ECONOMETRIC MODEL TO PREDICT THE EFFECT THAT VARIOUS WATER RESOURCE MANAGEMENT SCENARIOS WOULD HAVE ON SOUTH AFRICA'S ECONOMIC DEVELOPMENT

Report to the

Water Research Commission

by

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PLEASE NOTE:

By its very nature the model reported on in this project deals with the interaction between economic sectors at a macro level. This involves generalisations at the macro level as part of its input and structure. The model and its projections are thus not designed for, or intended to predict the outcome of interventions at the micro level. Fine distinction of the interaction between crop water use at the enterprise, farm and regional level as well as distinction between irrigation and rainfed agriculture is (for example) not possible.

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EXECUTIVE SUMMARY

1. Background to the Study

With water being a limited resource in South Africa, it is widely accepted that its availability will constrain the economic development of the country in the longer term future. In fact, water resources are already overcommitted in some areas of the country, with the result that economic expansion is already possibly being inhibited, particularly with regard to the rate of growth in the output and income of "high value" water uses.

In the South African context, water is first and foremost treated as a common (social) good. Water is recognised as being essential for sustaining life, and is a commodity to which people and the aquatic environment have a legally protected right. However, water is also recognised as an economic good, the use of which has a major impact on the creation of wealth and the well-being of people. Almost without exception, there is an increasing interest in assessing the economic value of water, and in using water as a catalyst for the generation of wealth and prosperity.

In many countries, the implementation of new water policies based on the overall management of the existing resources is being hampered by the lack of knowledge about the dynamic relationship that exists between water, the economy, and the broader society. Specifically, from an economic perspective, the tools necessary for the estimation and evaluation of the impact of water policies (such as changes to water tariffs) on production sectors, and/or the impact of sectoral economic policies (such as irrigation policies) on water resources have not yet been fully developed. Furthermore, using the presently available planning tools, it is very difficult to anticipate what unforeseen negative effects well intended water management and allocation decisions may have on socioeconomic development and the long-term economic prosperity of a country.

2. The Need for Research

The specific objective of this project is the development of an integrated macroeconometric model that considers the role of water as an input to the South African economy, and that can be used to predict and evaluate the likely effect of water management and policy interventions. This objective is directly linked to the WRC's research requirement for the development of an 'Appropriate and Scientifically Based Analytical Tool' that can be used for this particular purpose in the South African context.

It is against this background that this project examines the available macroeconometric models that, inter alia, establish the functional relationships that exist between the various production sectors and the water sector.

2.1 Overall Research Goals

Every country has its own unique economic, social and physical characteristics that require unique solutions to its developmental problems/goals. Therefore, the development of an appropriate econometric model capable of performing the required forecasting and impact analyses of the various development scenarios contained in the ToR for this study[1] must take these unique characteristics into consideration.

Models of this kind do exist in South Africa, however, these were tailored for use in other policy areas (i.e. housing, international trade, transport etc.). Therefore, in line with the ToR, an in-depth study has been undertaken to establish the extent to which use can be made of existing model infrastructures developed locally and internationally to derive a model suitable for this project's objectives.

2.2 Research Approach

The study was divided into ten so-called Deliverables, with the last deliverable being this Final Report. Together, the ten deliverables explain how a model was selected, and provides a demonstration of its abilities, and explore the way forward.

Details of this study can be found in the individual deliverable reports (see accompanying CD-ROM). The overall report is structured as follows:

- Deliverables 1-4: Literature Review and Model Selection.
- Deliverables 1, 5 and 6: Integrating a Water Sector Model into the Overall Modelling System.

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[1] See Annexure 1.

- Deliverables 7-9: Demonstrating the Analytical Capabilities of the Integrated Modelling System in the South African Context.
- Deliverable 10: Final Report.

3. Research Outcomes

3.1 Literature Survey and Choice of Model

A major part of the study was devoted to an extensive literature survey to, on the one hand establish the extent of international experience in this regard, and on the other hand, determine the strengths and weaknesses of various model designs in practice.

Based on the results of the literature survey, an evaluation was made of a range of empirical economic models' capabilities in measuring the impacts of policy changes, and in forecasting future economic developments. In essence, five categories of model were analysed:

- Input-Output Models (I-O)
- Computable General Equilibrium Models (CGE)
- Standard Macroeconometric Models (SM)
- Macroeconometric Models linked to Input-Output Tables (Macro I-O)
- Inter-Industry Macro Models (IMs)

The criteria used for evaluating these models ranged from the origin of their underlying economic theory, to their ability to analyse actual economic developments. The figure below provides a summary of the evaluation criteria used in this exercise.

Figure I: Evaluating Model Efficiencies

Model	***CGE***	***Macro-I-O***	***IM***	***I-O***	***Macroeconometric (SM)***
Neo-classical general equilibrium theory	8	4	5	4	5
Standard Micro Theory					
Prices	8	3	6	3	5
Price elasticities					
Technology (change)	8	3	6	3	5
	5	4	5	3	3
Maintenance	7	5	5	7	6
Functional forms influence	6	4	4	4	4
Quality of parameter values	5	4	7	4	4
Observed economy	4	6	8	4	7
Data requirements	6	5	5	6	7
Ease of use	6	7	6	7	6
Track record (econometric testing)	4	7	8	4	6
Policy relevance/analyses	5	5	8	5	7
Equilibrium determinants	6	4	6	4	6
Dynamism	4	4	8	4	6
Presenting real world (incl. Sector specific)	5	6	8	4	7
International Linkability	5	3	8	4	6
Accommodating Imperfections	5	5	8	4	5
TOTAL	97	79	111	74	89
Efficiency Percentage	57%	46%	65%	44%	52%

Obviously it was no easy task to select the “right” model configuration from such a vast array of model types. However, by using weights allocated to each of the 17 attributes, it was possible for the project team to arrive at a “winner”.

As can be seen from the table, the Inter-Industry Macro model (IM) obtained the highest “efficiency percentage”, mainly because of its ability to track reality and imperfections in the economy better than for example CGE models, which, on the other hand, are strong in the field of theory.

3.1.1 Selecting the INFORUM sourced IM for the study

Before a final model choice was made for South Africa, the project team took cognisance of the unique South African situation regarding water management and water allocation that will require a unique analytical framework that would allow for the examination of economy-wide effects (including regional) of policy changes, such as water policy reforms.

Having regard for the goals of the study, and given the evaluation outcome, it was ultimately recommended that the Inter-Industry Macro (IM) Model genre should be used as point of departure for the proposed modelling framework whereby the water sector will be targeted in detail.

More specifically, the recommendation was made that the IM approach pioneered by the University of Maryland[2], known as the INFORUM model, be used. The fact that South Africa has been participating in the international endeavours to further develop and refine these models over the past number of years counted in favour of this particular model.

After setting up the model in South Africa, and further calibrating it to fit the South African requirements such as data availability, it was dubbed "SAFRIM", i.e. South African Inter-Industry Macro Model.

3.2 Extending SAFRIM to include a more detailed Water Sector

In line with the Australian approach (i.e. to link a sectorally based macroeconometric model with a regionally based water demand/supply structure), SAFRIM was linked to a so-called Water Satellite Model (WSM). The diagram below illustrates the linking of these two models.

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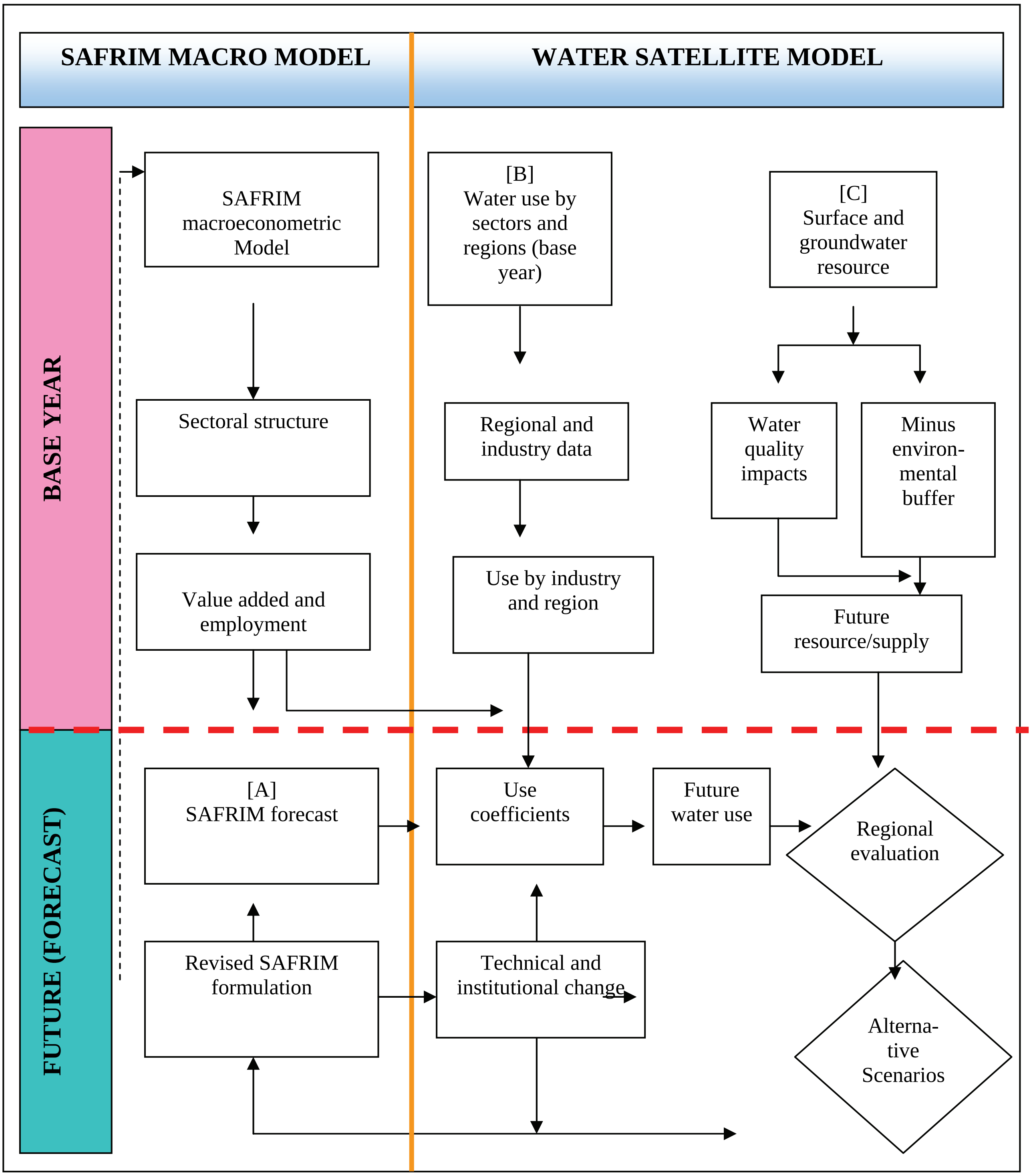
[2] The INFORUM approach to Interindustry Modelling – Clopper Almon, Economic System Research. Vol. 3, No. 1, 1991.

Diagram I: IM Model



As can be seen from the above diagram, a large measure of synergy exists between the two model configurations. SAFRIM, on the left hand side, provides the sectoral value added "drivers" for the water demand functions of the WSM that is reflected on the right-hand side. These water demand functions were 'borrowed' from the so-called Water Allocation

Model that was originally used for a study of the water situation in the Vaal Catchment Area.

Using the models in forecasting mode, one can see from the bottom right-hand corner of the diagram that it will be possible to arrive at future water demand/supply "balances" coupled with various scenarios for economic growth rates, both nationally and regionally.

Starting off with the 46-sector base of SAFRIM, and extending it to the 65 sectors incorporated in the WSM, it is possible to study water demand characteristics on a much more disaggregated level than was previously possible.

Using the Water Allocation Model for the Vaal Catchment Area as a proxy for the Vaal Water Management Area (VWMA) and for the economy as a whole, it was possible to produce first round forecasts of water demand in this important area of the country for the 2004 to 2020 period, which proved to be reasonably accurate for policy planning purposes.

3.3 Demonstrating the Models' Analytical Capabilities

In the closing part of the study, the SAFRIM/WSM modelling system was used specifically to address issues raised in the ToR, such as quantifying the importance of water in the economy, and establishing how the model can be "regionalised". The model was used to calculate so-called water multipliers, and was used to answer a number of "what if?" questions associated with a series of alternative water management scenarios, i.e. , what if the major industrial water users in the economy are "rationed" to some extent with their water supply?

3.3.1 The importance of Water in the Economy

The model allowed the calculation of so-called impact multipliers that are a good approximation of the economic value of water in the South African economy. The results of this exercise are summarised in the table below. Even though these figures are highly aggregated, they do show that agriculture uses water less "efficiently" than other sectors. However, this analysis does not take into consideration issues such as the value of food security and regional imbalances in the prevalence of poverty, where agriculture still plays an important role in combating poverty.

Table I: Weighted Average Multipliers (Rand per m^3 water)

No	***SAFRIM Sectoral Classification***	***GDP***	***Number of employees***	***Investment***	***Household Income***
		Weighted Average	***Weighted Average***	***Weighted Average***	***Weighted Average***
1	Agriculture	14	204	2	11
2	Coal Mining	110	883	20	73
	Gold & Uranium Ore Mining	90	942	16	57
	Other Mining	96	761	19	62
3	Secondary Sector	84	758	15	66
4	Tertiary Sector	106	951	18	84
	Total economy	95	847	17	74

Another way of illustrating the important role that water plays in the economy is to use the model for analysing different scenario settings. This approach is also an important method used worldwide to demonstrate the outcome of implementing different policy interventions, in this case, involving the role of water in the South African economy.

The table below provides a summary of the outcome of analysing a number of scenarios.

Table II: Regional Economic Impact: Average p.a., 2005-2020 (Rand Million, Constant 2000 Prices)

	Standard Scenario	***Scenario 1 High Growth***	***Scenario 2 Water Tariff Increase***	***Scenario 3 Constraint of Location***
Economic Levels				
Water (Million m^3)	3 289	3 718	3 132	3 186
GDP (Rand Million)	408 255	518 804	408 255	396 776
Employment (Number)	3 728 023	4 735 363	3 728 023	3 554 059

Note: The price mechanism does not affect GDP and Employment at this stage hence the impact is the same on both GDP and Employment.

Moving from a standard/baseline scenario (±3% GDP growth p.a.), to a high growth scenario, i.e. (±6% GDP growth p.a.), it is gratifying to see that, where average annual GDP measured in absolute terms rises by 27%[3], water consumption only rises by 13%[4].

The WSM showed its ability to simulate policy changes such as higher overall GDP growth, and water tariff increases. The scenario exercise also indicates an excess demand situation that tends to worsen "exponentially" towards the end of the forecasting period in the high growth scenario, and that brings forward the critical point where demand exceeds supply by a number of years.

Lastly, the analytical capabilities of the SAFRIM/WSM modelling system were employed to demonstrate the role of water in a regional context, using the VWMA. In this exercise, it was possible to calculate future water demand for 65 sectors in the VWMA in 2020, using the officially stated water supply/ demand situation in the base year (2000) as a departure point.

The water demand situation for the VWMA in 2020 is shown in the table below. As was the case with the national position, the high growth scenario implies a significant rise in water demand as compared to the baseline scenario. Restricting economic growth in this area does bring water demand down markedly but, naturally, the sustainable GDP level is also decreased.

However, it should be noted that macroeconomic models are not equipped to realistically simulate the outcome of such drastic interventions. As such, the results of this exercise provide an indication of the economic aggregates that could be influenced under certain strict assumptions.

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[3] $\left\{\left(\frac{518804}{408255}\right)-1\right\}x100$

[4] $\left\{\left(\frac{3718}{3289}\right)-1\right\}x100$

Table III: Historic Levels of Economic Aggregates (2004) and Forecasted (2020), VWMA (Rand Million, Constant 2000 Prices)

	2004	*Baseline Scenario 2020*	*Scenario 1 High Growth 2020*	*Scenario 2 Water Tariff Increase 2020*	*Scenario 3 Constraint of Location 2020*
Economic Aggregates					
Water (Million m^3)	2 920	3 744	4 742	3 559	3 569
GDP (Rand Million)	328 568	483 218	737 650	483 218	461 765
Employment (Number)	3 039 371	4 387 214	6 697 240	4 387 214	4 060 423

4. Conclusions/Recommendations

4.1 Main Conclusions

This study has been able to construct a macroeconometric model that is suitable for obtaining the main goals set out in the ToR, viz.:

- The ability to demonstrate the importance of water in the South African economy.
- The ability to provide the means of quantifying the impact on the South African economy of different water policy strategies and demand/supply scenarios.
- The ability to forecast the demand for water on both a national and a regional level in line with the overall expected socio-economic developments.

The project team has been able to operationalise a so-called IM modelling approach that is linked in an inter-active way to a Water Satellite Model that incorporates a regional component. This SAFRIM/WSM model now makes it possible to make water demand and supply forecasts on a regional level that coincide with the officially demarcated Water Management Areas

The SAFRIM/WSM framework devised and made operational through this project is not proposed as being a perfect solution, however, it does go a long way towards achieving the initial goals set out in the TOR of this study.

The international literature survey has demonstrated that the best model for any use is that model which has the characteristics that are strongest in the areas that are most important to the analysis being undertaken. The authors of this study believe that the SAFRIM/WSM modelling system easily fulfils the minimum requirements as prescribed by the South African situation at the moment. In the process it has demonstrated its capability to assist the agents responsible for implementing the NWRS (1998) in achieving the following objectives:

- The introduction of effective water conservation and demand management policies (WC/WDM).
- Formulating and over-arching water pricing strategy in line with marginal cost/benefit ratios.
- The possibility of re-allocating water between lower and higher economic uses.
- Closely monitoring the impact of macro economic policies in the areas of taxation, monetary policy, international trade, redistribution of income, etc on sectoral and overall water demand.

The process of model building forces analysts to come to grips with the complexities of the subject at hand, in this case, the role of water in the South African economy. By using the macroeconometric model developed in this study quantitative measurements of the importance of water in the South African economy has been measured through the use of sectoral multipliers and with scenario settings.

Recommendations

As is the case with any macroeconometric model of this size and complexity, a number of actions are required to keep it operational and to maintain the quality of its outputs. The project team has made a number of recommendations in this regard. These can be grouped into two major categories viz.:

- Technically “servicing” the model; including updating of the extensive data base as well as ensuring that the model’s technical coefficients remain statistically/econometrically sound in order to ensure that the quality of its outputs remain up to standard.
- Further research; the study highlights the need for more up-to-date research in the field of price elasticities of demand for water. More research in this area of interest is recommended, and it is believed that the WRC can once again play a crucial role here.

Lastly, knowing that water availability and demand has a pertinent regional basis, more research is needed to further extend the regional applicability of the model beyond the VWMA that was investigated in this study. This would mean that other WMAs should be further investigated with the aim of bringing their data bases at to the same level as that of the VWMA which will facilitate their eventual incorporation into the SAFRIM/WSM model.

ACKNOWLEDGEMENTS

The research in this report emanated from a project initiated by Water Research Commission and entitled:

"Econometric model to predict the effect that various water resource management scenarios would have on South Africa's economic development."

The Reference Group responsible for this project consisted of the following persons:

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Due to the nature of the project interviews were conducted with many individuals and organisations. The research team would like to thank them for their willingness to discuss issues and provide answers to the many issues that the team confronted them with.

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ACRONYMS

AGE	Applied General Equilibrium models
ASGISA	Accelerated Shared Growth Initiative of South Africa
AATE/IE	Australian Academy of Technological Sciences and Engineering/ Institution of Engineers
CE	Conningarth Economists
CEEPA	Centre for Environmental Economics and Policy in Africa
CGE	Computable General Equilibrium
COPS	Centre of Policy Studies
CSIR	Council for Scientific and Industrial Research
DBSA	Development Bank of Southern Africa
DTI	Department of Trade and Industry
DWAF	Department of Water Affairs and Forestry
EC	European Union Commission
ESKOM	Electricity Supply Commission
EU	European Union
GDI	Gross Disposable Income
GDP	Gross Domestic Product
GEM	General Equilibrium Model
GGP	Gross Geographic Product
GREEN	General Equilibrium Environmental Model
IDC	Industrial Development Corporation of South Africa
IEA	Integrated Economic Accounts
IM	Inter-Industry Macroeconometric Model
INFORUM	Inter-industry Forecasting at the University of Maryland
I-O	Input-Output
ISIC	International Standard Industrial Classification
ISP	Internal Strategic Perspective
IWRM	Integrated Water Resource Management
IWRP	Integrated Water Resource Planning
KSA	Key Strategic Area
LEI	Agricultural Economic Research Institute
LSU	Large Stock Unit
Macro-I-O	Macroeconomic Input-Output Models
MIDA	Maritime Industrial Development Area
MIT	Massachusetts Institute of Technology
NAFTA	North American Free Trade Agreement
NPISH	Non-profit Institutions Serving Households
NWRS	National Water Resource Strategy

OECD	Organization of Economic Developed Countries
RSA	Republic of South Africa
SAFRIM	South African Inter-Industry Model
SAM	Social Accounting Matrix
SARB	South African Reserve Bank
SEEA	Systems of Integrated Environmental and Economic Accounting
SIC	Standard Industrial Classification
SM	"Standard" Economic Model
SNA	System of National Accounts
StatsSA	Statistics South Africa
ToR	Terms of Reference
UN	United Nations
USA	United States of America
USAID	United States Agency of International Development
VAT	Value Added Tax
VWMA	Vaal Water Management Area
WC	Water Conservation
WDM	Water Demand Management
WMA	Water Management Area
WRA	Water Resource Accounts
WRC	Water Research Commission
WSM	Water Satellite Model
WTO	World Trade Organisation

CHAPTER 1 – INTRODUCTION

1.1 Introduction and Scope

With water being a limited resource in South Africa, it is widely accepted that its availability will constrain the economic development of the country in the longer term future. In fact, water resources are already overcommitted in some areas of the country, with the result that economic expansion is already possibly being inhibited, particularly with regard to the rate of growth in the output and income of “high value” water uses.

In the South African context, water is first and foremost treated as a common (social) good. Water is recognised as being essential for sustaining life, and is a commodity to which people and the aquatic environment have a legally protected right. However, water is also recognised as an economic good, the use of which has a major impact on the creation of wealth and the well-being of people. Almost without exception, there is an increasing interest in assessing the economic value of water, and in using water as a catalyst for the generation of wealth and prosperity.

In advanced economies, changes to the context in which water policy is being drawn up are increasingly highlighting the inadequacies of traditional responses to the management of water that have centred mainly on the management of the supply of water resources. Indeed, a paradigm shift in water policy definition and strategy is now in full swing with traditional supply-side solutions gradually giving way to mixed solutions in terms of which water management is increasingly being approached from the demand side, where the aim is to manage existing scarce resources more efficiently.

