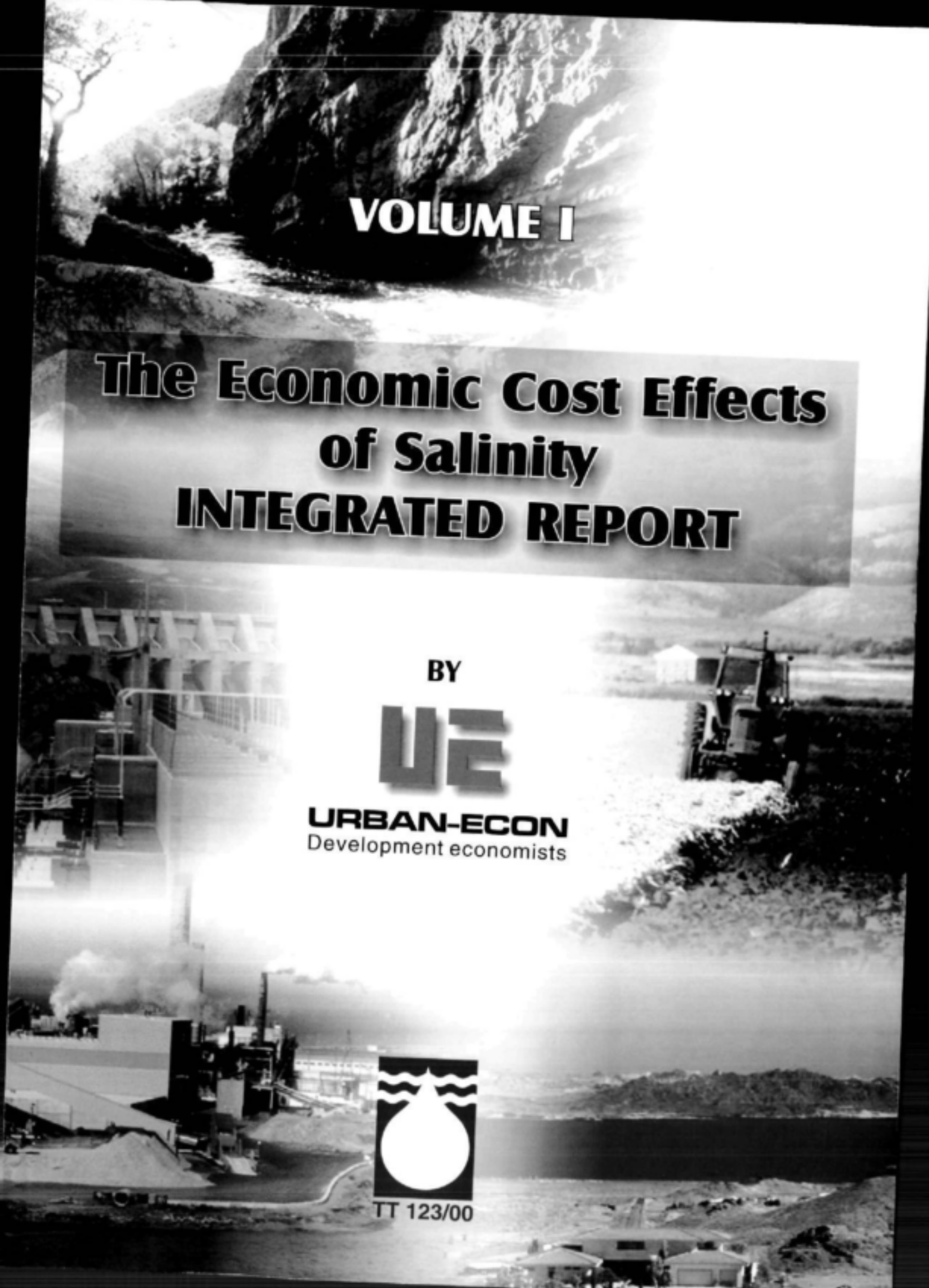

VOLUME I

The Economic Cost Effects of Salinity
INTEGRATED REPORT

BY

URBAN-ECON
Development economists

TT 123/00

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The Economic Cost Effects of Salinity
INTEGRATED REPORT

Report to the Water Research Commission
and the Department of Water Affairs and Forestry

by

URBAN ECON

Assisted by: Economic Project Evaluation and Corrolec CC

November 2000

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TABLE OF CONTENTS

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Prof G Gehrig

EXECUTIVE SUMMARY

1 PURPOSE OF THE STUDY

The Water Research Commission and the Department of Water Affairs and Forestry commissioned an investigation into the economic, social and behavioural impacts that would result due to changes in the salinity of South Africa's water resources.

The aim of the study was, primarily, to develop a generalised methodology model to determine the generic impact of changes in the total salt concentration found in South African rivers and to interpret these impacts in financial, economic and social terms. The resultant model was required to be:

i. comprehensive with respect to addressing the salinity problems
ii. applicable to any salinity situation in any water sector in South Africa.

An important role of the study was to verify the generalised model. This was achieved by applying it to a specific geographic area, namely the Middle Vaal River area. In order to achieve this, actual data gathering exercises were conducted and applied in the conceptual model. Based on this, a process of verification and model adjustments was undertaken, to incorporate the distinctive circumstances pertaining specifically to the Middle Vaal River area.

A generic model, making provision for all possible conceptual elements applicable to salinisation, has thus resulted. The model comprises separate equations representing the different sectors of the economy as well as the natural environment and water feeder systems. An outstanding feature of the model is that it is a generalised model and as such is applicable to any salinisation situation in South Africa.

The value of the study lies in applying the findings of the study in a policy environment. This means that the study results can provide motivation to formulate new policy directives for utilising water resources in a given area.

2 BACKGROUND TO STUDY

There has been a steady increase in the salt content of the Vaal River since 1935. This increase has accelerated markedly since 1965 with a further pronounced effect caused by the droughts prior to 1996. This increase in the salt content affects all water use components exposed to such water.

A major salinity problem exists in the Middle Vaal River area, between the Barrage and Bloemhof Dam. Various options for solving the problem have already been identified. All the options are, however, costly and it is important to quantify the benefits of a reduction in salt concentration in order to justify expenditure on measures to reduce the salinity.

3 OBJECTIVES

Prior to deciding how salinity in the water supply could be managed, it is necessary to determine the total cost of salinity to the economy, namely its direct, indirect and induced cost effects. Costs borne by the various sectors in the economy have to be determined, including the identification of behavioural impacts. The study addresses the impacts of increased level of salinity throughout the economy.

