, water from the Guernakop Dam costs R4.77/m^3, compared to R2.27/m^3 from the Churchill Dam, the most expensive current water. The capacity of the new dams is substantially smaller than the current dams and thus illustrates the impact of economies of scale. If nothing else, it reinforces the lesson that the number of effectual and economically efficient dams that can be constructed in an area is limited.

3.1.1.3 Cheapest options

The Baviaanskloof Trading scheme is the cheapest source of water in both graphs, largely due to the low start-up capital and low annual costs. There are only 16 major landowners in the Baviaanskloof area; a small enclave of agricultural activity within the Baviaanskloof Nature Reserve where livestock farming is the predominant activity (de Paoli, 2009). An estimated 300-500 hectares of land is irrigated and farmers envisage moving towards eco-tourism to supplement their earnings (Jansen, 2008). Given the type of farming activity and the low level of current irrigation usage, it seems that the opportunity cost of buying irrigation entitlements in this area is low. On the other hand, seeing that their farming activities are not wholly dependent on irrigation, they may be willing to sell their irrigation rights to supplement their incomes.

The Baviaans River feeds into the Kouga Dam, but only contributes an estimated 25-40 million m^3/annum (27% of instream flow). Given the low level of irrigation activity, it is not surprising that water trading in the Baviaanskloof will yield a mere 0.9 million m^3/annum. This source does not diversify NMBM's water supply sources as it experiences the same weather patterns and drought cycles as the Kouga Dam and does not supply NMBM with a vast additional amount of water.

The Kouga, Baviaans and Groot Rivers combine to create the Gamtoos River. However, the Kouga Dam has no flood outlet valves, and thus only supplies water to the Gamtoos in times of flood, when the dam overflows. The Gamtoos River is further restricted by the Loerie Dam. The Groot River is the only river that feeds the Gamtoos with free-flowing water, and as a result the Gamtoos River is starved, with high salt concentrations and high electrical conductivity, making it unusable for human consumption or irrigation.

The diversion of the lower Gamtoos River irrigation return flows provides the second cheapest source of water. The start up capital needed to construct the pipelines connecting the Gamtoos River to the Loerie Balancing Dam is a relatively low R102.4 million. Thereafter, the electricity costs, needed for pumping and reverse osmosis, needed due to the high salinity make up 79% of the annual costs at R0.53/m^3. The high dependency on electricity makes it vulnerable to future electricity price hikes. Gamtoos Valley irrigation farmers obtain all their water from the Kouga Dam, and thus this scheme enables more of the water from the Kouga Dam to be used by the NMBM. Nonetheless, during previous droughts water supplies to farmers from the Kouga Dam have been severely restricted, suggesting that this scheme will do little to supplement NMBM's water in times of drought.

The exploitation of ground water falls within the lower third of all the water costs. Ground water schemes' electricity costs make up 77% of the total annual costs. Although the additional yields are relatively low (ranging from 2-4 million m^3/annum), ground water provides a new source that is somewhat independent of the weather patterns and is not related to the other schemes. Ground water acts as some security against drought, although the pumping, and consequent electricity costs, will rise during droughts, when the water table falls. Ground water acts as a necessary component of the NMBM's bundle of water sources, as it provides a source of cheap water and acts as some security during droughts.

3.1.1.4 Recycling

These schemes deal with the augmentation of non-potable water, and are critical to meet the expected water demand increases as a result of Coega IDZ. Echodale is the most expensive scheme, because the intervention encompasses both the construction of a new dam and the recycling of water. The Fish Water Flats WTW and the treated effluent at Coega are both expensive schemes, but diversify NMBM's water portfolio by freeing up fresh potable water for residential consumption. Nevertheless, available water also tends to decline during droughts.

3.1.1.5 Capital intensive schemes

Nooitgedagt Low Level

The Low-Level scheme at Nooitgedagt is imperative to augment local supplies with Orange-River water. This scheme provides a substantial increase in allocation from the Gariep Dam. It augments supply by 30.5 million m^3/annum at R2.19/m^3 and because the supply comes from a different catchment, it spreads the risk of drought. As shown, there is a negative covariance between average volumes of dams in the Western System and the Gariep Dam. This scheme is crucial as it paves the way for schemes such as the Upper Fish transfers and the desalination of the Sundays River. This scheme provides the most water compared to any other proposed schemes, supplying 468million m^3 over 25 years.

Dams

Dams are capable of storing vast quantities of water; although they do have finite volumes. They need to be managed in a risk-averse manner as they generally act as a buffer stock of unused water, which is kept back in dry seasons, in case the dry spells persist. The proposed dams are all situated within the same catchment areas as the existing dams and thus although they will increase their storage, they will not diversify the current basket of water supply.

The Gamtoos Valley farmers will benefit from the Kouga Dam Replacement scheme as it will reduce competition between urban and agricultural water demand.

Desalination

Desalination plants provide the second most expensive source of water. Nevertheless, this option should not be discarded straight away. Unlike dams, desalination plants do not have a finite volume, and their entire capacity can be utilised. The plant provides risk-free water that can be employed in times of water shortages. Although the running costs are extremely high and they are heavily dependent on electricity, desalination plants make other sources more economically feasible and impact the way other supply sources can be operated and viewed.

If a dam manager knows that he has a desalination plant as reserve in case of drought, he can sell the cheaper dam water and treat the dams in a more risk-loving approach. Recycling of water becomes cheaper as this water does not have to be saved as a buffer.

It would be useful to have a desalination plant included into the bundle of water sources, as it provides a dependable water source that only has to be utilised in times of drought. Literature describes desalination plants as the ultimate 'back-stop' source (Rogers, 2002).

3.1.2 Sensitivity Analysis

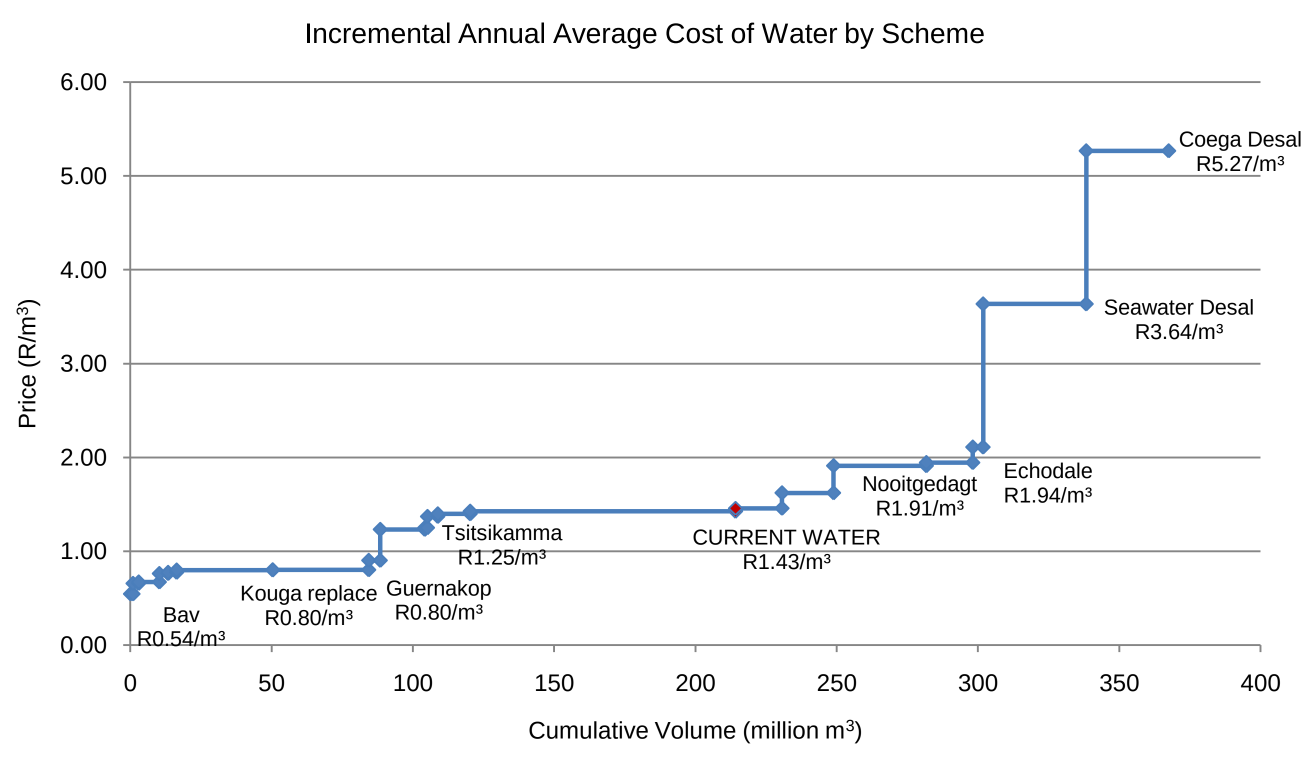
3.1.2.1 Annual Running Costs

It is interesting to analyse the cost of water for one year only. One assumes that capital costs are sunk costs and hence only the operating and running costs are evaluated. The current cost of water supply is incorporated into this analysis.

Most of these schemes will outlive the 25 year time frame examined, and the initial capital costs will slowly be amortised. The running costs examined will need to be recovered year after year if the schemes are to continue functioning. Figure 15 portrays the annual average costs of the respective schemes and includes the cost of current water at R1.43/m³. Further details pertaining to the ranking and annual costs of the scheme are displayed in the Appendix A: Table 62.

It is not surprising that desalination plants have the highest running costs per cubic metre of water produced. The annual running costs are expected to increase with rising electricity prices. A striking result is that the Guernakop and Kouga Replacement Dam are regarded as much more favourable options when only considering their annual running costs. The WC/WDM scheme jumps to the third most expensive scheme when accounting for the annual costs only.

Figure 13: Incremental Annual Average Cost of Water by Scheme



3.1.2.2 *Looking beyond 25 years*

The time frame is adjusted to 50 years ceteris paribus. This is a reasonable modification as most of the proposed schemes will last for more than the projected level of 25 years. It is also important to test whether the rank of the schemes changes significantly when the timeframe is extended to 50 years.

The average water costs are cheaper when examined over 50 years. There are no significant changes in the ranking when compared to the schemes after 25 years. Details of the schemes' average costs and rank are displayed in Appendix A: Table 63 and Figure 49.

The Coega Desalination overtakes the Seawater desalination and Echodale dam as the most expensive water in the long run. This can be attributed to the fact that the Coega desalination plant has the highest annual costs, and in the long run, the initial capital costs no longer have as great an influence on the average water costs.

4 Conclusions and Shortcomings

The water manager's main concern is to simultaneously augment supply, whilst minimising cost and risk. This chapter, through the construction of the incremental cost curves has been a useful heuristic in understanding current and historic policy. A summary of the proposed interventions as recommended in the Algoa Reconciliation Strategy and the associated average costs is in Appendix A: Table 64. The following conclusions can be deduced from the discussion above:

- Desalination Plants: expensive, but augment supply and minimise risk significantly
- Water Trading & Gamtoos Return Flows: cheapest options, but do not augment supply or minimise risk sufficiently
- Groundwater: relatively cheap, minimises risk, but does not augment supply sufficiently
- Nooitgedagt: expensive, but reduces risk considerably and augments supply amply
- Additional dams: expensive, augment supply but do not decrease systemic risk
- Recycling: expensive, but augments supply and reduces risk, though only to a degree

The Levelised Costing approach is advisable as it is rendered as a more conservative policy recommendation. The outcome yields higher costs per cubic metre and promises lower yields over both the 25 and 50 year timeframes. Seeing that the impact of Climate Change has been ignored in this analysis, one should adhere to a more conservative approach.

This chapter's major shortcoming is that only financial costs have been incorporated. The total economic cost of each scheme needs to be investigated and this includes the opportunity costs of the schemes and the quantification of externalities. The environmental and social impacts of the proposed schemes need to be quantified before a true cost comparison can be undertaken.

There is a limit to how useful the incremental cost curve is and a major limitation is its failure to incorporate risk. Climate change is a pressing concern and further research could examine different climate and weather change scenarios.

The results from this chapter will be used to compare the cost-effectiveness of land rehabilitation in Upper Kromme Catchment in Chapter 2 and water trading possibilities in Chapter 3. The Levelised Cost approach will be used in the remaining sections of this paper.

CHAPTER TWO

ECONOMIC APPRAISAL OF RESTORING THE UPPER KROMME RIVER CATCHMENT

This chapter investigates the economic viability of restoration in the Upper Kromme Catchment and assesses whether it should be considered as a scheme to augment NMBM's water supply. It has been argued that degradation of the natural capital is threatening the delivery of ecosystem services and therefore action needs to be taken to reverse the situation. In particular, it is believed that the degradation of the wetlands and the spread of alien infestations are threatening the supply and quality of water entering Churchill Dam. Nelson Mandela Bay Municipality is reliant on this water as it makes up a quarter of their demand.

It is hypothesized that the restoration of natural capital will improve water flow and water quality, land and agricultural productivity. The argument is that effective land management practises will increase the delivery of ecosystem services and optimise their economic benefits. 'Working for Water' and 'Working for Wetlands' in Kromme River form part of the proposed catchment management and it is suggested that their work will ensure the recovery of the natural capital, improving the delivery of watershed services.

It is anticipated that the restoration activities will have an impact on the ecosystem services, demonstrated in Table 11. The expected benefits resulting from restoration activities predominantly accrue to the NMBM, as they are the end-users of the water. The municipality's willingness to pay for these services will be influenced by the municipality's current supply cost curve and the costs of their alternative water sources.

Table 11: Expected change in ecosystem services provided by restored the Upper Kromme River Catchment

Classification	Ecosystem Service	Impact
Provisioning and Regulating Service	Water regulation & yield	Amplitude smoothing Stabilises stream flows; increases reliability and decreases risk; increase in yield
Regulatory Service	Water quality	Well functioning wetlands decrease turbidity & trap sediment & pollutants.
Regulatory Service	Flood attenuation	Reduces peak flows; curbs downstream damage; decreases sediment loads
Provisioning Service	Land productivity	Augmenting nutrients & soil fertility on floodplains

Source: Adapted from Millennium Ecosystem Assessment (2003), Turpie et al (2009), Costanza et al (1997) and NMBM (n.d)

This chapter begins with an overview of the selected site, providing background information to the geographic layout, the socio-economic and agricultural setup and insight into the restoration activities taking place in the Catchment. This is followed by a literature review on the valuation of ecosystem services and the Payment for Ecosystem Services (PES) scheme, which aims at linking conservation to the market place. An in-depth study of the costs and benefits associated with the restoration activities ensues, whereby a cost-benefit analysis is performed. The inclusion of restoration as a NMBM-funded scheme to augment the municipality's water supply is discussed.

It should be mentioned at the onset that due to ecological data limitations and poor archiving of economic data, an economic assessment of 'Working for Wetlands' could not be undertaken. Working for Wetlands has only been rehabilitating the wetlands since 2000 and thus it is too soon to measure their impact on the wetlands.

1 Background

1.1 Geographic Layout

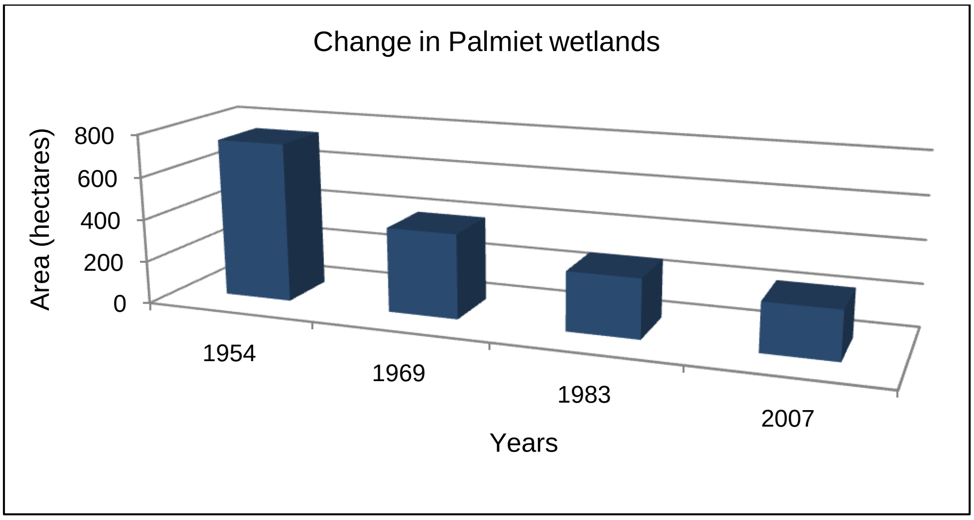
The Kromme River was named by the Dutch settlers, because of the numerous twists and turns it made in the narrow valley (Raymer 2008:52). Its catchment (Tertiary Catchment K90), is 155 631ha in extent and is situated in a ravine between the Suuranys Mountains in the interior and the Tsitsikamma Mountains towards the southern coast of the Eastern Cape (Haigh, Illgner, Wilmot and Buckle, 2008). The river, 95km long, runs past the town of Kareedouw, through agricultural zones, along the R62 before flowing into the Churchill Dam (34° 00'S 24°29'E). About 20km downstream, the Diep River joins the Kromme River and it flows into the Impofu Dam (34°05'S 24°42'E) (Mander *et al,* 2010:14; Haigh *et al,* 2008). The Kromme estuary, which is classified as permanently open and therefore a lagoon, opens at St Francis Bay (Sale, Hosking and Du Preez*,* 2009:263). The estuary is "fresh water starved" as the dams' storage exceeds the mean annual rainfall and therefore prevents the normal inflow of freshwater (Bate and Adams, 2000:329).

The Kromme River Catchment contains peatlands, mainly dominated by palmiet (*prionium serratum*). Historically peat basins covered 547ha (2.6% of the total area of the Kromme River) and were situated within K90A and K90B quaternary catchments (Kotze & Ellery, 2009:114). Alluvial fans, are a feature of the Kromme River valley floor, and are apparent at the distal ends of tributaries entering the Kromme. These fan-shaped deposits stretch into the palmiet wetlands, restricting their spatial coverage, and are also to blame for the increased rate of sediment delivery at these places (Haigh *et al*, 2008). Flooding erodes the distal ends of the fans which result in steep banks developing and contributes towards the advancement of headcuts.

Wetlands, another trait of the Kromme River, can be described as having a sponge-like effect, as they soak up water during wet seasons, which permeates into the ground water, augmenting base flows and regulating flow (NMBM, n.d). Wetlands provide important regulating services and have the ability to stabilise riverbanks thereby protecting the embankments from soil erosion. The palmiet bends sideways against the banks during excessive water flows, shielding the banks from erosion and lowering silt loads in the river. The Kromme River can be described as a high-energy system, which means the runoff is steep and moves very quickly. The wetlands play a significant hydrological buffering role in the Kromme system as they absorb initial flooding; hold back the water and hence break the force of the water flow. This regulatory ecosystem service can be classified as flood attenuation as it absorbs flood peaks and lengthens the flood period at a lower level, resulting in reduced flood damages to downstream users (Turpie, Lannas, Scovronick and Louw, 2009:31). The wetlands also act as natural water filters by trapping sediments and pollutants, thereby improving the water quality and reducing high sediment loads from entering the dams (Woodward & Wui, 2001:259; Turpie *et al*, 2009:35).

Since 1950, the deterioration of the wetlands and Kromme River has escalated and its health is under threat. The invasion of black wattle, overgrazing, draining and ploughing of the flood plains and wetlands, the tarring and construction of roads and bridges and the channelling of the river have accelerated the degradation. The catchment's health has been compromised and it is feared that much of the Upper Kromme Catchment can no longer provide important ecosystem services and that the alien invasive plants are compromising the water flow to NMBM and other users (Buckle, J pers. comm. 2010, 12 February).

Figure 14: Change in the size of palmiet wetlands from 1954-2007 in the Upper Kromme Catchment



Source: Rebelo, A (MSc dissertation in prep)

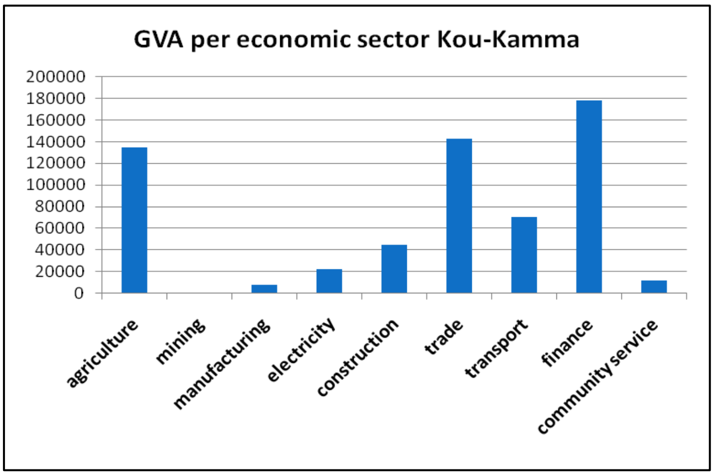
1.2 Socio-Economic Setup

The K90A and K90B quaternary catchments, the focus area for the study, form part of the Kou-Kamma Local District Municipality in the Eastern Cape. Joubertina, Louterwater and Kareedouw are the principal towns in this Local Municipality – with the latter town falling within the Upper

Catchment. Kareedouw, which was established in 1905, accommodates the administrative centre for the Kou-Kamma Municipality (Haigh *et al*, 2008).

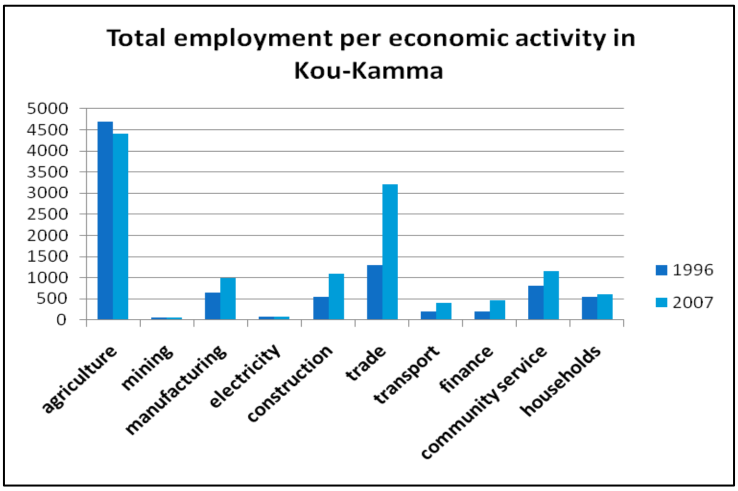
The Municipality has experienced positive economic growth in the past few years and according to the CDM report (2008) agriculture is the third highest contributing sector to the Local Municipality's economy, after finance and trade respectively, as portrayed in Figure 17. Agriculture is an integral part of the local economy – employing 46% of formal sector workers and 35% the total population of roughly 41 000(Cacadu District Municipality, 2008). As Figure 18 shows, agriculture is the largest employer in the Kou-Kamma Local Municipality. As stated in the CDM report (2008), a quarter of the population were living in poverty in 2007, though in that same year there was less than 10% unemployment. The Gini-coefficient was 0.64 in 2007, inequality having increased by 15% since 1996.

Figure 15: Contribution to Kou-Kamma economy per economic sector



Source: CDM (2008)

Figure 16: Total employment per economic activity in Kou-Kamma



Source: CDM (2008)

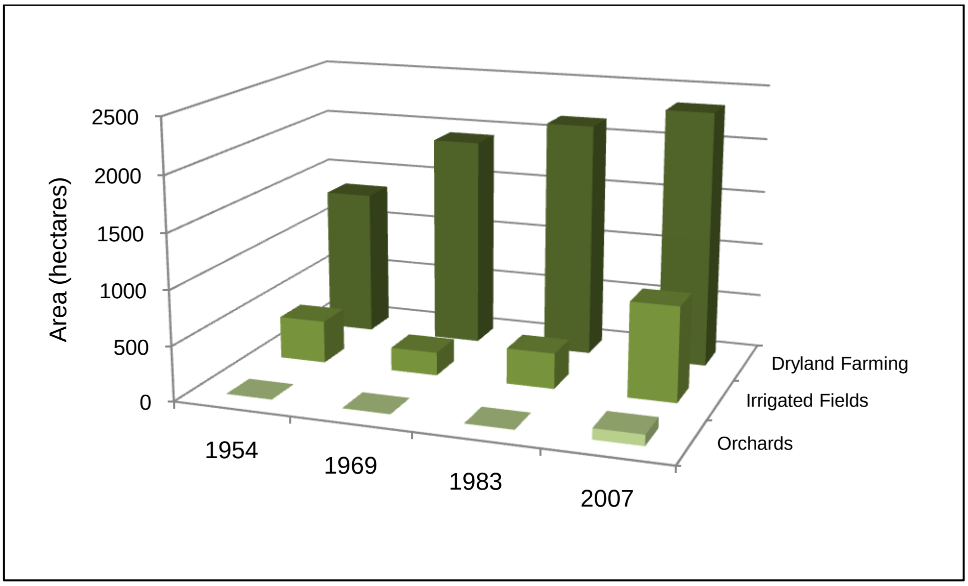
The town of Kareedouw which consists of an estimated 4 500 people, obtains its water from the Assegaai tributary and from storage tanks situated at *Drie Krone* on municipal land, as this is much cheaper than pumping from the Kromme River below them. This small town is known for its timber treatment industries and agricultural enterprises.

1.2.1 Agriculture

The Langkloof valley has long been an agricultural hub; the first grazing permits were rented as early as 1703 and title deeds were granted from 1820 onwards. In the 1800s, stock farming, mainly consisting of sheep and cattle, took place in the Kromme River. Minimal pastures were planted; instead the animals grazed on the veld which was burned regularly (Haigh, Grundling and Illgner*,* 2002). In the 1900s, apples and soft fruit became the popular choice of produce and World War I provided an impressive market for such fruit. The Apple Express assisted in transporting the fruit to the export market and in 1929, almost 20 000 tons left the Langkloof and Kromme River (Haigh *et al*, 2002). The 1931 flood ended a 3-year drought, but ripped up orchards and swept away topsoil causing substantial erosion. Many soft-fruit orchards were re-established, especially on floodplains (previously wetlands) and the temporary floodplain zones, which consisted of *themeda triandra* (red grass), were transformed to produce grains and fruit. Kikuyu was considered a successful pasture grass to plant and many farmers changed towards dairy and beef production after 1935 (Haigh *et al,* 2008).

Wetlands have been ploughed and rivers beds bulldozed to change the course of the river in order to plant pastures and orchards in the fertile flood plains. According to the Vincent Egan Report (Haigh *et al*, 2002), 95% of the wetlands at Krommedraai were destroyed, resulting in deep gully erosion. Overgrazing causes excessive silt to enter the river and the mining of rock and sand at Kammiesbos caused damage to the river beds and nearby wetlands.

Figure 17: Changes in agriculture in the Upper Kromme Catchment



Source: Rebelo, A (MSc dissertation in prep)

The changes in the extent of agricultural activity from 1954 to 2007 are indicated in Figure 19. The impacts of the changes in agriculture on the hydrology of the catchment were quantified by Rebelo (MSc dissertation in prep). The removal of AIPs is expected to have large positive externalities for agriculture, the economic benefits of which are computed in this paper.

1.3 Legal Considerations

The Kromme River Catchment (K90) falls into the Fish-Tsitsikamma Water Management Area (WMA) as declared in the National Water Act (Act 36 of 1998, Section 5). This framework aims to implement the national policy of protecting South Africa's water resources and associated ecosystems through promoting water conservation and demand management.

The agricultural activities in the Kromme Catchment need to be discussed and evaluated in light of the various environmental laws. The Conservation of Agricultural Resources Act (CARA Act 43 of 1983) endeavours to control the over-utilisation of natural agricultural resources and advance the conservation of soil and water resources and natural vegetation. It states that authorisation is needed in order to drain or cultivate any vlei, marsh or water sponge – which therefore includes wetlands. Permission is also needed before land can be cultivated within the flood area of a water course or within 10 metres of the flood area of a water course (CARA 1983). It would appear that the Kromme farmers do not abide by this law as many have planted pastures in the floodplains and the wetlands have been drained or cultivated. Nevertheless, it is possible that these areas were planted before the law was introduced. For example, Krommedraai, Krugersland and Jagersbos farms have orchards in the floodplains and Kammiesbos and Hudsonvale have kikuyu planted in the floodplains of the watercourse. The legal ramifications of these actions are beyond the scope of this paper and it is unknown whether these farms have authorisation to carry out these actions.

The New Government Regulation GNR 398 of 26 March 2004 authorises the impediment or diversion of water flow if the structure does not exceed a foundation width of 15 metres and a length of 200 metres. The GNR 389 of 24 March 2004 allows a person to alter the beds, banks or characteristics of a water course if the alteration activity does not extend for more than 50 metres continuously or is an accumulative distance of 100 metres. These regulations are consistent with the National Water Act (Act 36 of 1998). The modifying activities may not take place within 500 metres upstream or downstream from the boundary of a wetland. The government regulations only permit these actions if the water flow volume is not reduced, strict erosion control measures are put in place and if the water quality is not adversely affected.

Consistent with the GNR 1191 of October 1999 (Government Gazette 20526), the Kromme Catchment falls within Groundwater Abstraction Zone C. Abstraction from this drainage region is restricted to 300m^3 per hectare per annum. The Kromme Catchment is also excluded from the General

Authorization 399 (Government Gazette 26187, 2004) for taking surface water, which sets abstraction at 15litres per second. However, the legal limit for storing water, set at 50 000m^3, does apply to the Kromme River Catchment and authorisation is needed for storing more than 10 000m^3 of water per property (Gazette 26187, 2004). In June 2010, GNR 514 of June 2010 (Government Gazette 33290) restricted the abstraction of water by irrigators for agricultural use in the Kromme to 5 600m^3 per hectare per annum.

If enforced, these laws have the potential to protect the integrity of the Upper Kromme Catchment and the delivery of ecosystem services. The restoration activities carried out by 'Working for Water' and 'Working for Wetlands' need the support of these laws to ensure the benefits of their work are not reversed by illegal activities.

1.4 Restoration activities

1.4.1 Working for Water

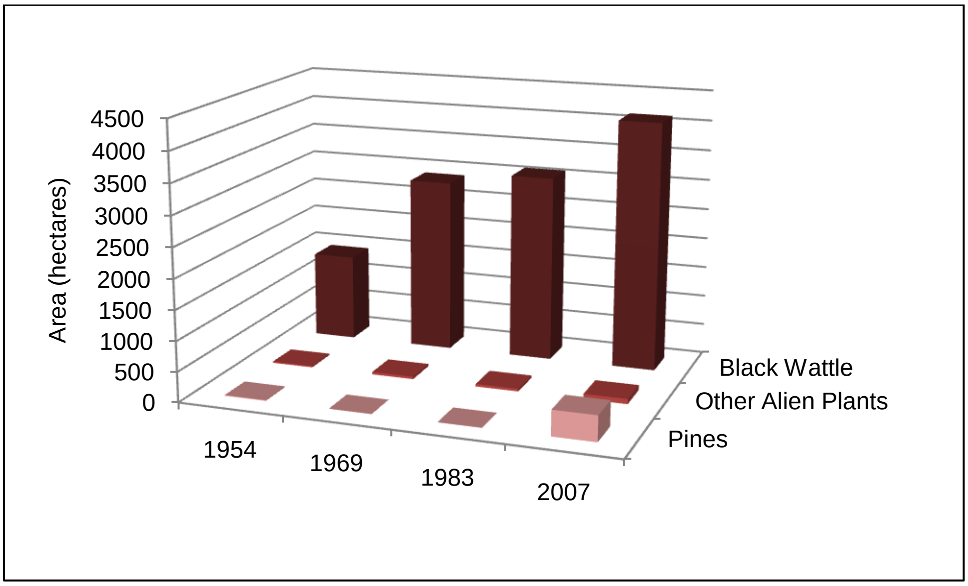
Concerns over introducing alien invasive plants to replace natural vegetation in South Africa can be traced back as early as 1888 and 1908 to Peter MacOwan and Rudolf Marloth respectively. However, Professor Wicht, in 1945, was the first to highlight the detrimental impact AIPs have on water supply (van Wilgen *et al*, 1997). Attempts to control AIPs were haphazard as ecological and concrete scientific evidence was still lacking. Hydrological experiments took place in Jonkershoek and between1970-1974, 18 000 hectares of AIPs were cleared. The clearing and control efforts slowed during the 1980s as management and funding was lacking. The end of the 1980s saw the publication of the Fynbos Biome Project which integrated the knowledge and understanding gained over the past decades. The publication's dire warnings and predictions led the then Minister of Water Affairs, Kader Asmal, to renew the alien control campaign through the programme: 'Working for Water' (van Wilgen *et al*, 1997).

It is now common knowledge that black wattle infestation reduces stream flow and catchment yield (de Wit, Crookes and van Wilgen, 2001; Marais and Wannenburgh, 2008; Cullis, Görgens and Marais, 2007). Cullis *et al* (2007) estimates that South Africa is losing 4.1% of registered water use due to invasive alien plants and this could rise to 16.1% if it is not controlled.

In 1996 'Working for Water' began clearing AIPs in the Upper Kromme Catchment. The invasion of AIPs, particularly *acacia mearnsii* (black wattles), has a damaging impact of the ecological system. Apparently, after the 1931, *acacia mearnsii* appeared in great numbers, particularly in the floodplains. They were used for firewood, and around 1945 their bark was stripped and sold to the tanneries in George (Haigh *et al*, 2002).

The roots of the *acacia mearnsii* create deep gullies, causing the river banks to weaken and collapse during floods, thereby exacerbating erosion. AIPs hinder the cultivation of grazing pastures as they occupy and therefore reduce the grazing potential of livestock (de Wit *et al*, 2001:168).

Figure 18: The change in alien invasive plants from 1954-2007 in the Upper Kromme Catchment



Source: Rebelo, A (MSc dissertation in prep)

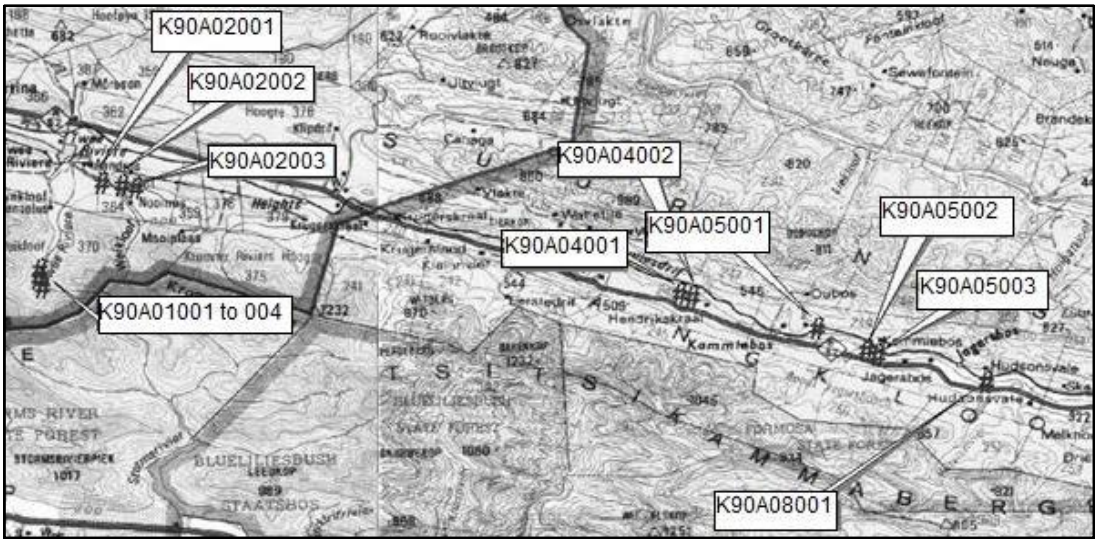
1.4.2 Working for Wetlands

'Working for Wetlands' began work on the rehabilitation of the wetlands in the Upper Kromme Catchment in 2000. The rehabilitation took the form of physical restoration, such as the construction of weirs, as illustrated in Figure 21.