In many countries, the implementation of new water policies based on the overall management of the existing resources is being hampered by the lack of knowledge about the dynamic relationship that exists between water, the economy, and the broader society. Specifically, from an economic perspective, the tools necessary for the estimation and evaluation of the impact of water policies (such as changes to water tariffs) on production sectors, and/or the impact of sectoral economic policies (such as irrigation policies) on water resources have not yet been fully developed. Furthermore, using the presently available planning tools, it is very difficult to anticipate what unforeseen negative effects well intended water management and allocation decisions may have on socioeconomic development and the long-term economic prosperity of a country.

1.1.1 Policy Developments in South Africa

The Department of Water Affairs and Forestry (DWAF) has embarked on a new planning and water management regime, generally referred to as the Integrated Water Resource Planning (IWRP) or Integrated Water Resource Management (IWRM) paradigm. Backed up by the Water Act and the National Water Resource Strategy (NWRS), the IWRP is not totally distinct from historical practices, however, it does contain functions that are not generally found in traditional water resource planning. There are four main considerations that deviate from past/current planning practices:

- Integration of planning throughout the supply chain in order to achieve the best results for society (end consumers), and to meet specific project objectives. Historically, traditional water resource planning practices focused on the best-perceived solution from a water resource perspective only.

- Ownership and responsibility of the planning must not be limited to the water resource manager or water management institutions only, and should require the involvement of all key stakeholders in the supply chain.

- The criteria used to evaluate the various developmental options must be comprehensive and must include social, economic, institutional and environmental objectives.

Within this context, water demand-side management measures are considered as an alternative resource option, and not as a separate function or campaign. As such, the IWRP approach is no longer limited to a water resource perspective only, but includes a number of other socio-economic consequences that are associated with changes in water demand.

1.2 Research Aims

The specific objective of this project is the development of an integrated macroeconometric model that considers the role of water as an input to the South African economy, and that can be used to predict and evaluate the likely effect of water management and policy interventions. This objective is directly linked to the WRC’s research requirement for the development of an 'Appropriate and Scientifically Based Analytical Tool' that can be used for this particular purpose in the South African context.

The unique South African situation with regard to water management and water allocation requires an appropriate analytical framework that would allow the examination of economy-wide effects of policy changes, such as water policy reforms. In this regard, an econometric model is the economist's version of a 'laboratory' in which it is possible to conduct 'experiments', i.e. assessing the economy-wide impacts of implementing the changes to water policy envisaged in the new NWRS. Such a model must translate the textbook description of an economy into a mathematical format that allows the researcher to simulate the economy with an 'outside shock' such as a water policy change, and to evaluate the impact of this outside shock on the broader economy.

It should be emphasised that water, as an input to economic processes, is only one of many such basic input requirements in the economy. As such, the demand for water is determined by the overall growth performance of the broader economy, as well as by specific sectoral developments, price movements, etc. Therefore, it is imperative that the role of water be considered in a wider economic context that can be provided by a macroeconometric model. It is against this background that this project examines the available macroeconometric models that, inter alia, establish the functional relationships that exist between the various production sectors and the water sector.

1.3 Research Approach

Every country has its own unique economic, social and physical characteristics that require unique solutions to its developmental problems/goals. Therefore, the development of an appropriate econometric model capable of performing the required forecasting and impact analyses of the various development scenarios contained in the ToR for this study[5] must take these unique characteristics into consideration.

Models of this kind do exist in South Africa, however, these were tailored for use in other policy areas (i.e. housing, international trade, transport etc.). Therefore, in line with the ToR, an in-depth study has been undertaken to establish the extent to which use can be made of existing model infrastructures developed locally and internationally to derive a model suitable for this project's objectives.

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[5] See Annexure 1.

1.3.1 Research Plan

This study was scheduled to be finalised within a period of three years (coinciding with the financial years of the WRC), starting on 1 April 2005. Originally, the research process used in this study was divided into ten so called Deliverables, with the last deliverable being this final report. The Deliverables can, to a large extent, be sub-divided into four main tasks, namely:

- The overall planning of research benchmarks and theoretical conceptualisation;
- The construction of the macroeconometric model and collation of input data;
- Technical validation of the model and scenario building; and
- Final report.

Based on the fact that each of the deliverables is interdependent, it was important that the determination of the initial research outcomes facilitated the successful completion of the subsequent deliverables. In light of this, most of the first year was taken up with planning of the overall research effort, and with ensuring that the modelling approach used is technically and theoretically sound, especially as compared with international experience in this regard. The second and third years involved the actual model building exercise, and the evaluation of a range of scenarios as set out in the ToR. .

The overall project was overseen by a Reference Group under the leadership of the WRC. This Reference Group discussed each of the nine Deliverable Reports as stipulated in the project ToR. In addition, valuable guidance and periodic approval was given to the project team in their endeavour to achieve the stated research objectives.

1.4 Structure of the Final Report

Compiling a final report that is based on a series of nine preliminary reports holds the danger of simply repeating the content of each contributing report, which could lead to unnecessary duplication. As such, it is the intention of the authors of this Final Report to avoid such an outcome. Nevertheless indications have been given in this report as to how the main findings of each preliminary report ultimately contributed to the attainment of the study's main objectives.

This report explains the overall process used in the development of the macroeconometric model, and provides some demonstration of its abilities. In addition, it also explores the way forward. However, and does not report in detail on the results obtained during the execution of the project. These details can be sourced from the nine preliminary deliverable reports that can be found on the accompanying CD-ROM.

The remaining chapters of this report are structured as follows:

Chapter 2: Literature Review and Model Selection (Deliverables 1-4).

Chapter 3: Integrating the Water Sector into the chosen overall Modelling System (Deliverables 1, 5 and 6).

Chapter 4: Demonstrating the Analytical Capabilities of the Integrated Modelling System in the South African Context (Deliverables 7-9).

Chapter 5: Overall Summary and Conclusions (Final Report).

CHAPTER 2 - LITERATURE REVIEW AND MODEL SELECTION

2.1 Introduction

This chapter consists of three sub-sections dealing, firstly, with the water situation in South Africa, including possible future developments in line with overall socio-economic expectations. Secondly, given the water situation, a case is made for an appropriate macroeconometric modelling capability that is required for strategic water policy impact analyses. Lastly, a literature review is given of modelling approaches that are available internationally and locally for this purpose. The Literature Survey then serves as a basis for selecting an appropriate macroeconometric model for South Africa.

2.2 The Water Situation in South Africa

South Africa is following a world-wide trend towards critically re-evaluating the way water use is managed (Saleth and Dinar, 1999). A new National Water Policy (1997) has been developed, followed by the National Water Act (1998). The overall aim of this new approach to water management is to achieve an efficient, equitable and sustainable use of water. The implementation of the new policy and legal framework is described in the National Water Resource Strategy 2004 (NWRS).

It has already been established that water is scarce in this country and is over-allocated in more than 50 percent of the catchments (NWRS, 2004, see table below), which necessitates that efficiency measures are put in place. Such measures include the most efficient distribution systems, as well as the most efficient methods of water use. This aim can best be achieved once the realisation has taken place that water is not a free good, and that users must pay for the cost of the sound water management practices that are required to provide water users with the assurance of water supply (from quantity and quality) that they require.

Water resource development and management in South Africa has, over the years, continuously evolved to meet the needs of a growing population and a vibrant economy. This has largely been made possible by recognising water as a national asset, thereby allowing its transportation from where it is available to where the greatest overall benefits for the nation can be achieved. Sufficient water resources have been developed and are available so as to ensure that all current requirements for water can reasonably be met without impairing the socio-economic development of the country.

However, in order to meet the future water requirements of South Africa's growing population and strong economy, water resources are highly developed and (over)utilised in large parts of the country. The general expectation is that trends towards the industrialisation of the economy and the urbanisation of the population are likely to continue for the foreseeable future, thus further affecting the country's ability to provide for its water requirements in an economically efficient way.

Against this background it is essential to present, in quantified terms, the total system water availability and requirements in South Africa. The table below reflects a reconciliation of the available water and total water requirements for the year 2000, including transfers between Water Management Areas (WMAs) and with two neighbouring countries.

Table IV: Water Availability and Requirements p.a., 2000 (Million m^3)

No	Water Management Area	Reliable Yield	Transfers-In	Requirements	Transfers-Out	Balance
1	Limpopo	281	18	322	0	-23
2	Luvuvhu / Letaba	310	0	333	13	-36
3	Crocodile West & Marico	716	519	1 184	10	41
4	Olifants	609	172	967	8	-194
5	Inkomati	897	0	844	311	-258
6	Usutu to Mhlatuze	1 110	40	717	114	319
7	Thukela	737	0	334	506	-103
8	Upper Vaal	1 130	1 311	1 045	1 379	17
9	Middle Vaal	50	829	369	502	8
10	Lower Vaal	126	548	643	0	31
11	Mvoti to Umzimkulu	523	34	798	0	-241
12	Mzimvubu to Keiskamma	854	0	374	0	480
13	Upper Orange	4 447	2	968	3 149	332
14	Lower Orange	-962	2 035	1 028	54	-9
15	Fish to Tsitsikamma	418	575	898	0	95
16	Gouritz	275	0	337	1	-63
17	Olifants / Doring	335	3	373	0	-35
18	Breede	866	1	633	196	38
19	Berg	505	194	704	0	-5
	Total For Country	*13 227*		*12 871*	*170*	*186*

Source: DWAF, NWRS, 2004.

The table above indicates that, already in the year 2000, ten of the countries in nineteen water management areas already had negative water balances. The situation is likely to continue (and, possibly, worsen) over time unless appropriate water management policies are implemented.

2.3 Literature Survey

Since the beginning of the 1980s, the use of macroeconomic models has become increasingly popular in analysing the consequences of macroeconomic policy choices, and in the allocation of scarce resources such as water in both developing and developed countries. Unfortunately, no comprehensive survey of all these model building attempts and their capabilities exists worldwide. However, enough information can be obtained from the economic literature that demonstrates the major developments in this field that has taken place in recent years.

It is well known that, in the model building fraternity worldwide, one will find strong differences in opinion regarding which kind of macroeconomic model is considered as the "best" type suitable for the kind of forecasting and policy impact analyses required for this WRC project. Hence, the requirement by the WRC that a thorough review be undertaken of the literature describing the spectrum of macroeconomic models presently available in the world. Such a review should then serve to provide enough information to a recommendation for a preferred model for the South African situation.

2.3.1 International Comparative Studies of all Model Types

Computable General Equilibrium Models (CGE) are probably the most well-known macroeconometric model frameworks used for economic analysis purposes. However, there are a number of other model types that have, in more recent times, proved themselves to be superior in particular circumstances. Consequently, as part of the literature survey, specific attention was given to studies that attempted to evaluate the appropriateness of these models for specific purposes. This was seen as an important precondition before any recommendation could be made of a particular model type in terms of the South African needs and objectives.

No comprehensive survey exists of all such macroeconomic models exists worldwide. However, enough information could be obtained from the various literature sources to demonstrate the main developments in this field in recent years.

It is interesting to note that a number of international research projects have followed a similar approach to reviewing the international literature as has been followed in this study. For example, in 1999, the European Union Commission (EC) financed a research project to review the suitability of the use of applied macroeconometric in the areas of international trade, agriculture and related resources, and environmental modelling (Van Jongeren "et al", 1999). This survey of models was part of a larger project that set out to investigate the usefulness of this type of modelling – and their associated databases – for dealing with policy issues in the European context.

In the above report, a comparative assessment was made of the various modelling types in terms of a fundamental set of criteria, viz.:

- Theoretical foundations
- Data requirements
- Institutional aspects surrounding model maintenance and data dissemination of results
- International applicability/linkability
- Dynamics
- Treatment of qualitative policies
- Parameters
- etc.

As part of this exercise, the models were grouped into three broad categories viz. Partial models; Economy wide models, and European Union (EU) -Agricultural models. Eighteen models were surveyed, and a summary of the results of this exercise is given in the table below.

Table V: Basic Modelling Design Choices: Eighteen Models grouped into Three Broad Modelling Categories and characterized by eight evaluation criteria.

	Partial Equilibrium Models	***Economy wide models***	***EU-Agricultural models***	***Total***
Scope of representation				
National economies:				
Partial	8	0	1	9
General	0	8	1	9
Regional scope:				
Global coverage	8	7	0	15
Non-global coverage	0	1	2	3
Regional unit of analysis:				
Linked country models	0	1	0	1
Parametric differences	8	7	2	17
Dynamics:				
Static	4	3	0	7
Recursive dynamic	4	4	2	10
Forward looking	0	1	0	1
Modelling of trade:				
Homogeneous	8	0	2	10
Armington	0	5	0	5
Monopolistic competit.	0	2	0	2
Other	0	1	0	1
Treatment of qualitative policies:				
Tariff/price equivalents	3	5	0	8
Explicit treatment	5	3	2	10
Data:				
Public data availability?				
Yes	3	5	1	9
No	5	3	1	9
Parameters:				
estimated	2	0	2	4
calibrated	6	8	0	14

Note: The table refers only to standard versions of models. Figures reported in the last column of the table represent the number of models that were sorted into a given category, and the two row totals in the Total column, therefore, always add up to 18.

Source: Van Tongeren, F. and Van Meijl, H. (1999). Review of applied models of international trade in agriculture and related resource and environmental modelling. Agricultural Economic Research Institute (LEI). The Hague, December 1999.

As part of the evaluation process, each model is briefly discussed in terms of its role and functioning in respect of each of the evaluation criteria used in this study.

Adherence to Standard Neoclassical Theory

As reported in the Literature Survey (Deliverables 1-4), a significant amount of controversy exists as to whether Inter-Industry Macro Models (IMs) adhere more closely to economic theory as compared to CGEs or not. In general, the supporters of IMs are of the opinion that, because of the classical theoretical structures inherent in these models such as consumer utility maximisation, profit maximisation, and the "closure" determinant of full employment in an equilibrium state, there performance in practice is heavily compromised. In other words, IM modellers believe that parameters should be calculated that fit the real developments instead of "forcing" the model's outcomes with predetermined, theoretically based parameters.

As indicated previously, IMs are required to have a strong relationship with available data, using the model characteristics to better track historical developments. The belief in some quarters is that a model that better tracks past developments must be better equipped to predict the future more accurately, as well as measuring the effects of proposed policy changes.

In addition, the theory of free markets and perfect competition, being the underlying principles that govern the economy, seems somewhat far removed from the South African situation and, for that matter, for many developing countries.

Easy to Implement Policy or Exogenous Changes

Both IM and CGE models are, by nature, detailed and, therefore, make it relatively easy to simulate the impact of a policy change on the economy in a sectoral context.

Track Record

It is important to know whether the model that is being used has been able to explain the behaviour of the economy in the past, and if it offers important insights into policy impacts or not. However, it is a fact that a model that provides good explanations of past developments or policy changes, may not in all cases be equipped to give realistic forecasts. In this context, IMs usually provide technical information on the error dispersion of their "in sample" forecasts, which is what users want to know.

Policy Relevant Results

IMs focus on directly measurable variables rather than on concepts that are difficult to measure properly (such as utility values not found in official data publications). In addition, IMs provide guidance as to how the economy responds over time to shocks or policy changes. IMs explicitly produce predictions of the economy's dynamic response to policy changes, right down to a sectoral level. Policymakers are generally interested in both the path to equilibrium, as well as the ultimate equilibrium point; and, because IMs provide sectoral dynamic paths, they have a significant advantage over CGE's.

Another important aspect of the IM approach is the inclusion of a meaningful financial sector, as well as accounting for international capital flows. These features are strongly present in the IMs, simply by virtue of having to allow for the macroeconomic side of the economy to play its full role in the modelling exercise. Having information regarding how the benefits (or harms) of policy changes can be magnified or mitigated by monetary policy (even though this might only occur in the short-term) is generally regarded as being useful for policymakers.

Maintenance and Care Costs

Due to their nature, IMs need data series for several years, with corresponding additional time for care, and the ongoing updating of databases. As such, it is generally recognised that, with so many equations to monitor, re-estimates and fine-tuning, IMs can be costly to operate. Nevertheless, with the progression in computing power and software enhancement, huge advances have been made in, for instance, conducting quick and efficient regression estimates. At the same time, the creation and continuous updating of standardised databases has become relatively easy with IT technologies. This is especially relevant in the case where IMs are linked internationally with other models and data bases of the same kind.

As is to be expected, no clear indication is given of each model's suitability for a particular set of policy objectives. However, the report does state quite clearly that the degree to which models will contribute to addressing new policy questions depends critically on their degree of adaptability. The investigation also found that the most important innovations to econometric modelling of late have not been theoretical, nor technological, but that: "The most significant changes have been of an institutional nature, albeit supported by recent computer and communications technologies" (EC Report, p. 53). The most important developments on the institutional side refer to the tendency to share data bases and computer codes internationally.

Another important aspect that emerged from this study is that building an applied econometric model is a costly exercise, and, therefore, once a particular route has been chosen, the cost to switch to a new modelling approach becomes prohibitive. The categorization used in this study also illustrates the extent to which these models can be regarded as suitable, depending upon the aim of the study.

Another prominent comparative exercise occurred in 1996, when "Resources for the Future" requested INFORUM (USA) to serve on a panel discussing alternative modelling strategies to be used for analysing the economic effects of proposals to limit greenhouse gas emissions; and again in 1997, when INFORUM made a presentation to the Joint Committee on Taxation of the US Congress on the feasibility of modelling the macroeconomic consequences of tax policy (Monaco, 1997).

These comparative exercises also used a range of criteria for evaluating all of the model types' main characteristics in terms of their applicability in certain circumstances. Three broad model types were investigated, viz. Computable General Equilibrium (CGE) models, Macroeconomic models linked to Input-Output Models (Macro-I-O), and Inter-Industry (IM) models. The main results of this comparative study are given in the tables below.

Table VI: Rankings of Model Characteristics for Model Builders

	CGE	***Macro-I-O***	***IM***
Standard micro theory	3.0	1.0	2.0
Data	1.0	2.0	3.0
Maintenance	3.0	2.0	1.0
Total	7.0	5.0	6.0

Table VII: Rankings of Model Characteristics for Model Users

	CGE	***Macro-I-O***	***IM***
Ease of Use	2.0	2.0	2.0
Track record	1.0	2.5	2.5
Policy relevance	1.0	2.0	3.0
Total	4.0	6.5	7.5

Where: 3 indicates the "best" model, and
1 indicates the "worst" model.

Two new aspects were brought into consideration, viz. the viewpoints of the model builders, and of the model users respectively.

What is of great importance here is that, from a model user perspective, IMs are especially strong in terms of having good capabilities for tracking historical economic developments, and for providing a superior infrastructure for simulating policy impacts.

As far as the model builder are concerned, CGE model types are regarded as being somewhat more acceptable, based on their more complete theoretical underpinnings, as well as the costs of maintaining these types of models (CGEs normally use a SAM for one calendar year as a base, which obviously limits data requirements to a certain extent).

2.3.2 Final Overview and Evaluation of Econometric Model types

Based on the results of the literature survey, including the international comparative studies, an evaluation was made of the existing range of empirical economic models' capabilities to measure impacts of policy changes, and to forecast future economic developments – exactly the kind of instruments that will be needed to model the role of water in the South African economy.

In essence five (5) model categories were analysed in terms of various criteria. These are:

- Input-Output Models (I-O).
- Computable General Equilibrium Models (CGE).
- Macroeconometric Models linked to Input-Output Tables (Macro I-O)
- Standard Macroeconometric Models (SM).
- Inter-Industry Macro Models (IM).

- **Input-Output (I-O) Models**

The I-O framework and equations can be thought of as a simple model of the economy that captures the way in which economic sectors interact, both in terms of the flow of goods and services, and in terms of prices. Many I-O models are as simple as the following equation demonstrates:

$$q = (I - A)^{-1} f$$

Where:

q = sectoral production

(I – A)-1 = Inverted input/output coefficients matrix
f = Final Demand per sector/commodity

Using these basic mathematical relationships (also known as technical/economic coefficients), the so-called impact multipliers can be calculated. These are quite ingenious coefficients that can be used for various policy impact analyses.

This type of model application was used in the South African context for a multiplier analysis of the wine industry in the Western Cape[6]. Numerous other studies have been performed in South Africa with this type of model. They are relatively uncomplicated, and can be used for a wide range of practical impact analysis purposes, as shown in the literature survey in this study (Deliverable 1). Their main weakness is that, basically, they are of a comparative static nature.

- **Computable General Equilibrium Models (CGE)**

CGE have recently become popular as tools for policy analysis, especially in the areas of tax policy and international trade policy. There is an extensive literature on the use of CGE models (Dervis, K., deMelo, J. Robinson, S. (1982) and Jorgenson, D.W. (1984)).

There are extensive debates in the economic literature concerning whether CGEs could, in essence, be made dynamic for analysis purposes (See for example the work of M. Grassini, University of Florence, Italy, 2003). However, CGE-models have a considerable number of appealing features. Firstly, they depend explicitly on neo-classical general equilibrium theory. Once the underlying structure and operation of the economy has been specified, markets are allowed to operate in determining prices, wages, and amounts demanded and supplied in factor and product markets. This conforms to the way many economists think the market economy should work, and certainly improves on the static I-O model.

a) International Experience with CGE models

CGE models are disaggregated representations of the economy that use the I-O structure for the production side of the economy. Data requirements are larger than those of classic I-O models since income distributions to the various sectors of households, government

[6] Conningarth Economists. The Macroeconomic Impact of the Wine Industry on the Western Cape. SAWIS, 2004.

and firms are also considered (consequently bringing Social Accounting Matrixes [SAM's] into play). However, the data set used in CGE model construction is usually limited to one year. CGE models also include sectoral-level production functions and disaggregated demand functions for consumption, imports, investment, etc. They combine I-O structure and behavioural functions. Normally, however, behavioural parameters are not estimated with regression analysis as in other macroeconometric models, but are deduced from the single year's set of data, or are specified exogenously. In the determination of prices, CGE models assume flexible prices that move to clear all the markets simultaneously. The models are used to describe differences between two equilibrium positions, rather than on a dynamic time path of an economy.

b) Walrasian CGE Models

Nicholson (2005) reviews a few types of CGE models, using the Walrasian CGE approach.

- One of the first uses for applied general equilibrium models was to study the impact of trade barriers on real wages. Some of the most extensive CGE modelling efforts have been devoted to analysing the impact of the North American Free Trade Agreement (NAFTA). A second major use of the Walrasian CGE models is to evaluate the impact of potential changes in a nation's tax and transfer policies. In these applications, considerable care must be taken in modelling the factor supply side of the models.

- Walrasian CGE models are also appropriate for understanding the ways in which environmental policies affect income distribution in a given economy. The General Equilibrium Environmental (GREEN) model developed by the Organisation of Economic Developed Countries (OECD) is perhaps the most elaborate of this kind.