In order to address the uncertainties with respect to the economic implications of salinity, the Water Research Commission identified the need to develop a methodology that can be utilised in difficult salinity situations.

The project was divided into two phases:

- The development of a generalised methodology for the determination of the generic impact of salt concentration of South African rivers and the interpretation of these impacts.
- The application of the methodology to an investigation of the impact of increased salt concentration in the Middle Vaal River.

4 FORMAT OF RESULTS

The research conducted to determine the economic effects of salinity is based on a sectoral approach. The economy had been classified into different sectors and research was conducted separately for each sector. These results were integrated to determine the total economic effects on the economy. On account of the volume of research results, the sectoral research is presented in separate volumes to support the integrated results contained in the main report (Volume I).

Each of the sectoral reports, combining its initial inputs for the generalised model with its findings in the case study, has been separately bound. These are individually available as:

Volume II	:	Household Sector
Volume III	:	Agriculture Sector
Volume IV	:	Mining Sector
Volume V	:	Industrial Sector
Volume VI	:	Services Sector
Volume VII	:	Water Quality Analysis, Feeder Systems, Natural Environment.

As the main report is an integration and interpretation of the background research, variations may occur. The background research should be interpreted as the development of a reference framework by the different specialists and during the course of the study, research findings were continually refined.

5 STUDY APPROACH

The approach followed with the study is based on economic theory by conceptualising sectoral behaviour within the economy. In quantifying these conceptual formulae, surveys were undertaken in the Middle Vaal River study area to obtain the direct costs related to salinity. These direct costs represent only a partial estimate of the total costs of salinity. In order to determine the indirect costs and other spin-off effects, an integrated costing framework had to be set up. This was done by utilising the input-output (IO) technique and a combination of IO applications.

Despite the inherent limitations of the IO technique, it is a very versatile and flexible model to simulate real-world situations. Furthermore, its ability to determine the indirect and induced cost effects, renders the approach as well as the results unique and comprehensive.

The sectors analysed are households, agriculture, mining, industry, services and feeder systems, as well as the natural environment. Conceptual cost formulae were formulated to determine the direct costs and behavioural impacts on costs for different levels of salinity. Based on this background research to set develop these formulae, the research results indicated that both the feeder systems and the natural environment would not incur significant (incremental) costs within the specified salinity range of

200 mg/ℓ to 1200 mg/ℓ Total Dissolved Solids (TDS). These two sectors were therefore not incorporated into the integrated model.

Upon conducting surveys in the study area to determine the direct sectoral costs, a variety of problems was encountered. The most important of these is the fact that many respondents (i.e. sectoral water users) are not aware of the costs of salinity and therefore assigning costs to behaviour becomes rather presumptuous. Behaviour does, however, play an important role in the household and agricultural sectors. With the other sectors, behaviour is driven by technology and production factors.

The survey results obtained in the Middle Vaal River study area were analysed and transformed where necessary, to be integrated into the IO modelling framework. The following approaches were followed:

- Conducting a multiplier analysis that provides a first approximation of the additional costs of salinity due to a change in the TDS and using this to rank sectoral sensitivities with respect to the impact of salinity.

- Setting up a pricing model that simulated the cost increases of different levels of salinity in terms of price changes being passed on as price increases. These price changes are passed on as price increases to all sectors of the economy and can be interpreted as proxies for changes in the Consumer Price Index (CPI) and Producer Price Index (PPI).

- Running an augmented IO model to estimate total additional resource usage as salinity rises. To cost this, a new industry was postulated to enter the economy to combat salinity. A new row and column representative of this industry was inserted into the IO table.

Each of these approaches focused on a different aspect in determining the total cost effects of different levels of salinity.

6 INTERPRETATION OF RESULTS

The results obtained with the IO analyses indicated that the total costs of salinity are significant in the Middle Vaal River study area.

6.1 Direct Cost Effects

The direct costs of salinity to the entire economy of the case study area are established from the mathematical combination of the survey data collected within each individual sector. There are constraints with much of the data, since most interviewees were unable to supply data for any conditions other than those currently being experienced and were generally rather uninformed about salinity and its potential effects.

Despite the drawbacks, the data provided some indication of the direct economic effects of increased salinity. The collected data was centred around 500 mg/ℓ which is the average salinity level presently experienced in the study area. Data for salinity levels below 500 mg/ℓ implies a corresponding saving at these lower salinity levels. A 100 mg/ℓ increase in the TDS to 600 mg/ℓ is expected to effect a R26 million increase in annual direct costs in the study area (refer to Table 1). Increasing the TDS to the highest limit (1200 mg/ℓ) is expected to result in a direct cost of R183 million/a to the region. Conversely, a saving of R80 million/a is anticipated should the salinity drop from current levels to 200 mg/ℓ.

Table 1. Direct Costs of Salinity, (1995 Values in Millions of SA rands)

SALINITY / SECTOR	mg/ℓ TDS						% Contribution at 600 mg/ℓ
	200	400	600	800/	1000	1200	
Mining	(7.309)	(2.212)	0.844	4.863	10.209	17.816	3.17
Business and Services	(1.843)	0.487	1.211	1.707	2.209	2.697	4.55
Manufacturing 1	(0.145)	0.028	0.086	0.123	0.160	0.198	0.32
Manufacturing 2	(2.825)	0.294	1.351	1.993	2.635	3.278	5.07
Agriculture	0.000	0.000	0.439	0.439	0.427	0.503	1.65
Households (suburban)	(35.121)	(11.707)	11.707	35.121	58.535	81.949	43.94
Households (township)	(27.927)	(9.309)	9.309	27.927	46.544	65.162	34.94
Households (informal)	(5.081)	(1.694)	1.694	5.081	8.469	11.855	6.36
TOTALS	(80.251)	(24.113)	26.640	77.253	129.225	183.457	100.00

In considering these direct cost changes the effects can be equated to changes in prices in the economy. The percentage direct impact of salinity abatement on CPI and PPI at a salinity level of 600 mg/ℓ TDS, amounts to 0.0013% and 0.0016% respectively. In effect this implies a relatively small change in these indices which can be equated to changes in inflation.

The greatest direct cost implications occur to the household sector. The direct costs to the households comprise approximately 85% of the total direct costs within the economy under investigation. This is not unexpected, since the household sector comprises the largest group of treated water users in the economy even though the per capita cost increases are not the highest. Conversely, the sectors that use very little water and those using predominantly untreated water are expected to have lower direct cost effects.