The reason for the concrete and gabion weirs is to prevent further gully erosion and to prevent further reduction in the peat basins. The aim is to lift the water table in the existing wetlands and to create silt traps (SANBI database: http://sanbi.isoftnet.co.za/scripts/runisa.dll?NBI accessed 5 May 2010). The rehabilitation aims at restoring the wetlands' ecosystem services, which provide both direct and indirect use values such as their hydrological buffering effect and water purification services (MEA, 2003:57).

The rehabilitation began in 2000, with the construction of four gabion weirs to tackle the gullies in the Upper Kromme Catchment (K90A-01-001 to 004). Working for Wetlands also embarked upon the building of large gabion structures at Kompanjiesdrif (K90A-04-002) and at Hudsonvale (K90A-08-001) to stabilise headcuts threatening peat basins (Kotze & Ellery 2009:152). The three concrete structures were erected in 2001-02 in Krugerskraal to address deep headcuts and prevent erosion further destroying the wetlands (Buckle, J, pers. comm. 2010, 31 August). The planning and construction of the concrete and gabion structure (K90A-05-001) at Hendrikskraal, below the convergence with the Eerstedrif River, began in 2003-04. Two additional weirs were constructed further downstream in the following years. The 2007 flood caused damage to many structures, washed away collected rocks and silted up excavations which had taken place (SANBI database). In the subsequent years, maintenance of the structures has taken priority, with plans to continue building in the future.

Figure 19: Working for Wetlands' weirs 2000-2010



Source: Buckle, J. 2010, pers. comm. 31 August

The relative costs of the restoration activities undertaken by 'Working for Water' and 'Working for Wetlands' need to be compared to their associated benefits. Increased water yield and decreased erosion are expected due to the removal of alien invasive plants, while improved baseflow and water quality, and flood attenuation are anticipated due to the rehabilitation of the wetlands. In comparing the costs and benefits, the decision whether to continue investing in restoration can be addressed.

1.4.3 Biodiversity Stewardship Strategy

The Eastern Cape Parks Board endeavours to execute the National Biodiversity Framework's policy of developing and intensifying provincial biodiversity stewardship programmes and the Kromme River Catchment falls within their jurisdiction. According to the Biodiversity Stewardship Strategy document (Steyn, 2010); the goal is to "secure biodiversity assets of both immediate and long-term value through voluntary agreements with private and communal landowners/users." Biodiversity extends to "all living things and also a series of actions and interactions which sustain living components and enables their persistence over time" (Vromans *et al*, 2010). Biodiversity is essentially a term for nature and it underlies all ecosystem functioning and ecosystem goods and services. The degradation of natural capital brings about a loss of biodiversity, thereby compromising ecosystem functioning and the delivery of ecosystem goods and services.

The establishment of the Stewardship Programme rests on identifying the Critical Biodiversity Areas as these will become stewardship priority areas. Critical Biodiversity Areas is land or water fundamental for "biodiversity and to the maintenance of ecosystem functioning" (Vromans *et al*, 2010). Critical Biodiversity Areas need to be preserved in their natural or near natural state. Ecological Support Areas are "supporting zones" and need to be protected as they support the Critical Biodiversity Areas and formal Protected Areas (Vromans *et al*, 2010). The overarching vision is to establish corridors of intact vegetation across terrains to enable species migration and the Stewardship Programme is believed to be one of the stepping stones needed to realise this initiative.

The Stewardship Programme aims to create contractual agreements with landowners to ensure the protection of Critical Biodiversity Areas. The intention is to safeguard important biodiversity areas which fall within production landscapes, and at the same time, keep the land in agricultural production. The intent is for agricultural activities to remain, but for farmers to enter into agreements to preserve portions of land not utilised for agricultural production. The success of the Stewardship Programme is grounded in building relationships with landowners and land users.

The Stewardship Programme is another form of restoration and rehabilitation and therefore close collaboration is needed between existing involved parties. Partnerships and strategy schemes need to be developed between 'Working for Water', 'Working for Wetlands', 'Working on Fire' and the Eastern Capes Stewardship Programme to ensure that each does not work independently and haphazardly. Resources and knowledge of the area should be shared so that the most efficient outcome of restoration can be realised[3].

Figure 22indicates the areas of ecological importance in the southern section of the Kromme River Catchment. Even though this map only includes half the study site, it reaffirms the ecological importance of the Kromme wetlands as seen by the light and dark shades of green. These colours indicate the Ecological Support Areas and Critical Biodiversity Areas respectively. The map illustrates the Kromme River's crucial role as both a supporting zone and an area which contains pockets of critical ecological functioning. The Formosa Nature Reserve, a formally protected area, is illustrated in dark blue.

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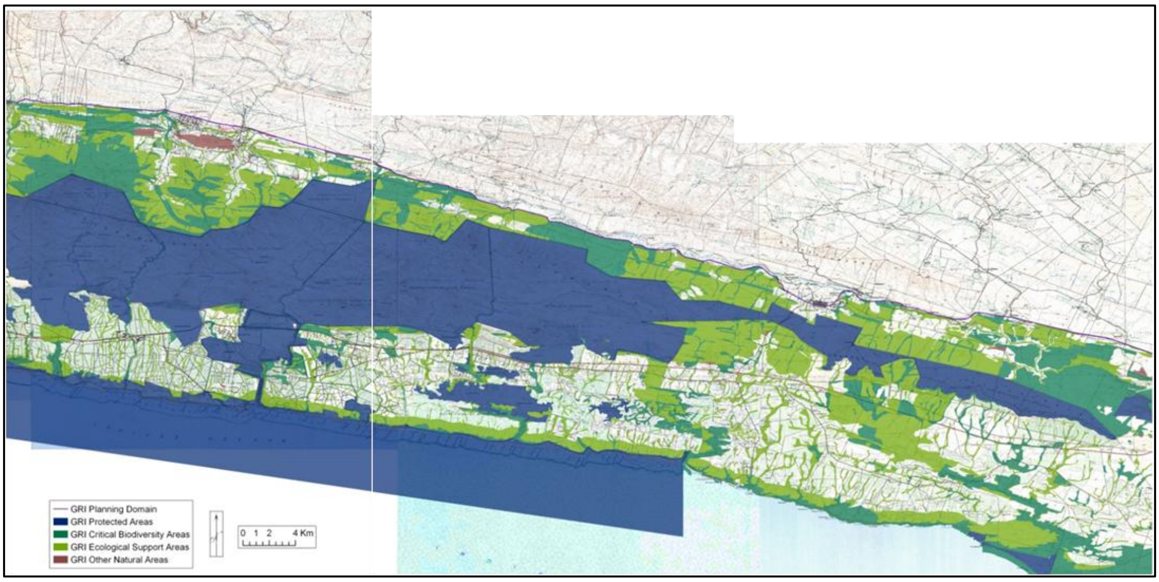
[3] Since our initial meetings with some of the respective organisations, a workshop was held by the Living Lands PRESENCE network whereby the interested parties had a chance to interact and discuss the developments of the Kromme River. Another workshop is being held with the Kromme landowners in March 2012.

Figure 20: A section of the Critical Biodiversity Areas of the Garden Route, which identifies the Critical Biodiversity Areas and Ecological Support Areas in the upper Kromme Catchment



Source: Holness *et al* (2010)

1.5 Previous Kromme Studies

The most recent study on the Kromme is the Baviaanskloof-Tsitsikamma PES Pilot Study by Mander *et al* (2010), which aimed to quantify the impact of various restoration and management options on the delivery of ecosystem goods and services. A Payment for Watershed Services (PWS) scheme was investigated where Nelson Mandela Municipality was the buyer of the watershed services and the Tsitsikamma, Kouga and Kromme watersheds were the suppliers. The report allowed for different management alternatives, such as clearing alien invasive plants only; considering revegetation, and adopting land practises, which either maximise baseflow and/or optimise yield.

It was estimated that by only removing alien invasive plants, an increased streamflow of over 4 million m^3/annum and a baseflow increase of 2.4 million m^3/annum was realised. This translated into economic benefits of R344/ha in water sales (Mander *et al*, 2010:19&38). It was concluded that a management option of both clearing alien invasive plants and revegetating is the most economically and financially feasible option for the development of a PWS scheme in the entire Baviaanskloof-Tsitsikamma area. Potential economic benefits calculated from this scheme ranged from carbon sequestration, biodiversity and eco-tourism, decreased sediment yields and increased baseflow and yield (Mander *et al*, 2010:27).

The coarseness of the data, assumptions and results pertaining to the Kromme River Catchment in this report was attributed to the fact that they were based on a desktop study. For this reason an in-depth analysis of the Kromme River Catchment is being investigated.

The Kromme Report compiled by the Institute of Water Research (2005), recognised the river as an important source of water for the NMBM and thus recommended either enforcing restricted access or buying the intact areas of the Kromme River. The report proposed buying cooperation from the farmers in the form of a contract fee as they concluded that black wattles, farming activities and rundown farming infrastructure (such as broken dam walls) were to blame for the degradation of the river and the decline in ecosystem goods and services.

The effect of freshwater inflows into the Kromme estuary on recreational value was investigated by Sale *et al* (2009) who found a marginal willingness to pay for incremental freshwater inflow of R0.013/m^3. The study adopted contingent valuation techniques and respondents were asked the maximum amount they would be willing to pay towards a project that could secure freshwater inflow into the estuary and thus safeguard fishing and birding activities (Sale *et al*, 2009:263).

2 Ecosystem Services

2.1.1 Identification of ecosystem services

"Ecosystem goods and services represent the benefits human populations derive, directly and indirectly, from ecosystem functions (Costanza *et al*, 1997:253)." This definition of ecosystem services adopts an anthropocentric viewpoint, emphasising the role played by ecosystem services' to sustain human life (Daly, 1997:3). Functional analysis translates the internal complexities and functions of ecosystems, necessary for their self preservation, into a range of ecosystem goods and services (de Groot, 2006:175). The services are essentially the result of human construction as the size and scope of them depends on how the boundaries are designed (Freeman III, 2003:457).

The Millennium Ecosystem Assessment (MA) (2003:57) adopts a functional classification of ecosystem services, categorising them into four main functions: provisioning, regulating, cultural and supporting. Provisioning functions provide the photosynthesizing processes and carbohydrate structures needed to supply humans with ecosystem goods (de Groot, Wilson and Boumans, 2002:395). Provisioning services are the supply of ecosystem goods, such as edible plants and animals, fresh water and timber (MA, 2003:57). Regulating functions only indirectly affect humans, yet they provide invaluable services such as the purification of air and water, the regulation of climate and erosion control. Ecosystems' cultural functions encompass nonmaterial services associated with spiritual enrichment, aesthetic values, as well as cultural, historical and scientific information and recreational enjoyment (MA, 2003:58-59). Supporting functions grant the necessary environment for refuge and reproduction of all plant and animal species and therefore its services are required for production of all other ecosystem services (de Groot *et al*, 2002:400).

Human wellbeing depends on the health of the ecosystems and those that are damaged and degraded ecosystems should be viewed as liabilities (Aronson, Blignaut, Milton and Clewel, 2006:1). Transitions of ecosystems into new collapsed states are usually irreversible and therefore it is critical to invest in their rehabilitation and restoration before it is too late (Limburg, O'Neill, Costanza and Farber, 2002:410). While the deterioration of ecosystems imposes social costs, it is clear that their maintenance involves opportunity costs in a country like South Africa where inadequate water supplies often restrain economic advancement (Binns, Illgner, and Nel, 2001:342). It has been shown that restoration does improve the delivery of ecosystem goods and services and as a result, investing in the limiting factor (natural capital) should be adopted as economic development strategy (Blignaut and Mander, 2009: 3). Humans are part of ecosystems and in order to preserve human welfare and biodiversity, the restoration of natural capital is the only sustainable approach (Aronson *et al*, 2006:1).

2.1.2 Valuation of Ecosystem Services

Market failure is often blamed for the degradation and neglect of natural capital (Wertz-Kanounnikoff 2006:5). Most ecosystems are public goods, implying that people often have a less than optimal incentive to conserve or protect ecosystems (Daly *et al*, 2000:395). Pritchard *et al* (2000:36) contend that without economic valuation, people are unaware of the potential economic benefits that derive from ecosystem services and are oblivious of their importance and their crucial link to human welfare. They argue that this information failure has potential detrimental effects. However, this proposition can be countered because one can be quite aware that ecosystems give direct benefits without having any notion of their economic value. Daly *et al* assert that by awarding a value to ecosystem services an efficient allocation and optimal usage is achieved because the value reflects their true and relative scarcity, condition and importance (2000:395). This can be disputed as efficient allocation depends on whether the ecosystem is valued correctly and whether it is being used as a basis for policy.

Most mining based economies initially expand at the expense of its natural resources. Ecosystem degradation is a form of asset depreciation, and as a result it is only with proper accounting for ecosystem degradation that national income can be taken to reflect true income net of depreciation. Economic valuation gives ecosystems a voice, displaying their health and usage levels and alerting humans to their unsustainable consumption patterns (Blignaut and Aronson, 2008:12).

Since ecosystems are public goods and externalities are present, "stakeholders who benefit from the degrading ecosystem are often not the same as those who bear the cost" (Turpie *et al*, 2009:18). Where conflicting interests arise, economic quantification is necessary to measure all possible options so that it can assist in guiding rational decision making (Pagiola, Bishop and von Ritter, 2004:18). Economic valuation is also fundamental to conducting cost-benefit analyses and ensures that the tradeoffs are valued in the same unit of measurement (Pritchard *et al*, 2000:37). Decisions to invest in restoration and rehabilitation are the same as any other economic decisions and capital expenditure needs to be justified on grounds of economic efficiency. Public funding needed for conservation projects also needs to be justified especially where strong competition for funds exist (van Wilgen, Cowling and Burgers, 1996:184).

Economic valuation creates the possibility of establishing incentive and market-based mechanisms where restoration is financed in a sustainable way; Payment for Ecosystem Services (PES) is one such mechanism. A PES scheme is based on a "willing buyer, willing seller" approach in which ecosystem services are traded to fund the longevity of a healthy functioning ecosystem. In this way, conservation plans can be incorporated into mainstream economic policies and influence peoples' habits and behaviour (Cowling *et al*, 2008:9483).

The theory of economic valuation of ecosystem services is rooted in neoclassical welfare economics which assumes that the purpose of economic activity it to increase individuals' welfare, measured as utility (Freeman III, 2003:7). Another underlying assumption is that each individual is the best judge of his/her welfare (Young, 2005:28). Welfare is contingent upon individuals' consumption of goods – private goods, goods provided from the government or goods and services flowing from the environment. There is a stark anthropocentric standpoint in welfare economics and it would seem that there is no interest in the wellbeing of other species. Yet the value of other species' existence or survival is incorporated in our own individual value systems and utility functions (Freeman III, 2003:7). These values are represented through willingness to pay (WTP) or willingness to accept compensation (WTA), which in turn are based on the theory of substitutability (Freeman III, 2003:9; Young, 2006:29).

The Total Economic Value (TEV) framework, which encapsulates use values and non-use values, has become entrenched in the field of environmental economics (Young, 2005:40). Use values can be further divided into direct-use, indirect-use and option/bequest values. Non-use values are unrelated to any actual or potential use of a good and refer to the intrinsic value embodied in the environment, alternatively named existence values (Pearce and Turner, 1990). When measuring use-values, revealed preference techniques are usually adopted for determining the WTP, either from existing markets or from surrogate markets (Garrod and Willis, 1999:6). Stated preference techniques are used for non-use value whereby hypothetical markets are constructed (Pearce, Atkinson and Mourato, 2006:88).

Using the TEV framework, the direct economic impact of restoration - such as increased returns to the land or increased job opportunities - can be established along with the indirect benefits of improved delivery of ecosystem goods and services. It allows for the true economic costs and benefits to be realised and therefore a more accurate economic cost-benefit analysis.

2.1.3 Payment for Ecosystem Services

Innovative schemes that address conservation in a sustainable way are needed. Lobbying for government funds is not easy and it has become crucial to muster new support especially from the private sector. Payment for Ecosystem Services is such a scheme as it takes the responsibility away from the government and gives it to the users and beneficiaries of the ecosystem services – generating its funds through self-interest (Wunder, Engel and Pagiola, 2008:351; Pagiola 2007). According to

Wunder (2005:3), PES is a "voluntary transaction where a well defined ecosystem service is bought by at least one buyer from a minimum of one environmental service provider if and only if the service provider secures its provision." It requires the conversion of environmental services into tradable commodities (Kosoy and Corbera, 2010:1229). Commodities such as watershed services, carbon sequestration and energy are usually labelled as 'umbrella services," and are the predominant services included in PES. The arrangement increases landowners' involvement and commitment to the restoration process and incentivises them to adopt land practises that protect and promote the delivery of ecosystem services. Collaboration between conservationists and landowners is required in order for their goals to be aligned (Wunder, 2007: 48). According to Engel, Pagiola, and Wunder (2008: 663), PES is able to transform the value of environmental externalities into real financial incentives for landowners who provide the environmental services. Economic incentives are the heart of PES making it a driver that can influences a change in behaviour and therefore land management (Muradian *et al*, 2010:1205).

The notion that PES improves economic efficiency is rooted in the Coase theorem, which states that in a competitive market with functioning property rights and no transaction costs, bargaining between two parties will ensure an efficient outcome (Kosoy, Martinez-Tuna, Muradian and Martinez-Alier, , 2007:446). The Coase theorem assumes that under strong assumptions of prefect competition and fully allocatable property rights, governments and institutional frameworks are superfluous and that trade will achieve a social optimum. However, recent literature suggests that this conceptualisation, which assumes full information, cannot be easily generalised and put into practise through PES schemes in most situations (Muradian *et al*, 2010:1204). Uncertainties regarding the supply of the environmental service exist due to complexities relating to the correlation between land-use and environmental services. Transaction costs are pushed up due to expenses of gathering information making PES an unattractive option. In other cases estimates are assumed because information is lacking; highlighting that the assumption of full information is hardly ever met (Muradian *et al*, 2010:1204). It is crucial to account for the uncertainties when measuring the provision of ecosystem services so that the PES can be accurately implemented (Muradian *et al*, 2010:1204).

A PES-like system has emerged in South Africa, through the Working for Water (WfW) Programme (Turpie, Marais and Blignaut, 2008:789). Working for Water is a government-funded Programme, which control the spread of alien invasive plants (AIPs). Not only do alien invasive plants have a devastating impact on our nation's water supply, it also "changes the structural make-up, genetic diversity and organisation of biodiversity and effectively eroding the foundations of ecosystems" (Turpie, 2004:89). As in other PES schemes, the beneficiaries of the improved ecosystem services, pay for their services in the form of water tariffs. The Department of Water Affairs charges consumers an additional fee for water resource management and this goes towards the clearing of AIPs (Turpie *et al*, 2008: 792). WfW is the service provider in this case and they perform restoration work on any land, securing the watershed services.

3 Cost-Benefit Analysis

This section will assess the economic viability of restoration activities in the Upper Kromme River Catchment. The restoration interventions are divided into two distinct activities which will be evaluated separately. Both private and public benefits accrue as a result of restoration and these will be discussed independently.

The 'Working for Wetlands' (WfWet) intervention is analysed first. Improved water quality, increased longevity of the Churchill Dam and flood attenuation are the expected improved ecosystem services. The lack of data and inadequate hydrological results means that the economic results pertaining to 'Working for Wetlands' are inconclusive. For this reason, a cost-benefit analysis for this intervention cannot be performed, but related information is nevertheless included.

'Working for Water,' (WfW) considered as the predominant intervention, will be analysed thereafter. It is expected that the provisioning ecosystem services, additional water yield and improved land productivity will accrue in response to AIP clearing. The other expected benefit of water regulation and assurance of supply cannot be measured due to still incomplete hydrological results from a concurrent study, (Rebelo,A. MSc dissertation in prep). An economic cost-benefit analysis of the 'Working for Water' intervention is performed over a 25 year time-frame. The intervention is compared to the other water supply augmentation schemes investigated by NMBM in order to observe how restoration fares as a possible scheme.

A cost-benefit analysis is used as a decision-aiding tool, reflecting the economic efficiency of a given project, displaying the relative scarcity of resources and indicating whether the restoration should be implemented in the Kromme in the future. It aims to test the economic soundness of continued investment of restoration in the catchment.

A cost-benefit analysis is a method of choice because it takes into consideration all beneficiaries and losers in both 'spatial and temporal dimensions (Pearce *et al*, 2006:34). Time is accounted for using appropriate discount rates. Once all the impacts have been established and the costs and benefits quantified, it discounting is used to convert them into Present Values (PV):

$$PV(X_t) = \frac{X_t}{(1+i)^t}$$

The decision rule

$$NPV = \sum \frac{(B_t - C_t)}{(1+s)^t}$$

illustrates the discounted costs and benefits over the period of time *t*. If the Net Present Value (NPV) is greater than zero, it represents an efficient shift in resources (Hanley and Barbier, 2009:6). B_t

represents the benefits in period *t*, C_t represents the costs in period *t,* and *s* is the appropriate discount rate, in this case, the social discount rate.

3.1 Working for Wetlands

3.1.1 Costs

The data was sourced from the Working for Wetlands' implementing agency, GIB from 2001-2011. The programme is funded by the South African National Biodiversity Institute (SANBI) and the cost data is broken down into the categories portrayed in Appendix B: Table 72. It shows that the contract wages and materials and equipment account for the largest expenses. The total cost over the duration of the programme thus far is indicated in Appendix B: Table 73. The Present Value of the total costs of the scheme over a 25 year timeframe is portrayed at various interest rates.

Table 12: Present Value of Total Cost over 25 years

Interest Rate	PV Total Cost
4%	R 23 011 721.52
6%	R 20 910 245.97
8%	R 19 132 067.24

Employment is a major cost in Working for Wetlands and needs to be treated as such in a cost-benefit analysis. The unit *Person Days* (PD), calculated as the number of people employed multiplied by the number of days worked, is also used in Working for Wetlands' records. Table 13 displays the number of people and *Person Days* worked over the past 10 years and the total cost per *Person Day.*

Table 13: Working for Wetlands' Person Days in the Kromme Catchment

Year	Person Day (PD)	Number of people	Cost/PD
2001	4 315	215	R 958.09
2002	8 113	429	R 351.81
2003	96	12	R 1 001.76
2004	5 520	40	R 244.38
2005	5 040	30	R 425.34
2006	9 230	74	R 280.04
2007	5 490	47	R 366.08
2008	8 964	60	R 283.55
2009	6 883	63	R 278.02
2010	10 642	49	R 264.02

Source: SANBI database

3.1.2 Indirect Benefits

Water Quality Benefits

Water quality is expected to improve due to the filtering capacity of the wetlands, thereby decreasing the quantities of silt and pollution in the water. The improved water quality is expected to decrease purification and treatment costs as less silt and pollutants are entering the dam. The decreased silt loads increase the life expectancy of the dam, prolonging the time for the dam to become silted up and its storage capacity compromised. Unfortunately, limited silt surveys have been conducted on the Churchill Dam and therefore this anticipated benefit cannot be measured.

Silt Surveys

The Department of Water Affairs provided silt surveys of the Churchill Dam (Ferreira, C. pers. comm. 2010, 27 July) Silt surveys have only taken place four times since the construction of the dam and therefore no time series data exists to do this assessment. Table 14 portrays the results of the silt surveys taken place at the Churchill Dam. The surface area and gross capacity have increased since the initial construction of the dam because of extension works performed on the dam.

Table 14: Area and Capacity Table of Churchill Dam

Date RL/Gauge (m)	**Full Supply** RL/Gauge (m)	**Lowest Outlet** RL/Gauge (m)	**Gauge Zero** RL/Gauge (m)	**Surface Area** ha	**Net Capacity** Mil m^3	**Gross Capacity** Mil m^3	**Reason**
1948/09/01 00:00	155.450/24.380	125.520/-5.550	131.070/ 0.000	235.91	34.12	34.29	Original
1972/11/01 08:00	155.450/30.510	125.520/ 0.580	124.940/ 0.000	235.91	34.12	34.29	A01 - Adjusted
1987/10/01 00:00	156.030/30.510	125.520/ 0.000	125.520/ 0.000	240.9	35.51	35.68	Basin survey
2006/12/01 00:00	156.030/30.510	125.520/ 0.000	125.520/ 0.000	242.63	35.24	35.4	Basin survey

Source: unpublished DWA data (Ferreira, C. pers. comm. 2010, 27 July)

If healthier wetlands reduce the turbidity in dams, the treatment costs of raw water may decline. Such avoided treatment costs are used as a proxy for municipal benefits. It is hypothesized that the municipality's producer surplus will increase because of the decreased treatment costs needed to make water potable. Thus, the benefits of the wetland restoration are portrayed through the municipality's reduced need to pay for treatment costs.

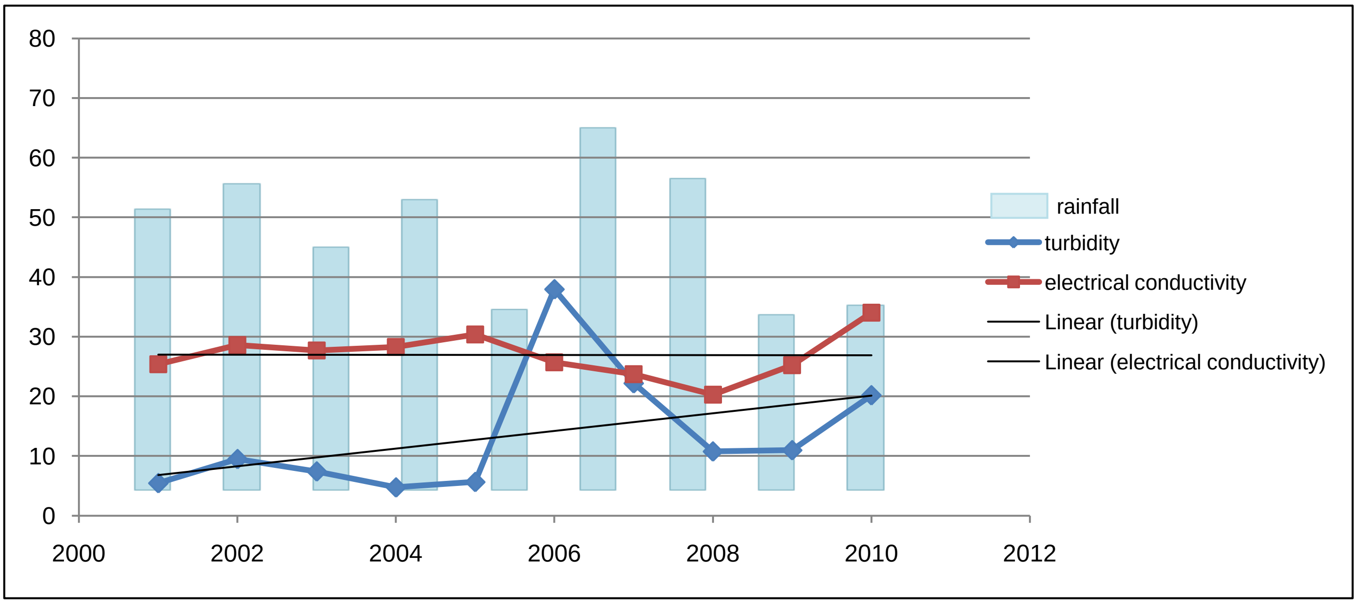
3.1.2.1 Water Quality Determinants

The pH measures the acidity and alkalinity of the water and the South African standards (SANS241) advocate that the water must be between 5.0 - 9.5 pH units. Turbidity relates the particles suspended in the water and electrical conductivity is also dependent on the amount of dissolved solids in the water. These indicators are analysed because they are influenced by the condition of the catchment. High levels of erosion are typical of a degraded catchment, increasing both the turbidity and electrical conductivity of the water flowing into the dam.

Data pertaining to water quality determinants of the Churchill Dam was sourced from the NMBM Scientific Service's Laboratory (Morakabi, M pers. comm. 2011, 8 April). The data represents weekly raw water flow at the Churchill dam relating to the period from 2001-2011.

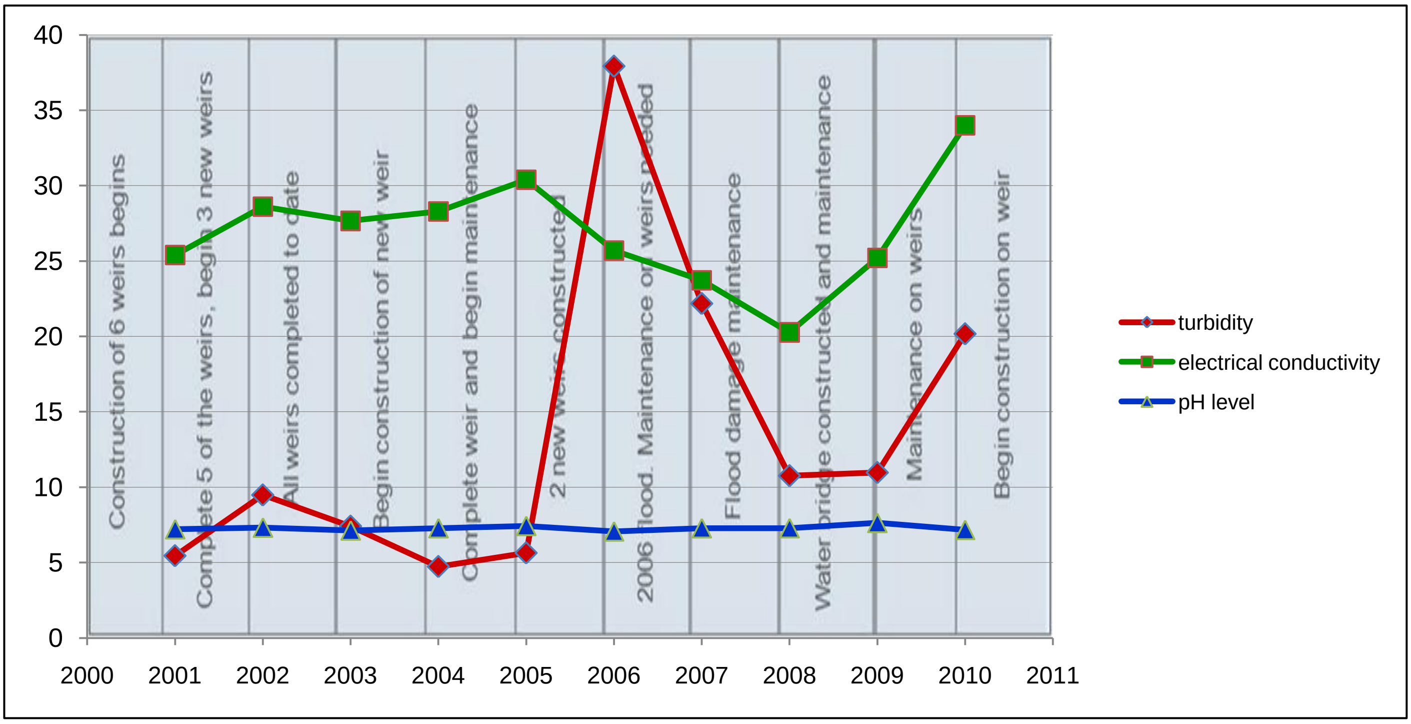
Coarse annual rainfall estimates from 2001-2009 underlie the quality determinants in Figure 23. The strong spikes in 2006/7 relate to the last Kromme River Catchment floods. It would appear that the turbidity and electrical conductivity are positively correlated to rainfall, with a correlation coefficient of 0.597 and 0.119 respectively. An increasing positive trend line for the turbidity is visible over the past 10 years. Electrical conductivity, on the other hand is remains constant throughout the past 10 years

Figure 21: Annual rainfall overlaid by annual turbidity and electrical conductivity indicators for Churchill Dam



The restoration activities of the past 10 years underlie the quality determinants in Figure 24. The past 10 years have been spent building the weirs and investing in maintenance. Although the hypothesis postulates that the restoration of the wetlands will improve water quality, the results show that there is a water quality marker, indicating a decrease in water quality. Before the hypothesis is rejected, it should be noted that a time-lag between the restoration of the wetlands and the delivery of services is expected. One would expect to see the tangible benefits in future years.

Figure 22: Turbidity, electrical conductivity and pH levels of water flow into Churchill Dam with restoration activities underlain



Treatment Costs

Previous Studies

Previous studies have shown that there is a direct connection between the health of the catchment and water treatment costs (Forster and Murray, 2007; Forster *et al*, 1987; Dearmont *et al*, 1988 in Forster and Murray, 2007). Studies have also focussed specifically on farm management practises and water treatment costs, thereby showing the positive relationship between the use of pesticides and tillage practises and water quality (Forster and Murray, 2007).

Foster and Murray (2007) investigated the relationship between water quality and water treatment costs. Turbidity was assumed an appropriate measure for water quality and a function of upstream farming and land-use practices. Due to the short study period, fixed costs were ignored and average variable costs (AVC) were divided into average chemical costs (ACC) and non-chemical costs, accounting for energy and labour costs (Forster and Murray, 2007:116-119).

A Cobb-Douglas function was used to measure the relationships between variables. A negative and significant relationship was found between average non-chemical costs and volume treated. This can be attributed to economies of scale. Pesticide usage and turbidity had a positive and significant relationship with average chemical costs (Foster and Murray, 2007:124).

Churchill Dam Chemical Data

Hardcopies of the Monthly Treatment Works Reports dating back to 1987 were collected from the Churchill Dam and used to assess the change in purification costs and treatment chemicals used over the period of 1987-2010 (Roux, E., pers. comm. 2010, 27 July). The change in variable costs, namely, the change in chemical costs, has been used to indicate the changes in total treatment costs.

The percentages of different chemicals used per Ml of water are also analysed, so that any changes in the treatment chemicals can be identified. There was substantial amount of data missing from these records and the validity of some data entries is contentious. Illegible handwriting also created problems in collating the data. In 2002, PAC replaced the use of Floc Aid and Alum[4] chemicals and thus there is difficulty in assessing the historical trends.

These chemicals are used to clarify and balance the pH of the water so that the water is potable upon delivery in NMBM. This means that the chemicals used take into consideration the storage, the time-lag and the conveyance of the water from the dam to the municipality. Chemical treatment depends on the standards and the minimum requirements imposed, and thus the treatment is often unrelated to small variations in water quality. Water treatment chemicals are therefore not only a function of upstream activities, but also a function of downstream activities and demands.

The graphs in Appendix B: Figure 50 to Figure 54 indicate the percentages of chemicals used per unit of water flow. The changes in chemical consumption are evident in these figures.