- Another way in which CGE models can be used is to examine economic issues that have important spatial dimensions. Construction of such models requires careful attention to issues of transportation costs for goods and moving costs associated with labour mobility, because particular interest is focused on where transactions occur.

c) Macro CGE Models

Johansen's (1960) model, with simultaneous determination of the effects of quantities and prices on sectoral aspects of growth with sectoral re-allocation of labour and capital in the Norwegian economy, is generally seen as the first model in this category of CGE models. These types of models are further extended with, for instance, the ORANI/MONASH models of Australia (Powell and Lawson, 1990), the IMAGE model of the Irish agricultural sector (O'Toole and Matthews, 2002), and many more models of developing countries (Decaluwe and Martens, 1988).

The MONASH model was made more dynamic for purposes of forecasting[7]. In the process, however, it acquired certain elements of other IMs – such as making a number of "top-down" calculations derived from external data sources. Intrinsic to CGE models, use has to be made of a "closure" strategy to ensure that the forecasting capabilities of the model will be realised. MONASH, generally take in specialist forecasts for macroeconomic variables and for prospects in the markets for the economy's major exports: agriculture, mining and tourism. Also included are the government's plans for changes in industrial policy, and historically based scenarios on changes in technology and household tastes.

d) Egyptian Experience

Egypt[8] has a long history of CGE model building, starting with the Cairo University – Massachusetts Institute of Technology (MIT) research project in 1999 (Taylor, 1979; McCarthy, 1983), and a joint research project of the Cairo University, United States Agency of International Development (USAID), and the World Bank (1985). There were two "streams" of CGE model builders viz. Walrasian CGE models, and Macro CGE models (discussed above).

Walrasian models were constructed mainly for the purpose of analysing the quantitative effects of exogenous changes on the optimal allocation of resources, efficiency and welfare. These models can be categorised in three groups:

- Fiscal Policy models.
- Environmental models.

[7] Forecasting and Policy Analysis with the MONASH Model, BR Parmenter(David check spelling), Centre of Policy Studies, Monash University, Australia (1995).
[8] Two Decades of CGE Modelling Lessons from models for Egypt – Mark Thissen; SOM Research Report 99CO2, University of Graungen, 1998.

- Trade liberalisation models.

The macro CGE models for Egypt can be divided into the following four main groups:

- General purpose models.
- Agricultural models.
- Water Allocation models.
- Energy models.

Even though Egypt has, for many years, been experimenting with a wide variety of CGE models to address specific policy issues, it would seem that the application of their policy outcomes was limited. Egypt has a highly regulated economy, with non-performing markets. As such, it is difficult to model these structural deficiencies into a general equilibrium model based on neo-classical theory.

On the positive side, Egypt's experience with water and land allocation CGE-models was much more promising. These models are proposed to be used in improving water use, also through demand management. However, as is the case with many other developing countries, these models will have to be modified in order to improve their medium to longer-term forecasts and policy impact analysis.

e) South African Experience

It is important to take note of the fact that CGE modelling has also taken root in South Africa. Mention should be made of two instances, viz. (1). The Provide Project, and (2). Industrial Development Corporation of South Africa (IDC) and the Department of Trade and Industry (DTI).

The IDC model is based on the Australian MONASH model developed by the Centre of Policy Studies (COPS) of that University. One of the main aims was to provide sectoral growth forecasts (± 80 industries) with the IDC-GEM.

The IDC-GEM is a large-scale general equilibrium model of the South African economy. The model has proved itself as a valuable quantitative tool to facilitate the evaluation of economic policy and its impacts on the economy, as well as to provide medium-term forecasts on an industry basis. The IDC-GEM is based on neo-classical economic theory and a disaggregated data base represented by the SAM. The advantages of this type of modelling technique over traditional I-O modelling are that it:

- Addresses structural changes in the economy through elasticities of substitution and transformation;

- Incorporates non-linear behavioural equations;
- Does not assume fixed prices – in fact, prices adjust until demand equals supply; and
- Includes dynamic features such as capital accumulation over time, and investment decisions based on expected rates of return.

The IDC-GEM was extensively used to quantify the impact on the South African economy of re-entry into international markets, as well as the freeing of international trade, with South Africa being a member of the World Trade Organisation (WTO).

Some simulated policy impact results with regard to South Africa's involvement in international trade, given a new tariff regime, are given in the table below.

Table VIII: RSA's involvement in International Trade, 1996-2001

	Import Penetration		***Export Propensity***	
	1996	***2001***	***1996***	***2001***
Agricultural	6.8 %	8.3%	13.2%	14.6%
Mining	32.4%	40.7%	66.3%	66.9%
Manufacturing	28.2%	33.3%	18.7%	24.6%
- Food	9.3%	13.3%	8.0%	11.3%
- Textiles, Clothing and Footwear	22.5%	32.0%	13.8%	22.1%
- Wood, Furniture and Paper	15.5%	18.5%	13.9%	17.3%
- Chemical Products	23.2%	27.7%	13.3%	17.5%
- Non-Metallic Mineral Products	15.3%	18.9%	7.3%	10.2%
- Basic Metals	19.9%	20.3%	64.9%	69.1%
- Metal Products	51.5%	28.8%	20.5%	28.3%
- Transport Equipment	35.5%	36.5%	11.0%	20.4%

IDC-GEM is a hybrid model, with characteristics of I-O models and IM linked to it. This all contributes to its dynamism and ability to simulate policy shocks. These characteristics were further developed and refined to achieve the 1999 version of the CGE model to forecast water demand for Australia (discussed in the next section). The pros and cons of using a CGE model for policy impact analysis and for forecasting purposes will be summarised at a later point in this chapter.

f) The Australian Experience

Australia, like South Africa, is a dry country, with water resources being very scarce. As a result, the Australians have undertaken a significant amount of research into instruments that analyse the relationship between the economy and water with the help of various macroeconometric models. Reference is made here to a mammoth study in terms of which a CGE was used as the primary driver of a modelling framework for analyzing the role of water in the Australian economy. This study made use of the MONASH macroeconometric model of the Australian economy, which is the dynamic successor to ORANI that was designed to examine the implications of different macroeconomic policies on the Australian economy.

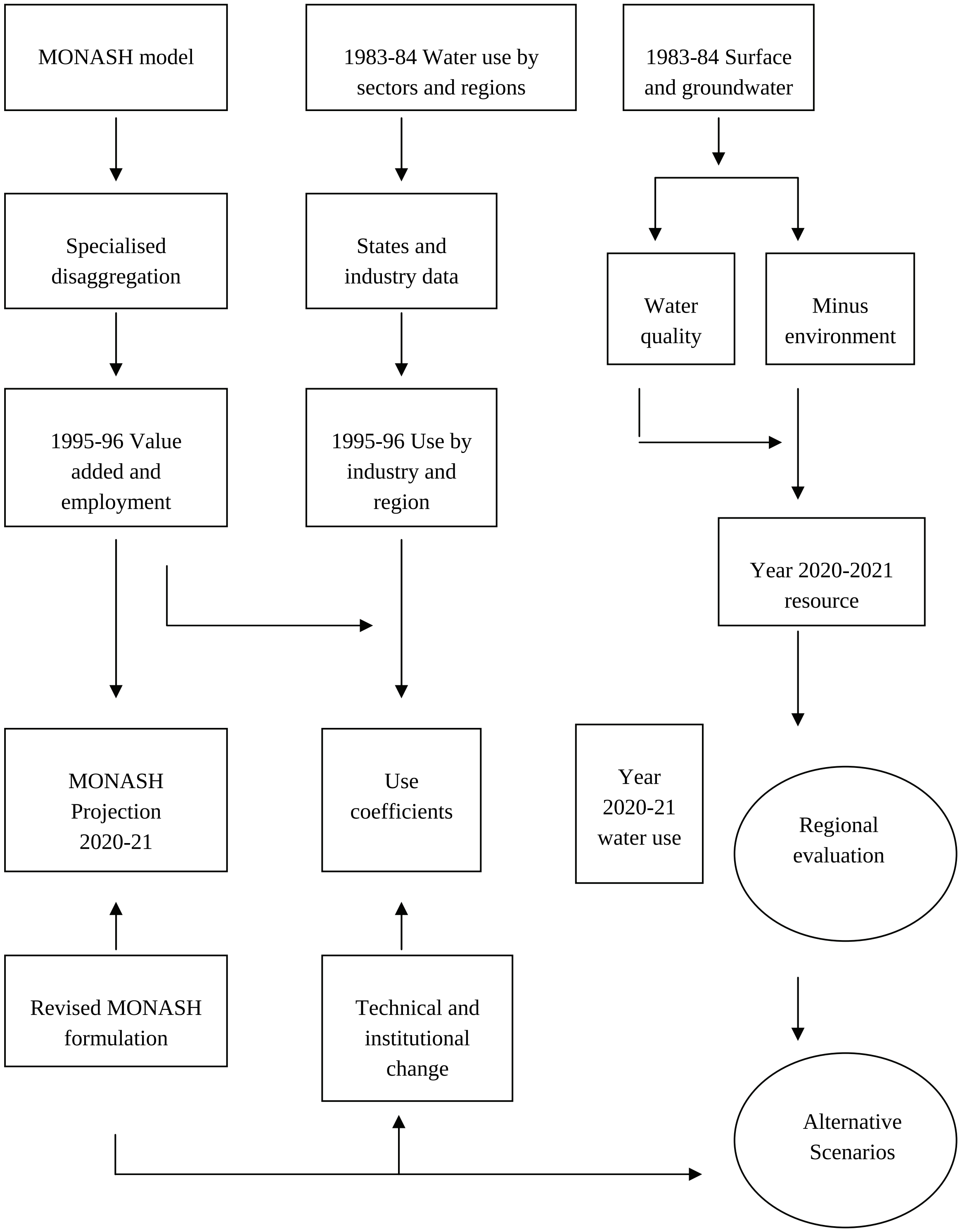
With regard to its application to water resource management, the MONASH model was used to describe the relationship between trends in economic activity and water demand in 18 study regions within Australia. The model was "extended" to forecast water demand on a so-called satellite basis. As one could expect, this is a huge model, with heavy data requirements, especially surrounding water use and supply data on a regional basis.

This model describes the relationship between present and future trends in the expected growth in production and economic activity on a sectoral level, and water demand/supply through inter-linkages. The Australian model set-up consists of the following main components:

a) An existing (sectoral) CGE econometric model of the Australian economy that is used to forecast macroeconomic variables, quantities and prices of, for example, exports, changes in industrial technologies, household preferences, population growth forecasts, etc.
b) A sectoral and regional estimate of the water use that would result from a given level of economic activity. This is where the water sector has been disaggregated to reflect its regional profile, i.e. in major catchment areas.
c) A comparison between the water use estimated in (b) with the availability and quality in the region(s). Any surplus/deficit situation with regard to water is then re-introduced into the model to simulate an equilibrium situation and, hopefully, the attainment of a more efficient utilization of scarce water resources.
d) Allowances for future technical and institutional change.

A diagram of the Australian model is given in the figure below.

Figure II: Model Configuration



Where a summary is given above of the outcome of the comparative study between various model types, the specific viewpoint with regard to the appropriateness of the Australian model framework in a South African context is given in more detail.

- **Macroeconomic Models linked to Input-Output Tables(Macro-IO)**

The main characteristic of this modelling approach is that a macro model is used to "drive" an I-O model. A simple static I-O model requires some exogenous means to estimate the final demand vector. This "two-model" approach uses the macro model to generate the final demand totals, then forces the I-O final demand vectors to move like the total GDP. For example, the macro model's prediction for growth in total consumer spending would provide the growth rate for each of the consumer spending categories in the I-O model. A more sophisticated version would allow the relative industry shares to vary with the available aggregates whilst maintaining the constraint that the predicted shares themselves always sum to unity determined by the macro model. Then the final demand vectors are used in conjunction with an I-O Table to produce forecasts/simulations of output changes.

This approach is usually referred to as "top-down". In general Macro I-O models are criticised because industry results tend not to affect the overall outcomes in the macro economy. The characteristics of different industries, and thus the resulting differences in projected outcomes, are not allowed to influence the overall economy. Not only does this not conform to how the economy works, but it can provide misleading industry results in the long-term, or in cases where the shocks are sector-specific.

- **"Standard" Macroeconomic Models (SM)**

A macroeconomic model is a collection of equations – with parameters estimated using regression analysis – that relate economic aggregates to one another. Useful macro models may consist of several hundred equations, or they can be as small as 3 to 4 equations. Almon (1996), Taylor (1993) and Brayton (1997)).

Most macro models themselves have little, if any, meaningful sectoral detail. Many separate agriculture from the rest of the economy, and many have equations for a few broad types of consumer goods or investment goods. However, whatever sectoral detail there is does not usually have meaningful economic content for other parts of the model. For example, there may be a regression equation that predicts consumer buying behaviour for semi-durable goods, but changes in such production or imports do not lead directly to increases in employment in those industries – increases in such purchases tend to raise aggregate demand, which tends to raise aggregate employment.

A similar problem occurs on the price side, where there is usually a single price level equation that usually takes account of only a few sectoral supply-shock variables such as food and transport costs. Oil prices, or the gold price, may appear as independent variables in many different regression equations. These models are heavily dependent on data, usually national income, production and expenditure data presented in time series to capture relationships between economic variables. Regression equations are typically estimated in an attempt to capture relationships between economic variables.

Macro econometric models have come in for severe criticism, especially when they were unable to foresee the effects of the oil shocks and the stagflation phenomenon of the 70s and 80s. However, proponents of these models have worked hard to improve their capability of simulating structural changes in the economy. Most new macro-models now have good long term forecasting abilities, as well as improvements in their use for policy impact analysis.

- **Inter-Industry Macro Models (IMs)**

This type of model can be described as macroeconomic, dynamic and multi-sectoral. It combines the main features of the models discussed above, i.e. they are macroeconomic since they depict the behaviour of the economy as a whole, and produce projections for aggregate GDP and its components; they are multisectoral and include I-O accounting that shows intermediate consumption, and they integrate intermediate input prices with sectoral price formation.

In contrast to classic I-O models, however, macroeconomic multisectoral models connect the production and price sides of the economy through behavioural equations for final demand that depend on prices and output, and functions for income that depend on production, employment and other variables. Furthermore, unlike (older) CGE models, they are dynamic from the outset, that is, they produce projections of a time path of the economy rather than differences between “equilibrium” positions. Therefore, macroeconomic multisectoral models are more suited for forecasting.

An important feature of this macroeconomic multisectoral model is its bottom-up technique. In this approach, the model works like the actual economy in that the macroeconomic aggregates are built up from detailed projections at the industry or product level, rather than being estimated and distributed between sectors.

However, these models also have their weaknesses, for example the proponents of CGEs usually criticise IMs for their lack of a genuine microeconomic theoretical base.

Furthermore, due to its theoretical/technical specifications, IMs require more data input than other model types. With so many equations to monitor, re-estimates and fine-tune, IMs can become costly and time consuming to set up and maintain.

What the surveys again brought to the fore is that it is important for decision makers who have to decide on which model approach is to be used, that a number of important questions be answered up front. They know that the choice of the model will be scrutinised, and also will have to be justified to higher levels of responsibility.

2.3.3 Selection of Model for Use in this Study

One of the most important findings of the model assessment exercise is that there is no ideal model that can serve all of the stated purposes. The choice of theoretical framework, the extent of regional and sectoral disaggregation, and the choice of datasets and estimation methods determine the domain of applicability of the model. However, potential users of applied models should be aware of strengths and weaknesses of alternative approaches. Strengths and weaknesses, however, is a relative concept, depending of course, on the use the researcher wants to put the model to. Nevertheless, as part of the evaluation process, an attempt has been made to evaluate each model type on the basis of a number of characteristics that are intrinsic to every type of model. These characteristics more or less coincide with the aspects highlighted in the previous section.

This section primarily presents a summary of the actual findings of the evaluation process, but with a more explicit emphasis on those aspects that influenced the decision in favour of using an IM for this study.

Table IX: Evaluating Model Efficiencies in terms of Economic Theory and Applications, based on a Weighted Qualitative Assessment

Model	*CGE*	*Macro-IO*	*IM*	*IO*	*Macroeconometric*
Neo-classical general equilibrium theory	8	4	5	4	5
Standard Micro Theory					
Prices	8	3	6	3	5
Price elasticities	8	3	6	3	5
Technology (change)	5	4	5	3	3
Maintenance	7	5	5	7	6
Functional forms influence	6	4	4	4	4
Quality of parameter values	5	4	7	4	4
Observed economy	4	6	8	4	7
Data requirements	6	5	5	6	7
Ease of use	6	7	6	7	6
Track record (econometric testing)	4	7	8	4	6
Policy relevance/analyses	5	5	8	5	7
Equilibrium determinants	6	4	6	4	6
Dynamism	4	4	8	4	6
Presenting real world (incl. Sector specific)	5	6	8	4	7
International Linkability	5	3	8	4	6
Accommodating Imperfections	5	5	8	4	5
TOTAL	97	79	111	74	89
Efficiency Percentage	57%	46%	65%	44%	52%

In establishing the above checklist, it was hoped that it would assist in deciding which model would best suite the study's needs and aims. However, this should not be viewed as a rigorous, infallible method for choosing between models. The rankings are based on "weighted" qualitative assessments of the common elements of models in terms of economic theory and applications.

In this table, the common characteristics of all models are ranked on the scale of 1-10. The rankings scales are as follows:

- Below average to weak <5
- Average 5
- Good to excellent >5

The results of rating model efficiencies in terms of specified criteria as presented in the table above provide interesting reading. Again, one must warn against the unqualified interpretation of these results. The rating was done subjectively by the project team, and should be regarded as quasi-scientific. Nevertheless, it does provide at least a starting point when having to decide on a specific model to address the specific study objectives. Every situation would also require giving weights to specific elements of a model such as its data requirements, etc.

Having regard to the goals of the present study, the evaluation exercise pointed, on balance, towards the IM genre as being the best option. In conclusion, a summary of the strengths and weaknesses that were considered, and which led to the decision to recommend the IM type as appropriate for this study is given below.

IM-type models have been in use for a reasonably long time (almost four decades), and they have a very good track record. They have established themselves as being appropriate tools to apply in economic analyses, especially where sectoral detail is required.

Strengths

- This type of model contains important features of other well-known modelling types, such as I-O models, CGE Models, Macro Models linked to I-O models, etc. Therefore, the behaviour of the economy as a whole is simultaneously and dynamically depicted so that more realistic projections for GDP and its components are produced. On balance they would seem to integrate these elements into a more effective whole as an analytical instrument.
- Unlike an I-O model, the production and price sides of the economy are connected through behavioural equations.
- As opposed to CGE models, which determine the difference in equilibrium positions, this model is more dynamic. That is, a time path of projections is produced, which makes IMs more suited for forecasting.
- An important feature is the bottom-up workings of the model. Macroeconomic aggregates are built up from detailed projections at industry or product level. It is therefore possible to describe how changes in one industry affect related sectors, the general economy, and vice versa. This ensures economic consistency.
- The advantages of disaggregation are:
  - richer depiction of the structure of the economy.
  - more accurate description of economic behaviour.
  - that it is more useful to business planners as they can provide specific information regarding the customer, supplier and the own industry of a business.
  - that it permits the modelling of prices by industry. It is therefore possible to explore the effects of relative price changes.

- Parameters are not calibrated but are estimated by applying regression techniques. Parameters differ between product and industries, reflecting differences in consumer preferences, price elasticities, foreign trade and technology.
- Data sources are organised mainly based on national accounts.
- They are ideal for investigating national policy issues and industrial forecasting.
- IM models are internationally linkable.
- They have rich product detail.
- The behavioural approach to investment completely eliminates the non-economic instability of dynamic I-O models.
- There is accounting consistency.

Weaknesses

Like any econometric model, IMs also have their weaknesses that should not be ignored. These can be summed up as follows:

- The greater the disaggregation, the greater the:
  - Complexity of the model.
  - The limitations on published data.
- IM modelling can be costly. The major costs being the data base necessary to support the model, and the time and energy it takes to maintain and improve the detailed regression equations in order to keep it up-to-date. (The CGE-model, however, faces the same problems but from another angle).
- The stability of such models and the usability for purposes of sectoral forecasting is questioned from certain quarters. Due to the tightly linked nature of parts of these models, an equation for a small sector that strays off can inadvertently carry the whole model with it. While this is possible with any model using regression based parameters, this problem is sometimes magnified in IMs (but also in CGEs, etc.).
- It lacks strong, consistent, microeconomic underpinnings.
- They generally supply too little detail for a firm (like all other macro econometric model types). There are, however, well established methods to extend and disaggregate sectoral outcomes to the level of the firm.

2.3.4 Basic Operation of IMs

2.3.4.1 Introduction

The South African Inter-Industry Model (SAFRIM) developed in this study is a long-term IM aimed at tracing the industry development of South Africa from 1997 to 2020. It is based on a 46 sector – to sector I-O table of the South African economy, and follows the basic framework of the classic INFORUM model[9].

There are three logical components incorporated into SAFRIM: the real, or product, side; the price-income side; and the accountant. The real side estimates final demand, production and labour requirements. The price-income side determines factor income, or value added, and estimates prices. The accountant closes the model with respect to income, and computes economic aggregates based on sectoral variables. As such, SAFRIM is a large scale model that builds up macroeconomic forecasts from the bottom up.

SAFRIM is an IM in that most of its equations are estimated at an industry level, and the price and output solution by industry uses the fundamental I-O identities. The database of SAFRIM therefore consists not only of I-O matrices and vectors of expenditures, value added and employment, but also numerous macroeconomic variables.

2.3.4.2 An overview of the SAFRIM

Diagram II shows the main structure of the model in outline. For each year, the SAFRIM loop begins on the real side, where the expenditure components of GDP such as “Private Consumption”, “Government consumption”, Fixed Investment”, “Inventory Change”, and “Exports” are calculated using behavioural equations that have monetary and other macroeconomic variables as explanatory variables. Note that “Imports” are later calculated when the Seidel I-O solution solves jointly for sectoral “Production” and “Imports” using

[9] The INFORUM model is a multisectoral macroeconometric modelling system that originated from the inter-industry forecast project at the University of Maryland, USA.

the technical coefficients (A matrix). The individual technical coefficients can be modified at this point to model changes in technology.
Once the output loop has converged, the labour productivity equation is calculated that forecasts the ratio of output to employment. Together, “Productivity” and “Production” forecasts generate “Employment” by industry. At this stage, one can also calculate unemployment by subtracting this “Employment” from exogenous labour force projections. At this point, the real side of the model is finished. For almost all of the equations in the real side, information is needed on relative prices and the aggregated price level as well in order to generate real disposable income. However, until the price side of the model has been run, these prices must only be estimates.