Manufacturing 1, where water requires no treatment, has a relatively low water consumption and experiences less than 0.5% of the direct cost of salinity increases at 600 mg/ℓ. By way of contrast, business and services, a relatively large sector within the economy, can be attributed with 4.5% of the total direct costs, while Manufacturing 2 (which treats its water) will face cost increases owing to the costs of treatment. Thus, unsurprisingly, this latter sector experiences 5% of the direct costs to the economy.

Although the mining sector uses large volumes of water in terms of production, much of the water employed is used in re-circulating circuits. Further, this water does not, in general, require a high degree of purification and thus the costs are lower than might otherwise be expected (3%).

Similarly, most of the water employed in the agricultural sector is drawn directly from the river itself. The water costs to agriculture are low, and agriculture is a small sector, occupying a fairly narrow band along the Vaal River. Thus, agriculture occupies a small niche in the economy and its contribution of 1.5% of the total direct costs of the study region, is not unexpected.

6.2 Indirect and Induced Effects

The models employed for the case study calculated the direct, indirect and induced costs to the economy. Since the IO table was closed with respect to households, an allowance was made for the reciprocal relationships between income and consumption, as well as the impact on the economy, resulting from the interdependence of industries in their production process and the behaviour of households. The closing of the IO table effectively added another industry to the economy. Households have a large impact on the economic processes in the region of study and wider, resulting in the expectation of larger impacts than would have been anticipated if the table had been in its open format, considering direct and indirect effects alone.

Ratios of the direct, indirect and induced costs to the direct costs (Direct Cost Multipliers, DCM) determined by means of the multiplier analysis, range from 1 to about 3.3. This implies that the spin-off effects of increased salinity are significant and the direct costs alone are a poor reflection of the cost impacts of salinity.

The ranking of the sectors researched, based on the salinity multipliers, indicates that at relatively low levels of salinity it is the community and other service sectors which will be most adversely affected. At high levels of salinity the gold mining sector will have to incur the highest cost to combat salinity.

The results of the pricing model are expressed in terms of percentage changes in the consumer and producer price indices and essentially represent forward linkages. The impacts have been determined in terms of regional and national impacts. Considering only the impact on the productive sectors, results of the same order as the multipliers provided are found, but with less spread. The direct and indirect DCMs for PPI and CPI are found to lie between 1.36 and 1.84, whilst the direct, indirect and induced DCMs are found to lie between 1.96 and 3.5. It should be noted that the pricing model results indicate variables for a base year expressed in percentages. This implies annual changes in costs or prices.

The percentage total increases in CPI and PPI for salinity levels increases from 600 mg/ℓ to 1200 mg/ℓ can be summarised as indicates in Table 2:

Table 2: Percentage increase in price indices

Salinity abatement by :	CPI: % change	PPI: % change
Productive sectors	-0.008 to 0.01	-0.01 to 0.015
Productive sectors & households	-0.1. to 0.22	-0.11 to 0.26

These changes seem to be small but are significant when related to Rand values in regional and national context. This had been done and the regional and national annual impacts are summarised as indicated in Table 3:

Table 3: Impacts on price indices

IMPACTS	CPI	PPI
National increase		
600 mg/ℓ	R101.5m	R402.6m
1200 mg/ℓ	R647.5m	R2623.4m
Regional increase		
600 mg/ℓ	R7.4m	R18.0m
1200 mg/ℓ	R47.1m	R117.3m

The augmented model was executed using both regional and national IO tables to determine the total cost effects of salinity abatement. Multipliers were calculated for comparison with the other model applications.

The chief outcome was that the DCM was 3.0 for the national case, and 2.6 for the regional case. These figures did not change significantly over the salinity range of 600 mg/ℓ to 1200 mg/ℓ TDS. The difference in the national and regional DCM is due to the differences in structure between the national and the regional economies. Since the IO analysis is based upon coefficients, the actual size of the economies has no influence on the DCMs. Only changes in the size of the input (or technical) coefficients (which in turn reflects a change in the structure of the tables) would influence the outcome.

6.3 Behavioral Effects

The decisions regarding salinity changes made in the mining, business and services and the manufacturing sectors tend to be driven by technology and production regimes. These sectors are likely to make changes to combat the effects of salinity, based purely on the financial implications to the concern. As a result, there are few, if any, unexpected responses to salinity effects and the calculated costs can be accepted as reliable.

During the data collection in the agricultural sector, the cost effects of two possible scenarios, based on management decisions or behaviour, were established. These included a "best case" scenario, where the farmer would maintain the current levels of production, regardless of cost, and a second scenario, where the farmer would choose to allow the crop yields to be reduced. This was only done for the hybrid model and the overall costs to the economy were found to be hardly affected by the two alternatives. At the 600 mg/ℓ level, the total costs decrease by less than R0.3 million. The variations are found to be between 0.1% and 0.3% of the overall costs, which are less significant than the probable errors in the data. Thus, the different behavioural responses available in the agricultural sector are unlikely to impact on the total costs to the economy.

The most significant behavioural effects are, however, from the household sector. The responses to increased salinity, while to some extent determined by the need to adapt to the changes, are largely driven by the availability of finances to maintain the *status quo* and overcome the problems arising from increased salinity. These behavioural responses are more likely to appear in those sectors of lower earning potential, and the informal household sector is far less likely to effect changes arising from increased salinity than suburban households. This is borne out by the variance in the data collected.

7 CONCLUSIONS

Based on the output from the model established for the Middle Vaal River region, the economic costs attributable to changing salinity, have been determined.

There exists an effective limit to the cost of salinisation. This is determined by the cost of desalinating the bulk water supply which would represent the most costly option of water treatment. Care must be taken not to allow the costs of salinisation to reach high levels. The viability of desalinating may be increased if selective desalination is applied to the consumer sectors incurring the highest relative costs, although other options should be explored first.

This is obviously a simplistic first-line approach, but it highlights the need to consider bulk or partial treatment of the water supply in the Middle Vaal area as the *status quo* is already 500 mg/ℓ. Behavioural response is particularly important as the quality of the water in the area is already perceived to be problematic.

The results of the study identified the total economic effects of increased salinity levels for the Middle Vaal River area. Based on these findings and the knowledge gained with respect to behaviour, the following observations are made:

- The application of the generic model in the Middle Vaal River area was accompanied by some limitations mainly on account of the undiversified economic structure. Undiversified, in this regard, refers to the strong reliance of the economy on the mining and services sectors. Despite this, very significant information could be obtained on the relative importance of cost effects between the various sectors. To validate these, the model should be applied in a diversified economy such as that of the Gauteng area. More insight concerning relative costs could be obtained on, for instance, the manufacturing sector.