There is an increasing trend in the % use of lime and chlorine over the 23 years of data. This is not surprising since the water quality markers indicated declining water quality over the years. One can deduce that restoration of the wetlands by 'Working for Wetlands' has not yet made an impact on the water quality. The past ten years indicate that the water quality has not improved since restoration began, however the strong flooding in 2006 gave rise to the spike in turbidity levels and has thus negatively skewed the water quality indicators.

Chemical Costs

The chemical cost data has been adjusted for inflation and represents the total cost of chemicals per year (using 2009 prices). The trend in total chemical costs per mega litre of water from 1987 to 2010 is displayed in the Figure 25. Holding the amount of raw water treated constant, the change in the unit cost can be examined. Contrary to the hypothesis, the treatment costs are increasing over time. However, without the restoration of the wetlands, the turbidity levels during the flooding might have been more severe.

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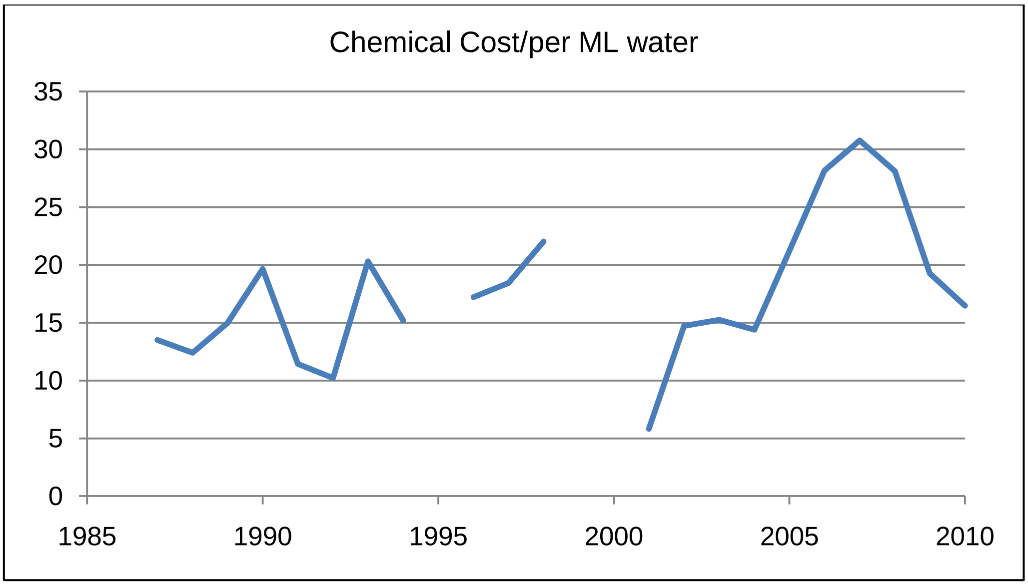
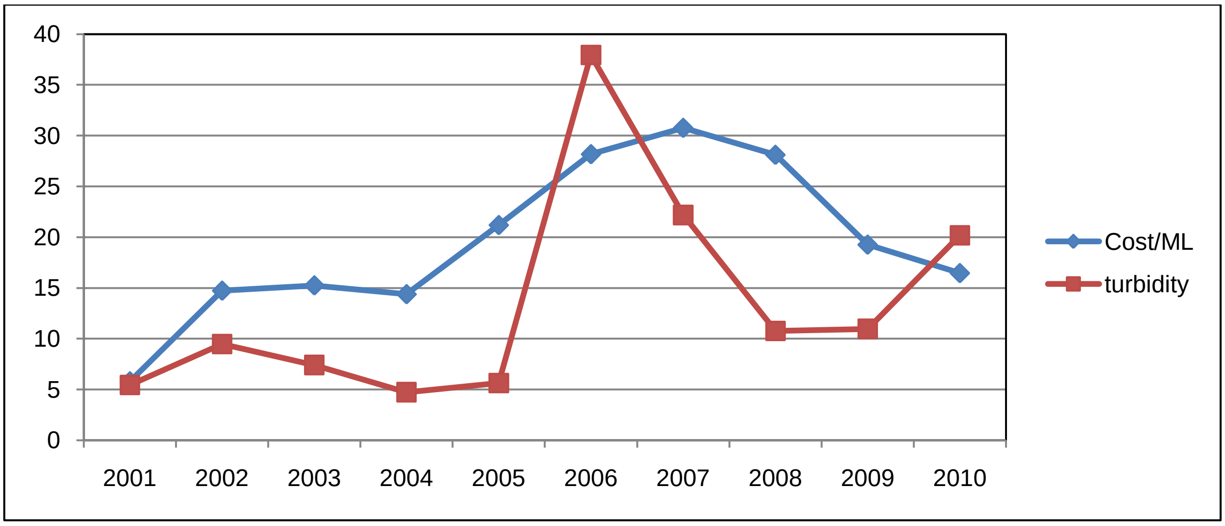
[4] PAC: Poly Aluminium Chloride; Alum: hydrated potassium aluminium sulphate (potassium alum); Floc Aid: flocculation aid

Figure 23: Trends in real annual chemical costs 1987-2010 (base year 2009)



It is important to examine the relationship between turbidity and the treatment cost of water. If, for example, the spike in 2006 is accompanied by a rise in treatment costs it would suggest that water quality does affect cost. The unit cost of water is compared to the turbidity determinants from 2001-2010 and displayed in Figure 26. Looking at the change in these variables over time, it appears that there is a correlation.

Figure 24: Cost and turbidity comparison



The scatter diagram in Figure 27 shows the distribution of the treatment cost per mega litre of water and the turbidity levels. The strength of the linear association is analysed using correlation analysis. A positive correlation coefficient of 0.62 is found between these variables. Using two-variable regression analysis, the stochastic variables were analysed. It was found that the coefficients were significant at the 5% level and overall significance indicator, the F-stat was also statistically significant at the 5% level.

Based on the ANOVA table, it is concluded that the relationship between turbidity and treatment costs are significant. It can therefore be deduced that the change in water quality impacts the water treatment costs. However, there were only nine observations and the adjusted R^2 coefficient, or the overall goodness of fit, was 0.3833.

Figure 25: Scatter diagram illustrating the distribution of treatment costs and turbidity (n = 10)

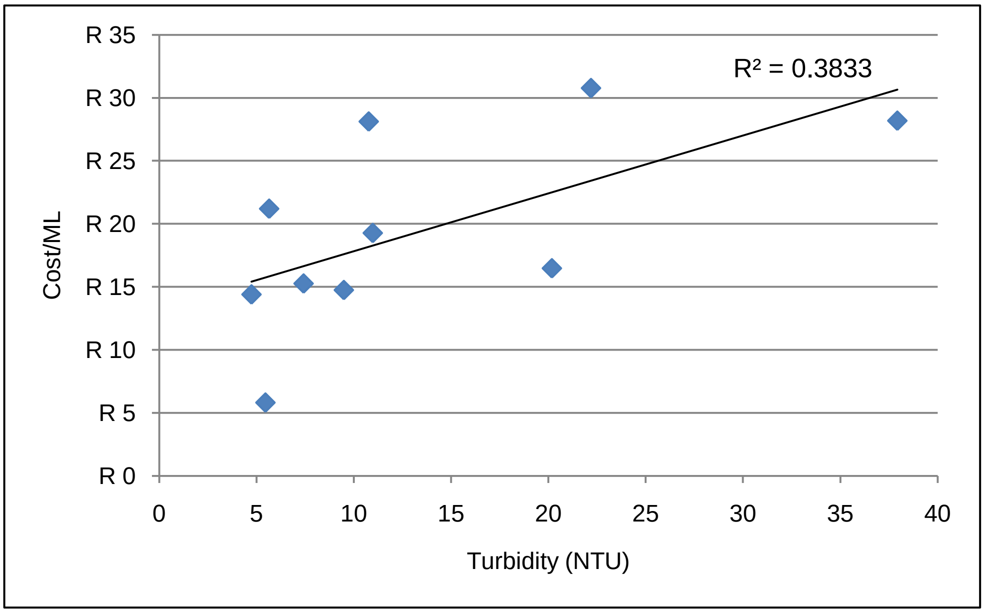
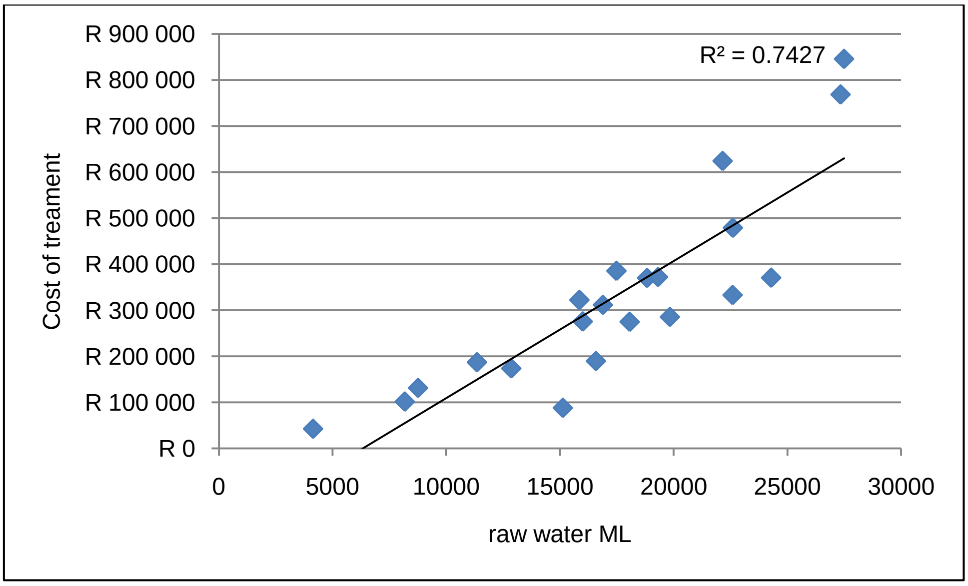


Figure 26: Scatter diagram illustrating the distribution of treatment costs and amount of water treated



It is important to assess whether the increase in treatment costs is linked to an increase in water being treated. Figure 28 is a scatter diagram showing the distribution of the cost of treatment variable and the amount of water being treated. There is a positive correlation coefficient of 0.861 and an adjusted R^2 of 0.742. It is evident there is a strong linear association between the chemical treatment costs and the amount of water being treated. If the flood event of 2006 is removed, the correlation coefficient remains a positive 0.863.

3.1.3 Conclusion and Limitations

A major shortcoming of this section is that there is no link between the change in the size of the wetlands and water quality. There is only 10 years of available data relating to the water quality indicators and only four measurements of wetland integrity (Rebelo, A. dissertation in prep) (Figure 16). The uneven scale of the analyses makes it difficult to draw any significant conclusions.

One can conclude that the water quality in the Upper Kromme Catchment has decreased from 1987 to 2010; nevertheless one can link it to a change in the wetland size or land practises. One would have expected the water quality to improve after 2000, when WfWet began in the catchment.

It was hypothesized that there would be a strong negative relationship between water quality and treatment chemicals, and the cost thereof. Using turbidity as a proxy for water quality, it was found that there was a positive and statistically significant relationship between turbidity and chemical costs.

It is noticed that the cost of treating water over time is increasing and one can link this to a decrease in water quality. The timeframe for the study is too limited as one expected to see the benefits of rehabilitation in future years. One cannot draw any conclusions pertaining to the economic benefits of restoring the wetlands from this study.

3.2 Working for Water

3.2.1 Costs

The direct costs are analysed in this section. The WfW Programme is predominantly funded as a poverty relief programme by the Expanded Public Works Programme. The WfW Programme falls under the Environment and Social Cluster and this funding provides 72% of the WfW Programme's expenditure. The Department of Water Affairs is allocated budgets by the National Treasury in the 3-year cycles of the Medium Term Expenditure Framework (Turpie *et al*, 2008).

Table 15: Sources of funding for the WfW Programme (1996-2006)

Source of Funding	**% contribution**
Poverty Relief programmes	72
DWA core funding	16
Water tariffs through DWA	5
Water tariffs through other water management authorities	2
Local authorities and Trans Caledon Tunnel Authority	2
Foreign funding	1
Private sector	1
Total	**100%**

Source: Turpie et al (2008)

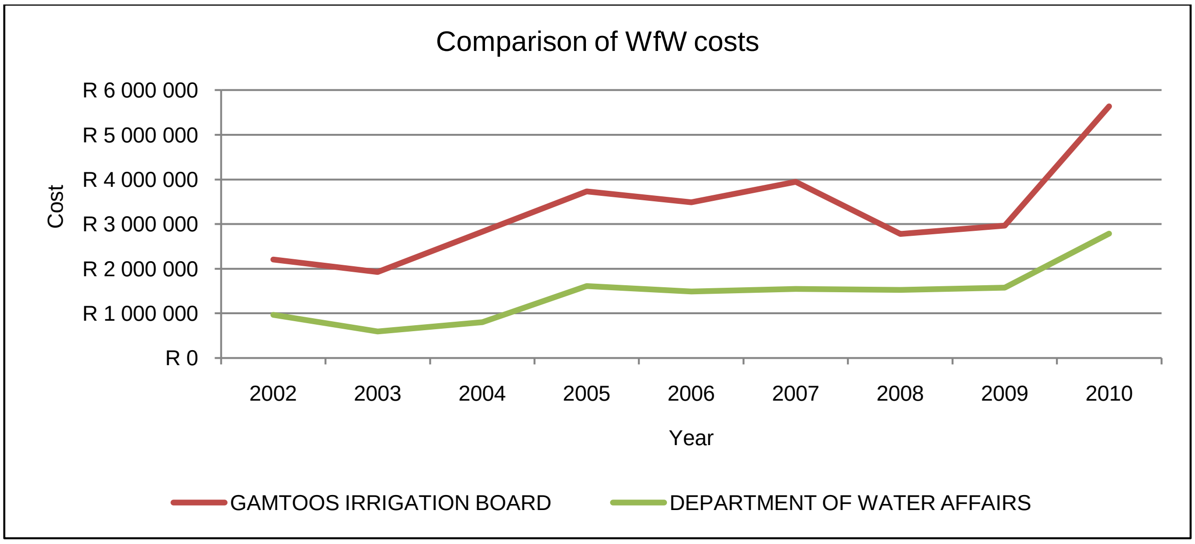
Although the majority of clearing takes place on private land, it is evident that public funds are primarily used to finance these activities.

3.2.1.1 Analysis of Costs

The cost data was sourced from the implementing agency, the Gamtoos Irrigation Board (GIB) and the Department of Water Affairs (DWA). The Working for Water Information Management System (WIMS) database, compiled by the DWA, is used to record the treatment of different alien invasive species and records the densities, costs of treatments and person days planned and implemented on a specific site. Since the system was only fully functional in 2002/2003, there are no records relating to the any treatments before 2002 (Marais & Wannenburgh, 2008). The GIB records only commence in 2004, and therefore 2002-2003 cost data has been extrapolated from the cost trends.

There is substantial variation between the two data sets, as seen in Figure 29 and Table 16. The DWA annual costs are on average R1.5 million less than the GIB records. The reason for this large discrepancy is that DWA archives only include contract costs, and exclude the management and implementing agency's costs.

Figure 27: Cost Comparison of WfW intervention 2002-2010



Source: Source: GIB unpublished raw data (pers. comm. 2010, Colesky, R., 29 July) and DWA unpublished raw data (pers. comm. 2011, McGear, J., 7 March)

Table 16: Total cost of WfW activities in the Kromme (2009 Rand)

Year	Total Cost (Rand)	
	Gamtoos Irrigation Board	Department of Water Affairs
2002	2 203 380.99	969 331.73
2003	1 924 140.63	592 101.03
2004	2 827 312.03	799 289.16
2005	3 735 092.47	1 613 297.89
2006	3 489 398.14	1 488 040.00
2007	3 946 448.59	1 545 462.25
2008	2 781 995.08	1 523 101.77
2009	2 968 666.00	1 572 884.20
2010	5 633 617.01	2 789 673.97

Source: GIB unpublished raw data (pers. comm. 2010, Colesky, R., 29 July) and DWA unpublished raw data (pers. comm. 2011, McGear, J., 7 March)

Most literature pertaining to WfW uses the Department's of Water Affairs WIMS database (Marais and Wannenburgh, 2008; Currie, Milton, and Steenkamp, 2009). The Gamtoos Irrigation Board is funded by the DWA and therefore the data should correspond. For these reasons, the DWA data will be used, although one must bear in mind that these figures present the lower-limit of total costs.

3.2.1.2 Analysis of Treatment Sites

Clarity is needed when discussing the volume of alien invasive vegetation cleared in the Kromme Catchment. The GIB and DWA records refer to the size of the treatment site, but do not refer to the density of the alien invasive plants, or the percentage cover of alien plants. Table 17 denotes the differences in reported treatment sites according to different sources.

Table 17: Comparison of the size of WfW treatment sites in the Kromme

Year	**Total ha of treatment sites**		
	GIB	DWA	McConnachie
2002	/	420	438
2003	/	726	1 168
2004	7 414	4 333	2 209
2005	5 518	4 645	895
2006	4 256	3 796	1 340
2007	2 676	3 105	1 276
2008	2 148	1 982	155
2009	2 427	2 426	273
2010	5 183	3 424	/
total	**29 622**	**24 856**	**7 753**

Source: GIB (pers. comm. 2010, Colesky, R., 29 July), DWA (pers. comm. 2011, McGear, J., 7 March) and McConnachie in prep (pers. comm. 2011. McConnachie, M, 29 June

McConnachie (doctoral dissertation in preparation, University of Rhodes) researched the cost-effectiveness of the Working for Water programmes in the Kromme and Kouga catchments. McConnachie based the treatment sites on the spatial data from WIMS and used helicopter aerial surveys to verify the data. The recorded treated hectares were then calibrated by a mapping consultant and cross-checked by WfW managers. McConnachie's alien clearing dataset has been used in this study as it provides both the most reliable data and consistency across all sites, as the hectares have been converted to condensed hectares. Condensed alien infestation hectares can be interpreted as an "area with a canopy cover of 100%" (Le Maitre, Versfeld and Chapman, 2000). The percentage of alien cover is multiplied by the treatment area to provide the condensed hectare of alien invasive vegetation.

The first recorded treatment was taken as the baseline year, and the alien invasive plant cover prior to any treatment (baseline year) was compared to the current alien invasive plant cover. The surveys were conducted at the end of 2008 and beginning of 2009 and therefore the analysis is projected over an 8 year period.

Table 18: Change in percentage cover of alien invasive plants as a result of WfW

Baseline % cover	**2009 % cover**	**% change**
30.97	9.99	20.98

Source: McConnachie in prep

According to McConnachie (doctoral dissertation in prep), a 21% decrease in alien invasive plant canopy cover was recorded over 8 years. These changes only pertain to the selected WfW treatment sites, and not the entire Kromme Catchment.

Table 19: Change in condensed hectares of alien invasive plants as a result of WfW

Baseline condensed ha	2009 condensed ha	Change in condensed ha
1 124.7	300.92	823.78

Source: McConnachie in prep

It is estimated that within the WfW treatment sites, there were 1 125 condensed hectares of alien invasive plants in 2002. Nevertheless, over the entire Upper Kromme Catchment, the number of AIPs was substantially more as 3 659 condensed hectares remain in the catchment in 2010. The WfW Programme is responsible for clearing 823.78 condensed hectares of alien invasive plants from 2002-2008. In 2009, 301 remaining condensed hectares of alien invasive plants were recorded at these sites by McConnachie (doctoral dissertation in prep).

Assuming a constant real cost per hectare, the condensed hectares cleared in 2009 and 2010 can be extrapolated from WfW's expenditure data. Using the DWA cost data, it is deduced that 421.28 condensed hectares were cleared over these years, which brings the total change in alien infestation to 1 245.06 condensed hectares. The cost of the WfW programme doubled in 2010, and as a result, substantially more hectares were cleared that year.

Table 20: Estimated annual alien rate of clearing based on constant cost per hectare

Year	Cleared condensed hectares
2002	93.61
2003	57.18
2004	77.19
2005	155.79
2006	143.70
2007	149.24
2008	147.08
2009	151.89
2010	269.39
mean	**138.34**

Using historical trends as a basis, it is assumed that 138.34 condensed hectares of AIPs are removed per year over the next 25 years. WIMS database shows that 66% of WfW's efforts are dedicated to clearing black wattle in the Upper Kromme Catchment. This means that WfW's rate of clearing black wattles is 91.3 condensed hectares per annum.

Table 21: WfW distribution of clearing of different AIP species

Species	% clearing
Black wattle	66%
Hakea	15%
Pine	14%
Other	5%

Source: WIMS database (pers. comm. 2011, McConnachie 29 June)

3.2.1.3 Rate of Spread

Rebelo, A (dissertation in prep) analysed the change in the Upper Kromme land-use from 1954-2007. The invasion of changes in land-use were modelled in a GIS system (ArcMap) using 1:20 000 aerial photographs. The change in invasion of the *acacia mearnsii* was modelled and the results shown in Table 22.

Table 22: Rate of Spread

acacia mearnsii	1954	1969	1983	2007
total hectares	1 440	2 886	3 097	4 134
ha/annum	27	96	15	43

Source: Rebelo, A dissertation in prep

The mean rate of spread for acacia mearnsii is 45.35 (Rebelo, unpublished) and 36.28 condensed hectares per annum. This shows that WfW clears more than three times the rate of the spread of black wattles. This does not include the labour time spent in 'follow-up', which is crucial to the success of WfW.

3.2.1.4 Employment

Although it is a social benefit, employment is a major cost in Working for Water and needs to be treated as such in a cost-benefit analysis. The unit, *Person Days* (PD) is calculated as the number of people employed multiplied by the number of days worked and is used in the WIMS system.

It is estimated that 80 *Person Days* are needed to clear one condensed hectare of alien invasive vegetation, as depicted in Table 23. The total cost per *Person Day* is R196.32.

Table 23: *Person Days* per hectare cleared 2002-2008 (2009 Rand)

Total PD	PD/ha
65 673	80

Since the costs per *PD* form part of the stream of costs, the total cost need to be discounted to a present value as depicted in Table 24.

Table 24: Total Cost per *Person Day* (2009 Rand)

Interest Rate	Total Cost per PD (R/PD)
4%	162.80
6%	149.18
8%	137.25

Seeing that the WfW falls under the Extended Public Works Programme, it is important to observe the actual employment data and quantify the impact it has on social development. This study takes a narrow interpretation of social development and merely considers the income benefits of the WfW programme.

Yet again, there is a discrepancy between the sources' data. DWA only deals with contractors' information and is therefore more relevant when analysing the impact the programme has on employment and job creation.

Table 25 contains the annual employment data. Although the Programme provides employment opportunities for a reasonable number of people, it is evident that the WfW Programme only provides them with jobs of one month out of the year; it does not, and was not intended to, provide sustainable income and long-term job security.

Table 25: Working for Water Person Days in the Kromme

Year	Person Day	No. people	No. Days
2002	7 101	306	23
2003	6 421	309	21
2004	5 334	219	24
2005	15 546	709	22
2006	10 450	537	19
2007	10 596	496	21
2008	10 225	484	21
2009	11 723	568	21
2010	17 745	997	18

Source: DWA (pers. comm. 2011, McGear, J., 7 March)

Assuming that all workers earn the same minimum wage rate, the total Present Value of employment expenditure by WfW are summarised in Table 26. The benefits per cleared hectare have only been taken for 2002-2008. These income benefits underestimate the total income benefits, because the contractors and senior members of the team earn salaries above the minimum wage rate.

Table 26: Financial benefits of Working for Water (lower limit)

Interest Rate	Employment expenditure (R)	Employment expenditure /ha (R/ha)
4%	4 597 633.57	3 994.18
6%	4 232 799.67	3 765.61
8%	3 912 416.01	3 558.73

It is shown that an estimate of R4.6 million was spent on wages and for every condensed hectare cleared, around R3 994 was spent on wages.

3.2.1.5 Limitation of Cost Data

Working for Water is governed by available funds, for which they reapply every three years. For this reason, there is no continuity between the years and as such, it is problematic when projecting trends into the future. Since there is no available data before 2002, the trends are based on a very limited timeframe. It is assumed that the government will continue to invest funds into the Programme and it is assumed WfW will continue in its same capacity in the Upper Kromme Catchment.

It is assumed that the average cost of clearing a condensed hectare of AIPs is constant. There is no data substantiating this claim. The hectares cleared on an annual basis, have been deduced based on this assumption. If the assumption is false, the annually reported cleared hectares will be incorrect. It is therefore necessary to treat the annual hectares as estimates.

The large discrepancy between cost data sources is of concern. The Gamtoos Irrigation Board submits their reports to the Department of Water Affairs and therefore both sources should show consistency. The legitimacy of the data is therefore questionable. It should be remembered that the GIB reported costs are more than double the reported DWA costs. This analysis describes the lower limit of costs and thus the 'better' case scenario.

3.2.2 Direct Private Benefits

Agricultural benefits

The removal of alien invasive plants is expected to increase the land productivity in the Upper Kromme Catchment. The quantitative agricultural benefits of the WfW programme is the additional land freed up due to the removal of aliens. Land that becomes available can be utilised and incorporated into the farming business, thereby increasing farmers' net revenue. Other expected positive spillovers include reliable water flow and reduced erosion. Although expected to improve the land's productivity, they will not be quantified in this paper, due to insufficient hydrological and ecological data.

In order to evaluate the agricultural benefits, the current land-use and the agricultural potential of the Kromme Catchment needs to be understood. This paper assumes that the additional land made available from the alien invasive clearing, will be used in the same proportion as the current land-use in the Kromme. An important caveat needs to be added here: this assumption leads to an overestimate of the economic benefits, because not all the alien infested land can be reached or utilised for agricultural purposes.

This section begins with an overview of the current land-use in the Kromme Catchment. The economic returns to the land are then analysed using gross margin analysis. The agricultural benefits of alien invasive clearing in the Kromme are evaluated, after which correlations between alien infestations and current income is analysed.

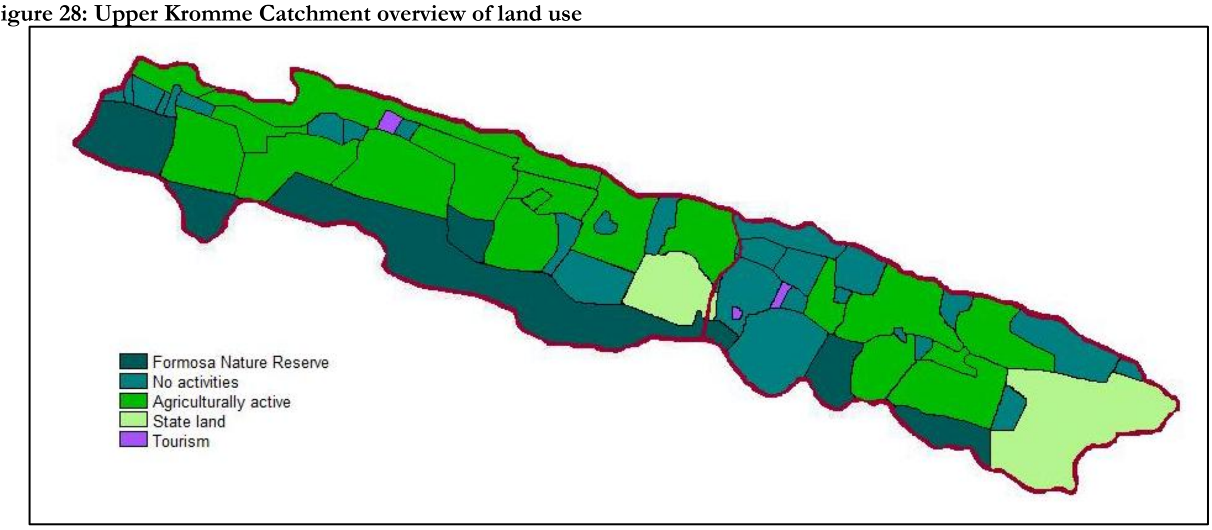
The information is based on informal interviews[5] with the landowners in the Kromme, meetings with experts in the field and talking to people with local knowledge. The local Agriculture extension office provided farm-level information and enterprise budgets were sourced from the Eastern Cape Department of Agriculture. Aerial photography, taken while in a helicopter flight over the catchment, has been used in verifying certain information.

Mapping of the Upper Kromme Catchment was done by Rebelo (dissertation in prep), using ArcGIS methodology. The maps displayed in this section have been adapted and adjusted to reflect economic and agricultural information collated. ArcReader and Microsoft paint were used to create the maps in this section.

3.2.2.1 Overview of the Catchment

The Kromme Catchment, approximately 36 000ha in area, consists of 49 private farms, a commonage, the Formosa Nature Reserve (7 600ha) and state land.

Figure 28: Upper Kromme Catchment overview of land use



Source: Rebelo (dissertation in prep); local Agricultural extension office

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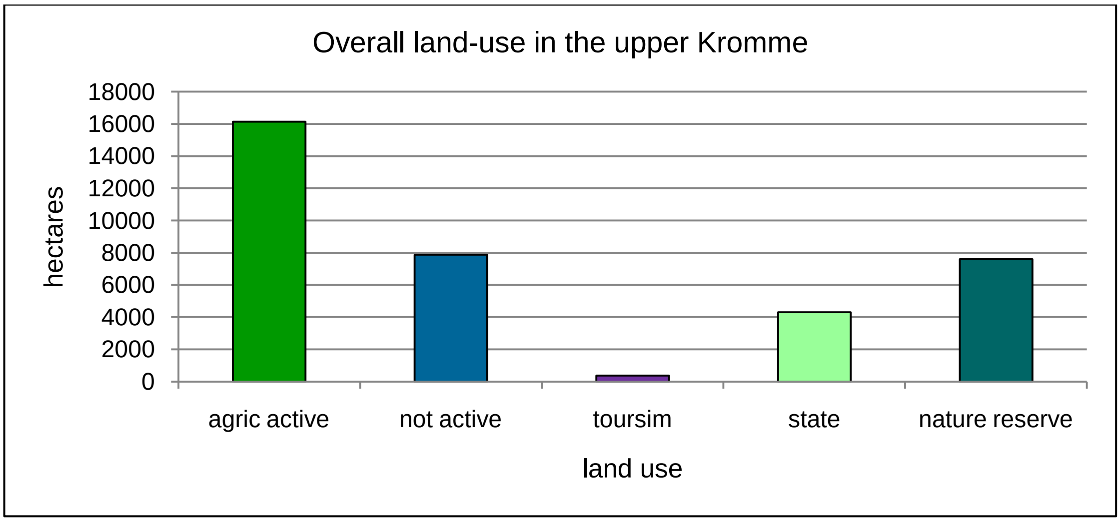
[5] A copy of the interview questionnaire is in Appendix B: Source 1: Kromme Interview

Figure 30 depicts the current land-use in the Kromme Catchment. 'The Formosa Nature Reserve' hugs the Tsitsikamma Mountains and is owned by the Eastern Cape Parks Board. 'State land' incorporates the commonage and the NMBM owned land on which the Churchill Dam is situated. The bright green highlights the areas which are 'agriculturally active'. Agriculturally active land is defined as land which is currently employed in agricultural activities to generate income. The purple indicates farmland that has been converted into tourism enterprises. Land which is not used for agricultural purposes or to generate any income is classified in blue. Landowners who have retired, or who work in the town of Kareedouw or further afield, fall into this category.

There was no available information for 25% of the farms and these farms have been classified as inactive. This assumption is justified on the basis that there are no agricultural records at the Agriculture extension office in Joubertina. Conversations and information gathered while interviewing neighbouring landowners substantiate this assumption. Nevertheless, this assumption may underestimate the agricultural benefits of WfW in the Kromme and will therefore be reviewed in the sensitivity analysis. Table 27 provides the size of the land occupied under the various land-uses.

Table 27: Area of land involved in various land-uses in the upper Kromme Catchment



Source: Joubertina Agricultural extension office

It is apparent that only 16 141 hectares, less than half the total area in the Kromme, are devoted to agriculture. This low agricultural productivity could be attributed to the geographical layout of the catchment. The higher lying areas tend to be steeply sloped and to have poor and sandy soils. This means that only the floodplains are suitable for cultivation; which subsequently place the fields and crops at the risk of floods.

Interviews with the landowners provided insight as to the dependency of landowners on their farms as a primary source of income**.** Table 28 provides information on the landowners' economic reliance on the land. This is important because it provides an indication as to how willing landowners may be to invest in alien clearing. One would expect landowners who derive their main source of income from the land to be more willing to invest in restoration activities to ensure the longevity of their farming success.

Less than half the landowners rely on agriculture in the Kromme as their main source of income. The 'other' category depicts landowners who have other jobs to support them, or landowners who rely on farms in other areas to generate their main source of income. Tourism is not relied upon as the main source of income and merely supplements landowners' revenues. It can therefore be deduced that for many, the landownership in the Kromme is a life-style choice, rather than an economic necessity.

Table 28: Description of Kromme landowners' main source of income (sample size 34)

Income source	% of farms
Kromme agriculture	47
Retired	15
Other source	38

Source: interviews with the farmers

3.2.2.2 Identifying typical farms

Livestock and dairy farming are the prominent farming activities in the catchment. Although almost all the farms are mixed, they have been grouped into typical farm categories, based on the highest earning enterprise.

The first classification is the 'sheep' farms, where dohne merinos are the species of choice. Other than 20 hectares of irrigated kikuyu pastures and 100-200 hectares of dryland pastures, the livestock graze extensively on the mixed fynbos and grassland vegetation.

The second classification is 'cattle' farms on which cattle graze extensively. Each farming unit farms between 120-150 heads of cattle.

'Dairy' farms are the third category and the farms' capacities range from 70 dairy cows to 600. Most of the dairy farms rely predominantly on the irrigated kikuyu pastures, which average 60 hectares. The larger dairies also take advantage of the riverbeds and cultivate the dryland pastures in the floodplains.

The honeybush plant, *Cyclopia Intermedia,* is found naturally in some parts of the catchment. Due to a shortage of information about the naturally harvested honeybush, only the farms that intensively propagate honeybush plant are incorporated into this study.

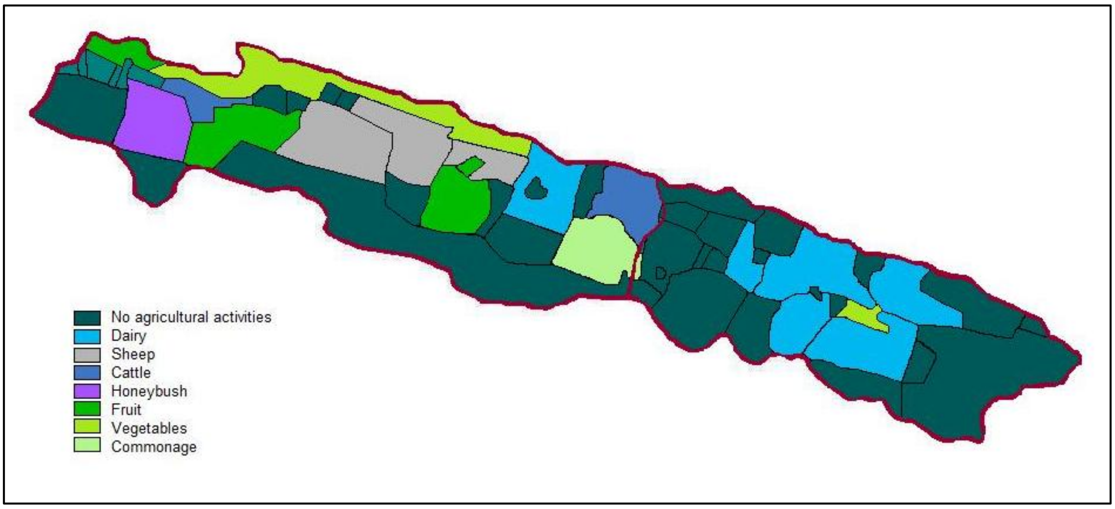
The fifth category is 'vegetable' farms; tomatoes being the predominant vegetable grown in the catchment. The land under cultivation is limited, and typically livestock utilise the rest of the farm.