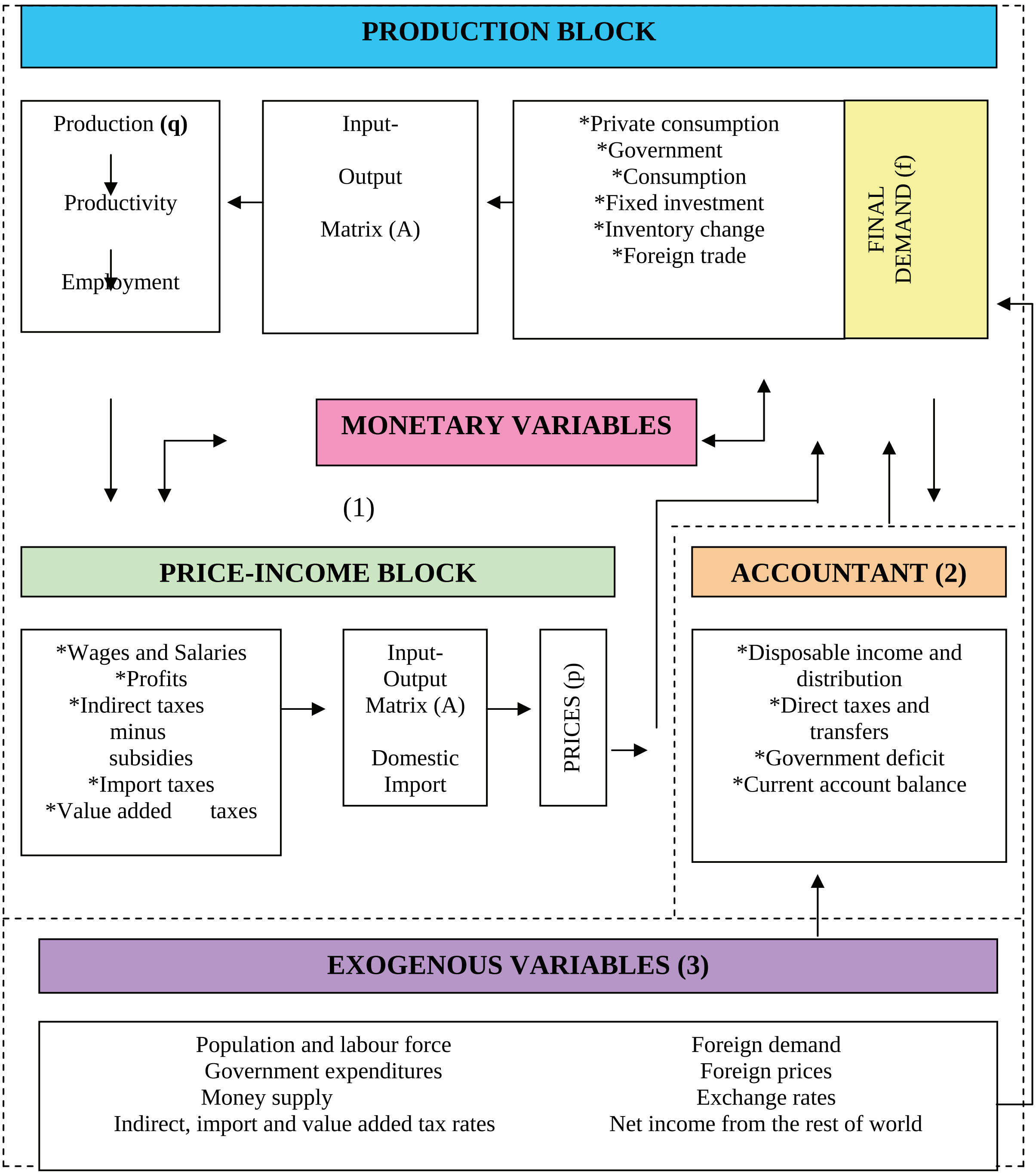
SAFRIM next turns to the important step of forecasting prices using variables such as “Production” and “Capital stock” from the real side among the explanatory variables. In this way, the variables serve as links between the real side and the price side. All components of value added are calculated first. The first operation determines labour compensation by industry. Then the model determines the components of capital income. Later on, “Indirect business taxes” are determined by multiplying exogenous indirect tax rates by output by industry. Before calculating prices, value added by industry is summed to arrive at total value added, and then is passed through the product-industry bridge, to obtain value added by product. Once value added at the product level has been obtained, commodity prices are calculated using an I-O equation for prices that also takes account of the import composition of intermediate consumption. The new prices are then fed into the next iteration of the real side to re-assess final demand until the model converges.

At this point, the Accountant element of SAFRIM is called into operation to compile the aggregate national accounting tables by the summing up of the sectoral details of final demand and income by industry. The information computed here includes “Disposable income”, “Direct taxes and transfers”, “Government deficit”, as well as “Current account balance”. Since SAFRIM uses an iteration procedure to solve the model, the Accountant also checks and determines the convergence of the iterations.

2.3.5 Data Implications of IM

The IM model is largely sectorally based in that the main macroeconomic aggregates are built up from sectoral level (i.e. production, value added, employment, etc.). The diagram below demonstrates how the structure of the IM model requires a unique set of national accounting data inputs to drive the model.

Diagram II: A More Detailed IM Structure – Data Needs



Source: Grassini, 1998.

Where (1) = Sectoral Section

(2) + (3) = Macro Section

The Data requirements can be divided into three broad categories:

Sectoral Data

As shown in the above diagram, the sectoral data involves an historical set of I-O Tables for 46 sectors that have been reconciled with the RSA’s National Accounts

Macro Aggregated Data

- **Institutional Accounts**

As part of the Accountant Module of the IM, several integrated economic accounts (IEAs) have to be compiled. These accounts actually represent, in summarised version, the economic/financial value of transactions between specific institutional units. It also shows how income is distributed and redistributed, and how saving is used to add wealth through investment in fixed and other financial assets. These institutions are:

- Non-financial corporations;
- Financial corporations;
- General government;
- Households;
- Non-profit institutions; and
- Rest of the world.

The main characteristics of institutional transactions are either of a stock or flow nature.

- **Other macro data**

As shown in the diagram above, in order to incorporate exogenous variables into the IM, a whole range of macroeconomic data series are required. In most cases these aggregates form part of the integrated economic accounts referred to in (2) in the above diagram.

The economic/technical structure of SAFRIM will be dealt with in more detail in Chapter 4.

CHAPTER 3 - INTEGRATING THE WATER SECTOR INTO THE OVERALL SAFRIM MODELLING SYSTEM

3.1 Introduction

After having selected the IM-based SAFRIM macroeconometric model as the main economic "driver" of the modelling system, the water sector and its interrelationships with the rest of the economy, was modeled and linked to the SAFRIM model (see Deliverables 5 and 6).

The Australian modelling framework discussed in the previous chapter, was, in principle, regarded as suitable for the South African requirements. However, the main difference being that, in the South African case, the SAFRIM/INFORUM-based macroeconometric model was substituted for the CGE model used in the Australian framework; and, on the water side, use was made of a model developed for the South African economy as a whole, as well as for the Vaal Water Management Area (VWMA).

3.2 South African Water Insitutions and Organisations

Every country has its own unique structure of organisations and institutions that are involved in the water industry, with each having its own responsibility in the water supply chain. A number of factors have had an influence on the ultimate character of this elaborate system, some of which are historical and some are legislative. It is important to understand the broad organisational and institutional set up of the water sector in South Africa before the WSMs main characteristics can be presented.

In 1998, the South African government adopted water legislation that incorporates some new, constitutionally-based aims for water management such as economic efficiency, social equity, and environmental sustainability, which are now the guiding criteria of the new South African water policy.

The new National Water Act of South Africa 1998 (NWA) promotes integrated and decentralised water resource management in a new institutional and organisational environment. The new act is radically different from previous water legislation, particularly with regards to water rights – under the new NWA, water is considered a public resource, and only the right of use – and not ownership – is granted to users through a licensing system for which they are required to pay.

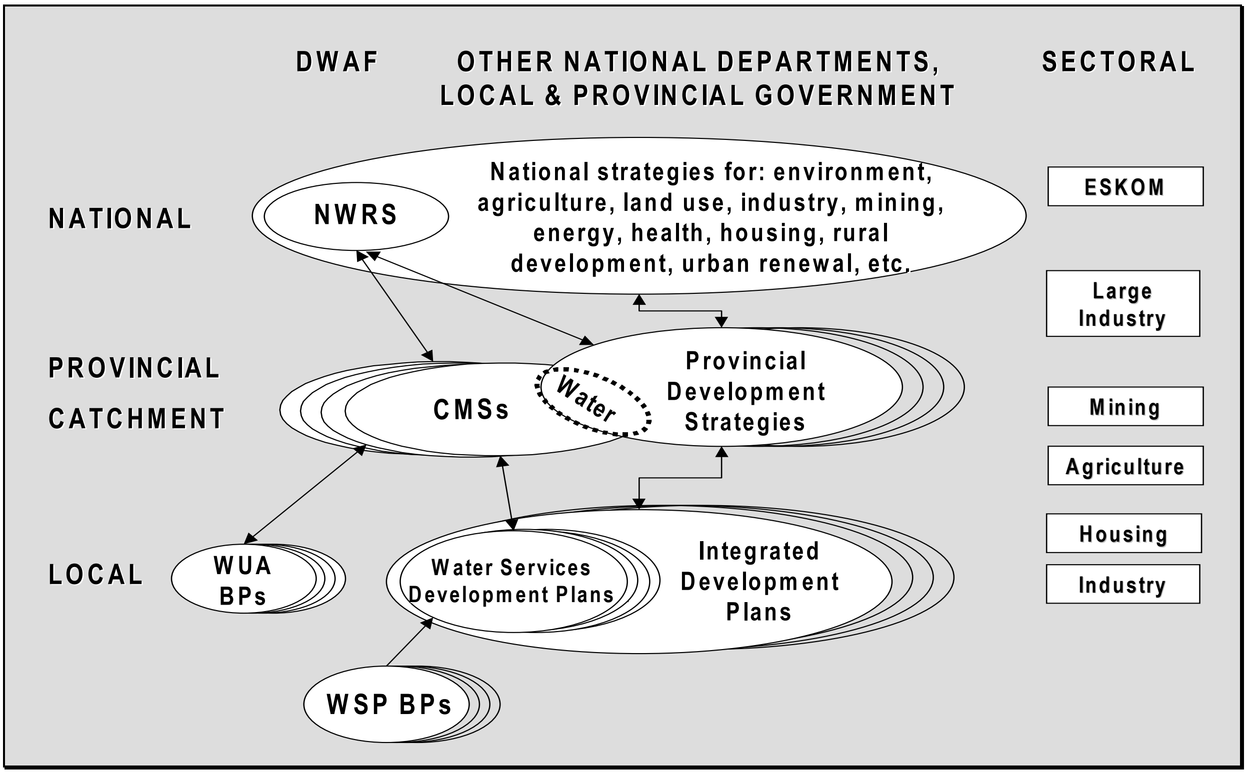
Another major feature of the NWA is decentralisation of water management. Water management will be implemented through decentralised institutions such as Catchment Management Agencies and Committees (CMA), Water Users' Associations (WUA), etc. These institutions will be in charge of local negotiations and the decision-making processes regarding resource allocation among stakeholders. Finally, protective measures have been introduced to secure water allocation for basic human needs and ecological and development purposes (the concept of the reserve).

Social development, economic growth, ecological integrity and equal access to water remain key objectives of the new water resource management legislation. The above mentioned institutions are currently being established at regional and local level, emphasizing a largely decentralized and participatory approach to water resource management. Such radical institutional changes however, require a long time horizon to implement. Therefore existing water rights will remain in place until the new water legislation is fully implemented.

The National Water Resource Strategy (NWRS) is the implementation vehicle for the NWA and provides the legal framework for the future management of water resources in South Africa (DWAF, 2002). The main objective of the NWRS is to match and balance water demand with water supply in accordance with the sustainability, equity and efficiency objectives of the NWA.

The institutional and organisational framework for water management and planning is provided in the diagram below.

Diagram III: Institutional Framework for Water Management



Source: NWRS.

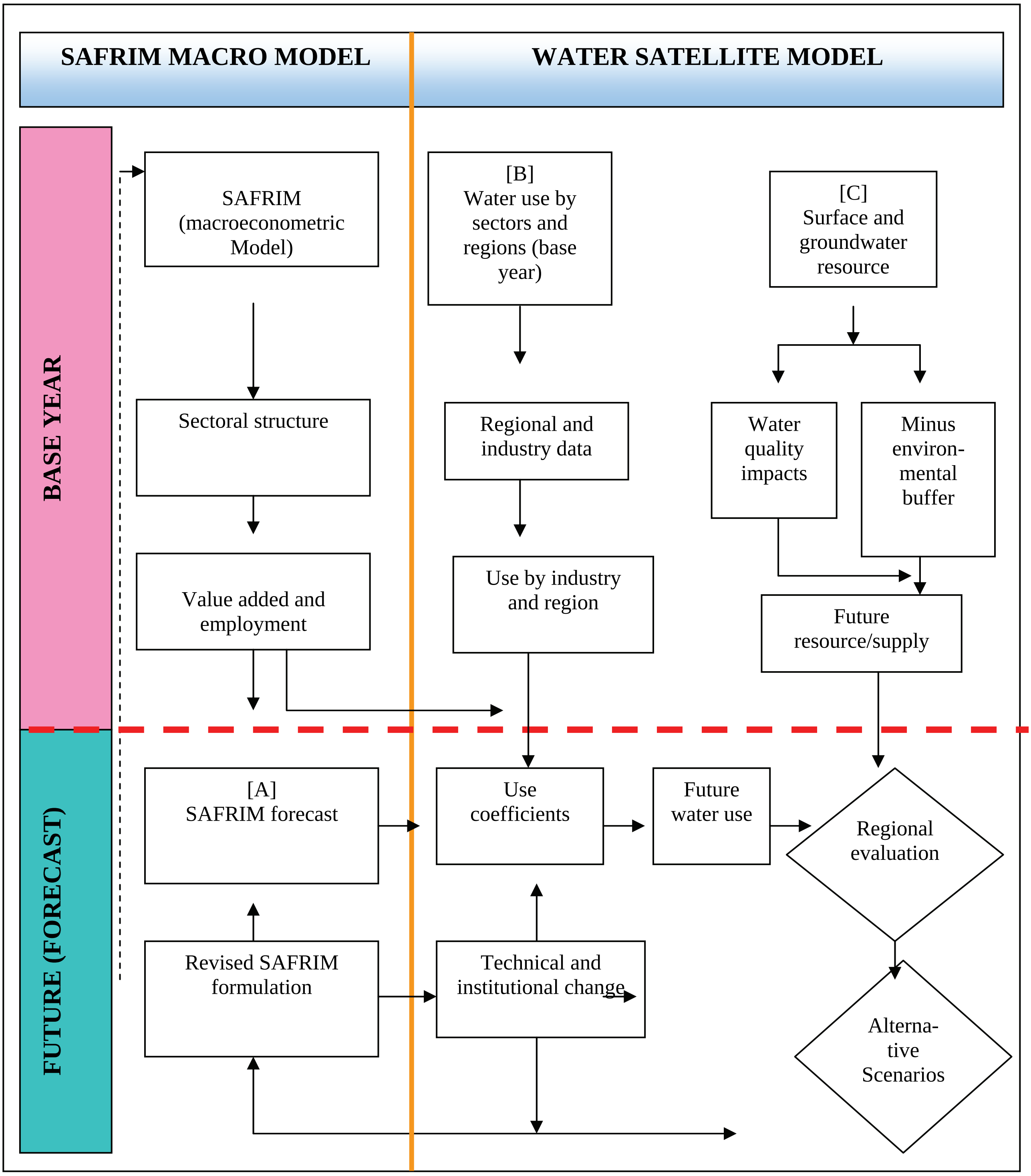
3.3 The South African Water Satellite Model

3.3.1 Broad Outline

In line with international practice in modelling the water sector as a functional element of the economy, the water sector is functionally linked to a macroeconometric model, as was done in Australia. The main reasons for doing this of a practical nature, i.e. when incorporating a number of sectors into a macroeconometric model, all sorts of statistical/economic problems can ensue, and when disaggregating sectors to the detailed level required, solving the model's equations simultaneously becomes progressively more difficult.

In view of this, it was decided that the SAFRIM-/INFORUM macroeconometric model (which is already sectorally based) would be linked to a Water Satellite Model (WSM) in the same way as in the Australian exercise. The South African system is presented in the diagram below.

Diagram IV: DIAGRAM of SAFRIM linked to the Water Satellite Model



A brief description of the structure of the South African WSM and how the SAFRIM sectoral production outcomes serve as its main drivers is provided in the following paragraphs. The model itself, in technical guise, is shown in the diagram below, whilst the actual coefficients for each equation are given in Deliverable 7, Annexure 3.

Diagram V: Theoretical Structure of SAFRIM Water Satellite Model

No	SAFRIM Sectoral Classification		A α = Unit use/Intercept (Water coefficients)		B β = Slope (β = (ε x α)) ε = elasticity		C Driver	D Source	
	TOTAL WATER USE	=	TOTAL AGRICULTURE	+	FISHERIES + MINING	+	TOTAL MANUFACTURING	+ TERTIARY SECTOR +	PARKS + HOUSEHOLDS
	TOTAL AGRICULTURE	=	IRRIGATION	+	LIVESTOCK	+	AFFORESTATION		
	IRRIGATION	=	SURFACE WATER	+	GROUND WATER				
IRRIGATION – SURFACE WATER			Intercept:average use / hectares						
1	Cereals	= (	α1	+	β1 * ΔP	) *	Hectares	Exogeneous	
2	Fodder & Grazing	= (	α2	+	β2 * ΔP	) *	Hectares	Exogeneous	
3	Cotton	= (	α3	+	β3 * ΔP	) *	Hectares	Exogeneous	
4	Tobacco	= (	α4	+	β4 * ΔP	) *	Hectares	Exogeneous	
5	Sugar Cane	= (	α5	+	β5 * ΔP	) *	Hectares	Exogeneous	
6	Citrus	= (	α6	+	β6 * ΔP	) *	Hectares	Exogeneous	
7	Sub-Tropical Fruit	= (	α7	+	β7 * ΔP	) *	Hectares	Exogeneous	
8	Deciduos Fruit	= (	α8	+	β8 * ΔP	) *	Hectares	Exogeneous	
9	Nuts	= (	α9	+	β9 * ΔP	) *	Hectares	Exogeneous	
10	Grapes	= (	α10	+	β10 * ΔP	) *	Hectares	Exogeneous	
11	Horticulture	= (	α11	+	β11 * ΔP	) *	Hectares	Exogeneous	
LIVESTOCK & GAME – SURFACE WATER			Intercept:average use / LSU						
12	Livestock	= (	α12	+	β12 * ΔP	) *	LSU population	Exogeneous	
13	Game	= (	α13	+	β13 * ΔP	) *	LSU population	Exogeneous	
14	AFFORESTATION & ALIEN PLANTS	= (	α14 Intercept:average use / hectares	+	β14 * ΔP	) *	Hectares	Exogeneous	
15	FISHERIES	= (	α15	+	β15 * ΔP	) *	Population	Exogeneous	
MINING			Intercept:average use / Production						
16	Coal Mining	= (	α16	+	β16 * ΔP	) *	Production	INFORUM	
17	Gold & Uranium Ore Mining	= (	α17	+	β17 * ΔP	) *	Production	INFORUM	
18	Other Mining	= (	α18	+	β18 * ΔP	) *	Production	INFORUM	
TOTAL MANUFACTURING			Intercept:average use / Production						
19	Food	= (	α19	+	β19 * ΔP	) *	Production	INFORUM	
20	Beverages	= (	α20	+	β20 * ΔP	) *	Production	INFORUM	
21	Tobacco	= (	α21	+	β21 * ΔP	) *	Production	INFORUM	
22	Textiles	= (	α22	+	β22 * ΔP	) *	Production	INFORUM	
23	Wearing Apparel	= (	α23	+	β23 * ΔP	) *	Production	INFORUM	
24	Leather & Leather Products	= (	α24	+	β24 * ΔP	) *	Production	INFORUM	
25	Footwear	= (	α25	+	β25 * ΔP	) *	Production	INFORUM	
26	Wood & Wood Products	= (	α26	+	β26 * ΔP	) *	Production	INFORUM	
27	Paper	= (	α27	+	β27 * ΔP	) *	Production	INFORUM	
28	Paper Products	= (	α28	+	β28 * ΔP	) *	Production	INFORUM	
29	Printing & Publishing	= (	α29	+	β29 * ΔP	) *	Production	INFORUM	
30	Coke & Refined Petroleum	= (	α30	+	β30 * ΔP	) *	Production	INFORUM	
31	Basic Chemicals	= (	α31	+	β31 * ΔP	) *	Production	INFORUM	
32	Other Chemicals & Man -Made Fibres	= (	α32	+	β32 * ΔP	) *	Production	INFORUM	

33	Rubber Products	= (	α33	+	β33 * ΔP	) *	Production	INFORUM
34	Plastic Products	= (	α34	+	β34 * ΔP	) *	Production	INFORUM
35	Glass & Glass Products	= (	α35	+	β35 * ΔP	) *	Production	INFORUM
36	Non-Metallic Minerals	= (	α36	+	β36 * ΔP	) *	Production	INFORUM
37	Basic Iron & Steel	= (	α37	+	β37 * ΔP	) *	Production	INFORUM
38	Basic Non-Ferrous Metals	= (	α38	+	β38 * ΔP	) *	Production	INFORUM
39	Metal Products-excluding	= (	α39	+	β39 * ΔP	) *	Production	INFORUM
40	Machinery & Equipment	= (	α40	+	β40 * ΔP	) *	Production	INFORUM
41	Electrical Machinery Apparatus	= (	α41	+	β41 * ΔP	) *	Production	INFORUM
42	Television, Radio & Communication Equipment	= (	α42	+	β42 * ΔP	) *	Production	INFORUM
43	Professional & Scientific Accessories	= (	α43	+	β43 * ΔP	) *	Production	INFORUM
44	Motor Vehicles,Parts & Accessories	= (	α44	+	β44 * ΔP	) *	Production	INFORUM
45	Other Transport Equipment	= (	α45	+	β45 * ΔP	) *	Production	INFORUM
46	Furniture	= (	α46	+	β46 * ΔP	) *	Production	INFORUM
47	Other Manufacturing	= (	α47	+	β47 * ΔP	) *	Production	INFORUM
TERTIARY SECTOR			**Intercept:average use / Production**					
48	Electricity	= (	α48	+	β48 * ΔP	) *	Production	INFORUM
49	W ater Supply	= (	α49	+	β49 * ΔP	) *	Production	INFORUM
50	Building Construction	= (	α50	+	β50 * ΔP	) *	Production	INFORUM
51	Civil Engineering	= (	α51	+	β51 * ΔP	) *	Production	INFORUM
52	Wholesale Retail Trade	= (	α52	+	β52 * ΔP	) *	Production	INFORUM
53	Catering & Accommodation	= (	α53	+	β53 * ΔP	) *	Production	INFORUM
54	Transport & Storage	= (	α54	+	β54 * ΔP	) *	Production	INFORUM
55	Communication	= (	α55	+	β55 * ΔP	) *	Production	INFORUM
56	Finance & Insurance	= (	α56	+	β56 * ΔP	) *	Production	INFORUM
57	Business Services	= (	α57	+	β57 * ΔP	) *	Production	INFORUM
58	Medical,Dental & Veterinary	= (	α58	+	β58 * ΔP	) *	Production	INFORUM
59	Excluding Medical & Dental	= (	α59	+	β59 * ΔP	) *	Production	INFORUM
60	Other Producers	= (	α60	+	β60 * ΔP	) *	Production	INFORUM
61	General Government	= (	α61	+	β61 * ΔP	) *	Production	INFORUM
62	**PARKS**	= (	α62 **Intercept:average use per capita**	+	β62 * ΔP	) *	Population	
HOUSEHOLDS			**Intercept:average use per capita**	+				
63	High Income	= (	α63	+	β63 * ΔP	) *	Population	INFORUM
64	Low Income	= (	α64	+	β64 * ΔP	) *	Population	INFORUM
65	Rural	= (	α65	+	β65 * ΔP	) *	Population	INFORUM
WATER RETURNED			**IRRIGATION WATER**	+	**WASTE WATER UNTREATED**	+	**OTHER**	
	Irrigation water	= (	fixed coefficients					
	Waste water untreated	= (	fixed coefficients					
	Other	= (	fixed coefficients					

3.3.2 System Dynamics of the WSM Model

A unique system dynamics model for water was constructed for the Vaal Catchment Area. This model provides useful information, especially in the area of demand/price relationships for each of the main water use categories.