- Differential desalination may be considered. The reason for this is that the household sector has been found to bear relatively high costs in terms of combating salinity, followed by the industrial and services sectors. It may be of value to motivate differential desalination of waters on a purely experimental basis, that is, to study the social and socio-economic benefits to be gained by households if the costs of salinity are decreased. This also implies that sectors that experience relatively low salinity costs may have to continue bearing these.

- It may benefit water users if a salinity awareness campaign were introduced. If end users were made aware of the cost effects, they might choose to behave differently and take informed decisions which may lessen the costs of salinity.

- A specialised database has been established. As part of an awareness campaign, users can contribute towards the refinement and extension of a more comprehensive database that can be utilised when the model is applied elsewhere. Since the availability of the data determines to a large extent the robustness of the model, such a database can contribute significantly to the ease of applying the model.

The interpretation of the findings of this study does not take into account alternative options with respect to water provision. This implies that the costs of salinity have not been related or compared to the situation of utilising transfer water and other allocation options. Furthermore, the results of the study are expressed in direct and spin-off effects and thus any further interpretation or comparison of these results with specific options, should be done in the same manner, namely to refer to total costs.

8 FURTHER RESEARCH

The value of the study lies in the fact that a first approximation of the spin-off effects of salinity on the economy had been determined. Furthermore, an indication of the behavioural costs for specific sectors has been obtained. On account of the specific study area chosen and the difficulties encountered in applying an integrated economic cost model to its specific considerations/circumstances, the following shortcomings may be addressed with further research:

- Application of the model in a relatively diversified economy such as that of Gauteng. In doing this, a more disaggregated model can be executed. Cost effects for more subsectors may then be identified, such as for the leather industry. Based on expectations the total costs of salinity may be higher.

- In applying the model to a chosen study area more significant costs may be identified if the study population is made aware of the problem in advance. The benefits arising from this approach, namely more accurate cost estimates and possibly more correct reporting of behaviour, could outweigh potentially over-reporting, due to increased awareness of the problem.

SECTION 1: INTRODUCTION

1.1 PURPOSE OF RESEARCH

The Water Research Commission (WRC) and the Department of Water Affairs and Forestry (DWAF) commissioned, in 1993, an investigation into the economic, social and behavioural impacts of changes in the salinisation of South Africa's water resources.

The aim of the study was, primarily, to develop a generalised methodology to determine the generic impact of changes in the total salt concentration found in South African rivers and to interpret these impacts in financial, economic and social terms. The resultant model has to be:

i. comprehensive with respect to addressing the salinity problems; and
ii. applicable to any salinity situation in any water sector in South Africa.

An important role of the study was to verify the generalised model. This was achieved by applying it to a specific geographic area, namely the Middle Vaal River area. In order to achieve this, actual data gathering exercises were conducted and applied in the conceptual model. Based on this, a process of verification and model adjustments were undertaken, to incorporate the distinctive circumstances pertaining specifically to the Middle Vaal River area.

A generic model, making provision for all possible conceptual elements applicable to salinisation, has thus resulted. The model comprises separate equations representing the different sectors of the economy as well as the natural environment and water feeder systems. An outstanding phenomenon of the model is that it is a generalised model and as such is applicable to any salinity situation in South Africa.

The value of the study lies in applying the findings in a policy environment. The study results can therefore provide motivation for formulating new policy directives for utilising water resources in a given area.

1.2 GENERAL APPROACH AND PRESENATION OF RESULTS

The research conducted to determine the economic effects of salinity was based on a sectoral approach. This means that the economy had been classified into different sectors and that research was conducted separately for each sector. The results had been integrated to determine the total economic effects on the economy. On account of the volume of research results the sectoral research is presented in separate volumes to support the integrated results contained in this volume.

Each of the sectoral reports, combining initial inputs for the generalised model with findings in the case study, has been separately bound.

They are individually available as:

Volume II	:	Household Sector
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Volume VI	:	Services Sector
Volume VII	:	Water Quality Analysis, Feeder Systems, Natural Environment.

It is important to point out that this main report is an interpretation and integration of the background research and that, as such, variations may occur. The background research should be interpreted as the development of a reference framework by the different specialists and, during the course of the study, research findings were continually refined.

1.3 CONTENTS OF REPORT

This report presents the results of the formulation of the generalised salinity model and its application to the case study area of the Middle Vaal River region. Emphasis has been placed on the main findings of the integrated model, incorporating summaries of the sectoral inputs.

This integrated report consists of the following sections:

Section 2 : Research Approach and Methodology
Section 3 : Assumptions and Conditions
Section 4 : Description of Model
Section 5 : Application of Model
Section 6 : Data Collection, Transformation and Model Use
Section 7 : Interpretation of Results
Section 8 : Conclusions
Section 9 : Further Research

The contents of this report are presented in a user-friendly format, by discussing the process and results of the study and presenting the supporting data tables in the report.

SECTION 2: RESEARCH IN PERSPECTIVE

This section discusses the background underlying the research and the approach followed to generate the required results.

2.1 BACKGROUND

The research conducted in this study is unique - no other comparable research exists.

Heynike (1987) prepared a report based on a study which addressed the economic effects of salinisation. This was essentially a "desk study" which focused on the direct effects of salinity on a number of predetermined sectors. However, the Heynike report was widely criticised, although it provided a foundation and identified further research requirements.

Steffen, et al (1989) published a review document from this document which included sectoral comments on the Heynike report (1987). The following comments are relevant to the current study (Steffen, et al, 1989).

- In analysing the household sector, due cognisance was not taken of the behavioural or non-scientific aspects relating to increased levels of salinisation. This implies that the cost of salinisation to households represents only those facts that can be scientifically measured and therefore cost values to households are questioned. It is thus suggested that the household sector be analysed in terms of its behaviour towards increased salinity levels.
- The impact of increased salinity levels on health conditions has not been adequately specified or delineated.
- Other economic sectors such as mining, industry, agriculture, etc, need to be analysed and verified by conducting primary research.
- The indirect effects of increased salinity costs throughout the economy have not been addressed.

These criticisms of the Heynike report (1987) were addressed in the current study. An important aspect of the effect of salinisation which had not been addressed by the Heynike report (1987) was the behavioural aspects relating to sectors other than the household sector. This too, formed an important element of the current study.

2.2 APPROACH

The approach of the current study is based on economic theory by conceptualising the *sectoral* behaviour within the economy. The disaggregation of the economy in the relevant sectors was thus of paramount importance in determining sectoral costs and behaviour impacts of salinity. The study was conducted in two distinct phases which had been integrated to produce the results discussed in this report. The first phase was aimed at the development of a generalised model, while the second phase was devoted to applying the generalised model to a case study area, viz the Middle Vaal River.