The final group is 'fruit' farms, where apples, pears and plums are grown. Historically, apple farms occupied more of the catchment, but due to a change in temperature in the flood plains, export market volatility, and increases in input costs, there are only three remaining fruit farms in the catchment.

The commonage has not been incorporated into this section. The section deals with private agricultural benefits generated by WfW, and thus does not apply to state-owned land.

The map in Figure 31 illustrates the different farm types in the Kromme and Figure 32 depicts the total area dedicated to each farm type. Table 29 and Table 30 provide further information on the typical farms in the Kromme Catchment.

Figure 29: Map depicting the typical farms in the upper Kromme Catchment



Source: farm interviews & Joubertina Agricultural Extension office

Figure 30: Total area of each classified farm type

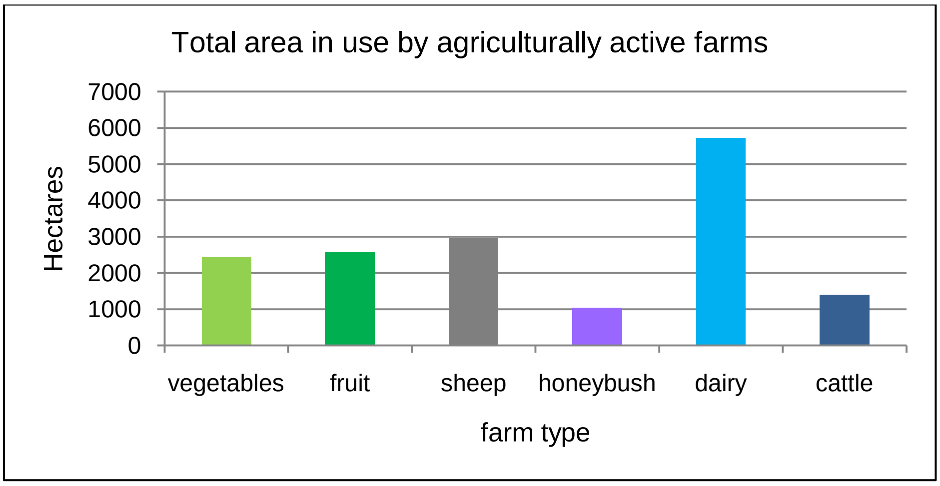


Table 29: Typical farms in the upper Kromme Catchment

Farm type	Average size veld (ha)	Average size irrigation (ha)	Average area crops (ha)
sheep	1 210.46	19.04	-
cattle	703.53	7.26	-
dairy	1 098.16	68.04	-
honeybush	1 037.4	40	-
vegetable	934.92	-	2
fruit	1 101.09	-	24

Source: adapted from Rebelo, A (unpublished master's dissertation); interviews with farmers

Table 30: Typical farms percentage gross income per enterprise

Farm type	Contribution to Gross Income of Selected Enterprises (% of income)					
	sheep	*cattle*	*dairy*	*honeybush*	*tomatoes*	*fruit*
sheep	81%	19%	-	-	-	-
cattle	17%	83%	-	-	-	-
dairy	12%	1%	87%	-	-	-
honeybush	-	-	-	100%	-	-
vegetable	17%	12%	-	-	71%	-
fruit	-	20%	-	-	12%	68%

Source: interviews with farmers

3.2.2.3 Alien Invasive Plant Infestations

The alien infestation cover in the Kromme, quantified by Rebelo (unpublished dissertation), is overlaid on the current land-use map. An 80% density for the alien invasive plants was assumed and this density is multiplied by the modelled canopy cover of infestation to obtain condensed hectares.

The high density and the characteristics of *acacia mearnsii*, the dominant alien invasive plant, mean that no agricultural activities are possible in the infested areas. The map in Figure 33 illustrates the distribution of the alien infestation in the Upper Catchment. It indicates that 56% of alien infestation occurs on agriculturally active land, whereas a mere 4% of infestation occurs in the Formosa Nature Reserve. State land contains 13% of all infestation levels in the Kromme and land with no agricultural activities comprises of 26% of all alien infestation.

The *acacia mearnsii* is the dominant alien invasive species, invading 3 307 condensed hectares, exclusively in the riparian zones (Rebelo, unpublished). Pines occupy 336 condensed hectares and other alien trees invade an estimated 69 condensed hectares. Although the WfW team clear hakea species, this alien invasive tree was not modelled because it was impossible to identify it from aerial photography, due to its similarities with fynbos.

Figure 31: The distribution of all Alien Invasive Plants in the Upper Catchment overlaid on the land-use map

Source: adapted from Rebelo (unpublished master's dissertation); interviews with farmers

Focussing on agriculturally active land only, the condensed hectareage of alien invasive plants per farm type is indicated in Table 31 and displayed visibly on the map in Figure 34. The alien infested land has been interpreted as a loss of agricultural potential.

Table 31: Total condensed hectares of Alien Invasive Plants per farm type

Farm type	**% of farm land "lost" to AIPs** (%)	**loss of agricultural land due AIPs** (condensed ha)
vegetables	14	347
fruit	5	127
sheep	9	273
honeybush	22	232
dairy	16	902
cattle	16	228

Source: adapted from Rebelo (unpublished master's dissertation)

Figure 32: Alien invasive distribution overlaid onto different farm types

Source: adapted from Rebelo (unpublished MSc dissertation); interviews with farmers

3.2.2.4 Gross Margin Analysis

Individual farm budgets were put together for 14 agriculturally active farms. Data was collected from face-to-face interviews, which took place from 7th-10th February 2011, and from local enterprise budgets, supplied by the Eastern Cape Department of Agriculture (pers. comm. 2011, Ntwanambi, Z., 21 April). Seeing that no enterprise budgets exist for the Kromme Catchment, enterprise budgets from similar areas were used and adjusted to suit the Kromme. Budgets were individually verified by the Agricultural extension officer, Mr van der Merwe (pers. comm. 2011, 24 August) and prices were adjusted to represent the 2009 Rand.

Gross margin analysis was chosen to denote the profitability of the farms. The gross margin is the difference between the gross production value and the directly allocatable variable costs (Gittinger, 1982). Fixed costs and payments to land are excluded from the analysis as they are deemed sunk costs and these costs would not change when additional land was made available to farm. This paper also assumes that the existing farmers will continue to farm after the clearing of alien invasive plants. The gross margins must not be mistaken for net farm profits, but are merely a representative for net income.

Gross margin analysis is dependent on numerous assumptions and is subject to many variables. Fluctuating market prices, the volatility of the export market and the impact of seasons on yields, means that the gross margins vary from year to year. Gross margin analyses are used to give indications of the returns to the agricultural land and should be treated as estimates.

The average gross margins per enterprise are portrayed in the tables below. Details of the individual farms and summarized budgets are attached in the Appendix B: Table 65 and Table 66.

Table 32: Gross margin above allocatable variable and fixed costs for each crop (R/ha)

enterprise	R/ha
fruit	59 627.45
honeybush	22 220.00
vegetables	66 961.40

Source: farm interviews & Joubertina Agricultural Extension office; Eastern Cape enterprise budgets

Fruit orchards were modelled over a 20 year timeframe, assuming 5% depreciation per annum. The gross margin analysis took both the allocatable variable and fixed costs into account. This is because in order for a fruit farm to expand, new trees need to be planted and therefore are deemed as variable rather than sunk costs in terms of the analysis.

Langkloof Valley 2008 apple and plum enterprise budgets were used and adjusted to 2009 prices. Fruit prices increased 4%, fertiliser decreased 23% and pesticides and herbicides increased 12% since 2008 (Directorate Agricultural Statistics, 2010). In the Kromme Catchment 80% of plum production and 50% of apple production are exported (pers. comm. 2011 van der Merwe, S. 24 August).

The demand for honeybush tea has expanded in the recent past, with prices almost tripling since 2009 (pers. comm. Mr van der Merwe). It was assumed that the honeybush plant takes 3 years before it reaches 100% production. The gross margin analysis deducted both variable and fixed costs from gross income and was modelled over a 20 year timeframe.

Tomato production in the Kromme Catchment supplies the local market only. The area under production is small, totalling a mere 8.75hectares. Enterprise budgets were sourced from the Eastern Cape Agricultural Department in Port Elizabeth and adjusted to the 2009 Rand. Gross margin above allocatable and fixed costs were calculated for tomato production for the same reason as above.

Table 33: Livestock gross margin above variable costs (R/LSU)

enterprise	R/LSU
sheep	2 912.18
cattle	1 524.01

Source: farm interviews, Eastern Cape enterprise budgets

The gross margin above allocatable variable costs was analysed for livestock farming. In livestock farming, fixed costs are considered sunk, because they will not change when an additional hectares of veld is used for livestock farming. For the purposes of this study, 1 Small Stock Unit (SSU) = 0.15 Large Stock Unit (LSU); 1ewe = 1.56 SSU; 1 boergoat ewe = 2.06 SSU and 1cow = 1.57 LSU. The lambing percentage is assumed at 110% and 90% weaning rate and a 95% calving rate and 90% weaning rate.

Table 34: Dairy gross margin above variable costs (R/cow)

enterprise	R/cow
dairy	3 310.54

Source: farm interviews, Eastern Cape enterprise budgets

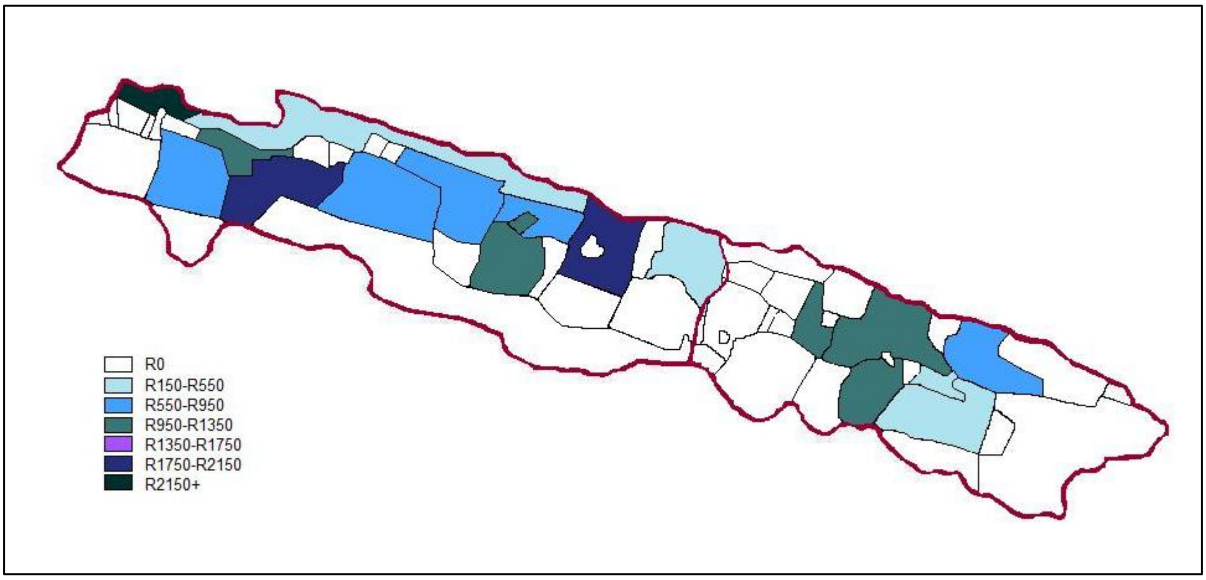
Dairy enterprise budgets for Humansdorp were sourced and adjusted to the 2009 Rand. Gross income consisted of milk income only and it was assumed that the price of milk decreased by 2% in 2009 (Directorate Agricultural Statistics, 2010).

3.2.2.5 Economic Value of Agriculture in the Upper Kromme

Figure 35 illustrates the distribution of the gross margins per hectare for all the individual agriculturally active farms. The analysis has been performed on a per hectare basis because it is directly comparable to the costs of clearing a hectare of alien invasive vegetation. In order to achieve an accurate per hectare average, the total gross margin per enterprise per farm was divided by the number of hectares employed in that enterprise and then weighted accordingly. It must be stressed that these gross margins should be treated as estimates and are used to provide a ballpark figure for the economic returns of a hectare of land in the Kromme.

This section measures the marginal agricultural returns that can be accrued on the freed up land, and thus presumes that the net returns on non-active farms is zero. Although the Formosa Nature Reserve and tourism enterprises generate income in the catchment, an additional hectare of cleared alien invasive land is assumed not to impact these returns in any significant manner.

Figure 33: Distribution of average gross margin above allocatable costs per hectare of land in the Kromme Catchment



Using the individual farms' gross margins, the average annual gross margin per farm type is identified and displayed in Table 35.

Table 35: Gross margin per ha per annum according to farm type (2009 Rand)

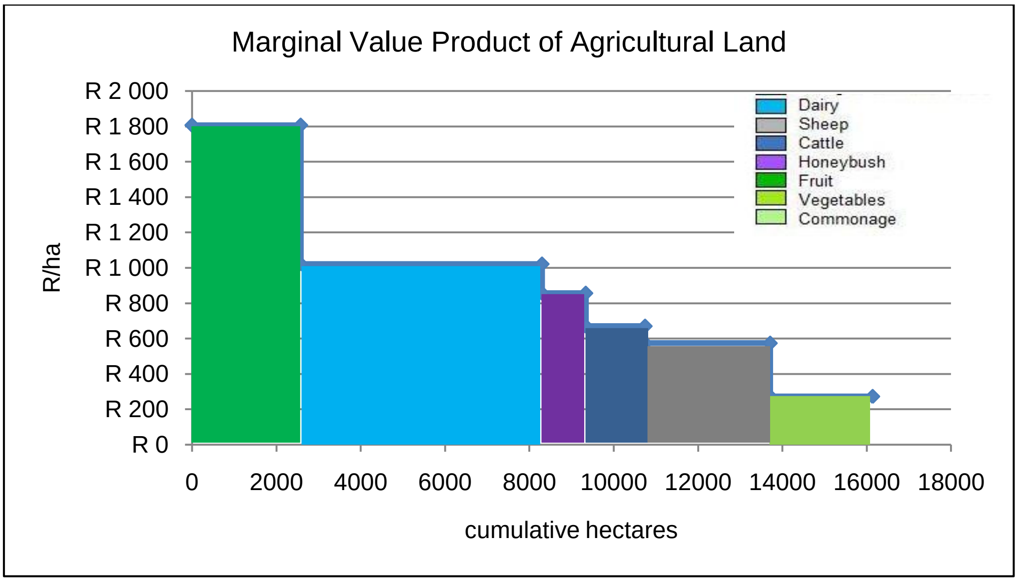
Farm type	Average gross margin per ha
vegetable	272.88
sheep	574.17
cattle	670.35
honeybush	856.76
dairy	1 021.77
fruit	1 807.18

Table 35 represents the economic benefits that can be accrued from clearing alien invasive plants on agriculturally active farms. 'Vegetable' farms realise the least income per hectare of cleared land, whereas fruit farms generate the highest per hectare turnover in this Catchment. Dairy farms also attain high returns per hectare and therefore have more incentive to clear alien invasive plants on their land, for example, than the livestock farms. These figures may appear low, but it should be reiterated that they represent the average hectare income over the whole farm. As shown, the majority of each farm is used for extensive grazing, and the intensive production of crops only occurs on a small percentage of the farm land.

The stepped curve in Figure 36 shows the marginal value product of agriculture land in the Kromme Catchment by different farm types. The area beneath the graph represents the total value product of land per farm type and the total gross margins per farm type are quantified in Appendix B: Table 67. The stepped graph illustrates how the agricultural benefits vary according to the farm type.

The graph illustrates that 'dairy' generates the highest economic returns in the Catchment, and they occupy the largest area. Dairy generates an estimated R5.85million per annum in the Upper Catchment. The graph demonstrates that vegetable farms generate the lowest return per hectare and produce the least economic returns in Catchment. Fruit farms have the highest marginal returns and thus are encouraged to expand further. 'Fruit' farms turnover an estimated R4.66 million per annum, but have the potential to enlarge. Honeybush tea is expected to become a major contributing factor in the valley as the demand for the tea. Although the land currently under cultivation is low, farmers are planning to expand.

Figure 34: Value of Marginal Product of Agricultural Land in the Kromme Catchment

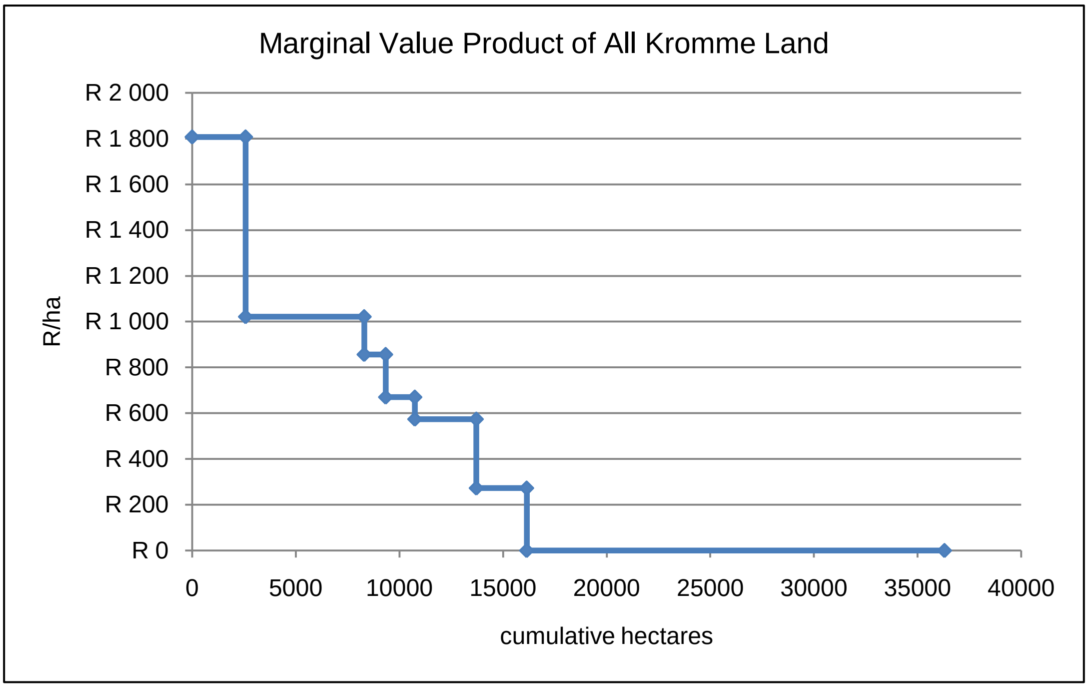


The Total Value Product of agricultural land in the Kromme, which can be calculated by summing the area beneath the Marginal Value Product stepped curve, is R14.7 million per annum. The weighted average economic benefit of agriculturally active land in the Kromme Catchment is R910.91/ha. This is based on the assumption that the gross margin above allocatable costs is representative of economic benefits.

WfW does not only clear on agriculturally active farms, and therefore the average economic value of all the land in Upper Kromme Catchment needs to be investigated. Figure 37 illustrates the Marginal Value Product of all land in the Upper Kromme Catchment.

The shape of the graph changes when the 20 000 hectares of land, with no economic value, is included. The average economic agricultural benefits are reduced substantially to R50.63/ha when the whole catchment is under focus.

Figure 35: Value of Marginal Product of all Land in the Upper Kromme Catchment



3.2.2.6 *Sensitivity Analysis/ Adjusting assumptions*

The agricultural benefits of WfW are directly dependent on the modelled agricultural productivity. It is necessary to test the foundations of the analysis to determine the robustness of the results.

25% of farms are unaccounted for due to missing data; this is a point of concern. It is likely that this unaccounted for land is farmed in an extensive manner. Aerial photography shows that the veld is ecologically disturbed and that the veld has been cultivated at a point in time. The mapping of the landscape performed by Rebelo (unpublished) confirms that some of this land could be currently used for agricultural purposes.

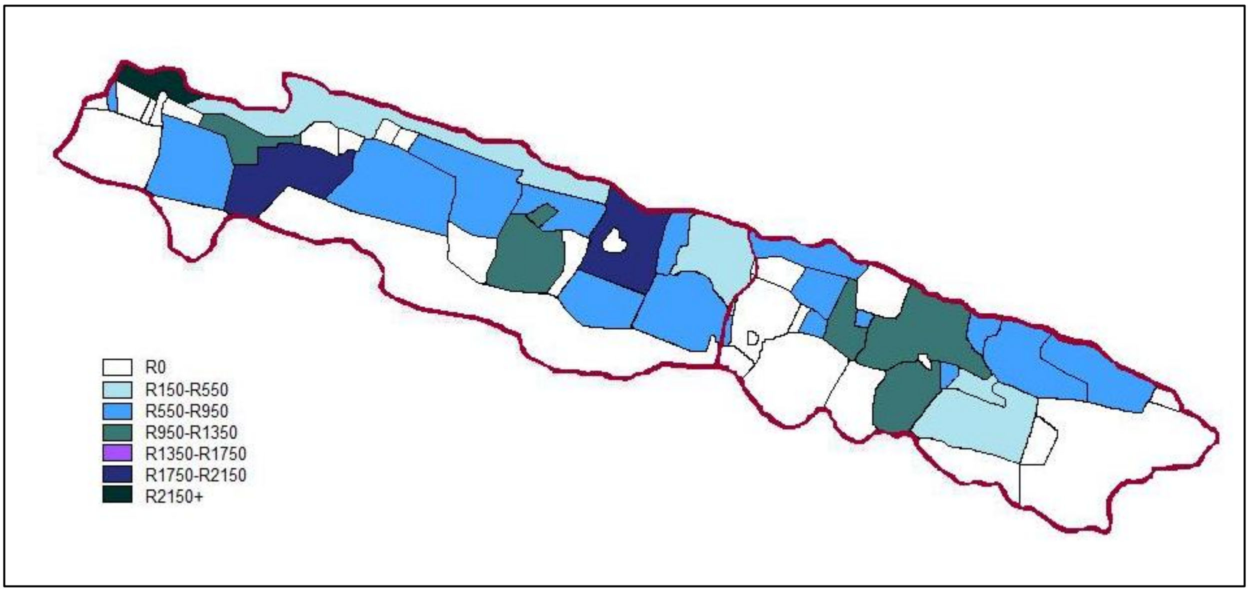
25% of the categorised 'inactive' land will thus be assumed and classified as 'livestock' farms. The gross margin is the mean value of the 'sheep' and 'cattle' farms.

Seeing that the commonage is productive land and income is agriculturally generated, it will be assumed that this land is private land. Using the enterprise average gross margin for cattle R 1 524.01/LSU, the gross margin above allocatable costs is estimated for the 300 heads of cattle farmed on this land.

Table 36: Additional farm type classification

Farm type	Gross margin (R)	Size (hectare)
livestock	622.26	2615.12
commonage	612.91	1171.16

Figure 36: New income distribution of the Kromme incorporating the livestock farms



The new distribution of income in the Kromme Catchment is shown in Figure 38. Although 45% of the land still produces no income, it is presumed that the average agricultural benefit as a result of additional freed up land by WfW rises to R469.60. The total gross margin for each land type in the Kromme using the new assumptions is in Appendix B: Table 68.

3.2.2.7 Agricultural Benefits of WfW in the Upper Kromme Catchment

The economic benefits of clearing AIPs in the Upper Kromme are based on the current land-use. It is assumed that additional land cleared by WfW is used in the same manner and proportions as the current land use. The current distribution of AIPs is used to assess the economic agricultural potential of WfW clearing.

The analysis takes place over the next 25 years and thus the potential agricultural benefits need to be established. It is thus justified to look to see where the current distributions of AIPs are invading and determine the potential economic benefits of that land. The current distribution of alien invasive plants according to the adjusted assumptions is displayed in Table 37.

Table 37: Distribution of Alien Invasive Plants on the different Land Types in Upper Kromme Catchment

Land Type	AIP condensed hectares	% total area invaded
commonage	118	3
fruit	127	3
Formosa Nature Reserve	132	4
sheep	183	5
cattle	228	6
honeybush	232	6
vegetables	347	9
state	371	10
livestock	392	11
nothing	628	17
dairy	902	25

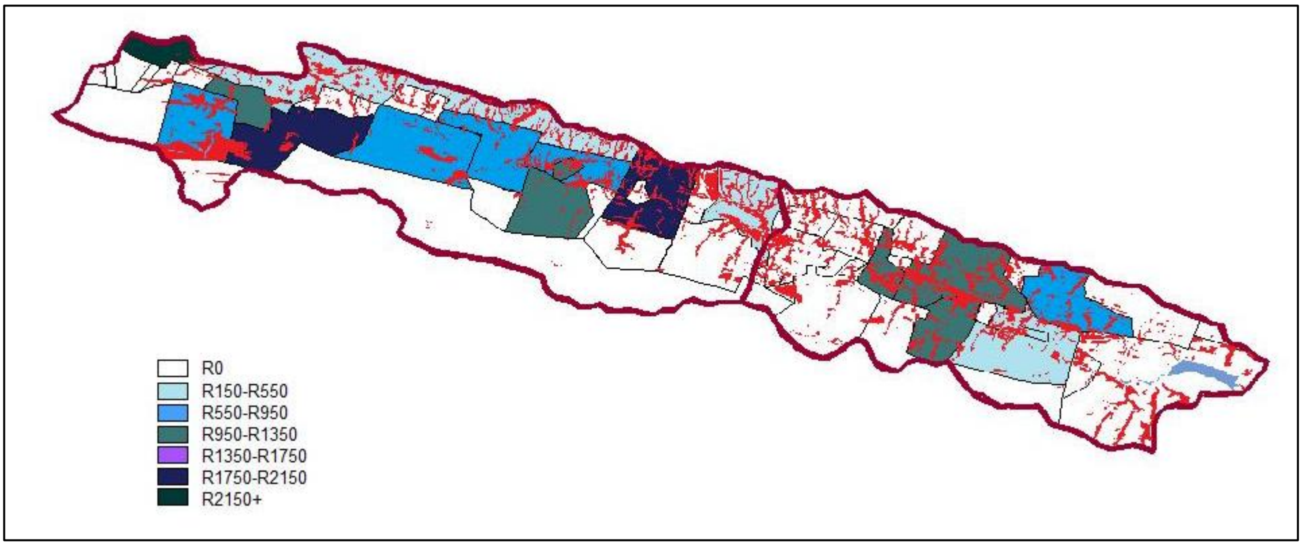
Source: adapted from Rebelo (dissertation in prep)

The potential mean gross margin per hectare of removing alien invasive plants ranges from R465.79/ha under the strict assumptions to R552.69/ha under the adjusted assumptions. The total agricultural benefits that can accrue from removing all the alien invasive plants range from R1.7 million/annum to R2 million/annum.

3.2.2.8 Alien infestation and Income distribution

The hypothesis that alien infestation decreases the agricultural productivity of the land suggests a negative correlation between income (gross margin) and infestation levels (ceteris paribus). Correlation analysis measures the strength of linear association between the two variables. Both variables are assumed to be random and the variables are treated as symmetrical (Gujarati, 2003:23-24).

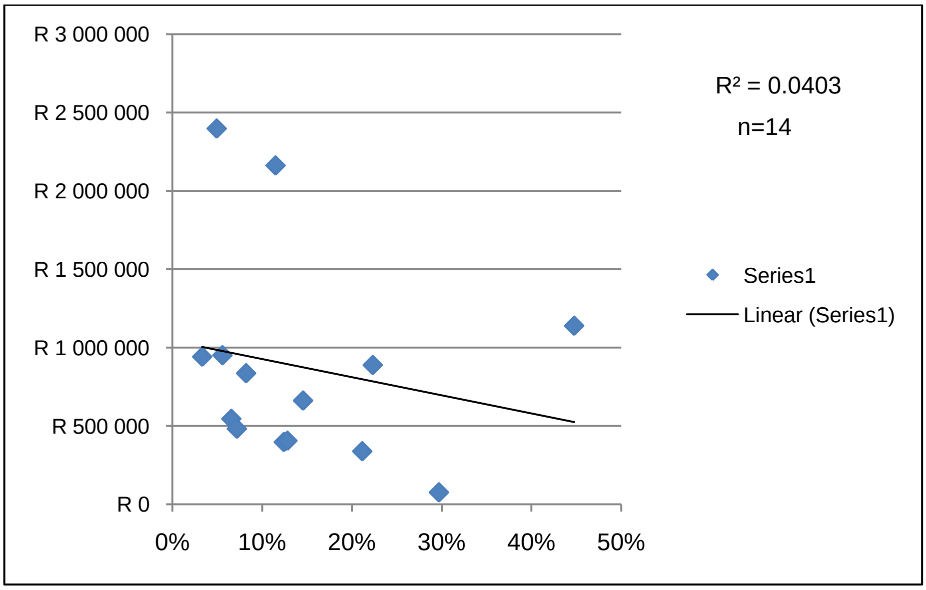
Figure 37: Income and alien infestation distribution in the upper Kromme



Source: adapted from Rebelo, A (dissertation in prep) & ARCReader

The scatter diagram shows the distribution of the average gross margins per agriculturally active farm and the percentage of condensed alien infestation per farm. The scatter diagram includes a sample of 14 individual farms.

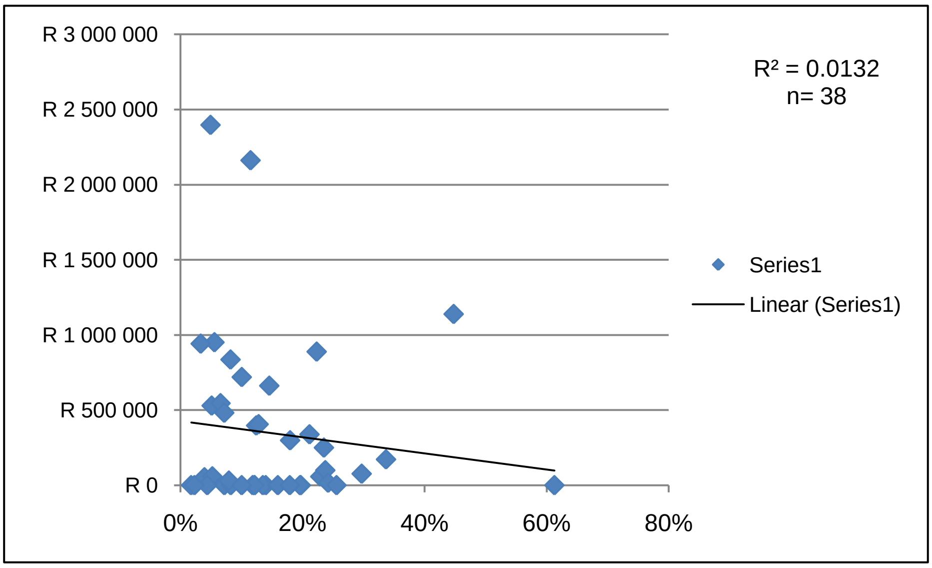
Figure 38: Scatter diagram illustrating the distribution of total gross margin and the % of alien infestation per agriculturally active farm (sample 14)



The trend line indicates that there is a negative correlation between level of infestation and total income. Although the correlation coefficient is -2.01, it is not statistically significant as the goodness of fit (R^2) is 0.0403.

If one includes all the land in the Upper Kromme Catchment, the analysis becomes distorted because of the number of farms yielding no income. The proportion of flat fertile land also varies from farm to farm, influencing farm income. The correlation coefficient, -0.115, is not statistically significant.

Figure 39: Scatter diagram illustrating the distribution of total gross margin and the % of alien infestation per agriculturally active farm (sample 38)



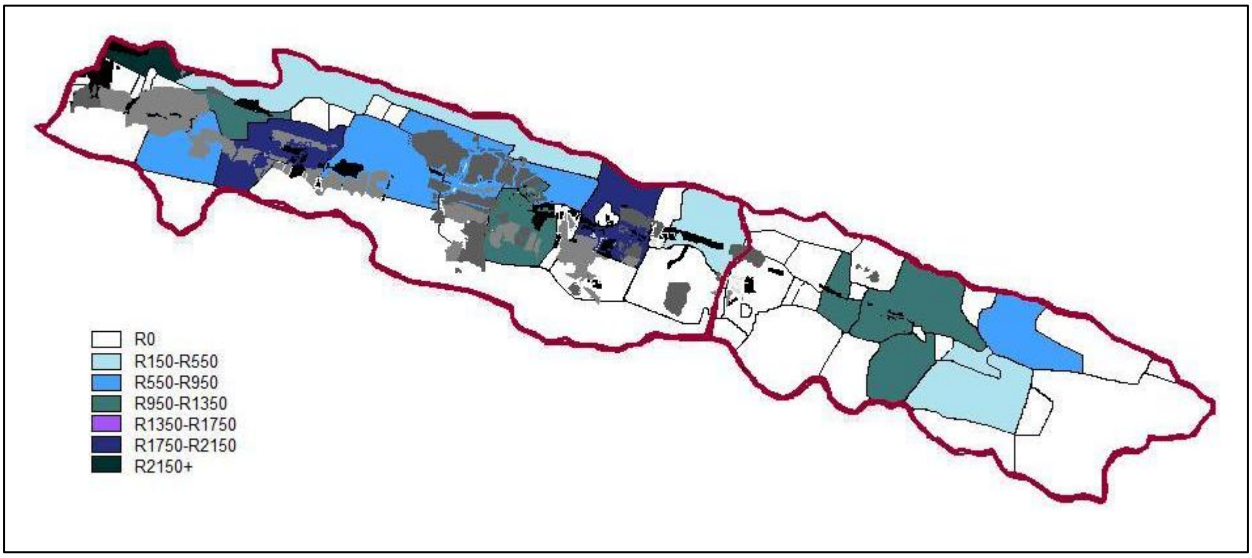
3.2.2.9 Discussion on Expected Private Benefits

Correlation analysis

The correlation analysis shows no statistically significant relationship between income levels and alien plant infestation. However, the sample size restricts the usefulness of the analysis and the large number of inactive farms distorts the study. This correlation analysis is based on future projections and many farmers have already exploited the most productive areas on their farms and AIPs are invading steep slopes and agriculturally low-yielding areas.

If accurate data pertaining to historically cleared sites were available, it would be useful to correlate the infestation levels and incomes on a time series for a given farm only such an approach could provide a reasonable counter-factual. Another approach is to look at the impacts of historic clearing on present land productivity. One would expect to see a positive correlation between these variables. Figure 42 depicts past treatment sites overlaid on current income distribution.