This system dynamics model was specifically developed to simulate a market clearing process, taking into account supply and use structures. The classification of user categories distinguished in the model is, to a large extent, consistent with those used in WRC Report No. 990/1/03, which covers the Vaal River Catchment Area. This classification serves the needs of the present study well.

Water demand curves were developed for each of the demand categories from which price elasticities could be derived. Mathematically the demand curve can be expressed as follows:

$$D = [a + b(\Delta T)]C$$

Where

D	=	Total use for a category
a	=	Average use per user unit
b	=	Change in unit use due to a given tariff change (price elasticity)
ΔT	=	Change in water tariff
C	=	Total number of user units (driver/exogenous variable)

The figure below illustrates the demand curve for heavy industry derived in this Vaal Catchment Area study – for the purposes of this study, it was assumed that the Vaal River Catchment Area coincides with the VWMA. The price elasticities of demand for the main user groups were calculated in a similar study for the Vaal River Catchment. .

Figure III: Demand Curve: Heavy Industry

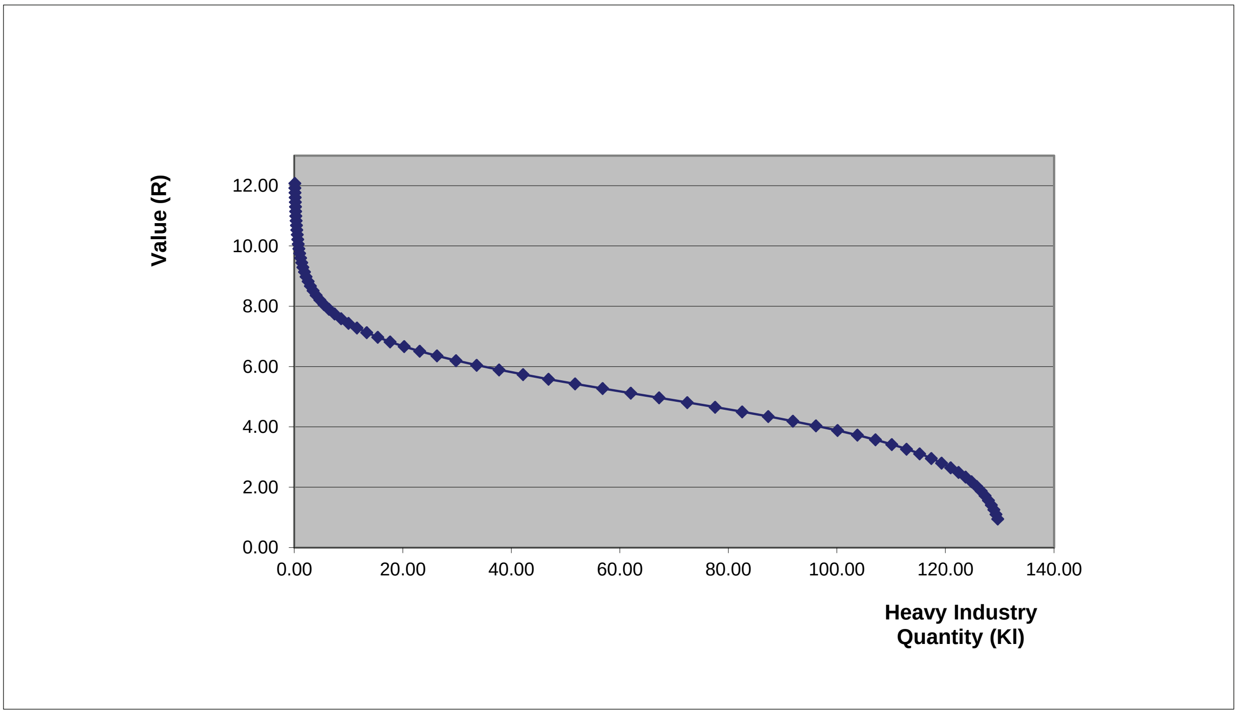


Figure IV: Water Use Classification per Main Users

1.	**MUNICIPAL USE**	* **Households (Domestic)**	• **High Income** **- Indoor** **- Outdoor** • **Low Income** **- Indoor** **- Outdoor**
		* **Light Industry** * **Parks**	
2.	**IRRIGATION USE**	* **Controlled Irrigation** * **Uncontrolled Irrigation**	
3.	**AFFORESTATION ****		
4.	**ELECTRICITY USE**		
5.	**HEAVY INDUSTRY USE**		
6.	**ECOLOGY**		
7.	**TRANSFERS OUT – OLIFANTS**		
8 = sum 1-7	**TOTAL USE: SURFACE WATER**		
9.	**TOTAL USE: GROUNDWATER**	* **Municipal (boreholes) **** * **Irrigation (boreholes) ****	
8+9	**TOTAL USE**		

** contra entries

3.3.3 Data Requirements and Regional Perspective

- **Water Balance**

Before future water demand/supply projections can be made with the WSM, it is important to establish the water supply and demand balance (both nationally and regionally/catchment wise) for the model's base year.

- **Water Coefficients**

Water coefficients reflect, in volume terms, the amount of water used/consumed per unit of sectoral production, or per capita in the case of human needs. One can also use various other norms and criteria, for example hectares irrigated, different water needs per type of crops, etc in establishing water coefficients. These coefficients obviously represent the outcome of various forces, i.e. technology; engineering; economic; prices; supply etc.

- **Price/Demand Curves/Institutional Aspects**

In South Africa, water tariffs (prices) have been regulated by government due to the fact that it has total control over the supply of primary water resources. However, the new NWRS provides for a movement towards giving more recognition to the role of demand management in terms of which the price mechanism (tariff) will be allowed to influence demand behaviour in favour of the more economic use of water.

It is necessary to obtain reliable information on all three levels distinguished above for the WSM to function effectively.

3.3.3.1 Data Requirements

- Water Balance

As was the case in the Australian exercise, use was made of the South African Water Resource Accounts (WRA) that are available for the country as a whole, and for the 19 catchment areas to compile a “water balance” for the base year of the model. This involved gathering information from the use, supply, and asset accounts for water on a sectoral basis.

A typical selection of water supply and water use components that are contained in the water accounts are as follows:

- Water Supply Components
  - Net Annual Run Off.
  - Dam storage and yields.
  - Transfers in.
  - Return flows.
  - Surface and/or groundwater.

- Water Use Sectors
  - Municipal use.
  - Irrigation use.
  - Afforestation use.
  - Electricity use.
  - Heavy Industry use.

More detailed information of the data sources that are available to populate the macroeconometric and WSM models is presented in Annexure 2.

3.3.4 The Modelling Approach

The manner in which water is handled in the SAFRIM/WSM model for forecasting purposes does not differ materially from the Australian study. However, there is one major difference in that the SAFRIM model is superior in terms of its dynamism and bottom-up approach as compared to the relative static CGE model used in the Australian study.

The following chapter describes how the overall modeling system is validated in terms of its ability to estimate actual water demand developments, as well as its ability to forecast possible future developments. In addition, this chapter also describes the impacts of a number of water policy interventions on the South African economy with the help of the overall modeling system.

CHAPTER 4 - DEMONSTRATION OF THE ANALYTICAL CAPABILITIES OF THE INTEGRATED MODELLING SYSTEM IN THE SOUTH AFRICAN CONTEXT

4.1 Validation of the SAFRIM/WSM Modelling System under South African Conditions

The process of testing and validating the performance of the SAFRIM/WSM model in terms of its forecasting and policy simulation capabilities has been achieved with the use of a few scenarios. Normally, macroeconometric models are validated by testing their ability to simulate actual or historical developments in the economy where the outcomes are known.

In the case of SAFRIM macroeconometric model, it has been demonstrated that it is capable of simulating actual developments within acceptable limits (see Deliverable 6, Annexures B1-C). However, validating the WSM model has proved to be more difficult as a result of the fact that annual historical water demand figures (either in volume or financial terms) are not available in South Africa on either a national, sectoral or regional levels. This makes it well nigh impossible to perform the necessary econometric validation tests on the outputs of the WSM.

Nevertheless, it was decided that some form of testing had to be done in order to provide a reasonable degree of certainty that the calculated sectoral water demand figures are within acceptable ranges.

4.2 Validation of the Water Satellite Model

Validation of the WSM has been conducted over two rounds, for both the national economy, and for the VWMA.

The first round validation exercise involved the “activation” of the WSM by feeding it with historical, actually observed, values for the drivers, as well as some other real exogenous variables such as ‘elasticities’ of water demand over the 2000-2006 period – note that sectoral production serves as the driver for all of the sectors except for “Agriculture” and “Forestry”, where hectares have been used; and for households, where “Population” is used as the driver. The resultant water demand estimates per sector over this period provided by the model are then regarded as the “benchmark” water demand figures that are used as a substitute for the non-existent actual figures.

The second round of this validation exercise involved a repetition of the first round, with sectoral production estimates now being derived from SAFRIM as the major drivers of the WSM.

A summary of the exogenous variables and the different types of drivers used in both the first and second rounds of the validation exercise are provided in the table below.

Table X: Selection of Drivers used to Run WSM (2000-2006)

	A *Water coefficients*	***B*** *Elasticities*	***AT*** *Tariff Changes (p.a.)*	***ΔC*** *(number of users)*
Irrigation	0.0077	-0.011518	0.2%	Hectares
Agriculture				Hectares
Forestry	0.00032	0.00	0.2%	Hectares
Livestock	45	0.00	0.2%	Stock population
Households				Population
High	101.8	-0.35	0.9%	
Low	20.3	-1.12	0.9%	
Rural	20.3	-0.12	0.9%	
Mining		-0.01589	0.9%	Production
Manufacturing		-0.01589	0.9%	Production
Electricity and water supply	0.00140	-0.00022	0.9%	
Tertiary sector		-0.01436	0.9%	Production
Parks	74.64	-0.91	0.9%	Hectares

Source: Detailed Water Satellite Model, Deliverable 7, Annexure 3.1.

National Level Results

Water demand figures for the 7 main user groups and the economy as a whole as calculated by the WSM, using historical and estimated sectoral production for the period 2000 to 2006, are given in Table XI and Table XII respectively. What is noticeable here is that, with the exception of the tertiary sector, all of the sectors' water demand growth rates were below that of the national economy's GDP growth.

In relative terms, it is also important to note that total water demand growth (2.9% p.a.) comprises ±70% of GDP growth (4.1% p.a.). This is in line with international experience (in Australia this ratio amounted to 46%). However, the relative slower water demand growth can be largely explained by slow growth in irrigation's and park's water demand, which accounts for more than 50% of water demand in the South African economy.

From a policy perspective, these figures are important, especially when looking forward and considering measures to reduce the "water intensity" of the economy.

Vaal Water Management Area Results

Table XIII provides a summary of estimated water demand figures for the 7 main user groups in the VWMA for 2000 to 2006, as calculated by the WSM, . From this table, it is evident that total water demand growth over the period is 2.05%. This is quite interesting in that water demand in this catchment is growing at a slower pace than for the economy as a whole. This is largely due to the unique sectoral demand structure of the Vaal Catchment Area as compared to that of the economy as a whole. Over time, the VWMA has been characterised by a decrease in gold mining, by households moving to smaller stands, and by an irrigation sector that is controlled by Government. This aspect will be reconfirmed when using the models to forecast future water demand for this region (see next section).

Table XI: Summary of Total Estimated Water Demand for the Main Sectors of the South African Economy, 2000-2006 (Million m^3)

	2000	2001	2002	2003	2004	2005	2006	Average annual growth rate	GDP average growth rate	Deviation
IRRIGATION	7 229.77	7 386.41	7 567.63	7 7772.33	7 999.93	8 250.13	8 522.88	2.78%		-1.32%
MINING	281.98	280.99	282.35	297.96	310.35	339.61	343.28	3.15%		-0.95%
LIGHT MANUFACTURING	214.61	217.09	228.25	237.32	254.02	278.17	277.93	4.42%		0.32%
HEAVY MANUFACTURING	406.15	412.90	441.07	462.40	466.61	527.05	525.28	4.44%		0.34%
TERTIARY	1 917.20	1 924.30	1 980.04	2 226.23	2 382.81	2 537.44	2 587.48	4.78%		0.68%
PARKS	243.43	247.10	252.71	258.54	264.51	270.61	276.86	2.17%		
HOUSEHOLDS	1 985.63	2 023.57	2 070.28	2 118.06	2 166.94	2 216.95	2 268.12	2.24%	5.11%	-2.78%
TOTAL RSA ECONOMY	13 531.09	13 745.91	14 077.66	14 630.23	15 105.01	15 682.67	16 067.82	2.91%	4.10%	

Table XII: Summary of "Benchmark" Sectoral and National Water Demand, 2000-2006 (Million m^3)

	2000	2001	2002	2003	2004	2005	2006	Average annual growth rate	GDP average growth rate	Deviation
IRRIGATION	7 229.77	7 386.41	7 567.63	7 7772.33	7 999.93	8 250.13	8 522.88	2.78%	4.10	-1.32%
MINING	275.86	277.06	280.74	292.57	301.84	309.68	307.66	1.95%	4.10	-2.15%
LIGHT MANUFACTURING	204.30	210.32	225.77	228.90	240.88	250.94	262.89	3.49%	4.10	-0.61%
HEAVY MANUFACTURING	390.45	402.63	436.81	448.08	445.80	468.24	490.55	3.07%	4.10	-1.02%
TERTIARY	1 824.16	1 876.94	1 961.93	2 161.50	2 284.66	2 369.83	2 477.10	4.29%	4.10	0.19%
PARKS	243.43	247.10	252.71	258.54	264.51	270.61	276.86	2.17%	4.10	
HOUSEHOLDS	1 985.63	2 023.57	2 070.28	2 118.06	2 166.94	2 216.95	2 268.12	2.24%	5.11%	-2.78%
TOTAL RSA ECONOMY	13 423.92	13 677.60	14 051.13	14 537.37	14 964.40	15 399.08	15 872.04	2.83%	4.10 %	-1.27%

Table XIII: Summary of Total Estimated Water Demand for the Main Sectors of the Vaal Water Management Area, 2000-2006 (Million m^3)

	2000	2001	2002	2003	2004	2005	2006	Average annual growth rate
IRRIGATION	797.64	816.31	836.85	859.21	883.40	909.44	937.36	2.73%
MINING	35.68	34.53	33.42	32.34	31.30	30.29	29.32	-3.22%
LIGHT MANUFACTURING	16.25	16.73	17.23	17.75	18.28	18.83	19.39	2.99%
HEAVY MANUFACTURING	141.91	146.13	150.51	155.01	159.65	164.43	169.35	2.99%
TERTIARY	167.16	172.60	178.30	184.28	190.57	197.17	204.11	3.38%
PARKS	13.12	13.20	13.39	13.58	13.78	13.98	14.18	1.30%
HOUSEHOLDS	799.78	806.89	818.53	830.33	842.30	854.45	866.77	1.35%
TOTAL VMA	2 073.90	2 108.23	2 149.61	2 193.58	2 240.21	2 289.61	2 341.94	2.05%

4.3 The Importance of Water to the South African Economy

The contribution of water to the South African economy has been the subject of several studies in the past, for example, see Nieuwoudt, Backeberg and Du Plessis, 2004, which produced useful information on the methodology to determine the contribution of water to the economy.

There are of course various approaches to measuring the contribution of water to the economy. The most popular approach is to determine the economic value of water in its various demand applications. Based on economic theory, the value of water (and, for that matter, any other commodity) for a private consumer can be quantified on two levels, viz.:

- The total value thereof; and
- The marginal value (utility) as reflected by the price.

The economic value of water per sector, quantified in some way, is generally used in local and international studies to establish the contribution of water to the economy. However, it is not easy to find a singularly acceptable method of determining the contribution of water to the economy. In the South African situation, for example, the contribution of the water sector to GDP is rather small (0.4%), and, as such, this measure cannot be regarded as an indication of the sector's strategic importance.

In order to overcome this problem in this stud , use has been made of the so-called multiplier concept to demonstrate, in quantitative terms, the levels of production that water is supposed to sustain in the various sectors – for the purpose of this study, water's contribution to the consumer's surplus will not be considered.

The calculation of water multipliers, i.e. the total increase in sectoral production, value added, employment, etc that results from a unit increase in water input (i.e. per m^3) should adequately demonstrate the importance of water's role in the economy. In this study, SAFRIM, coupled with the WSM, has been used to calculate water multipliers that express water's total contribution to various economic aggregates/indicators in the economy.

The Multiplier Concept

4.3.1 Input-Output (I-O) Based

The development of industry multipliers is mainly based on the pioneering work of Moore and Petersen (1955), and on the later contributions of Hirsch (1959) and Miernyk (1965).

Industry multipliers can effectively measure the influence of a change in an exogenous variable on the economy. This measurement can be refined further if the direct, indirect and induced effects of a change in the exogenous variable are taken into account. The measurement of the impact, by means of industry multipliers, can be done in terms of the changes in the value of production, income, the extent of employment, etc.

Industry multiplier analysis can be expanded vertically via the expansion of the levels of inter-linkage effects by consecutively taking into account the direct, indirect and induced effects. Horizontally, expansion can be achieved by measuring the impact in terms of an increasing diversity of economic quantities (i.e. production, income, employment, etc.).

The most elementary multiplier effect that can be measured with regard to individual sectors is the, so-called, Type I-industry multiplier. This kind of multiplier can be calculated for each sector by aggregating the elements in each column of the Leontief inverse. The main shortcoming of the Type I-industry multiplier in measuring the full extent of such an interaction effect is that the interaction process ceases after a limited number of rounds. However, the impact of changes beyond this interactive process can be effectively measured by applying a Type II-industry multiplier that is calculated from a transaction matrix that is closed with regard to households.

Using semi-closed I-O tables as the basis for a model, total (i.e. direct and indirect and induced) multipliers for the following range of multipliers can be calculated for water:

$$\text{Total Water Multipliers} = \frac{\text{Production (Rand millions)}}{\text{Water Consumption (Million m}^3\text{)}}$$

$$\text{Value Added/Water} = \frac{\text{Value added (Rand millions)}}{\text{Water Consumption (Million m}^3\text{)}}$$

$$\text{Labour/Water} = \frac{\text{Employment [numbers]}}{\text{Water Consumption (Million m}^3\text{)}}$$

$$\text{Capital/Water} = \frac{\text{Capital formation (Rand millions)}}{\text{Water Consumption (Million m}^3\text{)}}$$

$$\text{Households/Water} = \frac{\text{Household income (Rand millions)}}{\text{Water Consumption (Million m}^3\text{)}}$$

$$\text{Social Impacts/Water} = \frac{\text{Social impacts (numbers)}}{\text{Water Consumption (Million m}^3\text{)}}$$

In addition, the following standard economic multipliers can also be calculated:

Value Added Multipliers	=	<u>Value Added</u> Production
Labour Multipliers	=	Employment (Numbers)

Given the problem of homogeneity involved with calculating this kind of multiplier (Moore and Petersen 1955), together with the assumption of linear production and consumption functions inherent in this model, it is advisable to strive for something more representative of the actual, and more dynamic, interrelationships that exist in the economy. As a consequence, this study makes use of the capabilities of the SAFRM/WSM infrastructure to calculate water multipliers that will be more representative of the real situation.

SAFRIM/WSM Based Water Multipliers

4.3.2 Background

This section presents water multipliers that have been calculated using the integrated SAFRIM/WSM infrastructure in such a way that, wherever an exogenous impact is administered, its ultimate impact on endogenous economic aggregates (i.e. GDP, employment, investment, household consumption demand, etc) represents the total effect (i.e. direct, indirect and induced impacts).

The model has already demonstrated its ability to simulate actual developments over time (see Deliverable 7), and therefore, it can be regarded as being well equipped to calculate water multipliers in a more dynamic way as compared to a semi-closed system such as an I-O model.

4.3.2.1 Solving the model with changes in unit Water Consumption

The following steps were followed in preparing the model for the calculation of water multipliers:

Step 1: The SAFRIM produces, inter alia, 46 sectoral production figures as the endogenous outcomes of an exogenous change originating from any part of the model's configurations, e.g., changes in government expenditure, exports, etc.

A change in water demand per sector was proportionately aligned with a production increase/decrease. This ratio is directly based on the average water consumption per unit of production, or average water coefficients (see Deliverable 7, Annexure 3.1). For the purpose of this calculation, it is assumed that each sector receives in turn an additional one million m^3 of water, whilst keeping water demand of the other sectors in the economy constant.

Step 2: Having established the production value equivalent of one million m^3 of water consumed per sector, it is now possible to increase the final demand of each sector with this calculated amount. This demand vector is then fed into SAFRIM, which then in turn estimates the total increase in production per sector (46) flowing from this increase in water input per sector. It is important to emphasise again that the increase in production estimated by the model encompass the total (i.e. direct, indirect and induced) impact of an increase in water consumption.