2.2.1 Study Team

On account of the nature of the research problem, a team of specialists, rather than an individual, was utilised to produce the required inputs. The team comprised the following specialists:

INPUT	FIRM	PERSON
Project coordinator	Urban-Econ	Dr J Oberholzer
Household	Human Sciences Research Council	Dr T Emmett M O'Donovan & A Jooste
Agriculture	Loxton, Venn and Associates Afrosearch-Index Agtec	F Merryweather & J Howcroft A Gouws P Nel & Dr S Brooderyk
Mining	Loxton, Venn and Associates Pulles, Howard & De Lange	M Macgregor W Pulles & S von Bredow
Industrial and services	Urban-Econ	M Cook
Feeder systems	Africon	C Marx
Natural environment	Afridev	Dr M Chutter
Corrosion and scaling	Corrolec cc	N Webb & V Sealy-Fisher
Water quality analysis	University of Cape Town	Prof D Loewenthal
Integrated modelling and mathematical equations	Economic Project Evaluation Urban-Econ	C Williams & M Bill Dr J Oberholzer & M Cook

Apart from the project team, various independent specialists were consulted throughout the course of the study, either individually or in a workshop environment.

2.2.2 External Reviews

The research results and sectoral reports were subjected to external reviews by specialists to verify the approach, methodologies and results of the study. Valuable contributions were made by the external reviewers which led to significant improvements in the research findings. These specialists were:

- Dirk van Seventer, DBSA : Input-Output modelling specialist.
- Dr Hendrik Nel, CEAS : Economic Modelling and Input-Output Specialist.
- Prof Gerhard Gehrig, Germany : International Input-Output modelling specialist.
- Izak van Gass, Eskom : Social expert.
- Prof Charles Breen, University of Natal: Social specialist.
- Dr Johan du Pisanie, Ekobest : Economic Specialist.

2.2.3 The Generalised Model

The formulation of the generalised salinity model during the first phase of the study, resulted from the processes discussed hereafter.

2.2.3.1 Identification of main water-use sectors

Initially, the identification of the main water-use sectors was done to define the study applicability. This resulted in the definition of the sectors that were analysed in this study.

In general economic terms, an economy consists of a variety of sectors, each with its own distinctive production processes, output and behaviour patterns and trends. Furthermore, each sector has a different level of sensitivity towards water and salinity. In taking cognisance of these aspects, an economic sectoral classification based on water usage formed the basis for further research. The sectors identified and defined were:

- Households,
- Agriculture,
- Mining,
- Industry,
- Services,
- Feeder systems, and
- Natural environment.

The specific effects of corrosion and scaling were considered separately and the results were integrated within each appropriate sector.

2.2.3.2 Conceptualising the sectoral behaviour

Once the main water-use sectors had been identified, the sectoral behaviour towards the effects of salinisation was conceptualised and expressed as functional relationships.

Knowledge of specific water quality problems was, however, required and therefore a water quality analysis for the study area was undertaken. An integral part of this stage of the process was the verification of the conceptual relationships by means of expert workshops and interviews. This step culminated in conceptual/normative formulae for each sector.

2.2.3.3 Creation of the generalised model

On finalising the conceptual formulae within each sector, the various sectoral relationships and formulae were combined and integrated to create an interactive model. This model was designed to be used to simulate the various indirect and induced cost effects of specific changes in the salinity levels and water compositions in a given area. The resultant generalised model has the ability to be applied to analyse and simulate the effects of salinisation within any defined area.

2.2.4 The Case Study

The study area identified for applying the generic model, was the Middle Vaal River area, which stretches from the Barrage to Bloemhof Dam. There has been a steady increase in the salt content of the Vaal River since 1935. This increase has accelerated markedly since 1965 with a further pronounced effect caused by the recent droughts. This increase affects all water use components exposed to such water.

A major salinity problem exists in the Middle Vaal River area, between the Barrage and Bloemhof Dam. Various options for solving the problem have already been identified. All the options are, however, costly and it is important to quantify the benefits of a reduction in salt concentration in order to justify expenditure on measures to reduce the salinity.

The salinisation problem for users at the Barrage is at present being kept under control by the 300 mg/ℓ blending option. With this option Rand Water is able to withdraw enough water from the Vaal Dam to supply its users with water that does not exceed a Total Dissolved Salts (TDS) concentration of 300 mg/ℓ. The option is convenient and advantageous, since the additional withdrawal from the Vaal Dam has little effect on the supply of the Vaal River system as a whole. The water supply areas included in the study area are:

- <u>Western Transvaal Water Company</u>

- Stilfontein
- Klerksdorp
- Orkney

- <u>Goldfields Water</u>

- Leeudoringstad
- Allanridge
- Welkom
- Odendaalsrus
- Virginia
- Theunissen
- Wesselsbron
- Bothaville
- Ventersburg
- Hennenman
- Makwassie

- Note: Schweizer-Reneke has its own supply but is apparently interested in obtaining water from Goldfields Water. The town was not included in this study.

- <u>Other areas</u>

- Parys
- Viljoenskroon

This phase involved the application of the generalised model to the specified study area. The processes and practical stages employed, are outlined and described below.

2.2.4.1 Profile of economy

Each geographical area is unique with respect to its economic composition. It was thus important to make provision in the model for case study specific characteristics. This was achieved by compiling an economic profile of the study area.

Based on the input requirements of the model as well as the profiles of the study area, the specific data requirements for each sector were set out. These data requirements complied with the sectoral formulae developed in the first phase and represented the base line information required from the surveys and interviews.

Examples of data requirements are:

* Input costs for salinity ranging from 200 mg/ℓ Total Dissolved Solids (TDS) to 1200 mg/ℓ TDS at 200 mg/ℓ intervals. These were fixed parameters for the purposes of this study,

since the water quality constituents for each salinity level were analysed and defined during the first phase.

* Costs of water treatment and desalination needed to be expressed as annual costs in rands. This implied the necessity for certain transformations of data.
* Data used, was based on the 1994/1995 financial years, or was transformed to suit, if unavailable for the period of study.
* Data for confidence intervals to quantify behavioural aspects was required. This was obtained from information based on the probability of management decision likely to be made at each of the prescribed salinity levels.

It is evident from the above, that the required data was specific and focused. This defined the need for structured questionnaires to obtain specific data items from each of the establishments interviewed.