Figure 40: Past treatment sites of cleared AIPs overlaid on income distribution



Low private benefits

Gross margin analysis is commonly used in agricultural economics and calculates the income above variable costs. The expected agricultural benefits from clearing AIPs in the Upper Kromme are low and averages R500/ha. If the analysis only considered gross income, the average agricultural benefits of clearing a condensed hectare of AIPs is around R1 990. Nevertheless, this figure overestimates the true value of clearing because the allocatable costs are ignored.

Private benefits at the expense of public costs

The WfW is a public organisation using public funds, and therefore the alien clearing is not done at the expense of the private Kromme landowners. Although the expected agricultural benefits are low in the

Kromme, these are private gains and these benefits need to be compared to the cost of maintaining the clearing, rather than the total clearing costs itself.

Before WfW clears on private land, the landowner is expected to sign a contract with WfW. This contract asserts that the private landowner is responsible and liable to continue the follow-up maintenance needed to keep the alien invasive plants from returning. The results of the interviews conducted in the Kromme suggest that there is miscommunication and misunderstanding as to when the responsibility shifts from WfW to landowner. Nevertheless, is it sensible to assume that a proportion of the total cost is privately endured, assuming the private landowners are fulfilling their side of the contract and continuing the follow-ups.

Private benefits dependent on land-use and land potential

It is clear that the economic benefits vary according to the current land-use. It is also clear that there is a larger private incentive to maintain restoration or clear alien invasive plants on farms which experience higher economic returns. For example, dairy and fruit farmers have the highest incentive to sign contracts with WfW and continue with the follow-ups needed to prevent the re-growth as they can expect to receive average incomes of R1 000-R1 800/ha respectively.

Ecological versus economic incentives

Ecological and economic desires differ regarding newly cleared land. Ecologists would prefer to transform land into pristine state, therefore maximising the hydrological benefits and preserving the catchment's biodiversity. Alternatively, economic incentives rest upon the expected returns that can be generated from the newly cleared land. The analysis shows that greater returns can be expected by transforming new land into fields for dairy or orchards or fruit. These motives are contradictory and therefore a way of aligning the respective incentives needs to be found.

That said, although a substantial amount of cleared land in the flood plains has already been cultivated and utilised in an agriculturally productive manner; much of the remaining AIPs are situated in the steep ravines and up the mountains, where the only agricultural potential is as extensive grazing. The low carrying capacity means that farmers will not be able to increase stock numbers significantly, so it could be concluded that study in fact overestimates the future returns. AIPs which invade unproductive areas would bias the returns down even further.

Infestation Levels

The current infestation levels mapped by Rebelo (dissertation in prep) are depicted in Figure 39. Nevertheless, if AIPs are not maintained and consistently controlled they will spread very quickly. However, landowners are more likely to control and manage the spread of AIPs if the land is transformed into fields or orchards.

Potential benefits

There are 3 659 condensed hectares of alien invasive vegetation still remaining in the Upper Catchment. The total expected average agricultural benefits that can be accrued over 25 years are R1.7–R2 million. This figure is based on current agricultural activities and does not account for the agricultural potential for the area. If landowners converted to economically higher yielding activities, the benefits of WfW would be significantly greater. If the Upper Kromme Catchment was a high-yielding agricultural hub, the outcome would be very different.

3.2.3 Indirect Social Benefits

Water Yield

The hydrological benefits (additional water yield) are expected to be the major benefits of the Kromme restoration. Since the NMBM is the beneficiary of these benefits, the additional water will be valued at the price the municipality is willing to pay.

The hydrological modelling performed by Rebelo (dissertation in prep) and its associated shortfalls will be discussed first. The economic analysis involves a discussion around techniques to value water, but this paper used the opportunity cost, or the cost of the 'best alternative sacrificed' to value the additional yield. The incremental cost curve in Chapter 1 is referred to, as they indicate the bundle of all NMBM's water-supply options.

3.2.3.1 The additional water yield in the Kromme

The hydrological affect of alien clearing in the Kromme was modelled by Rebelo (master's dissertation in prep). The Agricultural Catchments Research Unit (ACRU4) Model was used to observe the impact of land-use changes on the hydrology of the catchment. According to Rebelo (dissertation in prep), the model is based on "multi-layer soil water budgeting" and is "sensitive to land-use changes, irrigation demands and onset degrees of water stress." It models evaporation as both soil evaporation and transpiration and thus used the different vegetations' water use coefficients (Rebelo, dissertation in prep).

The model has major constraints because ACRU4 is unable to model wetlands and riparian zones. Since the analysis is of a riparian zone, where wetlands are the main feature, this limitation had fundamental consequences on this study. As a means of overcoming the modelling constraint, Rebelo modelled the palmiet wetlands as dams, but substituted the palmiet's water-use coefficient. Black wattles, the predominant AIP in the site, invade riparian zones almost exclusively. ACRU4 modelled black wattles as water-stressed because there is not enough water in the system for them to use. It is likely that black wattles tap into ground water, and the model is unable to simulate this accurately. The ACRU4 reported an unrealistically low evapotranspiration rate for black wattles, which could not be accepted or used in this study.

It was accepted that the model could not be used to assess the impact of AIP's on the hydrology of the Upper Kromme Catchment. Expert advice, along with literature (Le Maitre, pers. comm. 2011; Rebelo, dissertation in prep) was consulted and it was assumed that the evapotranspiration rate for black wattle is 1380mm/annum. Table 38 shows the associated evapotranspiration rates for all the prevalent vegetation in the Upper Kromme Catchment.

These figures are used to evaluate the additional water yield released once the AIP vegetation is removed. The change in the vegetation's evapotranspiration rates 'before' and 'after' conveys the additional runoff that is made available.

Table 38: Vegetation prevalent in the Upper Kromme and associated evapotranspiration rates (mm/annum)

Vegetation	Source	Et (mm/annum)
Black Wattle	Literature (Dye *et al*. 2001, Dye & Jarmain 2004, Everson *et al*. 2007 in Rebelo dissertation in prep)	1380
Palmiet Wetlands	field work & remote-sensing (Rebelo, dissertation in prep)	1060
Kromme Irrigated Fields	ACRU (Rebelo, dissertation in prep)	649
Kromme Orchards	ACRU (Rebelo, dissertation in prep)	912
Pine	Le Maitre (pers. comm. 2011, 21 October)	650.75
Hakea	Le Maitre (pers. comm. 2011, 21 October)	630
Fynbos	Le Maitre (pers. comm. 2011, 21 October)	600
Other riparian	Le Maitre (pers. comm. 2011, 21 October)	1300

The following formula is used to determine the runoff of a catchment (Le Maitre, pers. comm. 2011).

$$Q = P - E_t \pm Storage$$

Q: Runoff
P: Precipitation
E_t: Evapotranspiration

It is assumed that 'storage' is equal to zero because it averages out over the long term and therefore is considered insignificant. In order to assess the beneficiary's additional yield, the yield factor is needed (Le Maitre, D, 2011, pers. comm., 17 October). The yield factor describes the reliability of the yield and guides the dam manager as to how much can be safely abstracted. Every dam has a 'dam equation' which is used to determine this yield factor. A 98% assurance of supply is used for the Churchill Dam (Raymer, D, 2011, pers. comm., 20 October).

Keeping in line with the agricultural assumptions, it is assumed that the current proportion of land-use will replace the clearing of AIPs. The proportions of different land-use covers are needed so that the change in their associated E_r's can be calculated. The land-areas are divided into two main categories: non-riparian and riparian. It is assumed that black wattles invade the riparian areas 90% of the time.

Table 39: Proportion of Vegetation land cover in riparian and non-riparian areas

Non-riparian	
Fynbos	42.4%
Disturbed Fynbos	45.7%
Dryland Agriculture	8.4%
Irrigation Agriculture	3.1%
Orchards	0.4%
Riparian	
Riparian Vegetation	34%
Wetlands	4%
Dryland Agriculture	16%
Irrigation Agriculture	44%
Orchards	2%

Source: adapted from Rebelo (dissertation in prep)

Using weighted averages and the WfW clearing distribution (Table 21), the change in runoff due to the removal of one condensed hectare of AIP is calculated. The figures in Table 40 have been converted to represent an additional cubic metre of water per hectare per annum. The difference between the additional runoff and yield is that the yield takes into account the yield factor.

Table 40: Additional Yield per cubic metre per hectare per annum

Unit	m^3/ha/annum
Additional runoff	3 272.33
Additional yield	3 206.88

Economic Value of Additional Yield

3.2.3.2 DWA raw water tariffs

Literature reveals that studies often use the raw water tariff to value the additional water yields made available from WfW clearing (Currie *et al* 2009; Marais and Wannenburgh, 2008). Raw water tariffs reveal the price at which the DWA sells the water and therefore indicates the additional revenue generated from selling water. It is often misinterpreted as the market price of water. Since the tariff is set by DWA and not by demand and supply, the tariff is generally underestimates the economic value of water.

The raw tariff does not represent the economic value of water, as it does not reflect the true scarcity of water. It is expressed in this paper for the purposes of comparison and to demonstrate the potential additional revenue that could be realised by DWA.

Raw Water Tariffs for Kromme

The Churchill Dam is owned by the NMBM and therefore the municipality does not pay a consumptive water charge to the DWA. Instead, the NMBM only pays a Water Resource Management (WRM) fee, based on the registered volume of water, and a Water Research Levy (WRL), based on actual water consumption to the DWA.

The NMBM pays a flat monthly fee of R29 225 for the fixed monthly registered water of 1.67million m^3 (NMBM, 2010). The annual WRL fee, which is dependent on consumption levels, is R0.039/m^3 (2009 prices). Since this fee is based on consumption levels, it will be used to represent the raw water tariffs for the Churchill Dam.

Tariff Type	Fee
Raw water	R 0.039/m^3

Full supply cost

The full supply cost incorporates the operations and maintenance (O & M) costs, capital charges and raw water tariffs paid to secure the supply of water (Rogers, de Silva and Bhatia , 1998). Most raw water tariffs aim to recover the cost of supplying water, but since the DWA does not own the dam, these costs are not reflected in their raw water tariffs. The full supply cost is a better indication of the cost of water; however it does not incorporate the total economic cost because the opportunity cost of the water is not captured. The full supply cost of the Churchill water therefore understates its economic value.

Full Supply Cost of Kromme water

The NMBM is responsible for the upkeep of the dam and the operations and management costs. The NMBM water tariffs aim to recover the cost of supplying the water. Not only does the NMBM account for the supply costs, but also takes into consideration the supply loss volume from the treatment works as well as the distribution losses and unmetered water consumption. It is estimated that more than a third of all water supplied is not billed and thus 36% of all water 'used' yields no revenue. Water is an economic and social good and the entitlement to clean safe water a constitutional right, and thus the cost of supplying water to indigent households is also incorporated into this cost.

The average cost of water from the Churchill Dam has been analysed because it was not possible to determine the marginal cost of water. The Churchill water treatment costs, extrapolated from Chapter 1, are adjusted to represent the cost of treating raw water (R0.47/m^3). The dam maintenance and capital depreciation costs are R0.01/m^3 (NMBM raw data, 2011). The fees paid to the DWA are also included to represent the average cost of water supplied from the Churchill Dam.

Table 41: Average Full Supply Cost of Water

Costs	Fee
Raw water tariff	R 0.462/m^3
O & M cost	R 0.468/m^3
Capital cost	R 0.014/m^3
total	R 0.944/m^3

3.2.3.3 *Opportunity Cost of Water*

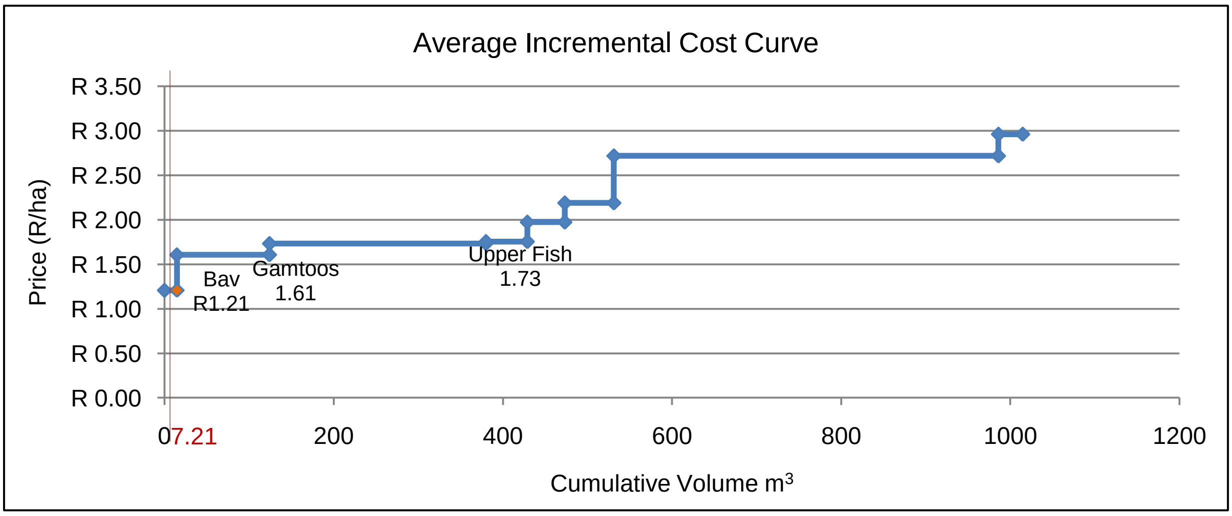
The methods discussed do not represent the total economic value of additional water. Using the 'opportunity cost valuation approach,' the true economic value is measured. The opportunity cost can be described as the "best alternative sacrificed" and is the willingness people would pay in a perfectly competitive world (Blignaut and de Wit, 2004).

NMBM's Willingness to Pay

The NMBM's willingness to pay for the water from any source is determined by the cost of the 'next best' water supply option, i.e. the opportunity cost of the water. The NMBM has a choice as to where to source additional water, and is looking for the cheapest option. It is assumed that the NMBM will be willing to pay this price for the additional water in the Kromme River.

The price of the additional water is the cost of the 'next best' new water source calculated in the Incremental Cost Curves, described in Chapter 1, Figure 14. As concluded in Chapter 1, Levelised Costing is used as it is a more conservative approach. The expected yield from the Kromme restoration is discounted over 25 years and it is found that an additional 0.288 million m^3/annum can be abstracted as a result of the restoration. The Incremental Cost Curve (Figure 43) shows the Baviaanskloof Water Trading scheme as the cheapest option, providing 0.58 million m^3 at R1.21/m^3.

Figure 41: A portion of the Incremental Cost of Water by Source (using Levelised Costs) over 25 years



The restoration provides an estimated 7.21 million m³/annum over a 25 year timeframe, which is less that the Baviaanskloof Trading scheme which provides 14.62 million m³/annum. This gives a value of R1.21/m³ for any additional water in the Upper Kromme and an indirect economic value of R3 880/ha for clearing a condensed hectare of AIPs.

Table 42: Opportunity cost of water in the Kromme

Opportunity Cost	R 1.21/m^3
Economic Value of Water/ha	R3 880/ha

3.2.4 Is WfW Economically Viable?

The economical viability of the restoration in the Upper Kromme Catchment is measured through a cost-benefit analysis:

$$NPV = \sum_{t=1}^{25} \frac{(B_t - C_t)}{(1+r)^t}$$

The cost benefit analysis is used to test the future viability of investing in the WfW Programme. A 25 year timeframe is selected and since the WfW Programme is a governmental run project it is appropriate to use a social discount rate of 4%. A 4% interest rate is roughly 10% nominal, which is well above the risk-free rate at which the State borrows long term money, and thus is a conservative view. The analysis is performed at different interest rates, displayed in Table 70.

Using historical trends as a guideline, it is assumed that an average of 138 condensed hectares will be cleared per annum. It is estimated that 3 459condensed hectares will be cleared over 25 years, out of the current 3 660 condensed hectares of AIPs. The additional expected yield as a result of restoration comes to 443 640 m³/annum assuming 138 condensed is cleared each year. Table 43 portrays the net present value of the costs of the programme at 4% discount rate. Further data and analysis is portrayed in the Appendix B: Table 69 and Table 70.

Table 43: Net Present Value of Total Costs over 25 years (2009 Rand)

Interest rate	**Present Value of Total Cost** (R)	**Cost per condensed ha** (R/ha)
4%	22 716 127	6 568.20

The net present values of the indirect and direct benefits are portrayed in Table 44. The adjusted agricultural assumptions, and thus the economic value of agricultural benefits represent the 'best-case' scenario. NMBM's willingness to pay for water is used to evaluate the hydrological benefits of the WfW Programme. It is clear that the hydrological benefits of WfW are substantially greater than the potential agricultural benefits.

Table 44: Present Value of Hydrological Benefits over 25 years

Benefits	Present Value of Total Benefits (R)	Present Value Benefits per ha (R/ha)
Agricultural Gross Margin	1 212 392	351
Hydrological Yield	8 512 031	2 461

Table 45: Cost-Benefit Analysis

	Private benefits	Social benefits	Total Benefits	WfW Costs	Benefits-Costs	BCR
per hectare	R 351	R 2 461	R 2 812	R 6 568	-R 3 756	0.43
total	R 1 212 392	R 8 685 745	R 9 898 137	R 22 329 867	-R 12 431 730	0.44

Table 45 reveals the best case scenario for 'Working for Water' over 25 years. Nevertheless, the Net-Present Value of the WfW Programme is negative and the Benefit-Cost Ratio is below 1. The results of the cost-benefit analysis reveal that the restoration in the Upper Kromme Catchment is not economically viable over 25 years.

3.2.5 Discussion and Limitations

The analysis reveals that investment in the programme is not economically viable even though the cost-benefit analysis reveals the best-case scenario. Under tighter assumptions, the Benefit-Cost Ratio becomes 0.13 (See Appendix B: Table 71). These tighter assumptions presume an agricultural benefit of R465.79/ha while using an Average Incremental Cost of R0.79/m^3 and the WfW costs reported by GIB .

If the time horizon is changed to 50 years and it is assumed that after 25 years, the private follow-up maintenance costs are 10% of the annual WfW costs, ceteris paribus, the Benefit-Cost Ratio becomes 0.56. The economic benefits of the restoration still do not outweigh the costs even under these revised conditions. If the cost of clearing is cut completely after 25 years, the Benefit-Cost Ratio only improves marginally to 0.59.

The poor economic performance of WfW in the Upper Kromme can be explained as follows:

1. Additional yield is the only hydrological benefit evaluated. The bundle of ecosystem services expected as a result of restoring the Kromme Catchment includes flow regulation and assurance of supply. However, due to the failure of the ACRU$_4$ model and the inability to accurately assess the other hydrological changes in the catchment, these could not be evaluated. This is a major shortcoming of the study and it is suggested that future research pays attention to assurance of supply as well as additional yield.

2. Although WfW do not experience high capital start-up costs, the programme entails very high annual running costs. The programme is labour intensive and for every condensed hectare cleared, a minimum of R3 994 is being spent on wages. This means that at least 60% of the cost being spent on labour. These costs also generate socio-economic benefits for the local poor, and these have been omitted from the analysis.

3. The agricultural potential in the Upper Kromme Catchment is low and thus the agricultural benefits of Working for Water are low. The grazing capacity of the fynbos dominated landscape is low and because of the steep valley slopes, the floodplains have the highest agricultural productivity. Agricultural profit margins are squeezed as input costs are increasing and profits are exposed to risk because of the volatility of the export market.

Although it is judged that WfW is not economically viable, the risk and subsequent cost of not removing AIPs is severe. Black wattles spread at the rate of 36 condensed hectares per annum (Rebelo A, dissertation in prep). This means that the NMBM could lose an estimated 0.115 million m^3/annum if no action is taken, worth an estimated R139 690/annum. This assumes that black wattles spread at a linear rate. The agricultural cost of taking action is an estimated R19 900/annum. This cost refers to the cost of losing further land to wattle infestations.

3.2.5.1 Yield vs. Baseflow

It is assumed that that the proportion of current land-use will be maintained after the WfW clearing activities. However, due to the ecological significance and fragility of the Kromme ecosystem and the importance it plays in securing the NMBM's water supply, it is necessary to evaluate the impact of a different land-use on the yield.

Using Rebelo's (dissertation in prep) mapping results, the 'ideal' state of the catchment is ascertained. The conditions of this 'ideal' state are indicated in Table 46.

Table 46: Distribution of vegetation in the 'Ideal' State

Riparian – 90% invasions	
Riparian vegetation	69%
Wetland	31%
Non-riparian – 10% invasions	
Fynbos	100%

The additional yield expected from transforming the land-use to its natural state is seen in Table 47.

Table 47: Additional Hydrological Yield expected from natural "ideal" state

Unit	m^3/ha/annum
Additional runoff	1 449.534
Additional Yield	1 420.543

The calculations show that less than half the yield is expected if the land is transformed back into its natural state, rather than the present land use patterns. These counterintuitive results are indicative of the trade-off between yield and baseflow.

A functioning catchment increases the baseflow of the river. In good seasons, the catchment absorbs and holds the water back, and then slowly and consistently releases it throughout the year. This increase in baseflow helps sustain the catchment through the dry seasons; however the catchment management reduces the amplitude of flows and decreases the runoff of the catchment.

An increase in baseflow is often deemed more important to municipalities and Nieuwoudt *et al* (2004:177) reveals that municipalities" generally place a higher value on assurance and reduced risk, rather than incremental units of water." It is during times of drought when the additional water is most needed.

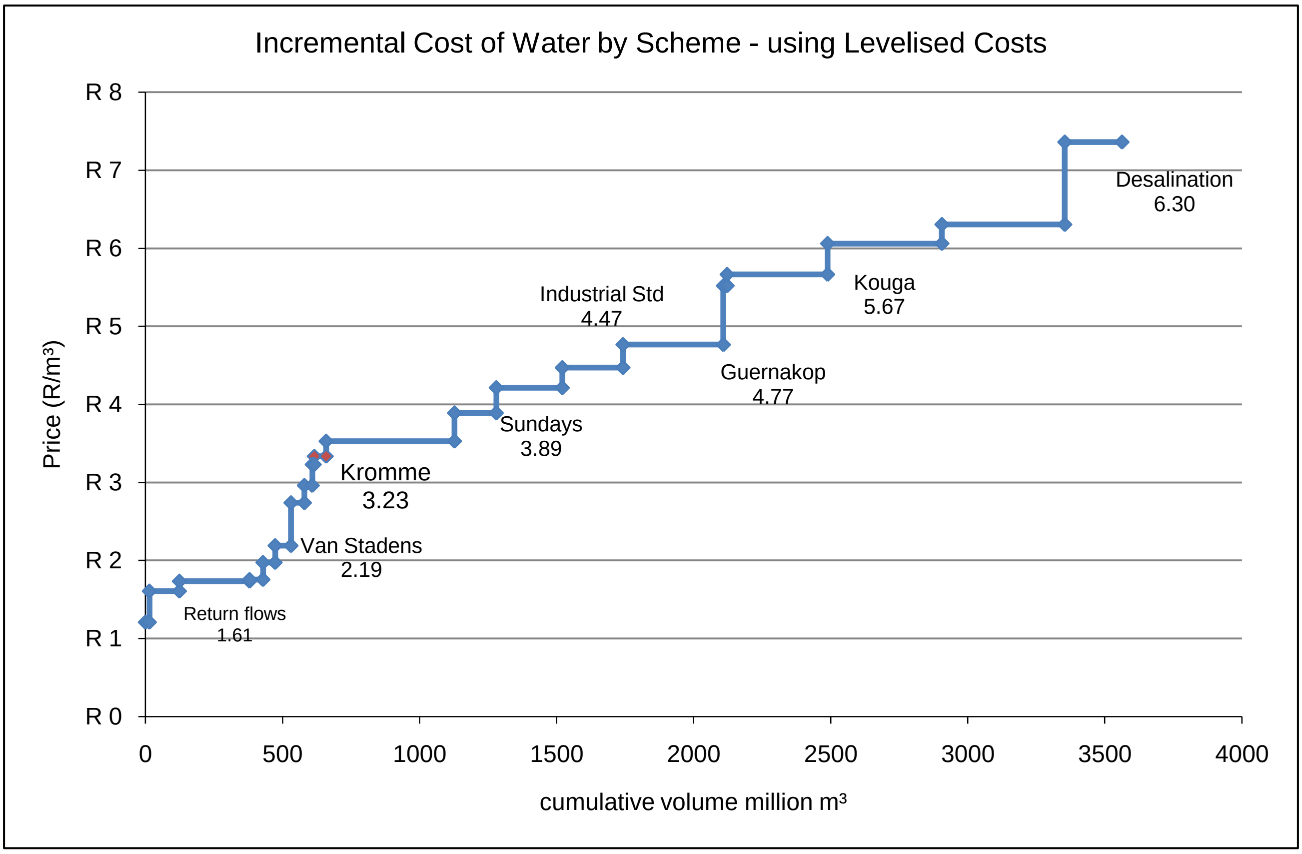
The literature stresses the importance of a catchment's ability to store and hold water (Mander *et al*, 2010). Wetlands, act as sinks, and ensure the flow regulation. This smoothes the volatility in water supply and reduces the damages done by high energy flooding and silting. Catchment management cannot focus only on maximising the yield of the catchment, as this will lead to perverse management and will have damaging consequences for the catchment and future security of water supply. The catchment will slowly become more degraded if the wetlands are stripped and more fields are planted, leading to higher erosion rates. The impact of floods will be more severe, washing more silt and sediment into the dam.

3.2.5.2 Should the restoration of the Upper Kromme Catchment be considered a possible augmentation scheme for NMBM?

It is important to observe how the WfW restoration in the Kromme fares in comparison to NMBM's other proposed schemes. It needs to be considered whether the NMBM should invest in proper catchment management in the form of WfW as a means of securing future water.

Using the levelised cost approach from Chapter 1, the Kromme restoration is included in the Incremental Cost Curve in Figure 44.

Figure 42: Incremental Cost Curve including the Kromme restoration- using Levelised Costs



The cost of WfW Kromme restoration is R3.23/m³. Although it falls within the cheaper end of the scale, the major concern is that it only supplies a mere 7.21 million m³ over the 25 year time frames. The Nooitgedagt Low-Level Scheme, for example costs R3.52/m³, and yet it provides an additional 470 million m³. When the schemes are examined on an annual basis, additional water from the Kromme becomes the third most expensive at R3.23/m³ and supplies the least yield (0.44 million m³/annum).

Nevertheless, one should not discard the importance of restoration as a means of catchment management. The delivery of the existing yield from the river will be threatened if no action is taken and it is important to look after the resources that are in place. However, it is not economically viable for NMBM to invest in this scheme for the purpose of increasing water yield and decreasing risk of water shortages in the future. Although restoration brings longevity to the dams and is important for the sustainability of the catchments, it does not diversify NMBM's current water supply bundle and does not act as insurance against drought.

Trading water with the Kromme farmers

This chapter has recognised that the agriculture in the Upper Kromme Catchment is limited and that farmers yield low agricultural returns. It needs to be questioned whether the NMBM values the water more than the farmers and if so, if possible water trading could occur. Chapter 3 investigates the economic value of water to the farmers in the light of the possibility of water trading.

CHAPTER 3
OPPORTUNITY COST OF WATER

Increasing industrial activities and economic growth, an expected rise in living standards, expanding irrigation-intensive agriculture, food-security concerns and compliance with the ecological reserve requirements and environmental interests indicate that conflict among these water-thirsty sectors are only likely to increase in the future. Ward and Michelson (2002:425) recognise that when the supply of a resource is scarce relative to its demand, the scarce resource takes on an economic value, because many users compete for it. Under such circumstances, there is a need for a rational allocation of scarce water among competing users and in the analysis of economic trade-offs, the economic value of water and the contribution that water makes in each sector needs to be studied. Economic efficiency becomes an important social objective and efficiency levels provide a practical way in resolving conflicts (Young, 2005:25). The economic value of water is reflected by the amount a rational user is willing to pay for it and this willingness to pay is measured by his or her respective demand function. Nevertheless, the individual's willingness to pay shows the personal marginal benefit and this value does not incorporate the indirect benefits accrued.

This conflict is prevalent between the irrigation-intensive agricultural areas surrounding the NMBM and the ever-growing municipality of Nelson Mandela Bay. In particular the Gamtoos Valley, the Lower Sundays River Valley and the Upper Kromme Catchment are in direct competition with the NMBM for raw water. This chapter seeks to calculate the economic trade-off by determining the opportunity cost of this water. The opportunity cost of water, in this case, is the foregone potential of agricultural production. It is the price people would pay in a perfectly competitive world, where the water price is its marginal value product. In order to calculate the price of this water, it is assumed that water rights are fully tradable and that perfect competition exists.

It must be noted from the onset that this is a conservative opportunity cost of water because it ignores the linkages between agriculture and other rural economic activities. In farming areas, most non-agricultural jobs depend on agriculture and thus, indirectly depend on farmers' irrigation water. This study acknowledges that the farmers' willingness to pay for water excludes these benefits and therefore underestimates its true value.

A study of the Lower Sundays and Gamtoos Valley sites illustrates the agricultural dynamics and water demand involved. The necessary information on the upper Kromme Catchment has already been explored in Chapter 2 Section 2, which reviewed the literature on the economic value of water in agriculture. Howe's (1985) methodology is used to value the opportunity cost of irrigation water.

This chapter seeks to answer the following questions:

1. What is the opportunity cost of obtaining water from the Upper Kromme Catchment, the Gamtoos Valley, and the Lower Sundays River Valley? How much water is associated at this price?
2. Does the current allocation of water rights meet the Pareto efficiency conditions? If not, in which direction should water transfers be considered?
3. How do these prices compare to the cost of water in the NMBM's proposed plans? Should water markets and trading be considered as a viable option in augmenting PE's water supply?

1 The Agricultural Locations

The Gamtoos Valley

The Kouga Dam, built in 1968, forms part of the NMBM Western Supply System and is a vital source of water for both agriculture in the Gamtoos Valley and the urban consumption of NMBM. It supplies the NMBM with 28% of its water demand (21M m^3/annum) and is the sole source of water for the Gamtoos Irrigation Board (GIB), which supplies the farms with the required 59.36M m^3/annum. The towns of Hankey and Patensie, in the Gamtoos Valley, are also reliant on the dam for their 0.441M m^3/annum.

There is direct competition for water between the farmers and NMBM. The municipality has the first right to the water and thus it can be viewed that agriculture in the Gamtoos Valley acts as a buffer for water. When there is excess water, it is sold to the farmers; however when there is a shortage, the Gamtoos Valley farmers give it up to supply the NMBM. In times of drought, the Gamtoos Valley farmers face severe water restrictions, and in 2010, the famers faced a 60% water quota reduction.

The economic impact of water restrictions is severe and farmers resort to private water trading among themselves during droughts. The price of water in 2010 was bid up from R0.155/m^3 to R2.49/m^3 to save their crops (Joubert, P. 2010 pers. comm. 29 July).

An Overview of Agriculture and Water Use in the Gamtoos Valley

The Gamtoos Valley comprises 10 000 hectares of farmland and is divided into three sub-districts, namely Patensie; Hankey; and Loerie and Mondplaas. The area is an agricultural hub, known for its production of citrus and cash crops. According to the 2002 Agricultural Census, the area generated output worth R382 million, with citrus and potatoes constituting 36% and 18% respectively of the total revenue. The Gamtoos Valley makes up 20% of the Eastern Cape's total vegetable revenue and 23% of the province's citrus income (StatsSA, 2006). The Valley not only contributes directly to the Province's agricultural revenue, but also generates employment opportunities, employing 5 000 full-time employees and 2 050 seasonal employees (StatsSA, 2006). This amounts to an average of 25 full time and 10 seasonal employees per farming unit and excludes the spillover effects of the packhouses and supporting industries.

The Gamtoos Irrigation Board (GIB) distributes water from the Kouga dam via concrete lined canals and pipelines to the farms. The system only loses 7.5%, as opposed to the NMBM's 38% distribution losses (NMBM, 2010). The DWA owns the dam and thus the GIB's core business involves the maintenance and operation of the Kouga Dam and the canal system and they have between 800-850 water meters to monitor water usage. The high salinity of the water in the Gamtoos River downstream of the Kouga Dam means that irrigation directly from the river is not feasible.

There are approximately 7 500 hectares scheduled for irrigation. The normal allocation of water to farmers is 8 000m^3/ha/annum. The water tariffs imposed by GIB cover the operational and maintenance costs, and are in place regardless of restrictions.

Due to a lack of data pertaining to some of the cash crops in the area, 900 hectares of the scheduled area have been excluded from this study. Crops such as tobacco, chicory, beans and beetroot are the main cash crops omitted from the analysis.

The Lower Sundays River Valley

The Lower Sundays River Valley, a centre of citrus production, relies on the Sundays River and augmented flows from the Orange-Fish-Sundays Transfer Scheme for irrigation water. The Orange River (Senqu River) originates in the Lesotho Highlands, from where it flows into the Gariep Dam, the largest dam in South Africa. Water from the Gariep Dam is either released downstream to the van der Kloof Dam or into the 82.8km Orange-Fish tunnel, through which it enters the Eastern Cape (DWAF, 2004). The Orange-Fish transfer scheme is a vital source of water to the Fish-Sundays River. Not only does it augment the rivers' flow by an estimated 575 million m^3/annum, but it also plays a crucial role in diluting the saline river flows. Additional volumes of water are needed each year solely to flush the river water and keep the river water quality at an acceptable level. The Sundays River receives an estimated 123 million m^3/annum from the transfer scheme (DWAF, 2005).

The main objective for the building of the transfer scheme in the 1960s was to 'store and divert water to promote irrigation and increase agricultural production along the Orange River and in the Eastern Cape regions' (WCD, 2000). The transfer of Orange River water supports 51 000 hectares of irrigated lands in the Fish and Lower Sundays River basins and an additional 4 000 hectares (155Mm^3/annum) has been reserved for future development (DWAF, 2005). It specifically supports 13 300 hectares in the Lower Sundays River Valley.

The Fish-Sundays transfer scheme is of critical importance to the Nelson Mandela Bay Municipality. The commissioning of the Orange River system in 1992 helped relieve the pressures on the Loerie dam. The NMBM reduced its dependency on the Loerie dam, by exchanging 13.5M m^3/annum for

Orange River water (DWAF, 2008). The legal registered water allocation for the NMBM is 17M m^3/annum; however actual water consumption is 25M m^3/annum, the infrastructure's limit. The Orange River water is increasing in importance as NMBM faces water shortages and the municipality's allocation will increase to 58.3M m^3/annum once the expansion of Nooitgedagt is complete. The additional water will come from the surplus supplies in the Gariep Dam, which otherwise would ultimately flow out into the Atlantic Ocean, near Alexander Bay. The system operates so that the DWA only releases water from the Gariep Dam when required. Currently, 7 million m^3/annum of Sundays River water flows out to the sea (DWAF, 2005).

The Sundays River Estuary has a recreational value and it now falls within the Greater Addo National Park. A decrease in river flows could have an ecological impact on this estuary and may impact the tourism in the area in the long run. The Water Act stipulates that the river's instream flow requirement must be recognised and should be seen as another user who competes for this water.