Step 3: The third, and crucial step, is to use these resulting production impact figures to "shock" the WSM. As is well-known by now, this WSM consists of 65 sectors, and that agriculture is "driven" by the number of hectares irrigated. As such, the production figure derived in step 2 have to be converted into hectares in order to activate that part of the model. Ultimately, the WSM provides the total water consumption per sector that is associated with a one million m^3 increase in water consumption per sector.

Step 4: Lastly, the results of steps 2 and 3 are divided into one another to provide a Water Multiplier as such – i.e. the amount of GDP, employment, investment and household income per (additional) cubic meter of water consumed (this can, to some extent, be construed as a crude measure of water's marginal productivity)

The detailed results of this entire exercise are provided in Annexure 1 of Deliverable 8, and are summarised in the table below for the main sectors (excluding households). The table below provides an interesting picture of water's contribution and involvement in the South African economy.

Table XIV: Weighted Average Multipliers for the main sectors (Rand per m^3 Water)

No	*SAFRIM Sectoral Classification*	*GDP*	*Number of employees*	*Investment*	*Household Income*
		Weighted Average	*Weighted Average*	*Weighted Average*	*Weighted Average*
1	Agriculture	14	204	2	11
2	Coal Mining	110	883	20	73
	Gold & Uranium Ore Mining	90	942	16	57
	Other Mining	96	761	19	62
3	Secondary Sector	84	758	15	66
4	Tertiary Sector	106	951	18	84
	Total economy	95	847	17	74

4.3.2.2 Summary of the estimated water multipliers

- GDP

As one would expect, agriculture shows a very low set of multipliers as compared to any other sector. To understand this, one must remember that irrigation agriculture is combined with the rest of the agricultural sector (i.e. dryland agriculture) in SAFRIM, and irrigation agriculture only contribute ±30% to total agricultural GDP in 2006. Consequently, the fact that irrigation agriculture's average contribution to GDP per unit of water consumed is higher than that of the non-irrigation part of agriculture still does not have a significant impact on the overall figure.

- Labour (Number of employees)

With the exception of agriculture, the weighted average multipliers of the various sectors do not differ materially from each other

- Investment

With the exception of agriculture, the weighted average multipliers of the various sectors do not differ materially from each other.

- Household Consumer Demand

Once again, the data shows that agriculture's figure of R11 per m^3 is well below the economy's average, which is an indication of agriculture's weak backward linkages and it's much lower than average GDP and labour multipliers. In contrast, the tertiary sector has an HHC figure of R84 per m^3 water used. The reason for the tertiary sector being so high is its high GDP (income) and employment multipliers, which give rise to strong backward linkages on the household income side and, ultimately, on consumer expenditure.

4.4 Effect of Water on the Economy – Scenario Setting

4.4.1 Background

Scenario assessment, with the help of an appropriate econometric model, is one way of demonstrating the importance/contribution that water can make to the economy in quantitative terms. A large part of the Deliverable 8 report was devoted to this aspect, which, to a large extent, demonstrates the forecasting and policy impact analysis capabilities of the modelling system.

A number of local and international scenario exercises were discussed in Chapters 4 to 6 of the Deliverable 2 report, especially with regard to utilising various analytical instruments such as macroeconometric models of different kinds, i.e. linear programming coupled with I-O tables, etc.

Based on these, and local experiences, the project team have drawn up a so-called 'standard template' that reflects generic information requirements for scenario building with econometric models (see Diagram 2, Deliverable 2).

For illustrative purposes three scenarios were formulated and analysed in this study.

Scenario 1: Current Economic Impact of Water Intensive Sectors, 2006

In this scenario, the immediate effect on the economy is calculated when the water intensive sectors stop production due to a total water cut-off. This scenario will give, in very broad terms, the size of the contribution of water to the economy via the water intensive sectors. Water intensive sectors in the South African economy are ranked by order of their water use as follows:

- Irrigation agriculture.
- Coal mining.
- Gold and uranium mining.
- Other mining.
- Leather and leather products.
- Paper and paper products.
- Basic chemicals.
- Basic iron and steel.
- Basic non-ferrous metals.

A further aim of this scenario is to estimate what the cost to the economy will be (in terms of lost income, employment, etc.) if these nine water intensive sectors were forced to stop production because of a water shortage, the idea being to demonstrate the impact on the economy of a severe curtailment of water supply to selected sectors.

Although somewhat unrealistic, this assumption has the advantage of highlighting the total (direct, indirect and induced) importance of water to the economy due to sectoral interdependencies. The detailed results of this exercise are given in the table below.

Table XV: Scenario 1, Estimate of the 'Opportunity Cost' of Water in Water Intensive Sectors, 2006

No	***SAFRIM Sectoral Classification***			***Total Aggregate p.a.***	
			With	***Without***	***%***
			Water	***Water***	***Impact***
1	GDP	Rand millions	1078297.30	600930.60	-44.27
2	Labour	Numbers	10115807	8579070	-15.00
3	Investment	Rand millions	186491.90	141119.00	-24.33
4	Household Final Demand	Rand millions	702865.80	629420.00	-10.45
5	Water	Million m^3	11809.00	8828.70	-25.24

The above table should be read with caution because of the assumption of linearity in the demand/supply relationships in production processes. Nevertheless, if these industries should cease production, close to 50% of national GDP can be lost. Even though employment will fall by (only) 15%, the impact on the nation would still be enormous.

Scenario 2: Future Economic Impact of Putting a Constraint on Water Intensive Sectors, 2006-2020

SAFRIM (and for that matter any model) loses its dynamism when it is forced into a situation such as the case in Scenario 1, which models a sudden catastrophe, as opposed to a more "normal" progression of developments that are usually associated with economic development over time. For this reason, it was decided to test the model's analytical abilities by capping the supply of water to the same water intensive sectors identified in the previous scenario at their base year (2006) water use levels.

The results of this scenario, as reported in Table XVI, suggest that limiting the supply of water to water intensive sectors only will produce a 2% p.a. reduction in the baseline water demand growth rate, which will, in turn, be accompanied by reductions in the following aggregates' growth rates:

- GDP growth rate is reduced by 0.73% p.a.
- Employment numbers are reduced by 0.82% p.a.
- Investment is reduced by 0.84% p.a.
- Household water demand is reduced by 0.76% p.a., and
- Water demand is reduced by ± 2.0% p.a.

The idea was not to recreate an exact response at enterprise level to such a targeted water restriction, because one can understand that each industry will respond in different ways, depending on their cost structures (average and marginal), as well as the demand curves for their own products, etc. The extent to which these industries can implement new water saving technologies has of course also not being considered. All these aspects and some more will of course play themselves out at an enterprise level, and will eventually determine commercial decisions involving the continuation of business, and at what levels financial viability can be achieved.

Therefore, the outcome of the above scenario must be viewed with caution, although impact dimensions can be regarded as possibly being at the extreme, and that the real outcome would be less than that modelled in this scenario.

Scenario 3: Putting a Future Water Constraint on Platinum Production, 2006-2020

The platinum sector is growing in importance relative to the national economy, and, like any mining sector, it is characterized by a very high level of water assurance. This scenario simulates the effect of a water constraint on the supply of water to this growing sector in order to estimate its absolute and marginal impacts on some important economic aggregates.

Bearing in mind the qualifications expressed in the previous scenario, an assumption was made that the water supply to the platinum industry is kept at its 2006 level. The effects of this assumption are presented in Table XVII. However, a cautionary note needs to be made at this point regarding the usefulness of these figures for interpretation purposes.

First of all, as was mentioned, the SAFRIM has not been deployed in full as the price/income and international sectors are still in the process of being refined. Furthermore, it should never be forgotten that water tariffs have in the past always been determined by the state. Consequently, it is very difficult to model the expected reaction of water users to drastic changes in either the supply of water, or tariff changes in the future. The question of the influence of technological changes in production processes due to significant changes in water costs have also not been addressed.

Table XVII suggests that constraining the platinum sector over time will not have a significant effect on certain economic aggregates. However, it must be kept in mind that the model has not been able to affect the impact on the RSA's balance of payments, which could ultimately lead to more significant negative results.

In addition, one should also not forget that, because the platinum industry is regionally concentrated, the impact should be much more severe in a regional context.

Table XVI: Scenario 2, Future Economic Impact of Implementing a Constraint on Water Intensive Sectors, 2006-2020

No	***SAFRIM Sectoral Classification***		***A***			***B***		
			Average Aggregate p.a. over period			***Growth p.a. over period (%)***		
			With Water	***Without Water***	***% Impact***	***With Water***	***Without Water***	***% Impact***
1	GDP	Rand millions	1271880.21	1194842.52	-6.06	2.63	1.87	-0.73
2	Labour	Numbers	11982156	11200517	-6.52	2.56	1.72	-0.82
3	Investment	Rand millions	220375.25	205969.21	-6.54	2.66	1.80	-0.84
4	Household Final Demand	Rand millions	824635.42	763799.69	-7.38	2.61	1.83	-0.76
5	Water	Million m^3	14827.23	13071.79	-11.84	2.51	0.55	-1.91

Table XVII: Scenario 3, Future Economic Impact of Implementing a Water Constraint on Platinum Production, 2006-2020

No	***SAFRIM Sectoral Classification***		***A***			***B***		
			Average Aggregate p.a.			***Growth p.a.***		
			With Water	***Constrains on Plat***	***% Impact***	***With Water***	***Constrains on Plat***	***% Impact***
1	GDP	Rand millions	1271880.21	1265378.95	-0.51	2.63	2.55	-0.08
2	Labour	Numbers	11982156	11960266	-0.18	2.56	2.53	-0.03
3	Investment	Rand millions	220375.25	218608.66	-0.80	2.66	2.52	-0.14
4	Household Final Demand	Rand millions	824635.42	826063.29	0.17	2.61	2.64	0.03
5	Water	Million m^3	14827.23	14812.45	-0.10	2.51	2.50	-0.01

4.4.1.1Future Economic Impacts of Different Policy Scenarios Pertaining to Water

Introduction – The Regional Perspective

The ultimate aim of this research study, as stipulated by the ToR, is to use the SAFRIM/WSM model framework to forecast water consumption on a regional level. Ideally, this would entail building a modelling system for each region, say nine in the SA situation, based on a set of WRAs each region. In addition, in order to "populate" the regional WSMs, price elasticities of water demand would be required for each region.

As can be deduced from all of the work that has gone before, this would not be an easy task in the South African context, mainly due to practical considerations such as the availability of data on a regional basis, including, more specifically, on a WMA level.

However, history has taught us that unit water demand per water user sector does not change much over the medium to longer term as water demand is determined by technology imperatives. As a result of these realities, it was agreed that, for the purposes of this study, the VWMA would be used to illustrate the power of the modelling system to forecast water demand growth in this area over the longer term.

The reasons for choosing the VWMA are rather obvious, viz. it is the largest area in South Africa in terms of economic activity, and the fact that a significant amount of research work on the water situation in this area has been undertaken provides vital data such as water resource accounts, price elasticities of water demand per major users, and even an econometric model for water demand. All of these outputs have proved useful in forecasting water demand with the SAFRIM/WSM modelling system.

The SAFRIM/WSM modelling system was used in Deliverables 7 and 8 to illustrate its analytical and forecasting capabilities. In Deliverable 7, an attempt was made to estimate the "actual" demand for water over the period 2000-2006, both nationally, and for the Vaal Catchment Area. The outcome of this exercise proved satisfactory, and provided enough evidence to endorse the forecasting and analytical attributes of the modelling system.

Incorporating a Regional Perspective into the SAFRIM/WSM Modelling System

A detailed exposition of the WSM was presented in Deliverable 6, including the general format of each equation and the sectoral classification of the VWSM. Water demand functions for the resulting 65 sectoral/industry divisions are consequently also distinguished for the VWMA

In this section, the focus will be on applying the model to the VWMA, i.e. the Upper, Lower and Middle Vaal areas.

4.4.2 Water Situation in Base Year

The table below provides a summary of total water use their water user group in the VWMA in 2000.

Table XVIII: Summary of Total Water Use per User Group: VWMA, 2000

Sector	*Water Use*	
	Mm^3	*Percentages*
Households: High Income	513	25%
Households: Low Income	270	13%
Households: Rural	17	0.8%
Parks	13	0.6%
Irrigation	798	38%
Livestock	102	5%
Forestry	0	0%
Light Industries: Manufacturing	16	0.8%
Heavy Industries: Manufacturing	142	7%
Light Industries: Tertiary Sector	71	3%
Mining	36	2%
Electricity	80	4%
Water Sector	16	0.8%
Total	2074	100%

Source: DWAF, ISP. 2005

It is important to note that irrigation still uses 30% of the water supplied to the VWMA. Urban water usage in the Upper Vaal (i.e. Gauteng) is by far the largest user, having to serve a highly diversified economy, as well as urbanised communities.

This table includes a sector referred to as the Water Sector. In view of the fact that the modelling approach is underpinned by an I-O framework, the water sector also interacts with itself. This water sector figure was calculated using a regional Social Accounting Matrix/IO table.

Table XIX: Total Water Use: Main Sub-Regions of the VWMA, 2000 (Million m^3)

	Middle Vaal	*Lower Vaal*	*Upper Vaal*	*Total*
Irrigation	159	526	114	800
Urban	93	68	635	796
Rural	32	44	43	119
Mining and Bulk	213	15	428	655
Power Generation	0	0	14	14
Afforestation	0	0	0	0
Water Sector				16
Total	497	653	1234	2700

Scenario Setting

4.4.2.1 Baseline Scenario

It is customary in the forecasting process to start off with a so-called “baseline scenario” against which the impact of assumed changes in policies and other socio-economic backdrops can be measured. The expected long-term growth rate, or growth potential, of any free market oriented economy can, in reality, be linked to the expected population growth rate, productivity improvements, and investment/savings rates.

In this particular instance, the “baseline” scenario would entail using the SAFRIM/WSM infrastructure to forecast the expected water demand in the VWSM area over the longer-term. This is regarded as the most likely outcome of future events, given the continuation of presently known policies and economic imperatives that will shape future developments.

When discussing the results of this baseline scenario, detail is given of the more important assumptions underlying the forecasts. The “baseline” scenario incorporates the following important assumptions:

National Economy

The National economy will grow at between 3-4% p.a. over the forecasting period, which is close to the historical long-term growth rate of the South African economy. The projected growth of the baseline scenario is based on the following assumptions:

- The projections of international trade, on a product basis, are supplied by the Bilateral Trade Model of the international INFORUM system. These projections form the basis for the assumptions made regarding future RSA imports and exports, which are assumed to be lower than in the previous few years. Taking into account the assumption of a slowdown in international trade, growth in RSA imports and exports will be between 4% and 5% respectively in real terms.

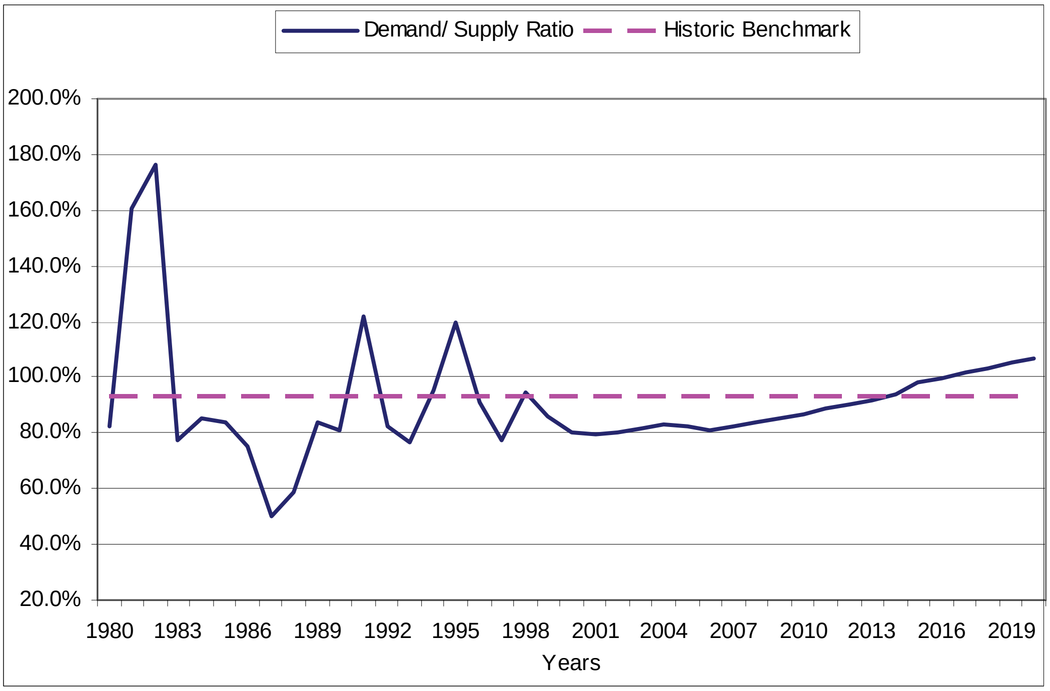
- Fixed investment will grow at around 6% p.a. Investment in electricity, road and water infrastructure is of paramount importance to support economic growth.
- Moderate government spending is a pre-requisite for sustainable growth. It is assumed that the government share will not increase over the programming period, which implies that it should not grow faster that 3-4% with respect to the national economy.
- Price stability should have a high priority over the programming period, which implies sound fiscal and monetary policy.

Water Supply and Use

- For forecasting purposes, an average annual rainfall has been assumed.
- All known current and future water schemes have been taken into account to forecast the future supply of water.
- Water for irrigation is dealt with exogenously in the system. No further expansion in irrigation is foreseen.
- Water demand for mining, manufacturing and the tertiary sectors are linked to the SAFRIM model, and are projected endogenously in the system.
- For modelling purposes, a ± 25% buffer supply has been assumed to ensure that no chronic cyclical shortages of water occur. This quantity is in line with official DWAF planning imperatives (2004), and it is also in line with the projected excess supply that will exist on average up until ± 2015 of the projection period.

The graph below illustrates the utilization level of water relative to supply over 1980-2020 for the baseline scenario.

Graph I: Baseline Scenario for the Water Demand-Supply Situation, 1980-2020



The graph shows that, even at the baseline economic growth rate, the water supply situation in the VWMA can show signs of tightening, starting in 2014.

4.4.2.2 High Growth Scenario

The South African economy has experienced accelerated economic growth over the past 10 years or so, with some years attaining a 5% (or higher) GDP growth rate. Government, through its Accelerated Shared Growth Initiative of South Africa (ASGISA) policy initiative, is in fact striving for a growth rate closer to 6% p.a. over the medium to long-term.

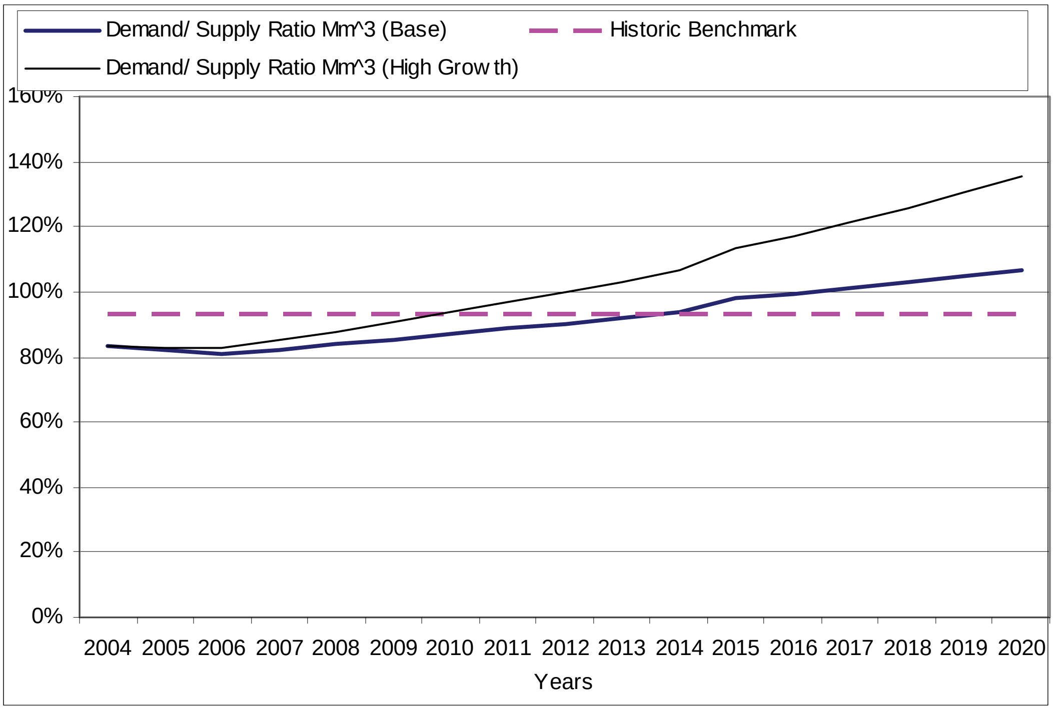
In view of the above, it was deemed appropriate to apply the modelling system to a high-growth scenario that suggests that, over the long term, the South African economy will in fact succeed in raising its performance levels above the historical benchmark. In effect, this indicates an improvement in export penetration of foreign markets, as well as a broadening and diversifying of the domestic economic base. Obviously, this pre-supposes the attainment of certain policy objectives, such as an adequate supply of skilled and semi-skilled labour, further improvement of economic infrastructure, etc. All of this assumes that the country's balance on the Current Account should not present insurmountable problems.

For purposes of this scenario, it was assumed that exports will grow much faster, and that imports will grow relatively slower, i.e. a growth rate of 6-7% for exports is needed to attain an overall growth of 6%; whilst to achieve a broadening and diversifying of the domestic economic base, imports should not grow at more than 5% in real terms.

To achieve these high objectives for imports and exports, additional support will have to be given to the private sector in terms of research and development, opening up of markets, and financial support in terms of lower interest rates and increased capital inflows. The rest of the economy (i.e. government spending, investment, etc.) will automatically follow with higher economic growth. However, sound general economic policy will still have to be maintained in order to keep a stable macroeconomic environment in place, which is a necessity for economic growth.

The graph below illustrates the impact that a GDP growth rate of 5% p.a. over the forecasting period (i.e. 2004-2020) produces on the demand for water in the VWSM. Given that irrigation hectares remain static, and that population growth is unchanged, the major acceleration in water demand will come from the manufacturing and services sectors. It is also apparent that, as compared to known future supply volumes, the water situation would become very tight, in all likelihood, 5-7 years in advance of the "Baseline" Scenario.

Graph II: Base Scenario Relative to High Growth Scenario: VWMA, 2004-2020



4.4.2.3 Effect of Outside Interventions on Water Demand

Following on from the above projections, as a logical progression, it was decided to use the model to demonstrate, in quantitative terms, what the effect of certain measures that are installed to ensure that water demand does not unduly outstrip supply would be on the economy of the VWMA. For this particular exercise, only two such interventions were entertained, viz.:

- A significantly "above average" increase in water tariffs; and
- Limiting the rate of growth of existing industries and new establishments in the VWMA.