2.2.4.2 Surveys

During the next stage, surveys were conducted and interviews undertaken to obtain the necessary up-to-date data to apply in the model. Separate data gathering actions were undertaken for each of the sectors, so that the data generated was useful as proxies for the requirements within each of the different sectoral formulae.

The surveys required that structured questionnaires and survey protocols be designed and that adequate sample sizes be established. The questionnaires focused mainly on obtaining information on two aspects, namely:

* *Technical data*: Technical cost elements related to the direct cost of combating salinity.
* *Behavioural data*: Behavioural aspects cannot be directly costed and therefore confidence intervals or bands needed to be established. These were based on the probability of decision-making related to increased costs of production, arising from the accrued costs of combating salinity.

Since each economic sector is different with respect to behaviour, production functions and information requirements, the surveys for each sector were approached in a different manner.

2.2.4.3 Data transformation

Raw data generated from the surveys was generally unsuitable for direct application to the formulae. As a result, data transformations were required to ensure general compatibility with the model. This was particularly true for that information relating to behavioural aspects and confidence intervals.

The transformation of data comprised two main elements, namely:

* Analysis of survey data - generally by means of conventional data analysis to obtain the required information.
* Adaptation for model acceptability - specific data transformations were required to ensure that the data could be directly related to the model.

2.2.4.4 Model use and refinement

The information gathered with the surveys was applied in the generalised Salinity Model. The data was fed into an interactive model to determine the total economic cost of salinity to the national economy due to changes in salinity in the Middle Vaal River area.

Once preliminary results had been obtained from the model, the validity of the results was tested by means of specialist feedback and the model was evaluated. Where the results from the model yielded problems and inconsistencies, the model was adjusted and the model assumptions were re-evaluated. Where necessary, additional data was obtained and used to rerun the model, and updated results were obtained.

Preliminary output from the model was tested against the opinion of the steering committee and the panel of experts mentioned above. As a result of their feedback, it was decided to implement two further models against which the output of the original model could be tested. These models also provided additional insight into the problem areas raised by the review process. Based on the results obtained, recommendations were formulated for the specific study area, both on a sectoral basis as well as at a general level, i.e. the overall impact of salinity on the Middle Vaal River area was discussed.

The presentation of this case study has resulted in an indication of the relative annual cost of salinity for each economic sector, i.e. the direct effects, as well as the total cost to the economy, incorporating the indirect and induced effects.

2.3 REFERENCE FRAMEWORK

The general economic reference framework of the integrated model was the input-output (IO) technique. This allowed the various sectoral formulae to be integrated in a systematic framework which complies with economic theory. By applying the IO model approach, both the direct and indirect annual cost effects to the economy could be accounted for.

The utilisation of the IO technique allows for a variety of applications to address specific issues, such as the resource usage within an economy, environmental problems, multiplier analyses as well as sectoral price increases. The latter two applications namely that of multiplier analyses and the pricing model, were used to generate the main results of the study and the other applications were used to elaborate on the model results and thus validate the results.

It is, however, important to realise that only the internal cost effects of each sector in the study area were modelled. This implies that the aggregation of the sectoral costs in the IO framework would render the total cost to the economy. Any downstream effects, such as the increased salinity levels in the total water system due to effluent discharge, were not considered.

SECTION 3: ASSUMPTIONS AND CONDITIONS

3.1 INTRODUCTION

The assumptions and conditions provided in this section are important aspects that came to the fore during the course of the study. In many instances these are rather stringent and are possibly indicative of problem areas. The assumptions pertaining to the general approach to the study, are provided.

3.2 GENERAL ASSUMPTIONS

All models operate under certain conditions and assumptions. Discussion of these and the reasons for them is vital for the correct interpretation and use of the model. The general assumptions of this study follow.

(i) Since the purpose of the study was to create a generalised model, sectoral assumptions and generalisations were required.

(ii) The behavioural impact of increased salinisation was expressed as functional relationships, since the behaviour of water users was deemed essential in establishing the total effect.

(iii) The aim of the study was to create a generalised model that could be applied in any of the national water subsystems. This implies that, in order to be able to cater for most conditions, the model should be flexible.

(iv) Although the objective was a generalised model, two practical considerations led to the fact that the generalised model was orientated towards the Middle Vaal River area:

- Chemistry limits: The TDS concentrations for the model were defined as ranging from a minimum of 200 mg/ℓ TDS to a maximum of 1200 mg/ℓ TDS (using 200 mg/ℓ TDS intervals) and a pH range between 6.5 and 9.0.
- The complexity of the sectoral situations demanded that a specific geographical area be used as a *reference framework*.

  (These two issues do not, however, imply that the model is not general enough to be applied in other geographical areas.)

(v) External influences, such as unemployment, increased urbanisation, and seasonal fluctuations in rainfall, amongst others, were not directly accounted for in the model. This is so, since it was assumed that these costs were indirectly considered in the cost components of the formulae.

(vi) The model consisted of direct cost equations for each sector. The indirect costs were determined by relating the direct cost equations to an IO matrix.

(vii) All costs of the model are expressed in rands per annum, which means that the model refers to annual costs.

(viii) The study is based on a norm of determining the cost to maintain the status quo in view of increased salinity. Behavioural aspects therefore represent costs to maintain the *status quo*.

(ix) The relationship between water constituents of the various salinity levels has been determined in the water quality analysis and accepted as fixed. This implies that ion-specific sensitivities had not been taken cognisance of.

(x) Temporary measures such as water restrictions were not considered as influencing long-term costs and thus behaviour.

(xi) Saline water may affect health negatively over the medium to long term after prolonged use of water with TDS levels in excess of 1100 mg/ℓ. Generally speaking, these levels fall outside the TDS range of the study.

(xii) Heated surfaces are most affected by high levels of salinity in the form of scaling which have impacts on the cost structures of concerns.

3.3 SECTORAL ASSUMPTIONS AND CONDITIONS

This section aims at discussing the assumptions underlying the various sectoral equations. These model regimes determined the manner in which data was obtained, as well as the transformations necessary to render data suitable for the interactive model. More importantly, however, the assumptions are indicative of the unique production structures and the potential for isolating behavioural aspects resulting from increased salinity.

3.3.1 Household sector

The assumptions underlying the household sector are important, since households are not exclusively driven by a single motivation in income maximisation. The household sector behaviour is determined by an interplay of ambiguous factors and this is exacerbated by relative unpredictability and lack of knowledge about human behaviour.