The surplus water from the Gariep and van der Kloof dams is used to generate hydropower for Eskom. Available surplus is released through hydropower turbines which results in a significant variation in releases as the operating rules are set to benefit hydropower generation. As the surplus declines, due to increased water demand, the rules will need to change to favour the existing users instead of hydropower generation. Thus, the opportunity cost of water for NMBM also should include reduced electricity supply. The energy production varies considerably across seasons, however Gariep Dam averages 320MW and Van der Kloof averages 220MW. (WCD, 2000)

There is no direct competition for Orange River water at this stage as the farmers in the Lower Sundays River Valley will not be affected by the increase in NMBM's allocation. Nevertheless, the Orange River water is not an unlimited source of supply, and thus, as the NMBM becomes more reliant on the Orange River water and the intensive agricultural unit looks to expand operations, conflict over this water is likely to arise.

Table 48: Orange/Fish/Sundays River demand 2011

Scheme	Section	Users	Industrial/ Domestic (Mm^3)	Irrigation (Mm^3)	% total demand
Fish River	Teebus	Great Fish WUA		57.95	9.1
	Grassridge	Great Fish WUA		187.05	29.4
		Cradock	2.9		0.5
	Elandsdrift & Canal system	Great Fish WUA		141.04	22.2
		Cookhouse	0.49		0.08
		Somerset East	0.87		0.14
		Bedford/Adelaide	0.7		0.11
	De Mistkraal Dam & Canal system	Great Fish WUA		31.75	5.0
	Darlington Dam	**Sundays River WUA**		**0.49**	**0.08**
Lower Sundays River	Lower Sundays Canal System & Scheepersvlakte Dam	**Sundays River WUA**		**155.15**	**24.4**
		Kirkwood	3		0.47
		Addo-Sunland-Paterson	6		0.94
		NMBM (*will increase to 58.3)*	25		6.3
Lower Fish River	Glen Melville Dam & Canal/pipeline system	Lower Fish River Irrigators		4.7	0.74
		Grahamstown	4.1		0.64
total (Mm^3)			**43.06**	**578.13**	**621.19**
%			6.93	93.07	100

Source: unpublished DWA, 2010 (Daniel, G., 2011. pers. comm. 16 February)

An Overview of Agriculture and Water Use in the Lower Sundays River Valley

The Lower Sundays River Valley, administered by the Kirkwood District is predominantly a citrus producing area, followed by vegetables. 88% of the district's R417 million annual gross income is generated from horticulture, with citrus producing R352 million/annum. The area generates 57% of the Eastern Cape's citrus revenue and 28% of the province's vegetable income (StatsSA, 2006). Agriculture in the Valley provides around direct 3 500 full-time jobs and 7 200 seasonal employment opportunities per annum. This figure excludes the impact of packhouses and secondary industries.

Conradie (2002) calculated the marginal value product of irrigation water in the Fish- Sundays River. Her results showed that agriculture in the Sundays River Valley contributed 71% to the total value of water in the region, highlighting the high returns experienced in citrus production. It is for this reason that the Lower Sundays River has been selected as a site for this study. This analysis will delve more deeply into the crop water relationships and production in the area.

Summary

What all three sites share is that the water being consumed for agricultural purposes is water consequently denied to the NMBM. The Upper Kromme Catchment's agricultural activities, albeit less irrigation-intensive, are situated above the Churchill Dam, therefore reducing the total river flow made available to the NMBM. The Gamtoos Valley farmers share the Kouga Dam's water with the municipality, resulting in conflict around water allocations. The Lower Sundays River farmers are the largest water consumers and competition for this water is increasing as the NMBM becomes more reliant on this Orange River water.

In a competitive water market, if farmers are offered “prices in excess of the net returns experienced per cubic metre of water consumed, they will sooner or later, be induced to sell that water.” (Howe: 1985) This study seeks to determine what this upper limit price would be and to assess whether water markets are worth developing in these areas.

2 Methodology

2.1 Literature Review

Although consumed as a final good by the public, water's main use is as an intermediate good in production, such as irrigation water in agriculture. In South Africa, agriculture is the major user of water accounting for 59% of consumption; in contrast in 1995 it accounted for 84% of water consumption in the United States of America (Young, 2005:3). Agriculture's status as the largest consumer of water heightens the need for efficiency in its use, especially in a climate of increasing scarcity and rising demands.

Sampath (1992:969) expands on the concept of Pareto efficiency in irrigation; he examines the idea of economic efficiency and relates it to four different time horizons. In the immediate run, economic efficiency is achieved when the social marginal value is equal across all users. In the short run, the decision is whether to increase supply, and this should be done when the additional marginal benefits outweigh the marginal costs. The decision of expanding the supply system and investing in new projects is made in the medium run and these ventures are permitted if the social returns exceed the social costs. The long-run dilemma is contrasting optimal investments in irrigation sector to alternative investments in possible water sector complements or substitutes. Johansson *et al* (2002:175) elaborates by stating that allocations, which maximise benefits in the absence of distortionary constraints, are labelled the first-best efficient outcome. The second-best efficient outcome occurs when maximisation happens under distortionary limitations.

Water as an input affects the producer's value of water and this concept is rooted in the microeconomic theory of the production function. The production function is a schedule, which represents the highest level of output a firm can achieve, given the combination of inputs. The firm aims to combine inputs in such a way as to achieve profit maximisation or cost minimisation. Producer welfare is measured by the change in producer surplus and the interest is to determine what a change in an unpriced input (water) has on welfare (Young, 2005:55).

The firm's production function is $Y = Y(X, W, K)$ and $P_y Y(X, W, K)$ is the Total Value Product (TVP). By taking the partial derivative of the production function with respect to the input (water), the Value Marginal Product (VMP) of water is found:

$$\frac{P_y \partial Y(X, W, K)}{\partial W}$$

In a competitive factor market the profit-maximising optimum is achieved when the VMP for each input is equal to its price. The VMP is a measure of producers' Willingness To Pay for changes in the quantity of an input and therefore is a reflection of the marginal economic value of water (Young, 2005:56). Deductive methods, such as the residual method, are frequently used to approximate the VMP of water . According to Young (2005:58), in neoclassical theory, the basic residual methods can be divided into the Production Exhaustion Theorem and the Theory of Economic Rents.

The premise for the Production Exhaustion Theorem is that the VMP of each input equals the marginal factor cost and in the long run, the sum of the VMPs equal the TVP. This is based on Euler's theorem, and is therefore only true if the production function is linear homogeneous. Two principles are at the heart of this theory. The principle assumption is that the Total Value Product can be divided into shares whereby each resource is paid according to its value marginal productivity. The second principle is that producers are profit maximisers, meaning that they continue to produce until the value marginal product is equal to the price of the inputs (Young, 2005:59).

According to these postulates in which total value product is exhausted and where the value marginal product is equal to input price, the production function:

$$Y = f(X_M X_H X_K X_L X_W)$$

becomes:

$$Y.P_Y = (P_M.X_M) + (P_H.X_H) + (P_K.X_K) + (P_L.X_L) + (P_W.X_W)$$

The Production Exhaustion Theorem was used by Chowdhury (2005) to estimate the marginal value product of irrigation water in dry seasons. The study ascertains the scarcity value of irrigation water in Bangladesh and compares it to India, particularly the Ganges-dependent districts. Bangladesh shares 54 rivers with India and receives the residual flow after India's utilisation upstream. Water shortages are therefore common, particularly in dry seasons. The production method relates crop production to the consumption of water and other inputs, and in this study, the crop produced was *borro* rice. The marginal physical productivity of water for an additional unit of water was multiplied by the crop price to determine the marginal value of each increment of water (Chowdhury, 2005:14).

$$\frac{\partial v}{\partial c_r} = \frac{\partial (pQ)}{\partial (wI)} = \frac{p \partial Q}{\partial I}$$

where v was the value of rice, c_r, the cost of irrigation and I , the amount of irrigation water measured in cubic meters (Chowdhury, 2005: 15). The marginal value of irrigation water, or the net returns to irrigation water, of *borro* rice in Bangladesh was between USD 0.002 – 0.015 per cubic meters. Farmers who farm on very small farms have the highest marginal value product of water, followed by large farmers (farm size greater than 0.40ha). Farmers in the South West region were willing to pay the highest amount for water and this reflected the higher scarcity levels and therefore high opportunity cost from competing users (Chowdhury, 2005:20).

The Theory of Economic Rents is particularly useful when water supply is limited, and so it is often used to value irrigation water. Economic, or Ricardian Rents are payments over and above the price needed to bring a resource into production (Young, 2005:63). A change in rents illustrates a change in welfare due to a change in the supply of water.

The equation, given by Young (2005:67), shows water rents equal to total revenue minus total variable costs, quasi-rents and non-water rents: $R^{W} = TR - TVC - QR - R^{NW}$

Theory states that under perfect competition, producers are price takers and therefore all payments to variable factors are exactly equal to the total revenue, resulting in zero economic profits. Economic profits arise when returns to fixed factors of production exist and this could include irrigation water (Conradie and Hoag, 2004:287).

Conradie and Hoag (2004:288) comment that Howe's analysis (1985) adopts the view that residual profits denote the water value. Uncertainties about future supplies, population and industrial growth led to an increase in water demand in the Lower Colorado Basin and a search for new supplies instigated Howe's study on interstate water transfers in the Colorado River (Howe, 1985:1227). Agricultural water rights were deemed an appropriate source for potential water transfers because agriculture is the main consumer of water, and water in agriculture is associated with lower economic returns. By assembling the seven crops grown in the Upper Basin in order of their net returns and the cumulating quantities of water associated at that net return, a crude demand curve of water was created (Howe, 1985:1228). The study was grounded in the assumption that farmers would be persuaded to sell water rights if they were offered prices which exceeded the net returns they experienced per acre-foor of water consumed. It was ascertained that by offering prices not exceeding $72 per acre foot, a total of 1.6 million acre-feet could potentially be available for sales or leases to the Lower basin (Howe, 1985:1229). The premise for the study was that water markets have the ability to allocate water away from low value users, which is the same argument used by Michelson and Young (1993). Another study set in Colorado, it illustrated how water could be transfered away from low economic returns generated from agriculture to higher value municpal uses. Conradie (2002:32) highlights that the difference between Howe's study and other water value models, such as Michelson and Young (1993) and Taylor and Young (1995) is that Howe used average value product instead of indicating the marginal value product, via shadow prices.

Taylor and Young (1995) assessed the benefit of transferring water in the Colorado Canal away from agriculture to meet competing demands. Water in agriculture was viewed as society's "direct foregone benefit" and they questioned whether new benefits from the transfer would outweigh the foregone benefits or opportunity cost. As theory dictates, they assume that producers are price takers and that the net welfare is measured by the input demand function. Mathematical programming techniques used in the study were developed by imputing the residual value of water from farm budgets similar to Williams *et al* (2008) and Conradie (2002).

Adopting an aggregate method to measure regional irrigation water demand, the model, maximised expected regional income across different crops types (corn, sorghum and lucerne), soil types (alkaline/saline to fertile), water yields and water delivery situations (Taylor and Young, 1995:250). The study used a discrete sequential stochastic programme (DSSP), which solves sequential problems based on past decisions and expected future events. It modelled three sequential stages in regional crop production together with the uncertainty of crop production and water supply. Decision choices were incorporated into the model so that decisions could be revised at each stage as new information became available. The model is unique in that it examines scenarios where farmers plant crops before they know how much water is available. Taylor and Young established that average value of irrigation water foregone was $37 per acre-foot and that risk reduced the value by $6 per acre-foot.

Locally Nieuwoudt *et al* (2004) surveyed studies into the economic value of water in South Africa. It suggested that, at a national scale, agriculture is an inefficient consumer of water, generating R1.5 gross income per cubic meter of water, compared to R157.4 generated by industries. Water plays an important role in agriculture by contributing an estimated 30% to the total value of farm output and therefore it is important to examine the marginal contribution water makes in agriculture. Investigating the price elasticities, Nieuwoudt *et al* (2004:177) discovered that non-agricultural users have low price elasticity of demand indicating they place a low value on additional units of water supply. Instead, they place a high value to the assurance and security of water.

Nieuwoudt *et al* (2004) used input-output tables out of which average relationships are determined. This approach is criticised for overestimating the willingness to pay for an increment of water because it fails to isolate the contribution that only one input (in this case, water) has on the output. It therefore accredits the productivity of all primary resources to the residual, thereby inflating this figure (Young, 2005:91). The contribution water makes to total value in agricultural production is significantly larger than in other industries. Thus, in manufacturing industries, capital and labour are the major factors of production, and yet the total production is still divided by the amount of water used. This presents an upward bias and overestimates the true value or contribution of water makes to the total output. It is important to take the marginal contribution: $\frac{\partial Q}{\partial W}$ and not $\frac{Q}{W}$.

Conradie (2002) chooses to value water using the more appropriate residual method, which assumes residual profits are payments to irrigation water. Set in the Fish-Sundays River Scheme in the Eastern Cape, it investigates the economic efficiency of water allocation to commercial farmers. Using linear programming, it models 16 typical farms to find the marginal and total water values at a farm-level scale. Linear programming is an effective tool to estimate shadow prices for water as it maximises economic returns subject to "resources, production and policy constraints" (Jabeen, Ashfaq and Baig, 2006:101). Conradie (2002) models six different crops, four livestock activities, five irrigation systems and accounts for risk using MOTAD, which maximises profit subject to an acceptable level of risk. Like Taylor and Young (1995), Conradie realises that risk reduces the total and marginal value of water.

Conradie (2002) observed that 'irrigation' and 'small stock' farms are the least profitable per cubic metre of water, with some farms in the Fish-Sundays experiencing zero marginal value of water. Within the Upper, Middle and Lower Fish River, 'dairy' farms have the highest returns per cubic meter of water, with values ranging from R980/ha/annum - R1 196/ha/annum. The Lower Sunday's River Valley citrus growers generally have substantially higher marginal water values, ranging from R1 522/ha/annum to R3 950/ha/annum for the large stable citrus farms. Large stable citrus growers experience the highest marginal value productivity of water at R0.44/m^3/annum (Conradie, 2002).

Allocation between agricultural and urban users is also not efficient as seen in Table 49 (Conradie, 2002). The municipal bulk tariff rates (2009) are higher than the highest agricultural marginal values of water. Conradie (2002) suggests that it is possible to reallocate water away from farmers who do not need it at the margin, to those municipalities who are willing to pay more for it. The more profitable Sunday's citrus farmers would be able to compete with the municipalities for scarce water (Conradie 2002).

Table 49: Municipal bulk tariff rates (2009) compared to adjusted 2002 agriculture marginal values

	Municipal R/m^3	**Agriculture** R/m^3
Middle Fish	0.125	0.089
Lower Fish	0.384	0.078
Sundays	0.509	0.439

Source: Conradie (2002); DWA (2010)

Williams *et al* (2008), another South African study, used linear programming to determine the water demand schedule for irrigation water in the Greater Letaba River Catchment. Enterprise budgets were used to create a regional farm budget; however, the different climatic conditions, diverse crop patterns and different farm sizes created difficulties. The regional farm budgets provided the main input in the linear programming, and although linear programming has its benefits, it was found that some detail was lost using this method. The marginal values of water derived from the aggregated agriculture demand schedule varied from R0.50/m^3 to R2.50/m^3 (Williams *et al*, 2008:82). These values are substantially higher than Conradie's findings in the Eastern Cape and this could be attributed to the fact that high-value crops such as citrus, avocadoes and mangoes are grown in the Greater Letaba Catchment area. Citrus and avocadoes are export-intensive and have higher margins and so this pushes up their shadow prices.

2.2 Howe's (1985) Methodology

This chapter will follow the same methodology as Howe's (1985) in determining the economic value of water. His approach deals with competition between urban and agricultural water demand and explores the option of transferring water rights to augment urban water supplies. The analysis aims to test whether the reallocation of water rights is justified and whether there is a potential market for water.

A crude demand function for water is established, based on the net returns of the individual crops and the cumulative water consumed at each net return (Howe, 1985). The annual consumptive use of water per crop and its associated gross margin is needed to create the demand curve. This procedure indicates the average value of water per crop, thereby indicating the price range at which NMBM could buy that water and the associated yield. Howe's (1985) approach is often referred to as a predecessor to linear programming techniques, important in assessing the possibility of a water market (Marais *et al*, 2001).

This method is useful in comparing the average values across crops and in distinguishing which crops are high-value users of water and which crops are not. It gives an indication as to the direction of a potential reallocation of water and represents the upper limit of rational a farmer's willingness to accept compensation for water lost.

This method does not provide the marginal value of water, as the contribution water makes to the net return is not isolated. One needs to be aware that the agricultural return is made up of many factors, such as fertilizer, improved seed, capital equipment and good management. The major shortcoming of this method is that it fails to subtract the value of any non-water input from the Total Value Product, therefore assigning the entire value of output to water and overestimating the value.

The model denotes the average value of water by assuming there is unlimited water supply and merely divides the residual by the net irrigation requirement. In comparison, marginal value of water is modelled by dividing the shadow price on a water constraint by the net irrigation requirement.

Marais *et al* (2001) comment that average values are often good proxies for marginal values, although there is no consistent relationship between these estimates. The similarity of the values depends on the elasticity of water demand and the more inelastic water demand is, the closer the values are. Marais *et al,* (2001) observe that farmers who employ water saving technologies, such as micro-irrigation used in orchards, have an inelastic demand for water because they cannot move towards more water efficient technologies. Farmers who use inefficient water using approaches, such as flood irrigation or sprinklers, have the option of reallocating water away and adopting more efficient methods of irrigation, causing the marginal value of water to increase, as demand becomes more inelastic. The average values of water do not denote the changes in water use patterns and are therefore tend to overestimate the marginal value productivity of water.

For the purposes of this study, it is not critical that the water values are overestimates of willingness to pay and therefore simplifying assumptions are justified (Marais *et al*, 2001). The opportunity cost of water can be extrapolated from this methodology in the sense that if the low-yielding uses of water are abandoned, the additional water released can potentially be sold to NMBM and the change in net earnings can be established if farmers were to switch to high-value crops.

2.3 Establishing the Agricultural Model

Farm budgets are needed to approximate each agricultural enterprise's production functions. Net revenue minus directly allocatable variable costs and fixed costs generates the net revenue per enterprise. Instead of using a farm-level approach, the study analyses the profitability of the individual crops and their associated water requirements and thus the analysis is based on a per hectare basis.

The analysis is founded on enterprise budgets provided by Eastern Cape Department of Agriculture and updated to reflect 2009 prices. The budgets were modified after interviews with Gamtoos Valley and Kromme farmers, meetings with the Kromme Agricultural Extension officer (van der Merwe, S 2011, pers. comm.), the CEO of the Gamtoos Irrigation Board and conversations with the Lower Sundays River Citrus Company (Gerber, D, 2011, pers. comm. 15 November). Enterprise budgets reported in Conradie (2002) have also been consulted and updated.

Enterprise Budgets

Enterprise budgets are useful in providing general information on the factor inputs and corresponding prices, expected yields, production technology and gross margins. Enterprise budgets work on the average and therefore should be treated as estimates. An example of the enterprise budget used for the field crops in this study is seen in Table 50 (van Zyl, Kirsten, Coetzee and Blignaut, 1999).

Table 50: Enterprise Budget Prototype

Gross Income
Marketing Costs
Gross Income After Marketing Costs
Allocated pre-harvesting costs
Seed
Casual planting labour
Fertilizer
Weed, Pest & Leaf nutrient control
Irrigation: (O&M)
Irrigation: water
Machinery & Implement costs
Allocated harvesting costs
Packing material
Casual labour
Transport to market
Machinery & Implement costs
Total allocated costs
Fixed overhead costs
Gross Margin above all costs

The gross income is calculated by multiplying the average yield for the area by the farm-gate price, less any marketing costs. The farm-gate prices were updated to reflect 2009 prices using national producer price indices, reported in the Abstract of Agricultural Statistics (DAFF, 2010).

The allocated pre-harvest costs are costs concerned with the preparation and cultivation of the land. The irrigation costs involve the electricity, labour and maintenance of the irrigation system.

Although the flat-rate water tariff is a fixed cost, it is incorporated as a variable cost in this study. The water tariff is based on crop-water relationships per hectare, because there is often more than one planting per season. This allows for the irrigation cost per crop to be isolated. The relative water tariffs are displayed in Table 51.

Table 51: Agricultural Water Tariffs per site

Water Tariff (R/m^3)	
Gamtoos Valley [a]	0.155
Upper Kromme [b]	0.039
Lower Sundays [c]	0.061

Source: [a] pers. comm. 2011 Joubert, P 29 July, [b] NMBM (2010), [c] unpublished DWA (2010 pers. comm. Daniel, G 16 February)

The machinery and implement costs include the operating costs, the maintenance of the machines, and the labour cost involved. The bulk of the harvesting costs involve the labour, packing costs and the cost of transporting the produce to market. The transport costs depend on the distance to the market as well as the weight of the produce.

Although labour is often deemed as a fixed cost, it has been divided into the various budget activities mentioned above. Fixed costs include payments to land, infrastructure and owner's management as well as administration costs, licenses, depreciation, general maintenance and rates and taxes (Conradie, 2002). Using the enterprise budgets and Conradie (2002) as a guideline, the estimated fixed costs are portrayed in Table 52. The fixed costs are estimated per hectare and are adjusted for land which has more than one planting per season.

Table 52: Fixed Costs according to crop and location (2009 prices)

	intensive fruit	field crops
Gamtoos Valley [a]	R 4 332.47	R 4 332.47
Upper Kromme [a]	R 4 332.47	R 1 083.12
Lower Sundays [b]	R 5 725.97	R 4 332.47

Source: [a] Department of Agriculture Eastern Cape (2008) [b] Conradie (2002),

The gross margin analysis has been analysed over a 20 year period and a real discount rate of 5% is assumed. The real discount rate has been assumed because this implicitly accounts for price growth rates.

Table 53 provides the net revenues per hectare per annum according to each crop across all three locations. The values represent 2009 prices. Enterprise budgets are displayed in Appendix C: Table 75.

Table 53: Net revenue/annum per hectare across crops and sites (2009 prices)

	Gamtoos Valley	Upper Kromme Catchment	Lower Sundays River
Broccoli	(R 347.57)		
Cabbage	R 2 003.29		R 1 600.55
Carrots	R 3 656.49		R 3 202.62
Cauliflower	R 2 888.59		
Citrus Mixed	R 11 201.87		
Citrus: Clementines			R 5 598.51
Citrus: Lemons			R 46 107.17
Citrus: Navels			R 6 702.70
Citrus: Valencias			R 7 730.10
Deciduous Fruit Mixed	R 1 929.88	R 2 253.88	
Deciduous Fruit: Apples		R 2 718.66	
Deciduous Fruit: Plums		R 1 789.10	
Kikuyu-Ryegrass	R 2 768.01	R 2 918.16	
Lucerne	R 3 610.89		
Maize	R 2 332.40		
Potatoes	R 6 391.84		R 5 703.64
S Potatoes	R 3 254.69		
Sweetcorn	R 4 520.50		
Teff + Sorghum	R 1 763.74		
Tomatoes	R 2 283.57	R 3 600.51	R 1 782.61
Wheat	R 330.82		

The Gamtoos Valley farmers tend to plant cash crops for the market and therefore their profit margins fluctuate dramatically as they are dependent on market forces. For example the unit price for cabbages in 2009 was R29 while in 2011 it dropped to R6.97. The kikuyu and lucerne crops in the Gamtoos Valley are not necessarily utilised for fodder, but instead are planted as part of their soil regimes to fix nitrogen into the soil and break pest cycles. These crops should be represented as costs, but instead have been evaluated as if they are fodder crops. The deciduous and citrus fruit variety mix is unknown and therefore an average is used to represent these fruit types.

In the Lower Sundays River Valley, lemons are the most profitable and this region generates more than a third of all South Africa's lemons. The unit price of lemons is 58% higher than the price of other citrus cultivars and each hectare produces 61% higher volumetric yields compared to other citrus fruits.

The main reason for the difference in net revenues across the same crops is the impact of variant water tariffs.

Net Irrigation Requirement

The net irrigation requirement is a benchmark for the amount of irrigation, above rainfall, needed per crop. The crop factor needed in calculating the net irrigation requirement takes into account the irrigation infrastructure, the crop information and the climatic conditions. The differences in rainfall and evaporation rates across locations are indicated in Table 54.

Table 54: Climatic characteristics of the sites

Location	Mean Annual Rainfall (mm)	Evaporation (mm)	Main rainfall season
Gamtoos Valley ⁺	420	1 295	summer
Upper Kromme Catchment ~	655	1 601	winter
Lower Sundays River ⁺	392	1 633	summer

Source: ⁺ Department of Agriculture Western Cape (2011), ~Rebelo (dissertation in prep)

The net irrigation requirements for the Gamtoos Valley are taken from the *Gamtoos Pilot Project Baseline Report* a report commissioned for the Water Conservation and Demand Management Strategy by DWAF (2008). It contains detailed analysis of the agricultural water consumption in the Valley and the different cropping systems and irrigation infrastructures used. It is assumed that all vegetables are irrigated under centre pivots and permanent crops are irrigated using drip irrigation (DWAF, 2008).

The irrigation requirements calculated for the Lower Sundays River Valley were taken from Conradie (2002) together with the crop factors supplied by the Department of Agriculture (2011). The most common form of irrigation in the Sundays is micro-jets (Conradie, 2002). The water requirements for the Upper Kromme Catchment were determined from the farm interviews, Rebelo's (dissertation in prep) modelling assumptions and the crop factors from the Department of Agriculture. Micro-jets are used to irrigate orchards and vegetables, whereas moveable sprinklers are used to irrigate the field crops in the Upper Kromme (interviews with farmers).

The net irrigation requirements for each crop across locations are displayed in Table 55.

Table 55: Net irrigation Requirements (mm/annum)

Crop	Gamtoos Valley ⁺	Upper Kromme Catchment ~	Lower Sundays River °
Broccoli	315		
Cabbage	286		472
Carrots	322		508
Cauliflower	322		
Citrus Mixed	781		
Citrus: Clementine			800
Citrus: Lemons			800
Citrus: Navels			800
Citrus: Valencia			800
Deciduous Fruit Mixed	1 094	639	
Deciduous Fruit: Apples		639	
Deciduous Fruit: Plums		639	
Kikuyu-Ryegrass	1 281	610	
Lucerne	1 281		
Maize	578		
Potatoes	488		674
S Potatoes	582		
Sweetcorn	313		
Teff + Sorghum	613		
Tomatoes	360	360	569
Wheat	429		

⁺ Gamtoos Pilot Baseline Report (2008)

~ Rebelo, (unpublished) & farm interviews (2010), DoA Western Cape (2011)

° Conradie (2002); DWAF (2011)

3 Results and Discussion

3.1 The opportunity cost at water each location

The area dedicated to each crop, the different crops' consumption of water and their corresponding net revenue per cubic metre of water, are indicated in the tables below. Using this information, it is possible to construct a crude agricultural water demand curve for each location as demonstrated in Figure 45 to Figure 47.

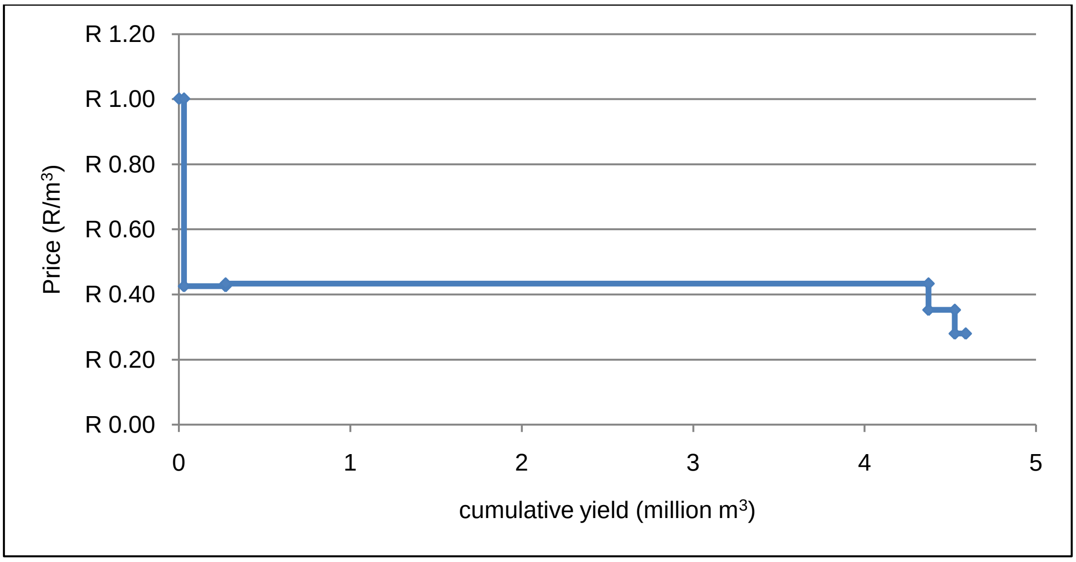
3.1.1 Upper Kromme Catchment

The analysis of the Upper Kromme Catchment illustrates that 4.59 million m^3/annum of irrigation water is consumed for agricultural purposes in the Kromme. Tomatoes have the highest value of water, and yet consume the least in the catchment (0.3 million m^3/annum), due to the small area planted to them. The average value of deciduous fruit ranges from R0.28/m^3 to R0.43/m^3. Most of irrigation water is consumed by kikuyu fodder crops, planted to support the dairy industry in the area. One would expect water to be transferred away from the lower-end users of water and reallocated towards the high-end value crops, such as tomatoes. Around 4.56 million m³/annum of water could be released for prices not exceeding R0.43/m³. The total water value in the Upper Kromme Catchment is R1.98 million/annum and the weighted average value of water is R0.43/m³.

Table 56: Upper Kromme Catchment

Crop	Area (ha)	Net return per cubic metre of water (R/m³)	Crop water use in the Gamtoos Valley (million m³)
Tomatoes	8	R 1.00	0.03
Apples	38	R 0.43	0.24
Kikuyu Fodder	610	R 0.43	4.10
Average Deciduous	24	R 0.35	0.15
Plums	10	R 0.28	0.06

Figure 43: Demand Curve for Water of Existing Agricultural Uses in the Upper Kromme Catchment



3.1.2 Gamtoos Valley

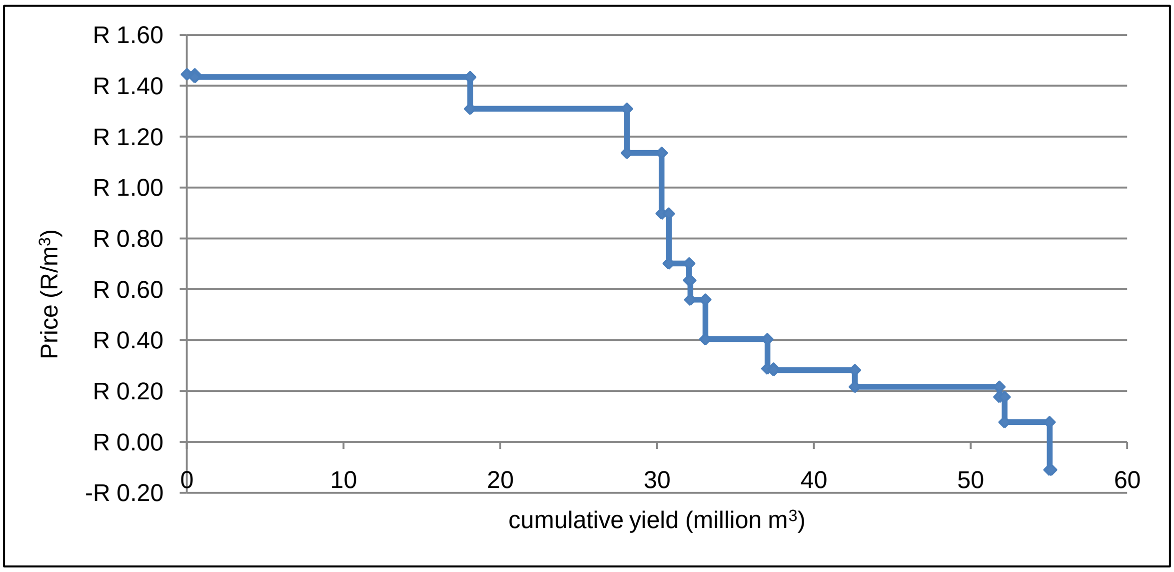
Table 57 focuses on the Gamtoos Valley, where 51.5 million m³ of irrigation water is being consumed for agriculture each year. Citrus and potatoes are the largest consumers of water in the Valley, and also have high average values of water at R1.43/m³ and R1.31/m³ alike. It would be economically efficient if water was transferred away from the low-yielding vegetables of broccoli and wheat, and used instead for high-yielding crops such as sweet corn or carrots. However, as mentioned, the prices and yields of the cash crops fluctuate rapidly from year to year and thus it is with caution that these recommendations are made. To manage risk, a farmer needs to diversify the selection of crops planted, and thus it is recommended that farmers diversify by planting high-yielding crops.

The weighted average value of water in the Gamtoos Valley is R 0.89/m³. The total agricultural value of water in the Gamtoos Valley is an estimated R48.92 million per annum.

Table 57: Gamtoos Valley

Crop	Area (ha)	Net return per cubic metre of water (R/m^3)	Crop water use in the Gamtoos Valley (million m^3)
Sweetcorn	160	R 1.45	0.50
Citrus: Mixed	2 250	R 1.43	17.57
Potatoes	2 050	R 1.31	10.00
Carrots	690	R 1.14	2.22
Cauliflower	140	R 0.90	0.45
Cabbages	455	R 0.70	1.30
Tomatoes	20	R 0.64	0.07
S Potatoes	165	R 0.56	0.96
Maize	685	R 0.40	3.96
Teff + Sorghum	65	R 0.29	0.40
Lucerne	405	R 0.28	5.19
Kikuyu-Ryegrass	720	R 0.22	9.22
Deciduous fruit: Mixed	30	R 0.18	0.33
Wheat	670	R 0.08	2.87
Broccoli	32	(R 0.11)	0.10

Figure 44: Demand Curve for Water of Existing Agricultural Uses in the Gamtoos Valley



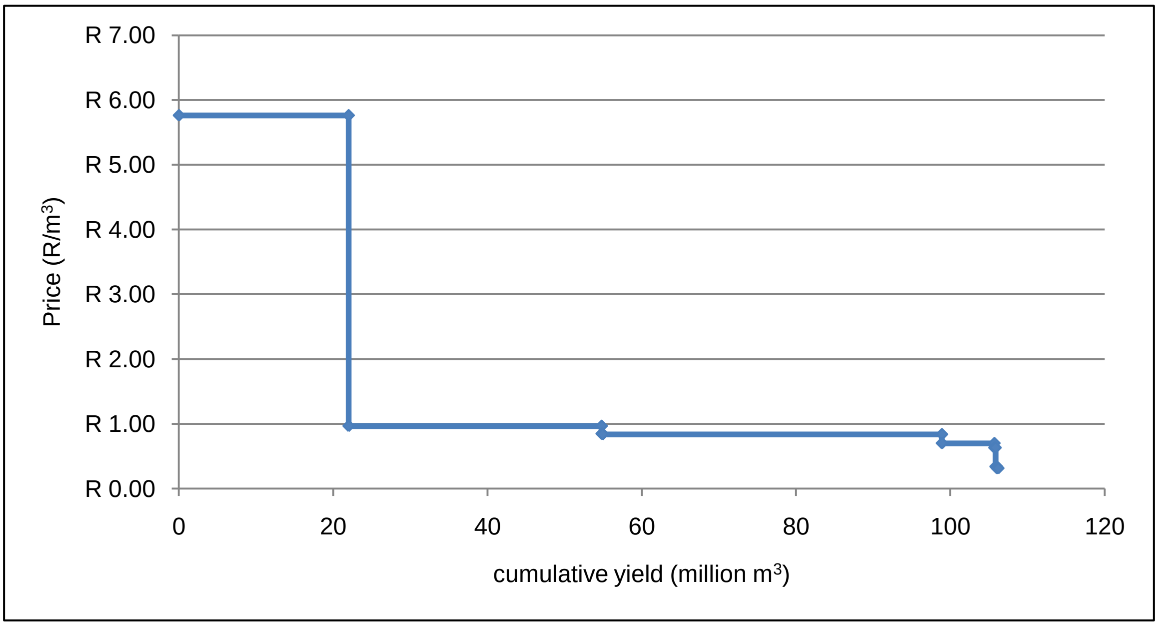
3.1.3 Lower Sundays River Valley

The market price of lemons is considerably higher than other citrus cultivars and therefore the average value of water for lemons (R5.76/m³) exceeds the other citrus cultivars markedly. However, 84million m³ of water could be transferred away from the other citrus and vegetables for prices not exceeding R0.97/m3. The average value of water in the Sundays River is higher than the other sites, averaging R1.89/m³, which means the total value of water in this area is R200.4 million/annum. The area produces citrus which is export driven and it is unsurprising that the water values in the Lower Sundays surpass those of the other locations.