As is well known by now, an important component of the WSM is its price/tariff element that measures the effect of water tariff changes on water demand. What is addressed here is the assumption of much higher than "average" tariff increases that are introduced to reduce water demand growth so that it is more in line with expected supply; or closer to the baseline outcomes. These above average tariff increases could be the forerunner of creating water markets, and water demand management.

Water users, especially those in the irrigation field, will be induced to value their water inputs more in line with their marginal cost/income ratios. Furthermore, these above average tariff increases could also lead to various outcomes at an enterprise level, such as the introduction of water saving technologies, or the selling of water rights to other more efficient water users (as was explained earlier in Scenario 2 above, this model, like all other macroeconometric models, is not equipped to operate at a micro, enterprise level).

Lastly, it is proposed to demonstrate, in more quantitative terms, the effect of limiting the growth of certain so-called "water intensive" industries on water demand on the one hand and on the economic growth of the region on the other.

(i) Water Tariff Increases

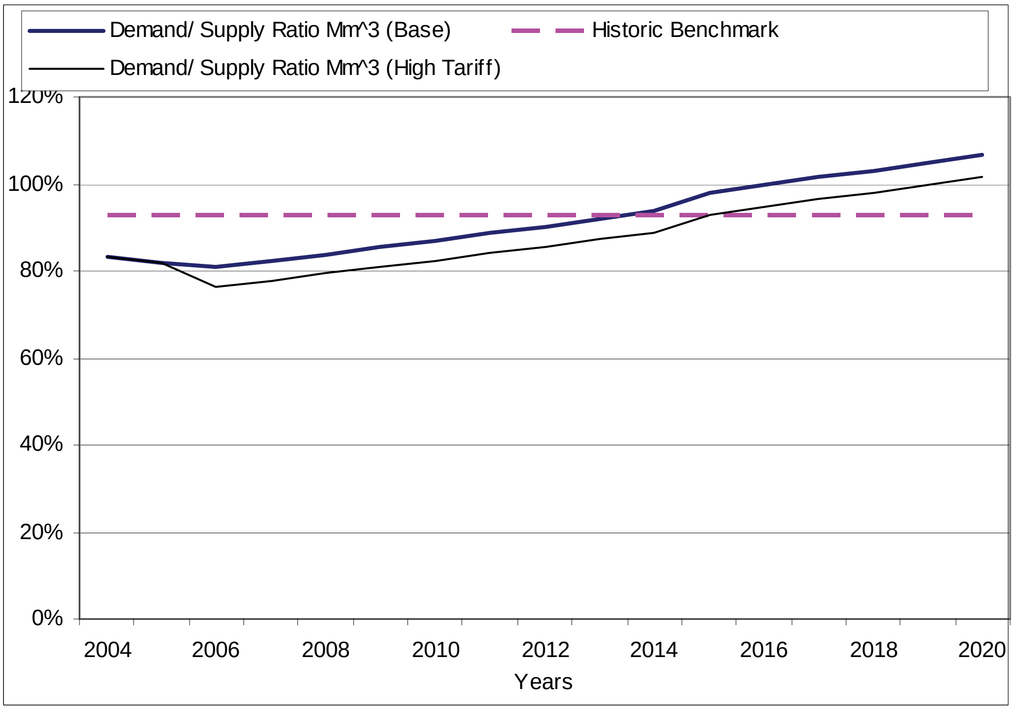
In both previous scenarios, the possibility of a water supply shortfall arises, especially towards the end of the forecasting period. The question now arises as to what kind of policy interventions would be necessary in order to bring the situation back to "normal", i.e. to more tolerable, "equilibrium" demand/supply positions.

In order to determine whether there is equilibrium, water use and supply is compared over the forecasting period. In the "Baseline" Scenario, it was assumed that the system is more or less balanced at minimum tariff increases that are equal to inflation. As such, any changes in supply or usage conditions from this departure point will disturb the "equilibrium" situation. In order to restore this balance, or bring it more into line, the water tariff is changed, which will result in a different water use composition.

In this section, the model is used to show how a 25% increase in water tariffs – over and above the "normal" price increases already incorporated in the "baseline scenario" – will affect water demand over the long-term. Obviously, water supply remains unchanged, as this can only be affected through capacity expansions that will not affect the situation materially before 2020.

The outcome of the major tariff increase is shown in the graph below. In short, achieving balance means limiting the baseline water demand growth to an average of 4.7%[10] p.a. over the forecasting period.

Graph III: Base Line Scenario Relative to High Tariff Scenario: VWMA, 2004-2020



The above graph indicates that an above average tariff increase does in fact postpone the point at which the demand curve moves above the average "equilibrium" position. The important thing to remember here is that, with higher water tariffs, it is possible to sustain a 3% GDP growth rate, but with lower levels of water consumption over the period in total.

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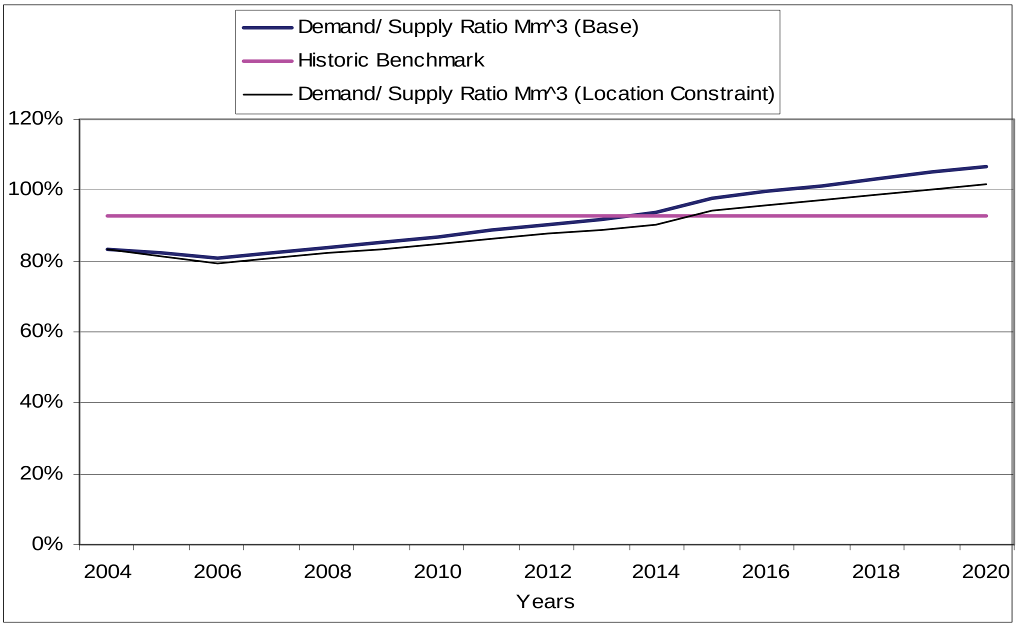
[10] $\left\{\left(\frac{3132}{3289}\right)-1\right\}$ x100

(ii) Location Constraint Scenario

At this early stage of the modelling and scenario analysis exercise, the conclusion can be made that, if one takes the forecasting/scenario outcomes for water demand presented above as given, tariff increases alone are not sufficient to bring the projected water shortage situation back to "equilibrium". Some other major dislocation that occurs in the economy as a whole will be necessary.

To illustrate this point, the model system has been used to demonstrate the impact on water demand over the long-term of the introduction of Government regulations that cause so-called "wet industries" in the VWMA to relocate (or to start new business ventures elsewhere) as of 2005[11]. This "draconian" and "deterministic" intervention has been selected only to illustrate how difficult it might be to actually bring water demand down to more acceptable levels, given the "failure" (or limited nature) of other measures. The graph below illustrates the outcome of this Location Constraint scenario.

Graph IV: Base Scenario Relative to Location Constraint Scenario: VWMA, 2004-2020



[11] It is accepted that it sounds absurd to start from 2005, which is already history, but due to historical data limitations the forecasting actually starts from 2005.

The graph above indicates that concentrating efforts on a few large water users only will not materially affect the demand situation. The results of this exercise are of the same magnitude as those of the 25% tariff increase scenario described above.

4.4.2.4 Summary

The following three tables provide a summary of the scenarios described above.

Table XX: Regional Economic Impact: Average p.a., 2005-2020 (Rand Million, Constant 2000 Prices)

	Standard Scenario	***Scenario 1 High Growth***	***Scenario 2 Water Tariff Increase***	***Scenario 3 Constraint of Location***
Economic Aggregates				
Water (Million m^3)	3 289	3 718	3 132	3 186
GDP (Rand Million)	408 255	518 804	408 255	396 776
Employment (Number)	3 728 023	4 735 363	3 728 023	3 554 059

Note: The price mechanism does not affect GDP and Employment at this stage, hence the impact is the same on both GDP and Employment.

Table XXI: Water Efficiency Criteria, 2005-2020 (Rand Million, Constant 2000 Prices)

	Standard Scenario (Level)	***Scenario 1 High Growth (Increment)***	***Scenario 2 Water Tariff Increase (Increment)***	***Scenario 3 Constraint of Location (Increment)***
Level Change of Economic Aggregate				
Water (Million m^3)	3 289	429	-157	-103
GDP (Rand Million)	408 255	110 549	n.a.	-11 480
Employment (Number)	3 728 023	1 007 340	n.a.	-173 964
Efficiency Criteria				
ΔGDP/ΔWater (ΔMm^3)		258	n.a.	112
ΔEmpl/ΔWater (ΔMm^3)		2 348	n.a.	1 697

Table XXII: Historic (2004) Levels and Forecasted (2020) Levels of Economic Aggregates: VWMA (Rand Million, Constant 2000 Prices)

	2004	***Standard Scenario 2020***	***Scenario 1 High Growth 2020***	***Scenario 2 Water Tariff Increase 2020***	***Scenario 3 Constraint of Location 2020***
Economic Aggregates					
Water (Million m^3)	2 920	3 744	4 742	3 559	3 569
GDP (Rand Million)	328 568	483 218	737 650	483 218	461 765
Employment (Number)	3 039 371	4 387 214	6 697 240	4 387 214	4 060 423

The above tables indicate that the excess demand situation tends to worsen "exponentially" towards the end of the forecasting period. In Tables XX and XXI (columns 2 and 3), one finds that the high growth water demand scenario exceeds the baseline scenario water demand by ±13%[12] on average, whilst Table XXII shows that, in 2020, water demand already exceeds supply by 27%[13] (these results are well illustrated in Graph II as well).

4.4.2.5 Conclusion

In Section 4.1, the question of validating the model's performance was approached at two levels. Firstly, the WSM was used to calculate the water demand in the South African economy for 65 sectors over the period 2000-2006. This was done by substituting actual production (so-called drivers) per sector into the WSM model, which then estimated "actual" water demand. Secondly, the exercise was repeated, but with the difference that actual production, as used in the previous exercise, was substituted by estimated production emanating from the SAFRIM model. Finally, a validation exercise was carried

[12] $\left\{\left(\frac{3718}{3289}\right)-1\right\}x100$

[13] $\left\{\left(\frac{4742}{3744}\right)-1\right\}x100$

out that compared the two sets of production figures with each other as they unfolded over time.

Water demand per sector was compared with the benchmark figures in order to test the validity of the more dynamic SAFRIM model's inputs into the WSM. The SAFRIM model showed excellent abilities to simulate important macroeconomic variables[14]. Its forecasts of production for 61 sectors were therefore used with confidence as major drivers of the WSM's demand function.

The ToR (see Deliverable 8) require that the consultants determine the contribution of water to the South African economy. Based on international and local research in this regard, it was decided to calculate so-called water multipliers with the use of SAFRIM/WSM modelling system in order to illustrate water's role in the economy. In addition, a number of water-based scenarios have been evaluated with the aid of the SAFRIM/WSM configuration to explain the role of water in more exact terms.

The overall conclusion is that South Africa still has some way to go in improving the productivity of water use in its economy. Obviously, this will follow as the economy moves towards maturity.

The final stage has been reached in Deliverable 9, where the analytical capabilities of the SAFRIM/WSM modelling system have once again been employed, this time to demonstrate the role of water in a regional context (i.e. in the VWMA). As part of this exercise, a number of scenarios have been developed and tested with the model. These indicate possible future water demand and supply developments in the VWMA, together with a demonstration of the possible impact on water demand and the economy of a number of policy interventions.

All in all, it has been possible to calculate an historical series of water demands for 65 sectors in the National economy and the VWMA that balanced with official water supply data for 2000.

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[14] The SAFRIM model did show some tendencies to overshoot a little but when approaching the end of the insample period. Further research should rectify this possible shortcoming.

Looking ahead, a certain degree of vigilance needs to be maintained by all parties concerned in constantly working towards improving the quality and quantity of data needed for the kind of economic analyses that are required for sound policy planning and strategic management in this field. This point is well illustrated by the exercises undertaken in this study.

CHAPTER 5 - CONCLUSIONS AND RECOMMENDATIONS

5.1 Appropriateness of an Integrated Modelling System

An important question now remains, viz. whether this major research effort into the theoretical/practical plausibility of building an appropriate macroeconometric model that can simulate the role of water in the South African economy, has been successful or not.

It is the contention of the authors that the ultimate outcome of the study proves beyond doubt that it was indeed a necessary and worthwhile exercise. Irrespective of the eventual model configuration that was recommended, the building and use of the model (in this case an IM model linked to a WSM) brings about the following benefits:

- Empirical economic models provide a bridge between the realm of pure theory and the real economic world.
- These models force analysts/policy makers to make their assumptions explicit as to how they believe the economy (should) work.
- Empirical models provide quantitative results from which the relative importance of certain assumptions (theoretical and practical) can be compared. Impact analysis via macroeconometric models provides the application of the well-known economic principle of trade-offs, i.e. providing systemised information that assists decision makers to attain the most economically viable and efficient outcomes.
- Lastly, a macroeconometric model does provide an indication of the total effect of a change in policy on the economy, i.e. direct, indirect and induced effects, which are often overlooked by policy makers.

To be sure, the IM/WSM framework devised and made operational through this project is not perfect. However, it does go a long way towards achieving the above mentioned benefits. The international literature survey has proved beyond doubt that the best model for any use is that model which has the characteristics that are the strongest in the areas that are most important to the analysis. It is believed that the IM/WSM model constructed in this study fulfils these requirements.

5.2 Important Results of the IM/WSM Application in a South African Context

As has been indicated before (and, in fact, continuously as the study developed), the process of model building forces analysts to come to grips with the complexities of the subject at hand, in this case, the role of water in the South African economy. By using the macroeconometric model developed in this study quantitative measurements of the importance of water in the South African economy has been measured through the use of sectoral multipliers and with scenario settings (see Deliverable 8).

Notwithstanding the first phase development status of the overall SAFRIM/WSM modelling framework, it has already demonstrated its usefulness to DWAF and other interested parties in implementing the NWRS (1998), and in achieving the following objectives:

- The introduction of effective water conservation and demand management policies (WC/WDM).
- Formulating and over-arching water pricing strategy in line with marginal cost/benefit ratios.
- The possibility of re-allocating water between lower and higher economic uses.
- Closely monitoring the impact of macro economic policies in the areas of taxation, monetary policy, international trade, redistribution of income, etc on sectoral and overall water demand.

Lastly, the IM/WSM framework has also demonstrated its ability to forecast water demand on a regional level (see Deliverable 9). This is a crucial outcome, considering the huge cost involved in water storage, transfer and distribution.

5.3 Recommendations

5.4 Responsibility for Model Operation

Keeping the SAFRIM/WSM modelling system operational will require a number of pertinent actions.

The major problem of the modelling system is that the software that drive the model is based on C++ programming, which, to a certain extent, is not widely used, nor is it user-friendly. The model is vast and very data intensive. Consequently, no other software system is available that will allow the model to be easily transferred from one institution to another. In view of this major constraint it is **recommended** that, until further notice, the model be situated at Conningarth Economists, which has the expertise to operate and maintain it.

5.5 Data Bases

As already indicated above, the SAFRIM, and its WSM satellite element, is data intensive. In order to keep the model operational, it is important that its associated data bases be kept up-to-date on a continuous basis – it is important to highlight the fact that most of the data underpinning SAFRIM is readily available from the following organizations:

- Quantec (Pty) Ltd
- South African Reserve Bank
- Statistics South Africa
- DWAF
- WRC

The raw data to update and to extend the model is therefore not a constraining factor. However, for the model to have an in-time interface with the data bases, it is **recommended** that Conningarth Economists be made responsible for updating the existing data bases that are essential for the model's operation

It is accepted that the model should, at some stage, be transferred to an agency that will benefit most from its use. However, due to the intricate nature of the model, and the fact that it is data intensive and requires end-users to have statistical and econometrics expertise, it is not opportune to do this at the current time. It is, nevertheless, **recommended** that an investigation be undertaken of a so-called digital archiving systems (DVD, CDs or even Internet) that might enable such a transfer in time.

5.6 Service Agreement

In order for a model to remain functional, and for it to be utilised for policy making purposes, it needs ongoing technical updating. Such updating requires the involvement of economic and econometric professionals to not only evaluate the structure of behavioural functions, but also to maintain the statistical soundness of modelling parameters (i.e. coefficients). Accepting that it is difficult to obtain the services of such qualified people, it is **recommended** that an agreement of some sort be entered into with the client to "service" the model in terms of its technical updating.

5.7 Further Research

During the course of building and operating the SAFRIM/WSM modelling system, a number of areas emerged which highlighted the need for further improvements. The following aspects can be singled out as being those that require further research and development:

- It is important that the regional reach of the WSM be expanded. Provincial SAMs already exist for the nine provinces, which is a great help in this regard. It is therefore recommended that water satellite models based on the one that was done for the Vaal Catchment Area, be constructed for the other eighteen WMAs in South Africa. DWAF has already accumulated (some) relevant data for the nineteen WMAs. In order to ensure that further data collected is usable for modelling purposes, it is **recommended** that discussions be held with DWAF in this regard.
- The model is currently based on historical research results, e.g. price elasticities of demand for water, unit water consumption statistics, etc. More recent and better coefficients will improve the WSM's analytical capabilities substantially. It is therefore **recommended** that the WRC embark on a pertinent research effort to enhance knowledge in this field.
- At this stage, the modelling system, and in particular the WSM, does not take into account the influence of technological changes. To further improve the model, it is recommended that appropriate research be conducted as to how changes in technology can be incorporated in the SAFRIM/WSM modelling system, taking note of how it was handled by other practitioners of the IM model genre internationally.

5.8 Promoting the Future Use of the SAFRIM/WSM Model

In line with all the above recommendations to ensure that the SAFRIM/WSM model's technical qualities will always remain at an acceptable standard, it is important that the model's existence and capabilities be more widely propagated and used for the purpose for which it was originally intended.

In order to move forward in this regard it is **recommended** that:

- A workshop be held with top DWAF management echelons who have an interest in the model's abilities, to discuss the possibility of taking primary responsibility for housing the model with DWAF.
- Consideration be given to holding a second workshop to which a wider public audience be invited with the aim of promoting the more widespread use of the SAFRIM/WSM modelling system.

Other important potential users such as ESKOM, TRANSNET, DOT, and other state departments could be involved in this second workshop.

BIBLIOGRAPHY

Almon, C. (1996). “A Perhaps Adequate Demand System”, INFORUM Working Paper, Department of Economics, University of Maryland.

Brayton, F. and Tinsley, P. (eds) (1996). “A Guide to FRB/US: A Macroeconomic Model of the United States”. Finance and Economics Discussion Series, 1996-42. (Board of Governors of the Federal Reserve System).

Cortes, Bienvenido S., Edgmand, Michael, R., and Rea, John, D. (1993). “A Firm Level Comparison of Alternative Theories of Business Fixed Investment”, Journal of Economics, Vol. 19, No. 1, pp. 65-72.

Council for Scientific and Industrial Research (CSIR). (1991-1998). Environmentek; Water Resource Accounts for South Africa.

Deaton, A.S. and Muellbauer, J. (1980). “Economics and consumer Behaviour”. Cambridge: Cambridge University Press.

Deculuwe, B. and Martens, A. (1988). “CGE Modelling and Developing Economies: A Concise Empirical Survey of 73 Applications to 26 Countries”. Journal of Policies Modelling (10): 529-568.

Department of Agriculture (2006). Abstract of Agricultural Statistics.

Department of Agriculture (2006). “Trends in the agricultural sector”. ISSN 1025-5028.

Department of Water Affairs and Forestry (2004). National Water Resource Strategy. First Edition. September.

Department of Water Affairs and Forestry (2005). Internal Strategic Perspective, Lower Vaal WMA. PWMA 10/000/00/0304.

Department of Water Affairs and Forestry (2005). Internal Strategic Perspective, Upper Vaal WMA. PWMA 08/000/00/0304.

Department of Water Affairs and Forestry (2005). Internal Strategic Perspective, Middle Vaal WMA: PWMA 09/000/00/0304.

Dervis, K., deMelo, J. and Robinson, S. (1982). “General Equilibrium Models for Development Policy”. Cambridge, MA: Cambridge University Press.

Development Bank of Southern Africa (1998). Gauteng Development Profile.

Development Bank of Southern Africa (1998). Northern Cape Development Profile.

Department of Water Affairs and Forestry (1995). Vaal Augmentation Planning Study. BKS. PC 000/00/14494.

Development Bank of Southern Africa (1998). North West Development Profile.

Development Bank of Southern Africa (1998). Mpumalanga Development Profile.

Development Bank of Southern Africa (1998). Free State Development Profile.

Farolfis and Perret (2006). "Intersectoral Competition for water allocation in Rural South Africa: Analysing a case study through a standard environmental economics approach. Working Paper: 2002-23. University of Pretoria.

Frankhauser, P., McCoy (1995). "Modelling the Economic Consequences of Environmental Policies: In Principles of Environment and Resources Economics. Edited by H. Falmer, H.L. Gabel, H. Opschoor.

Grassini, M. (2003). "Computable General Equilibrium Modelling Approach. Does it make sense?" Paper presented at the Eleventh Inforum World Conference, Suzdal, September.

Grassini, M., (1998). "The Core of the Multisectoral INFORUM Model". University of Florence, Italy. 12th International Conference on Input-Output Techniques. New York.

Health Systems Trust (2007). webmaster@hst.org.za

Henry, M.S. and Borwn, E. (1981). "A Methodology for Estimating the Value of Water among Sectors of a Regional Economy." Southern Journal of Agricultural Economics.

Hirsch, W.Z., (1959). "The review of economics and statistics", Vol. XLV.

Johansen, L. (1960). "A Multi-Sectoral Study of Economic Growth". North-Holland, Amsterdam.