The following major assumptions applied to the household sector:

* Households which have moved from a "low salinity" area to a "high salinity" area will exhibit altered behaviour in water utilisation. This can be quantified in costs.
* Adjusted behaviour of the sample population can be indicative of the type of adjustments which will be made by households of a similar socio-economic profile. Trends identified as similar, in two climatically, geographically, economically and socially diverse communities, can be attributed to the effect of salinity.
* The existence of universal patterns in diverse communities allows for the unambiguous attribution of behaviour patterns and trends to increased salinity of water.
* The qualitative analysis of in-depth interviews in one area can lead to the identification of behavioural and consumption trends, which can be compared with data gathered in a probability sample from another area.
* If increased salinity in water affects the behaviours and the budgets of households, the effect would have to be captured globally.

3.3.2 Agricultural sector

The agricultural model of salinity costs is influenced by a variety of aspects, including climatic conditions, soil properties and practices that are in place to manage the salt load contained in the water. Saline water will not only influence yield, but will also alter the soil, resulting in its becoming less productive and more costly to reclaim.

The following assumptions apply:

- Salinity will not directly influence the health or performance of animals. Indirect costs may occur in the production of animal feeds. These are expected to be insignificantly low for the current TDS range of the study.
- The adverse effects of salts on plants refer to osmotic or total salt effect, the specific ion effect and the specific ion effect of sodium on the soil properties.
- Aquaculture will not be affected within the given salinity levels.
- Crop yield does not decrease significantly until the salinity level in the soil-water exceeds a critical value (threshold value).
- Many food and fibre crops undergo a linear decrease in yield as salinity levels increase beyond the threshold value.
- Management decisions play an important role in agricultural production and cannot be separated from water quality in assessing the impact of salinity on agriculture.
- Management options are accepted to be any of the following:
    - accepting reduced yield
    - adopting irrigation management
    - changing cropping programmes to less sensitive crops
    - installing artificial drains
    - ceasing production.
- Poorer soils with restrictive drainage will require different management options and will experience salinity more severely than other soils.
- Decisions regarding future land use and enterprise selection are made on economic grounds.
- Farms have some non-arable land with water quotas, as well as productive land with irrigation potential, being under rainfall production.
- The size of land area under irrigation is determined by the size of water quota.

3.3.3 Mining sector

The following assumptions, regarding the mining sector have been made:

- Water quality related decisions are technologically and economically driven.
- Management and treatment of water in water circuits are generally optimised in terms of available technology, cost effectiveness and availability of water.

3.3.4 Industrial sector

The assumptions and conditions relating to the industrial sector are as follows :

- The behavioural aspects are mainly technology-driven, where water is used as process or end product water.
- Compensatory behaviour or related changes in water use, treatment, etc. by industry only become relevant when the water reaches specific salinity levels at which potential negative health effects may be observed.

* Obtaining information on the cost of salinity is greatly influenced by a general lack of knowledge on the issue.
* Subsectors included in the industrial sector are: manufacturing, electricity and construction.
* Due to the manner in which water is used in industry, the industrial sector is disaggregated into two groups, namely: manufacturing (1) and treatment manufacturing (2). The former group of industries does not use water in their production processes nor do they treat water to obtain specific levels of TDS. In contrast, the treatment manufacturing group has to treat water to a certain extent or has to incur maintenance costs to adhere to the technical standards necessary for efficient functioning of equipment.
* The behavioural information, particularly for treatment manufacturing, is confined to parameters provided by the technology of processes and equipment. This means that if a certain process requires water of a lower TDS value than the TDS of the intake water, the choice in behaviour is limited to that prescribed by technology.
* Behaviour in the manufacturing (1) group is limited, since water use is predominantly for human consumption. This implies that, depending on the cost of installing purification systems, for example, management may consider incurring costs to treat water to ensure that the water will have no adverse health effects.
* In general, industry will consider treatment plants and equipment only if the water reaches unmanageable levels of salinity, both in terms of technology and human consumption.

3.3.5 Services sector

The assumptions and conditions relating to the services sector are as follows:

* Compensatory behaviour or related changes in water use, treatment, etc. by services only become relevant when the water reaches specific salinity levels at which potential negative health effects may be observed.
* Obtaining information on the cost of salinity is greatly influenced by a general lack of knowledge on the issue.
* Subsectors included in the services sector are: trade, offices, government services, recreational services, storage, financial and personal services.
* The activities classified as services are aggregated into a single sector since the water usage patterns and behavioural aspects are found to be relatively similar.
* The main use of water in the services sector is for human consumption and related aspects.
* Behaviour in services is limited since water use is predominantly for human consumption. This implies that, depending on the cost of installing purification systems, for example, management may consider incurring costs to treat water to ensure that the water will have no adverse health effects.
* In general, services will consider treatment equipment only if the water reaches unmanageable levels of salinity, both in terms of technology and human consumption.

3.3.6 Feeder systems

The assumptions relating to feeder systems include the following:

* Increased salinity in water results in increased costs for water treatment and conveyance.

* Conveyance costs are accepted to be an indirect cost due to corrosion or additional maintenance, since the physical properties of water are not changed sufficiently to impact on the direct conveyance costs.
* Treatment costs or corrosion rates cannot be modelled with increased salinity, based purely on TDS measurements.
* The cost of desalination should be taken as the upper limit of the costs. If the sum of the individual costs exceeds this cost, desalination should be considered.

3.3.7 *Natural environment*

The assumptions relating to the natural environment include the following:

* Inclusion of all parameters results in a highly complex interaction between the various components. Thus, modifications have been made to withdraw any components which are unaffected within the TDS range being studied.
* The direct effects of TDS changes on snails and hyacinth, and the indirect effects of TDS on algal abundance are considered.
* Species loss has an undefined financial impact and can be defined has attributing a non-financial cost.
* The costs associated with changes in the environment can be incorporated within more traditionally acceptable sectors:
    - fish - recreation
    - hyacinth - recreation
    - algae - water treatment
    - disease vectors - agriculture
* Since the most important cost effects can be incorporated into other sectors, the Natural Environment, as an independent sector, is not included in the integrated formula. However, the sectoral report and formulae are available in Volume VII.

3.4 ASSUMPTIONS REGARDING THE NATURE OF THE COSTS

The impact of increased salinity of water on the economy is expressed in terms of costs. The costs to the economy include the following:

- direct costs or losses which can be translated into conceptual and mathematical formulae
- indirect costs as a result of linkages within the economy
- economic costs due to the increased use of factors of production - as water is a scarce resource, there will be an opportunity cost incurred by using more water
- economic losses related to the decrease in returns from factors of production
- economic losses due to a sector's reliance on raw material from a specific sector
- economic losses to a sector providing services, goods and capital goods to the specific sectors
- behavioural aspects referring to the decision-making processes of water users which imply cost implications.