Table 58: Lower Sundays River Valley

Crop	Area (ha)	Net return per cubic metre of water (R/m³)	Crop water use in the Gamtoos Valley (million m³)
Citrus: Lemons	2 750	R 5.76	22.00
Citrus: Valencia	4 100	R 0.97	32.80
Potatoes	18	R 0.85	0.12
Citrus: Navel	5 500	R 0.84	44.00
Citrus: Clementine	850	R 0.70	6.80
Carrot	29	R 0.63	0.15
Cabbage	40	R 0.34	0.19
Tomatoes	29	R 0.31	0.17

Figure 45: Demand Curve for Water of Existing Agricultural Uses in the Gamtoos Valley



3.1.4 The Opportunity Cost of Water in the Nelson Mandela Bay Municipality

In order to compare urban and agricultural willingness to pay for water, the opportunity cost of water in the NMBM needs to be ascertained. The opportunity cost is derived using the "next best scheme" approach and is interpreted as the price which the NMBM would have pay to obtain the same amount of water from elsewhere.

The urban and agricultural prices are compared to establish which user values water more highly. This indicates which direction transfers should happen to achieve Pareto efficiency.

The NMBM's opportunity cost of water has been calculated over a 25 year period and thus the annual expected agricultural yields and profits need to be converted over a 25 year timeframe. Using the levelised cost approach outlined in Chapter one, the yields and revenues are discounted at a 4% interest rate.

Table 59 compares the NMBM opportunity cost of water and the average agricultural opportunity cost at the corresponding yields. The agricultural opportunity costs are based on current agricultural practices and current water consumption.

Table 59: Comparison of NMBM and agricultural opportunity costs of water over 25 years

	Total Yield (million m³)	NMBM WTP (R/m^{3})	Agricultural price (R/m³)
Upper Kromme Catchment	74.58	1.61	0.46
Gamtoos Valley	896.00	3.53	0.88
Lower Sundays River Valley	1 725.79	4.47	2.26

The prices that the NMBM are willing to pay for at the associated level of water exceed the agricultural opportunity cost of water. This implies that water should be transferred away from the lower yielding agricultural consumptions to the high-yielding urban uses.

Table 60 compares the upper limit of farmers' willingness to pay for water. This assumes that farmers move away from the low-yielding crops and instead plant crops that yield higher returns per cubic metre of water.

Table 60: Comparison of NMBM and upper limit of agricultural opportunity costs of water over 25 years

	Total Yield (million m³)	NMBM Willingness to Pay (R/m^{3})	Agricultural value of water (R/m³)
Upper Kromme Catchment	74.58	1.61	0.99
Gamtoos Valley	896.00	3.53	1.44
Lower Sundays River Valley	1 725.79	4.47	6.46

The value of water in the Lower Sundays River Valley surpasses the NMBM's willingness to pay and suggests that future allocations should be directed towards the high-yielding citrus production, instead of the urban NMBM demand. Nevertheless, even at the upper limit of agricultural demand, willingness to pay in urban areas is greater than agriculture's willingness to pay in both the Upper Kromme Catchment and the Gamtoos Valley.

It is important to reiterate that the agricultural opportunity cost of water only incorporates the sum of the individual farmers. The value of water to the rural economy is not incorporated and thus the reported value underestimates the true agricultural value of water.

3.1.5 Water trading as a possible NMBM augmentation plan

Assuming that the cost of transferring water rights is based solely on the opportunity cost of water as calculated in this chapter, water trading is considered as a possible scheme to augment the NMBM's water supply. It is assumed that perfect competition and fully tradable water rights exist.

Using the methodology described in Chapter 1, Figure 48 shows the NMBM's supply cost curve including the proposed water trading options. The upper limit of agricultural willingness to pay for water has been used. Table 61 provides details on all the possible water augmentation schemes studied in this paper.

The incremental cost curve illustrates that possible water trading in the Upper Kromme Catchment is the cheapest of all the proposed schemes. The water trading scheme can supply an estimated 74.58 million m^3 over 25 years at a price of R0.99/m^3. It is interesting to note that water trading in the Upper Kromme is a considerably cheaper option than restoration in the Upper Kromme and it supplies a total of 67million m^3 more water. Nevertheless, the two schemes are linked: the continual degradation of the catchment and spread of AIPs compromises the additional water released by farmers through water trading.

Trading water rights in the Gamtoos Valley is the third cheapest augmentation scheme. This means that possible water trading in the Baviaanskloof, Gamtoos Valley and Upper Kromme are the three cheapest supply augmentation options for the NMBM. The Gamtoos Valley has the capacity to release 896 million m^3 over 20 years at a price of R1.44/m^3. The Gamtoos Valley contributes significantly to the province's horticultural production and provides significant employment opportunities. The forward and backward linkages of the Gamtoos Valley agriculture have not been quantified and therefore the true cost of trading water rights will be much higher. Without irrigation, agriculture in the valley would collapse and these far reaching economic and socio-economic consequences need to be considered.

Water trading in the Lower Sundays River Valley is the second most expensive scheme proposed to the NMBM. The high returns that can be generated per cubic metre of irrigation water, suggest that water trading should not be considered in the Valley. Water trading is more expensive than the desalination of seawater or constructing a new dam.

Figure 46: Incremental Cost of Water by Source using mean costs including the possibility of water trading

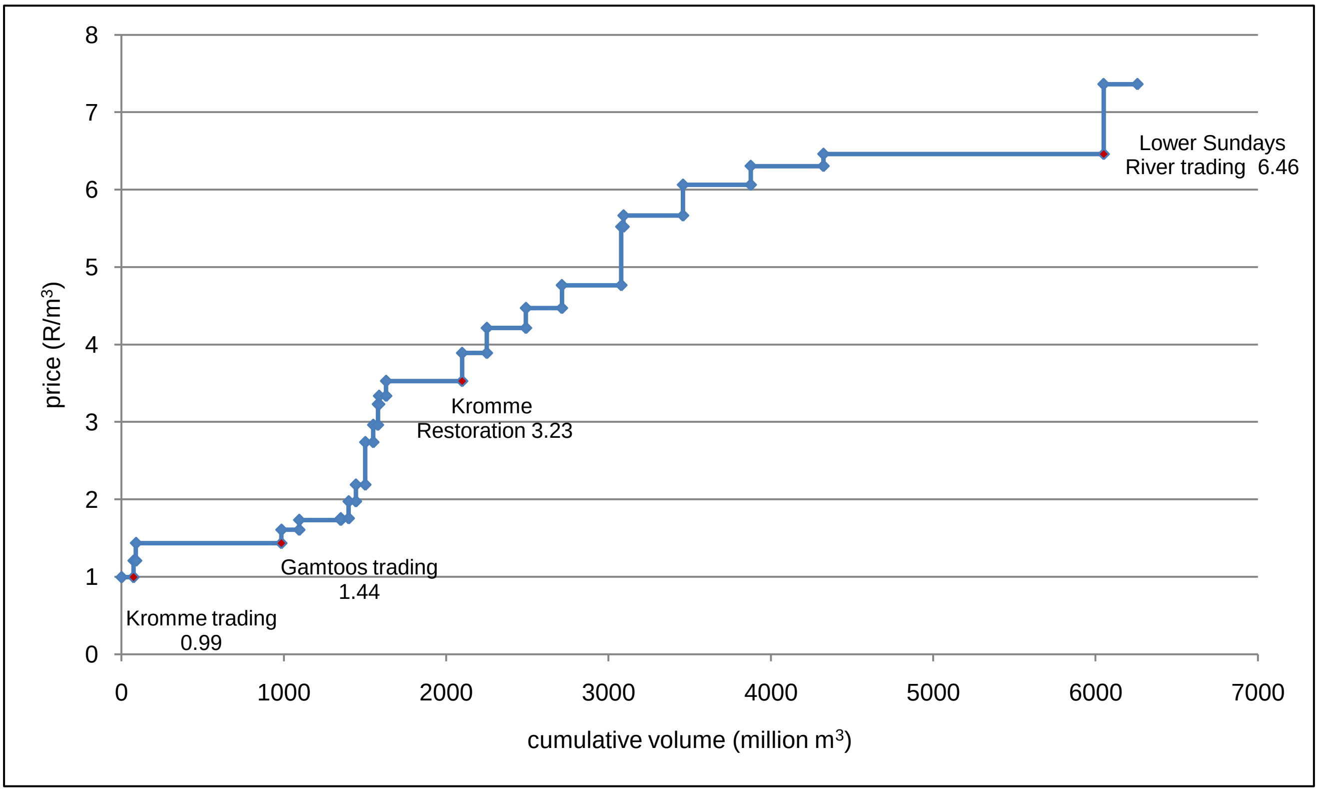


Table 61: Total costs and yields pertaining to each proposed augmentation scheme for NMBM

SCHEME	**PV total cost** (R million)	**Total discounted yield** (million m^3)	**Cumulative water volume** (million m^3)	**Price** (R/m^3)
Kromme Trading	34.01	74.58	74.58	0.99
Baviaanskloof	17.67	14.62	89.20	1.21
Gamtoos Trading	1 286.40	896.00	985.20	1.44
Gamtoos river irrigation return flows	176.03	109.55	1 094.75	1.61
Upper Fish River	443.59	255.89	1 350.64	1.73
Upstream of meters	85.83	48.90	1 399.54	1.76
Coega fault	87.48	44.32	1 443.86	1.97
Van Stadens	126.98	57.99	1 501.85	2.19
Downstream of meters	133.90	48.90	1 550.75	2.74
Bushy Park	84.92	28.68	1 579.43	2.96
Kromme river restoration	**23.28**	**7.21**	1 586.64	**3.23**
Jeffrey’s Arch	144.37	43.28	1 629.91	3.34
Nooitgedagt Low-Level	1 652.46	468.32	2 098.23	**3.53**
Sundays River	592.64	152.37	2 250.60	3.89
Treated effluent from Coega	1 015.20	240.98	2 491.58	4.21
Industrial standards FWF WWTW	989.39	221.33	2 712.91	4.47
Guernakop Dam	1 745.45	366.29	3 079.21	4.77
Tsitsikamma River diversion	75.71	13.71	3 092.92	5.52
Kouga replacement	2 075.04	366.29	3 459.21	5.66
Coega desalination	2 528.40	417.13	3 876.35	6.06
Seawater	2 825.95	448.24	4 324.59	6.30
Lower Sundays River Valley trading	11 142.10	1725.79	6 050.37	6.46
Echodale: potable standards	1 535.47	208.59	6 258.96	7.36

4 Conclusion and Limitations

The agricultural hubs investigated in this chapter already provide 73% of all NMBM's water. The costs of supply discussed in Chapter 1 reveal the storage, transport and treatment costs of obtaining water, but fail to account for the opportunity cost of using water for urban consumption. This analysis has aimed to shed light on this hidden cost by measuring the opportunity cost of water as agricultural revenue forgone.

Economic theory dictates that economic efficiency is achieved when additional economic returns cannot be achieved from reallocating resources. Based on this premise, the option of reallocating water away from low-yielding crops towards high-yielding crops was investigated. The study has uncovered that the Lower Sundays River Valley has the highest average value of water, with prices reaching R5.76/m^3. An estimated 106 million m^3/annum of irrigation water can be released at an upper limit of R5.76/m^3. The total value of water in the Lower Sundays according to the present agricultural water consumption patterns is R200 million/annum.

The Gamtoos Valley experiences highest net returns for sweet corn at R1.45/m^3. Around 4 300 hectares is planted towards citrus and potatoes and these crops yield prices of R1.43/m^3 and R1.31/m^3 indicating that water is being allocated in an efficient manner. Farmers in the Valley plant cash crops for the market and therefore their returns vary from year to year. They are susceptible to market forces which brings volatility and uncertainty into the farming profitability. The current total average value of water in the Gamtoos Valley is R48.89 million/annum and 55.15 million m^3/annum can be released for prices not exceeding R1.45/m^3.

Around 4.6million m^3/annum of irrigation water can be released from the Upper Kromme Catchment at prices not exceeding R1.00/m^3. The prices average R0.43/m^3, which is significantly cheaper than prices at the other locations. The majority of irrigation water is used for kikuyu fields, planted as fodder for livestock and dairy. The total average value of water in the Upper Kromme Catchment is R1.98 million/m^3.

The analysis exposes that water should be reallocated away from agriculture in the Upper Kromme Catchment and the Gamtoos Valley, but that it should be allocated away from urban consumption towards lemon production in the Lower Sundays River Valley

Assuming that the opportunity cost or the willingness to pay captures the total cost, the possibility of water trading as a means to augment NMBM water supply was considered. It transpired that water trading in the Upper Kromme Catchment is the cheapest of all potential schemes at R0.99/m^3, followed closely by water trading in the Gamtoos Valley costing R1.44/m^3. These costs do not take into account the impact of supporting industries or potential job losses in the area and therefore further research is needed.

4.1.1 Limitations of the study

Howe's (1985) methodology is useful for providing an indication as to the value of water across certain agricultural uses, but falls short of estimating the marginal value productivity of water. This methodology tends to overestimate the value of water and therefore the figures must be treated with caution. The study does not account for risk, which is known to reduce the value of water.

The specification of the agricultural model is also sensitive to problems. If the stipulated inputs and factor prices are either under or over-estimated, the error is magnified in the production values, thereby either over or under estimating the economic value of water (Young: 2008).

Enterprise budgets are subject to fluctuating local market prices, changing export prices, input costs and technologies. Seasons vary each year, with changing weather patterns, pests and diseases; factors which impact the crop yields and the profitability of harvests. For these reasons, gross margin analysis should be treated with caution.

For an example, increases in fixed overheads, water tariffs or labourers' wages ceteris paribus, will decrease the crop's profit margin and as a result decrease the average value of water of that crop. On the other hand, increases in crops' yields (keeping irrigation requirements fixed) or increases in the market prices will increase the profit margin and increase the average value of water per crop.

An overriding concern in this chapter is the fact that the local economies of the three regions have been ignored. The chapter has dealt only with individual farmers' willingness to pay for water, and has ignored the effect agriculture has on the economy of the rural sector and supporting industries. The agricultural value of water should not only include the individual farmers' crops, but extend to the entire local rural economy and therefore the values considered in this chapter, underestimate the true value of water. Further research is needed to capture the true value of water in these areas.

Another shortcoming is agricultural return flows have been ignored. Return flows in agriculture are significant and thus the estimated additional yields that the NMBM can expect from water trading are most probably lower than the pronounced figures.

CONCLUSION

SUMMARY OF KEY FINDINGS, LIMITATIONS AND FURTHER RESEARCH

Nelson Mandela Bay's water supply

Nelson Mandela Bay Municipality faced severe water shortages in 2010 and projections estimated that future demand would outstrip future supply if no action was taken. NMBM receives 70% of its water supply from the Western system, a concentrated area which experiences similar rainfall and weather patterns and has a positive covariance across dam volumes. As a result, the DWA and the NMBM are investigating supply schemes options with the intention to maximise supply, minimise risk and minimise average costs.

The proposed schemes include building a desalination plant, utilising groundwater, expanding existing dams and tapping into more of the Orange River water. An incremental cost curve, using the mean average cost of water, was created to compare the relative costs and supply of each proposed scheme. The comparison took place over a 25 year timeframe and examines different methodologies. The cost curve assists the water manager in choosing the most secure cheap water at each step of the way.

The analysis indicates that although the proposed desalination plant and the Nooitgedagt Low-Level schemes are expensive (averaging R6.18/m^3 and R3.52m^3 respectively), the schemes minimise the risk by diversifying the NMBM's current bundle of water supply and supply the most water (432 million m^3 and 468 million m^3 respectively). The cheapest water included water trading in the Baviaanskloof and the reuse of agricultural return flows, averaging R1.4/m^3. However, these schemes do not minimise risk and augment water by an estimated 61 million m^3 only.

Upper Kromme Catchment Restoration

It was investigated whether catchment management was economically viable in the Upper Kromme Catchment and whether it should be considered a possible water augmentation scheme for the NMBM. The Kromme River, which supplies the Western system's dams, provides 40% of NMBM's total water demand. However, the catchment is heavily degraded due to the invasion of alien invasive plants, the destruction of palmiet wetlands and poor farming practises. The degradation of natural capital is hindering the supply of ecosystem services and in the long-term could threaten the supply of water to the NMBM.

Restoration interventions in the form of 'Working for Water' and 'Working for Wetlands' have been working in the Kromme since 1996 and 2000 respectively. Restoration of natural capital is an activity that "invests in and replenishes natural capital stocks thereby improving the flow of ecosystem goods and services, while enhancing the wellbeing of people" (Blignaut, 2009:696). This paper translated the activity of restoration into economic costs and gains and assessed if the investment was founded in economic rationality and efficiency.

'Working for Wetlands'

The economic viability of 'Working for Wetlands' could not be considered due to a lack of ecological data and water treatment data, and the failure to model wetlands using ACRU4. Although trends show that water quality decreases over time, the change in quality cannot be linked to upstream activities. It was however shown that water treatment costs increase over time, and that this is statistically related to the water quality variable, turbidity. Water costs are also strongly correlated to amount of water being treated.

Wetlands provide many services such as water purification, flood mitigation and baseflow regulation. It is suggested that further research investigate the changes in these ecosystem services and translate them into economic gains.

'Working for Water'

'Working for Water' is a labour intensive and costly operation. According to DWA records, an investment of around R22.7 million has been spent in the catchment since 2002. In contrast, the GIB records reveal that WfW has cost around R51.4 million. The missing data from before 2002 and the large divergence in sources' data is a cause for concern.

Data concerning the actual areas cleared is also divergent and as a result McConnachie's (dissertation in prep) analysis of treatment sites was used. Using historical trends and assuming a constant real cost per hectare cleared, it was projected that 138.34 condensed hectares are cleared by WfW each year. It costs around R6 568 to clear one condensed hectare in the Kromme.

Since WfW falls under the Extended Public Works Programme, it is not surprising that employment is a major cost in WfW. A total of 4 625 people have been employed by the Kromme WfW team since 2002 and for every condensed hectare cleared, at least R3 994 goes towards wages.

Agricultural Benefits

Improved land productivity, a private benefit expected from WfW, was quantified as the additional land freed up due to the removal of alien invasive plants. It was assumed that additional freed up land would be used in the same proportion as current land-uses.

A summary of relevant information pertaining to the different farm types in the Kromme are revealed in the table below. Dairy farms have the highest level of infestations and also have the second highest gross margins, meaning they can accrue the highest economic benefits as a result of WfW clearing. Fruit farms can accrue the highest economic returns from clearing a hectare of land, although they have low levels of alien infestation.

Summary of farm type details

Farm type	Area (ha)	Average gross margin per ha (R/ha)	Alien Plant Invasion (ha)
vegetable	2 430	272.88	347
sheep	2 967	574.17	273
'livestock'	2 615	622.26	392
'commonage'	1 171	612.91	118
cattle	1 407	670.35	228
honeybush	1 037	856.76	232
dairy	5 723	1 021.77	902
fruit	2 577	1 807.18	127

Using a weighted average, it is estimated that the economic benefits of clearing in the Upper Kromme Catchment are between R465 and R552. The low returns are indicative of the low productivity in the area and the fact that only 44% of the land is used for agricultural activities. Gross margin analysis is dependent on many external variable factors and thus the figures should be treated with caution.

It was found that there is no statistically significant relationship between income and alien infestations. The sample size was limiting and the number of farms who experience no income distorted the findings. It would have been preferable to conduct a retrospective correlation analysis, but due to data limitations this was not possible.

Hydrological benefits

Expected quantifiable hydrological benefits measured in this paper consisted of increased river yield. Due to setbacks in Rebelo's (dissertation in prep) modelling results, the additional yield expected from of restoration was assumed as 3 206m^3/ha/annum. This projects to an additional 443 640m^3 of water per annum, assuming a 98% assurance of supply.

The opportunity cost approach was used to measure the NMBM's willingness to pay and was taken from the incremental cost curve in Chapter 1. Using the 'next best scheme' approach, it was found that the NMBM is willing to pay R1.21/m^3.

Cost-benefit analysis

The cost-benefit analysis showed that restoration is an uneconomically viable investment in Upper Kromme Catchment over both a 25 year and 50 year timeframe.

Summary of costs and benefits of WfW

	Private benefits	Social benefits	Total Benefits	WfW Costs	Benefits-Costs	BCR
per hectare	R 351	R 2 461	R 2 812	R 6 568	-R 3 756	0.43
total	R 1 212 392	R 8 685 745	R 9 898 137	R 22 329 867	-R 12 431 730	0.44

Using the incremental cost curve as the medium for comparison, it was investigated whether the Kromme Catchment should be considered a possible augmentation scheme for the NMBM.

Additional water from the Upper Kromme costs R3.23/m^3 and thus falls within the cheaper proposed options. Nevertheless, it only provides a mere 7.31million m^3 and does not contribute significantly to the augmentation of NMBM's water supply sources and at the same time, does little to minimise the risk.

One should not discard the importance of restoration as a means of catchment management. The delivery of the existing yield from the river will be threatened if no action is taken and river flow losses are estimated at 0.115 million m^3/annum, costing the NMBM just under R20 000/annum. The sustainability of restoration rests upon land management that ameliorates the delivery of ecosystem services. Changing behaviour and land practices through economic incentives is crucial to ensure that the interests of both conservationists and landowners are aligned.

Opportunity Cost of Water

The possibility of water trading within the agricultural sectors and across urban (NMBM) and agricultural sectors as a means of achieving allocative efficiency is explored in the final chapter. The opportunity cost of water, foregone agricultural benefits, is used as a proxy for the economic value of water. The Gamtoos Valley, Lower Sundays River and Upper Kromme Catchment were the selected sites because competition for water exists.

The agricultural value of water was based on the sum of individual farmers' values and thus excludes the value experienced by the rural sector economy and agricultural supporting industries. This is a major limitation of this section and needs to be addressed in future research. Howe's methodology whereby a crude demand function for water is established was used where demand is based on the net returns of the individual crops and the cumulative water consumed at each net return. The method is useful in comparing the average values across crops and distinguishing which crops are high-value users of water. A shortcoming of the methodology is that it fails to provide the marginal value productivity of water and thus fails to subtract the non-water inputs from the total value product.

The agricultural average value of water in the Upper Kromme is R0.43/m^3 and the total value of water is R1.98million per annum. Agriculture uses 4.59million m^3 of water per annum and dedicates 690 hectares to irrigated agriculture. It is suggested that farmers in the Upper Kromme move towards higher value crops such as tomatoes.

The weighted agricultural value of water in the Gamtoos Valley is R0.89/m^3 and the total value of water is R48.92 million. Irrigated agriculture uses 55.15 million m^3 of water per annum. The Lower Sundays River experiences the highest average value of water at R1.89/m^3. Irrigated agriculture uses

106.2 million m^3 of water per annum and the total value of water in the Lower Sundays is R200.4million per annum.

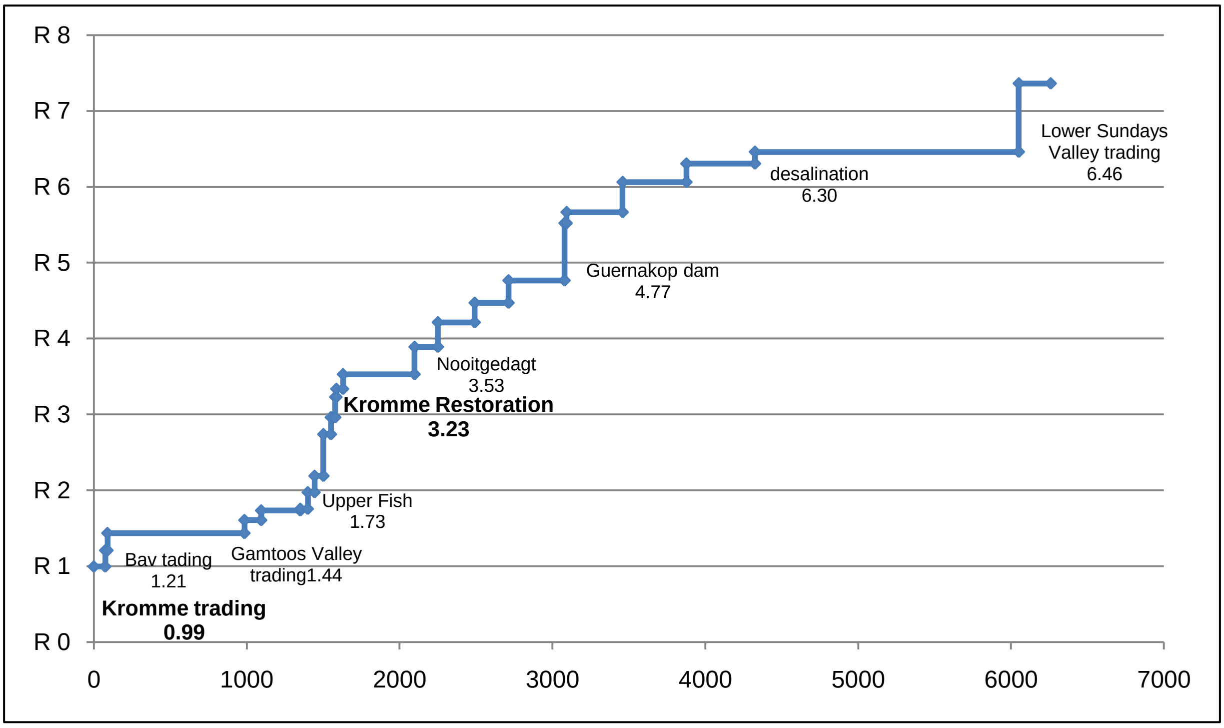
The agricultural value of water was compared to the urban NMBM value of water. In order to compare like to like, the agricultural values were adjusted to a 25 year timeframe and yields and values were discounted at 4% interest rate. The opportunity cost assumes that agriculture adopts an efficient allocation of water and moves towards crops which are high-value users of water.

Location	Total Yield (million m^3)	NMBM Opportunity Cost (R/m^3)	Agricultural Opportunity Cost (R/m^3)
Upper Kromme Catchment	74.58	1.61	0.99
Gamtoos Valley	896.00	3.53	1.44
Lower Sundays River Valley	1 725.79	4.47	6.46

The economic value of water in the NMBM is greater than the agricultural values of water in both the Upper Kromme Catchment and Gamtoos Valley. It is suggested that water is transferred away from low-yielding agricultural uses towards high end urban uses to achieve Pareto efficiency. On the other hand, water should be transferred away from NMBM towards agriculture in the Lower Sundays River Valley.

Assuming that the cost of transferring water rights is based on the opportunity cost of water, as calculated in this chapter, water trading is considered as a possible scheme for augmenting water in the NMBM. Water trading in the Upper Kromme Catchment proves to be the cheapest water according to the incremental cost curve below. It needs to be reiterated that the cost of water trading in this paper merely looks at the opportunity cost of water and does not incorporate the total cost of such a scheme. Further research is needed as this paper only sheds light as to the direction of possible water transfers.

Incremental Cost Curve using Levelised Costs



Further Research

Restoration in the Upper Kromme Catchment is not economically feasible and although action needs to be taken to restore the catchment, it is an expensive scheme for the NMBM to invest in. A major problem is that when only the annual costs are examined, it is the third most expensive water and yet only contributes 0.44 million m^3/annum. Private landowners' incentives need to be aligned with ecologists' in order to protect the catchment and ensure the ongoing sustainability of water yield. The farming activities that take place in the catchment are small; however it is often the location of the activities which cause damages to the river flow. Seeing that the agricultural value of water is low in the catchment, it is suggested that a form of water trading is considered. The graph shows that while restoration in the Upper Kromme costs R3.23/m^3, the opportunity cost of water is R0.99/m^3. If landowners are willing, water rights can be traded, thereby protecting the catchment and ensuring the delivery of water flow to the NMBM. Further research is needed to explore this possibility as a way to align incentives and safeguard the catchment.

It is suggested that municipalities move towards a more holistic approach in tackling water shortages. The number of dams that can be built is finite and large engineering schemes are costly. Municipalities need to be investing in their current resources to ensure that they are being fully utilised. Although this paper reveals that 'WfW' is not economically viable, conversations around integrated catchment management need to be brought to the table. Although this paper only focuses on one small catchment, the implications of the outcome have far reaching affects on other catchments in South Africa.

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APPENDIX A

Table 62: Scheme's Annual Running Costs and Yields

SCHEME	Annual Yield (Million m^3)	Annual Costs (R million)	Average Cost (R/m³)
Baviaanskloof	0.90	0.49	0.54
Bushy Park	2.01	1.32	0.66
Gamtoos River irrigation return flows	7.30	4.90	0.67
Coega fault	3.10	2.36	0.76
Jeffrey's Arch	3.03	2.35	0.77
Kouga replacement	34.00	27.16	0.80
Guernakop Dam	34.00	27.24	0.80
Van Stadens	4.09	3.69	0.90
Upper Fish River	15.75	19.40	1.23
Tsitsikamma River diversion	0.96	1.20	1.25
Upstream of meters	3.65	5.00	1.37
Sundays River	11.46	16.02	1.40
Current Water Cost	93.97	133.99	1.43
Industrial standards FWF WWTW	16.43	23.94	1.46
Treated effluent from Coega	18.25	29.60	1.62
Nooitgedagt Low-Level	32.85	62.76	1.91
Echodale: potable standards	16.43	31.95	1.94
Downstream of meters	3.65	7.70	2.11
Seawater	36.50	132.68	3.64
Coega desalination	29.20	153.80	5.27

Table 63: Comparison of schemes' average cost of water over a 50 year horizon

R/m³	SCHEMES - no discounting	SCHEMES -discounting	R/m³
R 0.44	Baviaanskloof	Baviaanskloof	R 1.03
R 0.56	Gamtoos River irrigation return flows	Gamtoos River irrigation return flows	R 1.34
R 0.65	Upstream (WC/WDM)	Upper Fish trading	R 1.60
R 0.66	Couga Fault Groundwater	Couga Fault Groundwater	R 1.61
R 0.69	Upper Fish trading	Upstream (WC/WDM)	R 1.63
R 0.73	Van Stadens Groundwater	Van Stadens Groundwater	R 1.80
R 0.93	Bushy Park Groundwater	Bushy Park Groundwater	R 2.27
R 1.01	Downstream (WC/WDM)	Downstream (WC/WDM)	R 2.54
R 1.04	Jeffrey's Arch Groundwater	Jeffrey's Arch Groundwater	R 2.55
R 1.23	Guernakop Dam	Nooitgedagt	R 3.04
R 1.23	Lower Sundays River	Lower Sundays River	R 3.11
R 1.24	Nooitgedagt	Guernakop Dam	R 3.33
R 1.35	Coega Desalination	Coega Desalination	R 3.39

R 1.41	Industrial Standards	Industrial Standards	R 3.53
R 1.45	Kouga replacement	Kouga replacement	R 3.91
R 1.73	Tsitsikamma River diversion	Tsitsikamma River diversion	R 4.24
R 2.10	Seawater Desalination	Seawater Desalination	R 5.42
R 2.19	Echodale	Echodale	R 5.60
R 2.38	Coega Desalination	Coega Desalination	R 5.82

Figure 47: Incremental Cost of Water by Scheme over 50 years - comparing methodologies

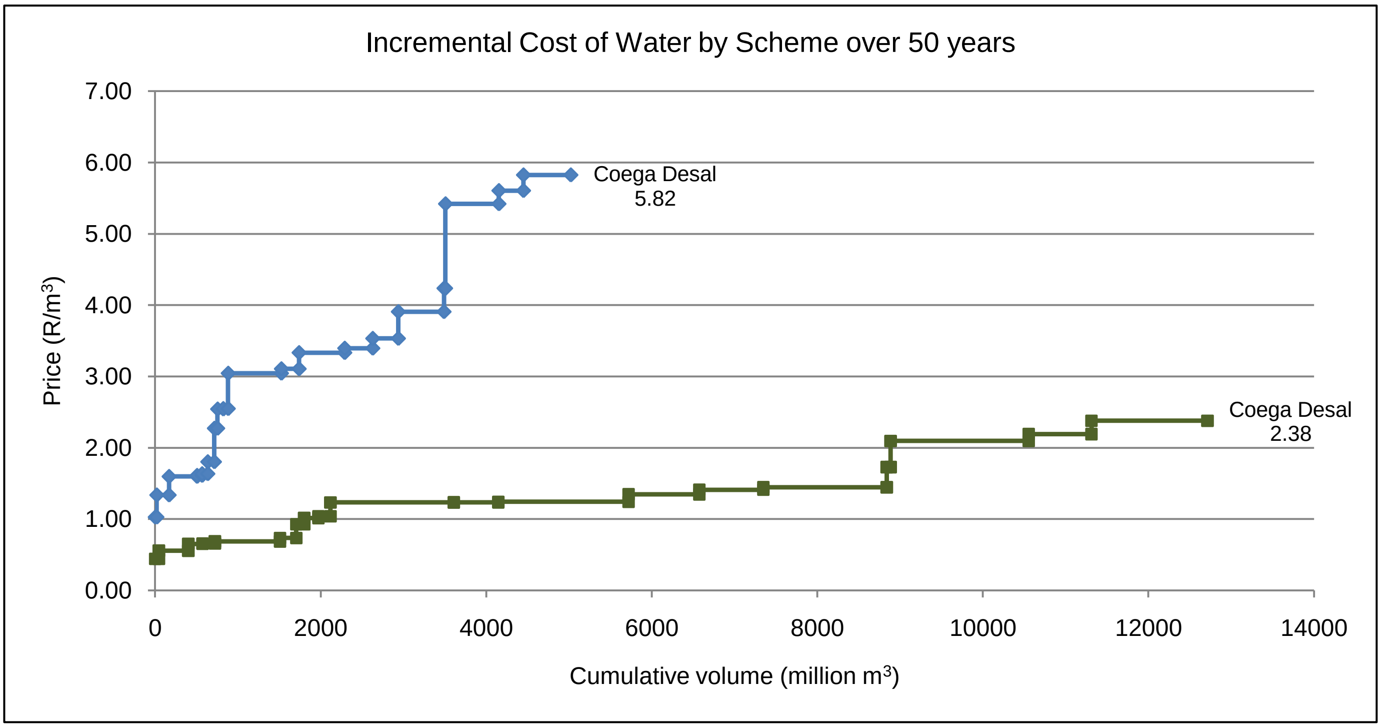

Table 64: Sequence of Proposed Interventions recommended in the *Algoa Reconciliation Strategy* with associated average per cubic metre costs