Jorgenson, D.W. (1984). "Econometric Models for Applied General Equilibrium Analysis, in Scarf, H.E. and Shoven, J.B. "Applied General Equilibrium Analysis". Cambridge: Cambridge University Press. Pp. 139-203.

Kopcke, Richard W. (1993). "Forecasting Investment with Models and Surveys of Capital Spending", New England Economic Review, Vol. 0, No. 0, pp. 47-69.

Meade, D. (1990). "Investment Functions in an I-O Framework", PhD dissertation, University of Maryland.

Meade, E. (1988). "Exchange Rate Adjustment and the J Curve", Federal Reserve Bulletin, October 1988.

Miernyk, W.H. (1965). "The elements of Input-Output Analysis", Random House INC., New York.

Monaco, R.M. (1997). "A Brief Review of Alternative Approaches To Inter-Sectoral Policy Analysis and Forecasting". http://www.inforum.umd.edu/Workpaper.html

Moore, F.J. & Petersen, J.W. (1955). "The review of Economics and Statistics", Vol. XXXV II.

National Treasury (2006). Administered Prices, Water.

National Water Resource Strategy; first Edition. Department of Water Affairs and Forestry, Chapter 2. 2004.

Nicholson, W. (2005). "Microeconomic Theory: Basic Principles and Extensions". Sixth edition. New York: Dryden Press.

Nieuwoudt, W.L., Backeberg, G.R., and Du Plessis, H.M. (2004) "The Value of Water in the South African Economy: Some Implications".

O'Toole, R. and Matthews, A. (2002). "The IMAGE CGE Model: Understanding the Model Structure, Code and Solution Methods". Working Paper: 5 February 2002. Trinity College Dublin, Dublin.

Powell, A.A. and Lawson, T. (1990). "A Decade of Applied General Equilibrium Modelling, in Bergman, D.L. *et al.* (eds), General Equilibrium Modelling Economic Policy Analysis". Basil Blackwell, Oxford.

Republic of South Africa. 1998. *National Water Act. Act 36 of 1998.* Government printers, Pretoria.

Social Accounting Matrix (2004). North-West Province. Compiled by Conningarth Economists.

Social Accounting Matrix (2004). Free State Province. Compiled by Conningarth Economists.

Social Accounting Matrix (2004). Northern Cape Province. Compiled by Conningarth Economists.

Social Accounting Matrix (2004). Gauteng Province. Compiled by Conningarth Economists.

South African National Biodiversity Institute (2006). Grasslands comparative agricultural economic and trends assessment.

South African Reserve Bank Quarterly Bulletin. (2007). March.

Statistics Denmark (2005). Danish Environmental Accounts.

Statistics South Africa (2006). Gross Domestic Product. Annual Estimates per region 1995-2005 Report No. P0441.

Statistics South Africa. (2006). Water Resource Accounts for 19 Water Management Areas. Report No. 04-05-01.

Statistics South Africa. (2006). Water Resource Accounts; Discussion Document, D. 0405. December.

Taylor, J.B. (1993). “Macroeconomic Policy in the World Economy: From Econometric Design to Practical Operation”. New York: W.W. Norton.

Taylor, L. (1979). “Macro Models for Developing Countries”. McGraw-Hill Book Company. New York.

Thomas, F.T. (1999). “Water and the Australian Economy”. Australian Academy of Technological Services and Engineering.

Van Tongeren, F. and Van Meijl, H. (1999). “Review of Applied Models of International Trade in Agriculture and Related Resource and Environmental Modelling”. Agricultural Economic Research Institute (LEI). The Hague.

Werling, Jeffrey F. (1992). “MIDE: A Macroeconomic Multisectoral Model of the Spanish Economy. Dissertation, Doctor of Philosophy. University of Maryland.

Annexure 1: Terms of Reference for this Solicited WRC Project

Key Strategic Area: Water Resource Management Thrust 4

Policy Development and Institutional Arrangements for Water Resource Management

Programme 1: Decision support for water policy formulation and implementation

Title: Econometric model to predict the effect various water resource management scenarios would have on South Africa's economic development

Objectives
General:

The development of an integrated econometric model that considers the role of water as input to the South African economy, that can be used to evaluate the role water is playing in the South African economy and to predict the likely effect of management and policy approaches on the efficient utilization of water resources.

Rationale

With water being a limited resource it is widely accepted that its availability will constrain the economic development of South Africa. In some areas of the country water resources are already overcommitted, with the likely result that economic expansion is being inhibited. Under these circumstances new development can only occur in areas where water resources are currently underdeveloped. The rate of growth, output and income of "high value" uses in water strained areas will thus be restricted. With the present tools at our disposal, it is, furthermore, very difficult to anticipate which unforeseen negative effects well intended water management and allocation decisions may have on development and the long term economic prosperity of the country.

Australia developed a model that considers the role of water as an input to the Australian economy and the way in which it may interact in future for various scenarios. The economic loss to the country of poor management of the resource can for example be compared with the effect of policies that promote the transfer of water from lower to higher-valued users. The Australian model make use of a simulation approach that (for 55 industry groups and across 18 regions) describes the relationship between present and future trends in water demand with potential growth in production and economic activity, through an inter-linkage of the following components. Feedback between components i and iv are used to generate alternative scenarios for the economy and water use.

i. An existing econometric model of the Australian economy that includes forecasts for macro-economic variables, quantities and prices of exports, forecasts of changes in industrial technologies and household preferences, population growth forecasts etc.

ii. An estimate of the water use that would result from a given level of economic activity (provided by the econometric model).

iii. A comparison between the water use estimated in ii with availability and quality in the region, and

iv. Make allowance for future technical and institutional change.

It is proposed that this project develop a similar model appropriate for and adapted to the South African situation.

Deliverables

1. Literature review covering the local and international experience with regard to developing the proposed model, available data sources and relationships that could be incorporated into the proposed model.
2. Report on the different scenarios that will be catered for in the developed model, and the process that was followed to develop them.
3. Report on interface with existing data sources (such as available from government departments) that would provide input to the model and be sources of future data updates.
4. Report on the selection of the existing econometric model that will be used for macro-economic forecasting and adaptations or expansions that are required for this purpose.
5. Report on the relationships between water use and production within defined sectors that will be used in the model and how these relationships are affected by the relationship between water availability and water price on the one hand and water price and use on the other.
6. Report on the structure and operation of the integrated model and provision that were made for future updates of input data and the relationships that were used.
7. Report on validation of integrated model for the present situation.
8. Report on the contribution that water is presently making to the South African economy.
9. Report on how water can be expected to affect economic development in different regions of the country under different policy scenarios.
10. A final report documenting the study, its results and findings.

Time Frame

3 years, from 1 April 2005 to 31 March 2008

Annexure 2: Section 2 – Data Requirements for Satellite Water Model

The main objective of this Annexure is to give a more detailed presentation of the nature and magnitude of data required for the compilation of the WSM. To run the WSM, WRA are needed. These accounts are used to determine the so called water use coefficients for various industries/sectors as well as the "water balance" for South Africa (Demand-Supply on institutional level). Lastly, price demand curves are needed to quantify the relationships between water tariffs (prices) and demand responses of various important water users. In this section an attempt is made to pin-point the availability of data necessary to fulfill the data needs of the WSM, moving from macro-national level to regional level impacts disproportionately on socio-economic data needs in the context of model building. This being the first attempt to build a regionally based macroeconometric model with the focus on water, prompted the researchers to limit the exercise to the Vaal Catchment Area, also having pre-knowledge of the amount of research that has already been done in the water field pertaining to this region. The objective is to arrive at a position at the end of the presentation where it will become clear that sufficient data sources are available to proceed with model building.

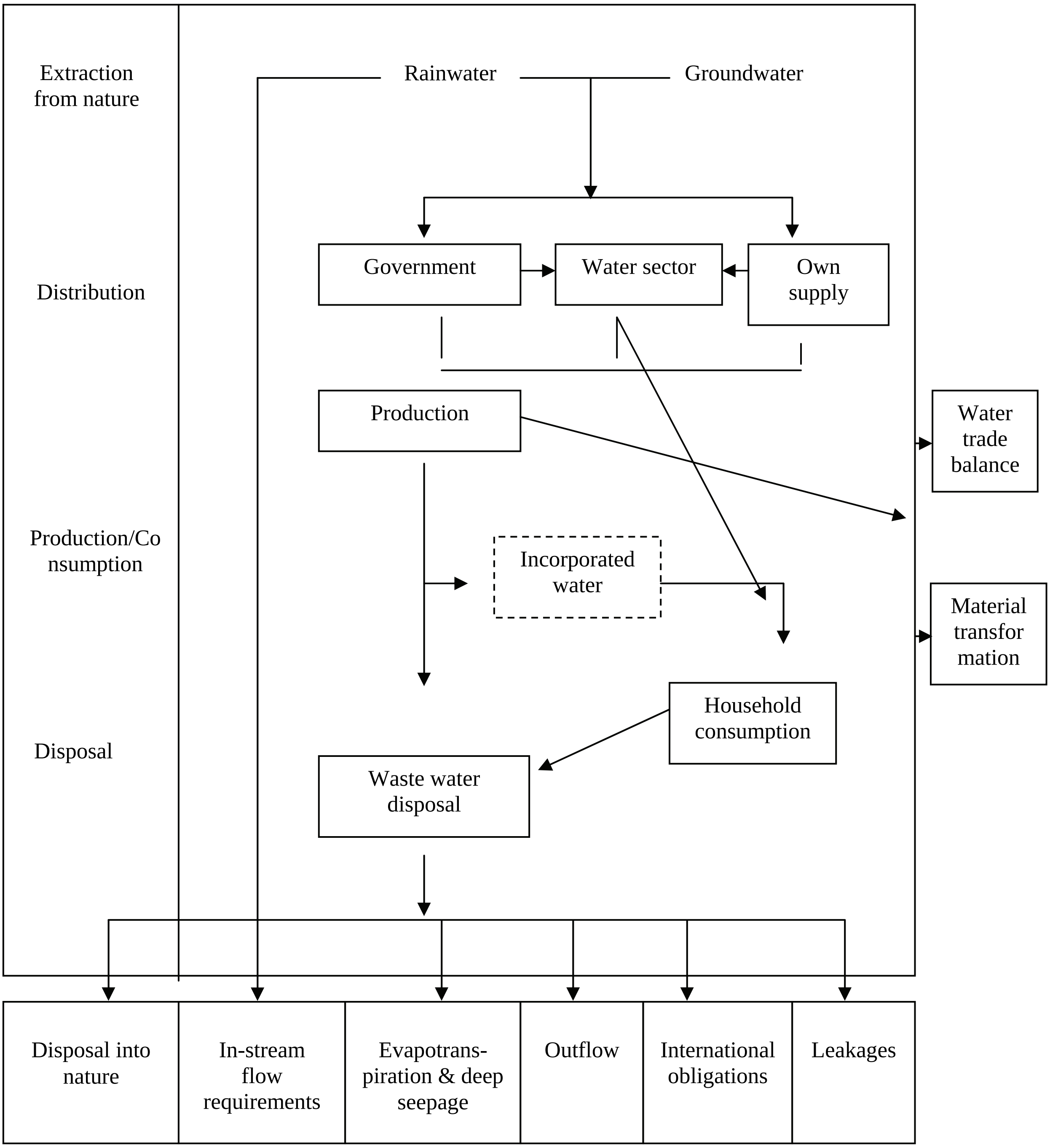
Water Resources Accounts

- **Water Mass Balance**

South Africa's WRA were developed with reference to its own objectives and priorities, and the physical characteristics of South Africa's water resources. It serves as a consolidating mechanism that draws data from different sources, compiling them into one information set. Using this data set, linkages may be made with other data sets, such as South Africa's National Accounts (SNA) or any other natural resources data sets.

The first important step in drawing up the South African WRA was the compilation of a water mass balance. This was done in order to describe the physical water supply situation as well as the relationship between the water resources used and economic activities in South Africa. The water balance shows all the water transactions between the relevant role-players that take place in South Africa in any given year, based on the assured yield concepts. In the figure below the physical flow of water, from its primary sources to end users and further disposal is shown clearly. It is also possible to demonstrate how the stock and flow aspects are reconciled with each other.

Figure V: Simplified water mass balance for South Africa



Source: Taken over form CSIR, Environmentek; Water Resource Accounts for South Africa, 1991-1998.

Stock and flow accounts were constructed, sourcing data from the water mass balance. The data analysis approach was based on the guidelines described in the Systems of Integrated Environmental and Economic Accounting (SEEA) Manual (UN, 2000).

In South Africa, approximately 90% of annual precipitation is intercepted by the natural habitat through a process of evapotranspiration, or seeps into the earth's surface. The rest of the water is available as runoff. As only runoff and groundwater can be stored, the stock accounts account only for the 10% runoff and the available groundwater in the country. The flow accounts do however, incorporate the evapotranspiration component.

- **Water Resource Accounts (WRAs)**

Having established the physical water balance situation in the base year, it is possible to move towards the establishment of WRAs (both in physical and monetary terms).

- Supply Estimates

As one could imagine, the supply side estimates of the WRAs are very much dependent on hydrological and engineering inputs. In all the publications dealing with water resource accounting for South Africa, the supply of water is dealt with very extensively. It is not the purpose of this study to investigate and evaluate each and every one of them. What is true however, is that most of these publications make use of water supply data that have been assembled in official publications over many years such as:

a. The National Water Resource Strategy for South Africa (NWRS). First Edition, 2004. DWAF, Pretoria.
b. The Internal Strategic Perspective (ISP) for various WMA as compiled by DWAF.
c. Water Resources of South Africa under the auspices of the WRC.
d. Water Accounts for 19 Water Management Areas. Report No. 04-05-01. Statistics South Africa.
e. Natural Resource Accounting: Water Accounts of the Upper Vaal Water Management Area: 1991-2000. Statistics South Africa.
f. CSIR Environmentek. Studies on Water Resource Accounts for RSA.
g. The Value of Water as an Economic Resource in the Vaal River Catchment. WRC Report No. 990.1/05.
h. Centre for Environmental Economics and Policy in Africa (CEEPA), University of Pretoria. Various Reports on Natural Resource Accounting for South Africa.

From the supply side, i.e. both the stock and flow entities, used in all these documents, are very much comparable and obtained mainly from the same source i.e. from DWAF.

- Ad(b): Water Resource Accounts for South Africa, 1991-1998. CSIR, Environmentek, Pretoria, April 2001

In this report, information is given on the Water Asset situation in South Africa. Based on these tables one can get detailed information on the water supply situation in South Africa as a whole as well as for 19 WMAs.

As far as the future supply of water is concerned, DWAF has provided information in its NWRS-document and accompanying White Paper on the realistic future availability of water.

- Ad(a): DWAF. National Water Resource Strategy, First Edition – September 2004

In this document, the supply situation (2000) for the country as a whole is given as well as for the 19 WMAs. An effort was also made to project the water availability for the year 2025, based on knowledge of new water storage schemes already under construction and those in the pipeline.

In conclusion then, as far as data on the supply of water is concerned, the statement can be made that enough information of good quality is available from the sources quoted above.

- Demand Estimates

As one could expect, most of the studies referred to above also dealt with the demand side of water in order to get a view on the supply/demand situation in South Africa. In contrast with the supply side, one will find that demand detail is somewhat more difficult to obtain. Nevertheless, in the NWRS document of DWAF and also many of the other documents referred to, sufficient information on the sectoral water demand is contained.

- Ad(a): National Water Resource Strategy of South Africa (NWRS), First Edition, 2004, DWAF Pretoria

In this document, linked with other data bases, an attempt was made to reconcile the demand for and supply of water for the year 2000 and 2025 for each of the 19 WMAs (presented in this publication). Provision is also made for a base and high scenario.

Good data sources are available to "populate" the supply and demand components of the WSM.

- **Water Use Coefficients**

The WSM also requires the calculation of water use coefficients. These coefficients actually represent the outcome of a number of forces, such as technological improvements, changes in production technologies, relative cost of other intermediate inputs, new products coming onto the market, institutional changes, etc. Obviously, the price (tariff) of water has its specific impact as well but will be discussed later.

As can be deduced from the above, once the demand of water per sector is known (volumes and monetary value) using relevant economic indicators, a whole range of so called water use coefficients can be calculated – depicting certain economic criteria involving a scarce economic resource such as:

Value of Output/Water (Rand/m^3)
GDP/Water (Rand/m^3)
Remuneration/Water (Rand/m^3)
Gross Operating Surplus/Water (Rand/m^3)

Conningarth Economists has over the years acquired a vast amount of information on especially the factors influencing water use in irrigation agriculture. Although to a lesser extent, the same kind of information is available for other sectors such as electricity generation, mining and households – the main non-agricultural water users.

- **Price Elasticities of Water Demand**

An important part of the WSM would be the incorporation of the role of water tariffs (prices) in the process of decision making. In other words, to simulate the reaction of the main users of water in the economy to changes in the cost of water. To put it another way, how can the price/cost of water be used to promote the more economical use of water in its various sectoral applications.

As also explained in that chapter, the aggregated water sector would in any case be part of the sectoral base of the IM, but because of the level of aggregation it would be difficult to isolate the role of water prices in the economy. This is also limited due to the fact that water tariffs have for decades been strictly regulated, so that it did not reflect actual long-term marginal costs in historical context. Given these problems, it was decided to link a Water Satellite structure to the IM, making it possible to model the water sector in more detail in terms of users and in the process makes it more sensitive to price movements.

As mentioned earlier, disaggregating a national macroeconometric model to regional levels will have a disproportional impact on data requirements. For this reason it was decided to concentrate on the Vaal Catchment area to serve as a "prototype". The other reason being the large amount of research that has been done on the role of water in the Vaal Catchment's economy.

- Ad(e): The Value of Water as an Economic Resource in the Vaal River Catchment. WRC Report No. 990/1/03

This particular study is of significance for the present research effort for various reasons. The main reasons being that:

- WRAs were developed for the Vaal River System;
- System Dynamic Model for the Vaal River System was developed that produced useful results; and
- Data Sources available for such a study.

Water Resource Accounts (including a water balance)

WRAs were compiled for the period 1980-1998. From these physical accounts it was possible to calculate the economic contribution of water usage by each user group. In this study the so called surplus value or so called economic value of water was used.

As one could expect the economic value of water is the highest in the non-primary sectors of the economy (Table 5.2 of the Vaal Report). This information also gives an indication of the ability of users to absorb tariff increases.

It is also important to highlight the fact that Statistics South Africa compiled a new version of WRA, with all the control totals for water resources reconciling with the official figures from DWAF.

- **System Dynamic Model**

Due to the fact that a unique system dynamics model for water was constructed for the Vaal Catchment Area, useful information was generated especially in the field of demand/price relationships in respect of the main water use categories. This system dynamics model was specifically developed to simulate a market clearing process, taking into account supply and use structure.

Demand curves were developed for each demand categories from which price elasticities could be derived.

Mathematically the demand curve can be expressed as follows:

$$D = [a + b(\Delta T)]C$$

Where

D	=	Total use for a category
a	=	Average use per user unit
b	=	Change in unit use due to a given tariff change
ΔT	=	Change in water tariff
C	=	Total number of user units (driver/exogenous variable)

Populating the model with data

For the model to generate reliable results, it should be based on a consistent data base where demand equals economic usage. The consequence of this is that a fairly complete natural resource accounting system had to be compiled for the Vaal River system as part of this study.

In compiling these accounts the following objectives were achieved:

1. The water balances for the historical period 1980-1998 were determined.
2. Demand schedules for water for the important water use sectors were derived.
3. The economic value of water was determined.
4. The delivery cost, tariffs and subsidies were estimated.

The remaining objective of the study was to explore a variety of scenarios and estimate the changes in the value and tariff of water resources that result from changes in supply or demand.

Annexure 3: Price Elasticity Formula

Elasticity formula:

$$\varepsilon = \quad (\Delta D/D) / (\Delta P_1 / P_1) \ldots\ldots\ldots\ldots..(1)$$

$= (\Delta D /D) / (\Delta P_1 / P_1)$

$= \Delta D / D) \times (P_1 / \Delta P_1)$

$= (\Delta D / \Delta P_1) \times (P_1 / D)$

$\Delta D \quad = \{(\in .D) / P_1\} \, . \, \Delta P_1$

$= \{(\in .D) / P_1\}. (P_2\text{-}P_1)$

$= (\in .D) \, . \, \{(P_2 - P_1) / P_1\} \times 100$

$= \beta \, (\Delta P \, \%)$

Where: $(\in .D) = \beta$ and

$\{(P_2 - P_1) / P_1\} \times 100 = (\Delta P \, \%)$

VOLUME

Demand = Ave Dem + Δ Demand

$= \alpha_1 + (\in .D)(\Delta P_1) \, \%$

$$Y_1 \quad = \alpha_1 + \beta_1(\Delta P_1) \, \% \ldots\ldots. (2)$$

MONETARY

(2)	=	(1) x P_2
Y_2	=	$Y_1 \times P_2$
P_2Y_1	=	$P_2 \, [\alpha_1 + \beta_1(\Delta P_1) \, \%]$
	=	$P_2\alpha_1 + P_2\beta_1(\Delta P_1) \, \%$

$$Y_2 = \alpha_2 + \beta_2 \, (\Delta P_1) \, \% \ldots\ldots\ldots. (3)$$

LEGEND:

D	=	Demand
ΔD	=	Change in Demand
P	=	Price
ΔP	=	Change in Price
(ΔP)%	=	Percentage Change in Price

Water Supply Low Access to Piped Water. . . for Various Reasons Multiple Players in the Urban Water Market The Role of Wells, Boreholes, and Surface Water. in the Rural Water Market Steep Growth of Wells and Boreholes as. Sources of Water Notes References.Â Subsidies under Various Scenarios 7.1 Water MDG Gap, 2006 7.2 Sanitation MDG Gap, 2006 7.3 Population Split across Water and Sanitation.Â All the under-lying data and models are available to the public through a Web portal (http://www.infrastructureafrica .org), allowing users to download customized data reports and perform various simulation exercises. security, water resources and ecosystem services would likely have severe consequence on lives and sustainable development prospects in Africa.[4] Managing this risk requires integration of mitigation and adaptation strategies in the management of ecosystem goods and services, and the agriculture production systems in Africa.[5]. Generally, observed surface temperatures have increased over Africa since the late 19th century to the early 21st century by about 0.5 Â°C while observed precipitation trends indicate spatial and temporal discrepancies in variability.[6][2] The observed changes in temp Using different water reallocation scenarios, the simulation results indicate that water reallocation from agriculture to the non-agriculture sectors beyond the level of market allocation scenario will lead to a decline in total sectoral output and a significant deterioration of the welfare of poor households. Thus, it undermines development efforts aimed at reducing the exiting poverty level of the country. View. Show abstract. Simulating present and future climates of southern Africa using general circulation models. Article. Jan 1997.