Year	Intervention	Price (R/m³)		
2010-2012	WC/WDM Upstream & Downstream	1.76	2.74	
2011	Nooitgedagt Low-Level Scheme; Swartkops Desalination & Bushy Parks Groundwater	3.53	6.18	2.96
2021	Coega Wastewater Treatment Works (WWTW)		4.21	
2025	Fishwater Flats WWTW Re-use Scheme		4.47	
2029-2031	Van Stadens, Coega & Jeffrey's Arch Groundwater schemes	2.19	1.97	3.34
2031	Orange River Project transfers & introduce the trading of irrigation allocations		1.73	
2031	Raising of Kouga Dam		5.66	
2032	Coega Industrial Development Zone (IDZ) Desalination scheme		6.06	
2035	Sundays River Return Flow Desalination Scheme		3.89	

Source: DWA (2010)

APPENDIX B

Table 65: Upper Kromme Catchment Farm details

	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5
classification	dairy	dairy	dairy	dairy	cattle
size (ha)	1 273.22	991.72	1 068.80	1 058.89	909.28
irrigated pastures (ha)	33	60	89.14	90	14.51
orchards	/	/	/	/	/
irrigation system	23ha permanent; 10ha dragline	2 centre pivots & 300m dragline	centre pivot & draglines	dragline, centre pivot	sprinklers, gravity fed
type of pastures	kikuyu/ryegrass	kikuyu	kikuyu	kikuyu	kikuyu
vegetable	/	/	/	/	/
registered water m³/a	548 239	270 000	280 800	561 600	54 750
dryland grazing (ha)	280	97.88	82.45	181.11	90.90
alien invasive plants (ha)	197.68	180.37	598.01	151.97	240.31

	Farm 6	Farm 7	Farm 8	Farm 9	Farm 10
classification	sheep	sheep	cattle	fruit	fruit
size (ha)	926.68	1 494.24	497.78	930.88	1 271.30
irrigated pastures (ha)	18.07	20.00	0		104.00
orchards	/	/	/	33.86	31.30
irrigation system	gravity led sprinklers	gravity permanent sprinklers	/	drip, micro jets	drip, pipelines
type of pastures	kikuyu	kikuyu	/	kikuyu	lucerne
vegetable	/	/	/		
registered water m³/a	63 000	260 000	/	115 000	115 000
dryland grazing (ha)	115.25	240.76	111.56	97.36	130.95

alien invasive plants (ha)	75.99	153.24	44.63	64.78	78.29

	Farm 11	**Farm 12**	**Farm 13**	**Farm 14**
classification	fruit	vegetable	vegetable	Honey bush
size (ha)	374.70	2 219.77	210.31	1 037.40
irrigated pastures (ha)	35.25	10.35		40
orchards	8	/	3.5	/
irrigation system	/	dragline	/	drip
type of pastures	kikuyu	kikuyu	/	Honey bush
vegetable	5	3	1	/
registered water m³/a	/	/	/	/
dryland grazing (ha)	137.14	28.24	29.66	0
alien invasive plants (ha)	15.52	355.38	78.05	289.38

Table 66: Summarized farm budget details

Farm 1	gross income per farm	total variable costs per farm	gross margin per farm	gross margin per ha (R/ha)
Dormer	R 292 000	R 127 000	R 165 000	133.04
Dairy	R 1 374 845	R 1 143 107	R 231 738	7022.36
total	R 1 666 845	R 1 270 107	R 396 738	311.60

Farm 2	gross income per farm	total variable costs per farm	gross margin per farm	gross margin per ha (R/ha)
Dairy	R 3 338 909	R 2 776 116	R 562 792	9379.87
Sheep	R 160 326	R 61 010	R 99 316	255.45
total	R 3 499 235	R 1 657 371	R 662 108	667.63

Farm 3	gross income per farm	total variable costs per farm	gross margin per farm	gross margin per ha (R/ha)
Dairy	R 5 892 191.71	R 4 899 029	R 993 163	11141.39
Sheep	R 235 774.25	R 89 721	R 146 053	149.09
total	R 6 127 966	R 2 442 504	R 3 685 461	1065.89

Farm 4	gross income per farm	total variable costs per farm	gross margin per farm	gross margin per ha (R/ha)
Dairy	R 11 784 383	R 9 798 058	R 1 986 325	22070.28
Cattle	R 300 141.1	R 124 254	R 175 887	181.54
total	R 12 084 525	R 9 922 312	R 2 162 213	2041.97

Farm 5	gross income per farm	total variable costs per farm	gross margin per farm	gross margin per ha (R/ha)
cattle	R 570 640	R 223 843	R 346 796	381.39
total	R 570 640	R 223 843	R 346 796	R 381

Farm 6	gross income per farm	total variable costs per farm	gross margin per farm	gross margin per ha (R/ha)
Dohne Merinos	R 775 200.00	R 324 515.54	R 450 684.46	486.34
Cattle	R 184 213.21	R 78 985.08	R 105 228.13	113.55
total	R 959 413	R 413 863	R 545 551	599.90

Farm 7	gross income per farm	total variable costs per farm	gross margin per farm	gross margin per ha (R/ha)
Dohne Merinos	R 1 162 800.00	R 431 020.19	R 731 779.81	489.74
Cattle	R 261 498.50	R 145 606.49	R 115 892.01	77.56
Boer goats	R 20 888.40	R 2 348.40	R 18 540.00	12.41
total	R 1 445 187	R 608 984	R 836 203	559.62

Farm 8	gross income per farm	total variable costs per farm	gross margin per farm	gross margin per ha (R/ha)
Dohne Merinos	R 228 000.00	R 94 710.93	R 133 289.07	267.77
Cattle	R 454 711.71	R 105 926.94	R 348 784.77	700.68
total	R 682 712	R 200 638	R 482 074	968.44

Farm 9	gross income per farm	total variable costs per farm	gross margin per farm	gross margin per ha (R/ha)
cattle	R 443 118.91	R 97 593.48	R 345 525.43	385.25
plums	R 1 492 781.52	R 1 008 243.17	R 484 538.35	48453.83
pears	R 373 195.38	R 252 060.79	R 121 134.59	5047.27
total	R 2 309 096		R 951 198	1021.82

Farm 10	gross income per farm	total variable costs per farm	gross margin per farm	gross margin per ha (R/ha)
cattle	R 454 711.71	R 98 247.48	R 356 464.23	287.47
apples	R 6 321 578.33	R 4 280 372.25	R 2 041 206.08	65204.27
total	R 6 776 290		R 2 397 670.31	1886.00

Farm 11	gross income per farm	total variable costs per farm	gross margin per farm	gross margin per ha (R/ha)
cattle	R 145 570.57	R 60 202.70	R 85 367.87	236.02
tomatoes	R 858 153.47	R 523 346.46	R 334 807.01	66961.40
apples	R 1 615 738.87	R 1 094 024.86	R 521 714.01	65214.25
total	R 2 619 463	R 1 677 574	R 941 888.89	2513.73

Farm 12	gross income per farm	total variable costs per farm	gross margin per farm	gross margin per ha (R/ha)
cattle	R 184 213.21	R 35 030.41	R 149 182.80	67.30
sheep	R 65 940.30	R 10 242.08	R 55 698.21	25.13
tomatoes	R 514 892.08	R 314 007.87	R 200 884.21	66961.40
total	R 765 046	R 325 604	R 405 765.22	182.80

Farm 13	gross income per farm	total variable costs per farm	gross margin per farm	gross margin per ha (R/ha)
Honey bush tea	2520000	R 1 631 200.00	R 888 800.00	22220.00
total	R 2 520 000.00	R 1 631 200.00	R 888 800.00	856.76

Farm 14	gross income per farm	total variable costs per farm	gross margin per farm	gross margin per ha (R/ha)
tomatoes	R 128 723.02	R 78 501.97	R 50 221.05	66961.40
sheep	R 43 800.00	R 19 050.00	R 24 750.00	205.81
total	R 172 523.02	R 97 551.97	R 74 971.05	362.96

Table 67: Total Value Product per Farm Type in the Upper Kromme

Farm Type	Area (hectares)	Total Value Product
vegetables	2 430	R 663 112
fruit	2 577	R 4 656 897
sheep	2 967	R 1 703 361
honeybush	1 037	R 888 800
dairy	5 723	R 5 847 703
cattle	1 407	R 943 222
total	**16 141**	**R 14 703 095**

Figures may not add up due to rounding up

Table 68 Total gross margins per land type with corresponding hectares devoted to each

Land type	Size (hectare)	Total gross margin (R)
vegetables	2 430	663 111.98
fruit	2 577	4 656 896.90
sheep	2 967	1 703 360.89
tea	1 037	888 800.28
dairy	5 723	5 847 702.53
cattle	1 407	943 222.27
livestock	2 615	1 627 276.64
nothing	16 376	0.00
commonage	1 171	717 810.21
total	**36 303**	**17 048 181.69**

Figures may not add up due to rounding up

Table 69: Data pertaining to Cost-Benefit Analysis

YEAR	**WFW**	**YIELD/M^3**		**SOCIAL COSTS**		**PRIVATE BENEFITS**		**SOCIAL BENEFITS**				
	cleared ha	ideal land use	current land use	CLEARING COSTS		AGRICULTURE BENEFITS		WATER BENEFITS: PRESENT LAND-USE				NATURAL STATE
		1449.53	**3206.88**	***GIB***	***DWA***	**a**	**b**	**A**	**B**	**C°**	**C^1**	**C^1**
1	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
2	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
3	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
4	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
5	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
6	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
7	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
8	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
9	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
10	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
11	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
12	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
13	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
14	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
15	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
16	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
17	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
18	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
19	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
20	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
21	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
22	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
23	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
24	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640
25	138.34	200529	443640	R 3 278 895	R 1 432 576	R 64 438	R 76 459	R 204 962	R 418 797	R 350 476	R 536 805	R 242 640

a: R465.79; b: R552.69; A: R0.46; B: R0.94; C°: R0.79; C^1: R1.21

Table 70: Present Value of Costs and Benefits of different assumptions

2009 PRICES	**interest rates**		
25 years	**4%**	**6%**	**8%**
Social Costs			
PV: WfW Restoration GIB	R 51 423 532.69	R 42 834 260.81	R 36 316 662.68
PV: WfW/ha	R 14 868.73	R 12 385.21	R 10 500.69
PV: WfW Restoration DWA	R 22 716 127.28	R 19 058 098.49	R 16 289 903.61
PV: WfW/ha	R 6 568.20	R 5 510.51	R 4 710.10
Private Benefits			
PV: Agricultural benefits **a**	R 1 021 782.64	R 857 242.70	R 732 727.92
PV: R/ha	R 295.44	R 247.87	R 211.86
PV: Agricultural benefits **b**	R 1 212 391.64	R 1 017 157.50	R 869 415.05
PV: R/ha	R 350.55	R 294.10	R 251.38
Social Benefits			
PV: Water Sales DWA raw tariff **A**	R 3 250 048.03	R 2 726 685.52	R 2 330 633.58
PV: R/ha	R 939.73	R 788.40	R 673.89
PV: Full supply cost price **B**	R 6 640 790.77	R 5 571 409.38	R 4 762 160.39
PV: R/ha	R 1 920.13	R 1 610.93	R 1 376.94
PV: economic value oppo cost **C°**	R 5 557 441.43	R 4 662 514.20	R 3 985 282.53
PV: R/ha	R 1 606.89	R 1 348.13	R 1 152.31
PV: economic value oppo cost **C^1**	R 8 512 030.55	R 7 141 319.22	R 6 104 040.33
PV: R/ha	R 2 461.19	R 2 064.86	R 1 764.94

A: DWA tariff; B: full cost supply; C° opportunity cost using average incremental costs; C^1: opportunity cost using levelised cost methodology

Table 71: Tighter assumptions

	Private benefits	**Social benefits**	**Total Benefits**	**WfW Costs**	**Benefits-Costs**	**BCR**
per ha	R 295	R 1 607	R 1 902	R 14 869	-R 12 966	0.13
total	R 1 021 783	R 5 557 441	R 6 579 224	R 51 423 533	-R 44 844 309	0.13

Table 72: Working for Wetlands Cost Category

Cost Category	**%**
Implementer Fees	5.8
Professional Fees	0.3
Training and Capacity Building	0.2
Administration	3.1
Contract wages	39.4
Salaries professional staff	1.5
Materials and Equipment	34.0
Transport: Project Management	1.3
Transport: Operational	6.4

Transport: Contractors	7.8
Subsistence and Travel	0.3

Source: SANBI database

Table 73: Total Cost of Working for Wetlands per annum (2009 Rand)

Year	Total Cost
2001	R 4 134 170.14
2002	R 2 854 273.60
2003	R 96 168.93
2004	R 1 348 961.79
2005	R 2 143 694.04
2006	R 2 584 755.14
2007	R 2 009 766.26
2008	R 2 541 772.02
2009	R 1 913 641.61
2010	R 2 809 710.04

Figure 48: Illustration of monthly trends of % Lime to Ml water 1987-2010

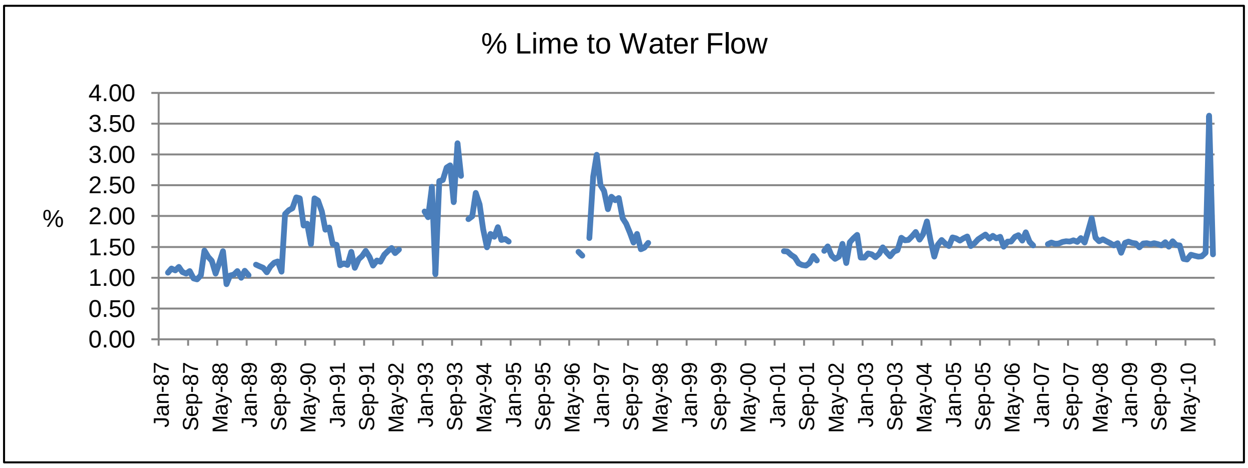

Figure 49: Illustration of monthly trends of % Chlorine to Ml water 1987-2010

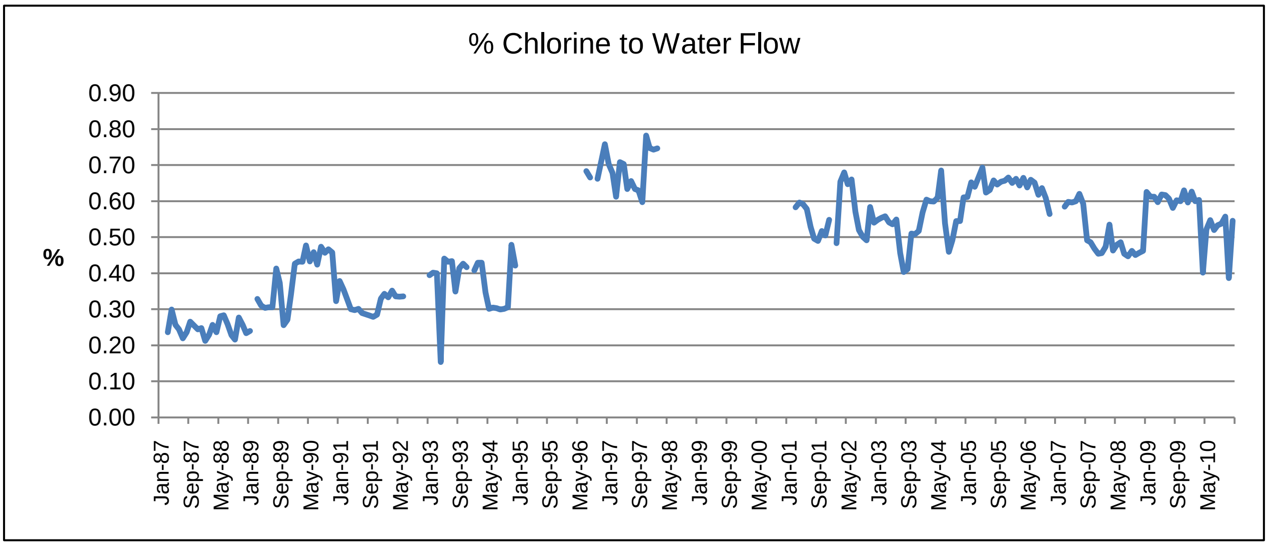

Figure 50: Illustration of monthly trends of % Floc Aid to Ml water 1987-1997

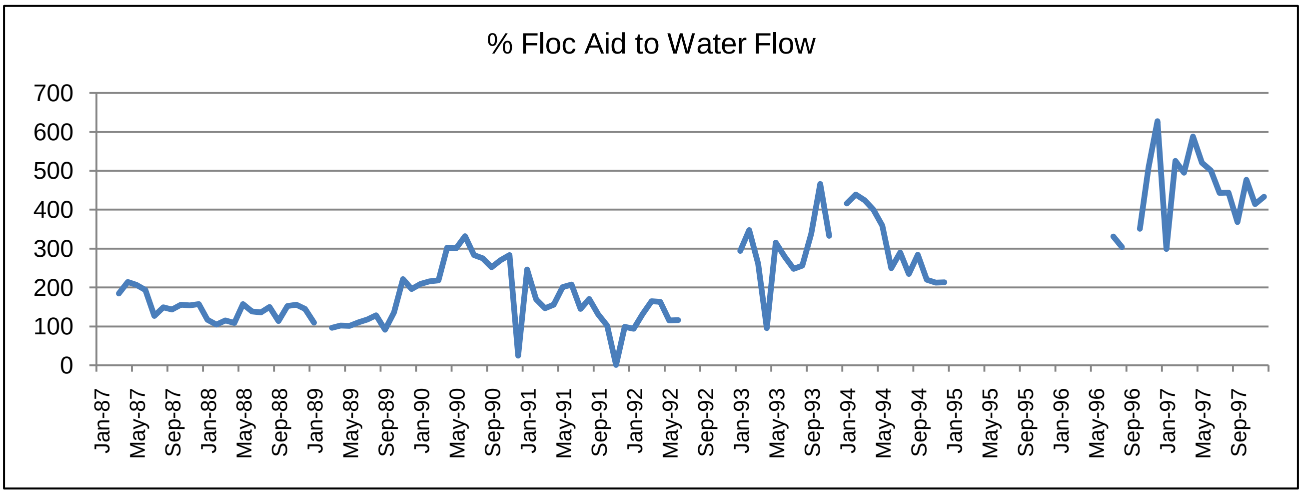

Figure 51: Illustration of monthly trends of % Alum to Ml water 1987-1997

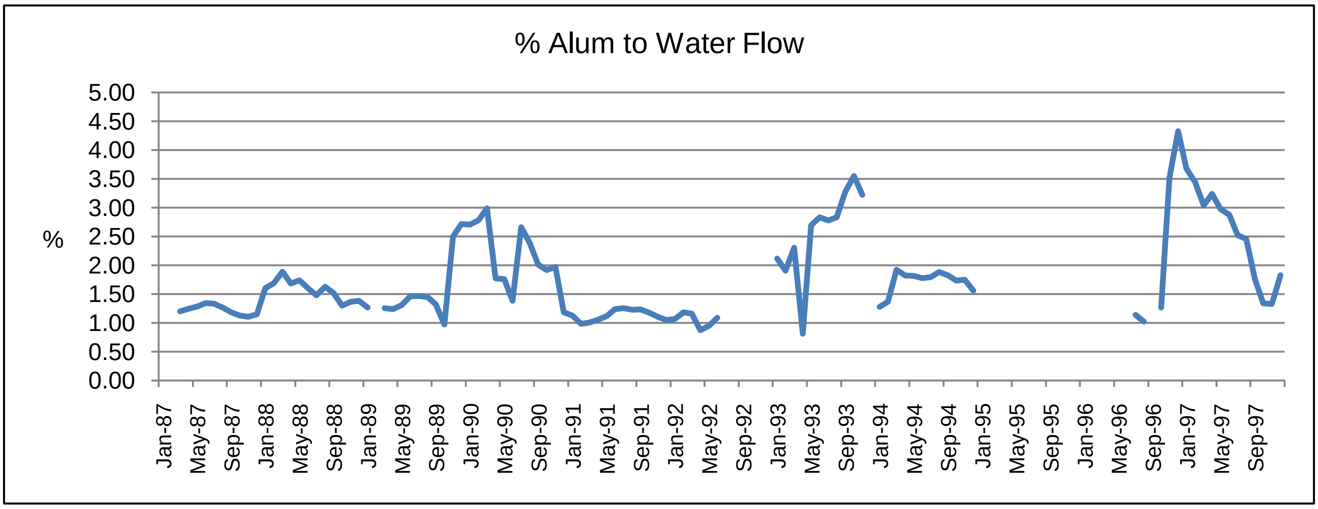

Figure 52: Illustration of monthly trends of % PAC to Ml water 2001-2010

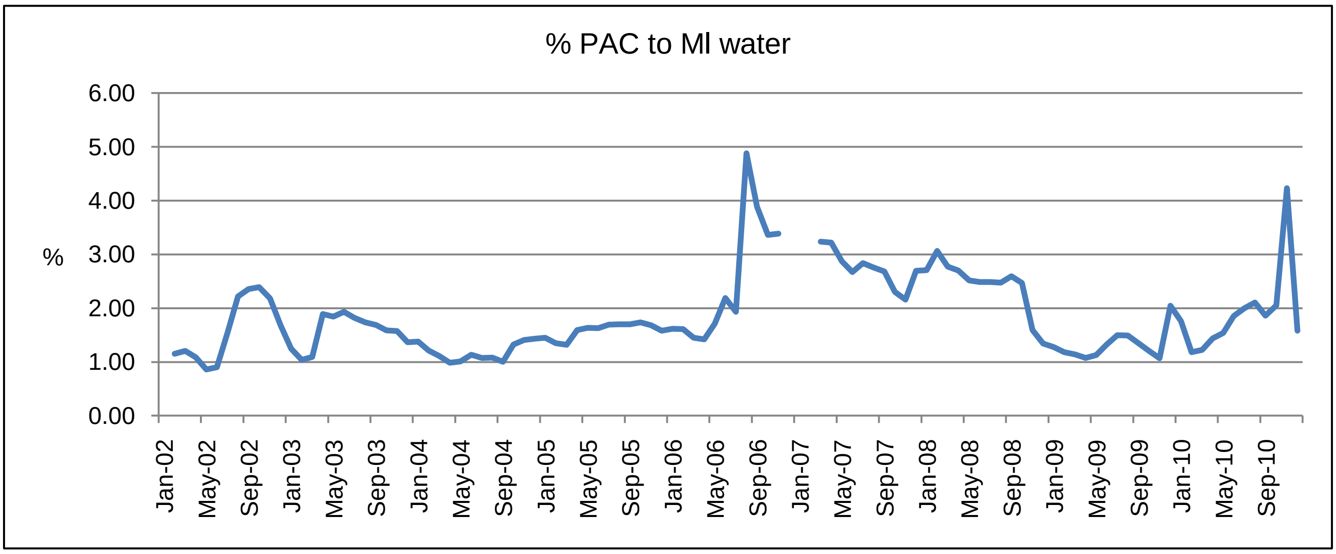

Table 74: Chemical cost data 1987-2010

YEAR	LIME	CHLORINE	ALUM	FLOC AID	PAC	TOTAL COST
1987	R 26 280.22	R 46 827.33	R 52 674.08	R 47 808.12		R 173 589.76
1988	R 15 290.63	R 23 095.47	R 42 717.29	R 20 310.15		R 101 413.54
1989	R 20 122.79	R 33 477.49	R 56 335.28	R 21 194.29		R 131 129.85
1990	R 56 327.32	R 103 737.93	R 142 865.16	R 67 012.54		R 369 942.96
1991	R 29 532.69	R 62 815.15	R 58 996.12	R 38 119.08		R 189 463.03
1992	R 6 828.12	R 16 731.58	R 12 525.08	R 6 302.08		R 42 386.86
1993	R 66 396.14	R 74 301.72	R 127 026.83	R 54 437.28		R 322 161.97
1994	R 59 940.56	R 69 138.86	R 86 602.21	R 59 023.10		R 274 704.73
1995	*Missing*	*Missing*	*Missing*	*Missing*		*Missing*
1996	R 59 345.95	R 70 691.46	R 85 054.22	R 60 339.82		R 275 431.45
1997	R 64 369.51	R 74 689.22	R 100 537.01	R 71 861.42		R 311 457.15
1998	R 80 089.75	R 128 170.19	R 58 465.66	R 118 555.75		R 385 281.34
1999	*Missing*	*Missing*	*Missing*	*Missing*		*Missing*
2000	*Missing*	*Missing*	*Missing*	*Missing*		*Missing*
2001	R 28 956.47	R 58 906.74				R 87 863.21
2002	R 46 415.55	R 95 781.18			R 190 672.48	R 332 869.21
2003	R 51 111.80	R 106 310.01			R 213 021.91	R 370 443.72
2004	R 51 991.43	R 98 621.62			R 134 732.57	R 285 345.61
2005	R 89 450.20	R 134 529.09			R 254 979.27	R 478 958.55
2006	R 81 564.49	R 127 156.20			R 415 271.13	R 623 991.82
2007	R 100 040.37	R 142 469.49			R 603 083.69	R 845 593.56
2008	R 56 000.38	R 100 782.91			R 611 593.26	R 768 376.54
2009	R 35 160.35	R 71 889.74			R 264 929.18	R 371 979.27
2010	R 25 713.47	R 41 072.13			R 120 071.38	R 186 856.99

Source 1: Kromme Interview

Date: ___________________
Farm Name: _______________________________________
Farmer Name: ______________________________________
Family: ____
Contact Details: ______________________________________

Farm Questions

1. How long have you been farming in the Kromme River Catchment?
2. How many hectares is your farm?
3. What proportions are cultivated arable or uncultivated arable or unused?
4. What do you farm? What are you producing?

Irrigation/water-use

1. Do you have any irrigation?
2. Do you know how much water do you use annually?
3. If yes, what type, what do you grow and how many hectares do you irrigate?
4. Where do you get this water? Boreholes/runoff/directly pumped from river?
5. How often do you irrigate?
6. Do you have any farm dams? How many and how big?
7. Is water for irrigation purposes a constraint on your choice of crops or yield/ha with current crops?
8. How much water do you estimate your livestock use per head per day?

Income

1. Is farming your main source of income/revenue?
2. What is your percentage gross income per farming enterprise?
3. Can you estimate what you turnover is per hectare?
4. If you had an additional hectare of arable land, but no extra water, how would this affect your operations?
5. If you had the water to irrigate the extra hectare of arable land, how would this affect your answer?

Costs

1. How many labourers work for you? How many are permanent/temporary?
2. What are your major capital costs/largest expenses?
3. What production technology do you employ?
4. What are the major problems you face as a farmer in this area? How have these changed over the years?

Working for Water/Wetlands

1. What do you think of WfW and their requirements from you?
2. Do you think there are any private benefits associated with WfW?
3. Do the wetlands provide you with any benefits? Have you noticed any affect on the river with and without wetlands/peatlands?
4. Who do you think should control the WfW process?
5. Are you prepared to allow aliens cleared on your land, if it will increase the water flow for your neighbors downstream?
6. Is it a feasible way to relax your own water constraint?
7. If you were managing PE's water board, would you try and get more water out of the Kromme? Or would you look elsewhere?

Appendix C

Table 75: Crop enterprise budgets

	POTATOES	CABBAGES	BROCCOLI	CAULIFLOWER	CARROTS	KIKUYU	MAIZE
INCOME AFTER MARKETING COSTS	**R 84 088**	**R 43 627.39**	**R 37 525.06**	**R 40 315.66**	**R 40 770.00**	**R 15 727.24**	**R 17 291.52**
Allocated pre-harvesting costs							
Seed	R 25 194.14	R 7 444.85	R 7 444.85	R 7 444.85	R 1 318.47	R 510.97	R 897.89
Casual planting labour	R 97.75	R 1 666.06	R 1 666.06	R 1 666.06	R 1 222.83	R 782.61	R 1 222.83
Fertilizer	R 6 524.39	R 5 300.57	R 3 996.19	R 3 996.19	R 6 524.39	R 5 727.00	R 5 499.85
Weed control	R 431.39	R 423.24	R 423.24	R 423.24	R 259.40	R 71.77	R 770.96
Pest control	R 9 399.92	R 3 019.14	R 3 019.14	R 3 019.14	R 150.52	R 723.07	R 770.96
Leaf nutrient	R 6 698.70	R 904.22	R 904.22	R 904.22	R 3 286.90	R 723.07	R 0.00
Irrigation: electricity ,maintenance	R 5 204.69	R 5 204.69	R 5 204.69	R 5 204.69	R 5 204.69	R 194.26	R 174.87
Irrigation: water	R 795.32	R 465.43	R 513.91	R 513.91	R 524.51	R 345.00	R 942.00
Machinery costs	R 1 291.65	R 1 961.69	R 1 961.69	R 1 961.69	R 2 114.70	R 1 192.44	R 828.11
Implement costs	R 800.57	R 533.71	R 533.71	R 533.71	R 175.39	R 328.63	R 103.17
sub-total	R 56 438.52	R 26 923.59	R 25 667.69	R 25 667.69	R 20 606.40	R 10 598.82	R 11 210.62
Allocated harvesting costs							
Packing material	R 8 010.86	R 397.70	R 397.70	R 397.70	R 3 380.47	R 0.00	R 545.42
Casual labour	R 3 714.78	R 3 804.35	R 3 804.35	R 3 804.35	R 3 500.00	R 0.00	R 234.78
Transport	R 3 109.32	R 6 570.28	R 5 316.99	R 5 316.99	R 5 316.99	R 0.00	R 0.00
Machinery & Implement costs	R 878.68	R 703.34	R 703.34	R 703.34	R 211.21	R 0.00	R 652.67
sub-total	R 15 713.63	R 11 475.67	R 10 222.38	R 10 222.38	R 12 408.67	R 0.00	R 1 432.87
Total allocated costs	**R 72 152.15**	**R 38 399.26**	**R 35 890.07**	**R 35 890.07**	**R 33 015.07**	**R 10 598.82**	**R 12 643.49**
Gross Margin above variable costs	**R 11 935.72**	**R 5 228.13**	**R 1 635.00**	**R 4 425.60**	**R 7 754.93**	**R 5 128.42**	**R 4 648.03**

	WHEAT	LUCERNE	SWEET POTATO	SWEETCORN	SORGHUM	TOMATOES
INCOME AFTER MARKETING COSTS	**R 9 378.00**	**R 13 949.90**	**R 36 271.82**	**R 41 002.06**	**R 8 165.33**	**R 85 815.35**
Allocated pre-harvesting costs						
Seed	R 500.61	R 505.86	R 5 636.06	R 439.70	R 260.60	R 1 521.55
Casual planting labour	R 286.54	R 61.10	R 462.79	R 5 148.02	R 74.44	R 14 591.17
Fertilizer	R 4 302.83	R 3 339.47	R 3 476.53	R 2 479.05	R 848.15	R 6 069.55
Weed control	R 358.89	R 179.19	R 597.31	R 301.48	R 792.38	R 5 686.88
Pest control	R 358.89	R 179.19	R 80.89	R 442.47	R 792.38	R 5 686.88
Leaf nutrient	R 39.64	R 179.19	R 295.81	R 0.00	R 0.00	R 971.95
Irrigation: electricity ,maintenance	R 143.64	R 375.51	R 5 782.99	R 5 782.99	R 148.57	R 5 632.68
Irrigation: water	R 698.35	R 2 087.71	R 509.70	R 509.70	R 998.22	R 578.94
Machinery costs	R 772.18	R 706.32	R 3 043.87	R 490.54	R 819.74	R 1 038.71
Implement costs	R 98.07	R 175.39	R 702.90	R 163.91	R 91.03	R 800.57
sub-total	R 7 559.63	R 7 788.93	R 20 588.86	R 15 757.86	R 4 825.51	R 42 578.87
Allocated harvesting costs						
Packing material	R 0.00	R 41.09	R 1 960.10	R 11 493.59	R 0.00	R 9 601.66
Casual labour	R 22.82	R 77.08	R 4 139.13	R 1 760.63	R 2.38	R 24 157.82
Transport	R 0.00	R 0.00	R 1 554.66	R 3 109.32	R 0.00	R 3 109.32
Machinery & Implement costs	R 229.62	R 523.80	R 888.27	R 888.27	R 641.69	R 711.16
sub-total	R 229.62	R 641.97	R 8 542.16	R 17 251.80	R 644.07	R 37 579.96
Total allocated costs	**R 7 789.25**	**R 8 430.91**	**R 29 131.02**	**R 33 009.66**	**R 5 469.58**	**R 80 158.83**
Gross Margin above variable costs	**R 1 588.75**	**R 5 518.99**	**R 7 140.80**	**R 7 992.39**	**R 2 695.75**	**R 5 656.51**

	Navels	Valencias	Lemons	Clementines
Year 1				
planting cost & replacement cost	-R 60 608.21	-R 60 608.21	-R 60 608.21	-R 60 608.21
Year 2				
maintenance	-R 12 773.83	-R 12 773.83	-R 12 773.83	-R 12 773.83
Year 3				
maintenance	-R 12 773.83	-R 12 773.83	-R 12 773.83	-R 12 773.83
Year 4				
25% production	R 14 500.00	R 15 187.50	R 38 937.50	R 11 542.99
pre harvesting & harvesting costs	-R 28 429.06	-R 28 633.67	-R 35 271.01	-R 31 492.04
Year 5				
38% production	R 22 040.00	R 21 262.50	R 59 185.00	R 17 545.34
pre harvesting & harvesting costs	-R 28 429.06	-R 28 633.67	-R 35 271.01	-R 31 492.04
Year 6				
63% production	R 36 540.00	R 38 272.50	R 98 122.50	R 29 088.33
pre harvesting & harvesting costs	-R 28 429.06	-R 28 633.67	-R 35 271.01	-R 31 492.04
Year 7				
100% production	R 58 000.00	R 60 750.00	R 155 750.00	R 60 750.00
pre harvesting & harvesting costs	-R 28 429.06	-R 28 633.67	-R 35 271.01	-R 31 492.04