Since the salinity levels of the water are predetermined to start at 200 mg/ℓ TDS and to increase at intervals of 200 mg/ℓ to reach a maximum of 1200 mg/1 TDS, it is assumed that the 200 mg/ℓ TDS was the zero cost datum for this model.

Since the IO model is generally based on annual production costs, the model considered costs over a period of a year, i.e. annual costs, and these have been factored, if necessary.

SECTION 4: DESCRIPTION OF MODEL

4.1 THE MODEL

The generalised model provides a system for integrating the separate formulae prepared for each sector. This model provided the reference framework and the parameters within which the subsequent data gathering was conducted.

The postulated model comprises a set of cost equations, used for calculating the direct costs resulting from salinity effects in each sector. The IO technique is used to determine the indirect costs.

The general concept of the model can be expressed as follows:

Cost of salinity = $f\,(H, A, M, I, S, F, N)$

where

$$H = f\,(K_H, \ldots\ldots\ldots, K_N)_{all\ TDS}$$

$$\vdots \qquad\qquad \vdots$$

$$N = f\,(K_H, \ldots\ldots\ldots, K_N)_{all\ TDS}$$

and

H	=	the direct cost of salinity to the household sector
A	=	the direct cost of salinity to the agricultural sector
M	=	the direct cost of salinity to the mining sector
I	=	the direct cost of salinity to the industries (or manufacturing) sector
S	=	the direct cost of salinity to the services sector
F	=	the direct cost of salinity to the feeder systems (or water supply) sector
N	=	the direct cost of salinity to the natural environment sector
K_H	=	the contribution to costs of inputs from the household sector
K_A	=	the contribution to costs of inputs from the agricultural sector
K_M	=	the contribution to costs of inputs from the mining sector
K_I	=	the contribution to costs of inputs from the industries sector
K_S	=	the contribution to costs of inputs from the services sector
K_F	=	the contribution to costs of inputs from the feeder systems sector
K_N	=	the contribution to costs of inputs from the natural environment sector

This formula states that the cost of salinity is determined by the sum of all the costs incurred by the various sectors in the economy.

These direct cost equations represent the costs to any sector (or IO sector) as a result of a given level of salinity in the water used by that sector, and can be more conveniently expressed as follows:

$$K_j = \sum_{i=1}^{j} \Delta X_{ij}$$

where
K_j is the direct cost to any given sector j, and
ΔX_{ij} is the contribution to costs of sector i of inputs from sector j.

These direct cost equations form a system of n equations in n unknowns. If this set of equations could be solved mathematically (or by computer), a computable general equilibrium model (CGEM) could be created. However, it is anticipated that many of the cost equations would either be non-linear, or discontinuous, and would not, therefore, readily lend themselves to the simultaneous solution required.

The generic sectoral equations were used as basis for collecting cost data. In addition to collecting data in the field, the appropriate section of the generic model to project the costs, which result from coping with changing salinity over the complete range being studied, was used. Costs developed represent the *direct salinity costs* to each sector.

In order to get a complete picture, the indirect and induced costs associated with the direct costs also needed to be calculated.

Since mathematically solving the direct cost equations was deemed unlikely, an alternative method was sought. One method of obtaining a CGEM is to incorporate all of the direct costs into an IO table or Social Accounting Matrix (SAM). Incorporating the direct costs into an IO table and then performing a standard IO analysis would yield the indirect costs.

The integrated model created for this study is based on the IO technique. This implies that all of the sectoral formulae were formulated to generate the necessary inputs required by an IO model and the generic equations were structured in such a way that contributions from all other sectors to the final costs of a given sector could be identified. This procedure enabled the cost data to be compatible with information available in standard IO tables.

4.2 DIRECT SECTORAL COST EQUATIONS

Since the generalised model comprises a mathematical combination of the direct cost equations for each sector, it is deemed necessary to provide a general description of the initial seven sectors and their associated direct cost equations. These equations were utilised to generate the costs that are incorporated into the IO model, to determine the total cost of salinisation to the economy.

4.2.1 Households

4.2.1.1 Description

The household sector is the primary sector of domestic water consumption. The following effects of increased salinity in water on households are considered to be important:

- household plumbing, including piping and taps
- hot water geysers
- household appliances, including kettles, washing machines, dishwashers and steam irons
- use of soaps, detergent and fabric softeners
- potential health impacts.

In general, income provides a more accurate form of differentiation of the South African population than race. The current racially skewed distribution of income and other resources, such as services and water supply, may be important.

For purposes of the general model, the household sector can be categorised as follows:

- low income
- medium income
- high income.

Rural and urban differences could be crucial with regard to a variety of factors, including income, cultural orientation, water supply systems, etc. The focus of this study, however, was urban communities.

Although certain categories of the population may be at greater risk when consuming water high in TDS, it will not be possible to account for these risks until greater clarity is obtained on the health effects associated with increased salinity.

Previous research pointed to the importance of the awareness of private householders of salinity being a form of pollution. Such awareness is likely to be related to the level of education of householders.

4.2.1.2 Conditions

In economic terms the household sector has a utility function and therefore cost impacts may not be easily quantified. This is especially true for the behavioural aspects which are important in water usage and salinity issues.

Health and quality of life issues have not been translated into equations as a result of the indirect nature of cost effects. Furthermore, these issues are not easily quantifiable as they are directly related to behaviour. Therefore, these issues were accounted for by making use of a probabilistic approach.

4.2.1.3 Equations

The total costs of salinity for the household sector are determined by maintenance costs (covering geysers as well as plumbing); accelerated replacement costs (of geysers, anodes, piping, fabrics and appliances); costs of soaps and detergents, as well as the current or anticipated level of salinity. These costs are calculated for all three household groups by applying a usage and wear index for a given level of salinity:

$$\mathrm{K}_{\mathrm{HTot}} = f(M, R, D, S)$$

i.e., $K_{HTot} = \left[K_{HM} + K_{HR} + K_{HD}\right]_{PDj}$

where

$$K_{HM} = \sum_{LS,j} |\Delta_{LS}| \left(Rs_{LS} * M_{HLSj}\right) * NH_{LS}$$

or

$$K_{HM} = |\Delta_{Hi}| \left(Rs_{LS} * M_{HLSj}\right) * NH_{Hi} + |\Delta_{Med}| \left(Rs_{LS} * M_{HLSj}\right) * NH_{Med} + |\Delta_{Lo}| \left(Rs_{LS} * M_{HLSj}\right) * NH_{Lo}$$

Similarly,

$$K_{HR} = \sum_{LS,j} |\Delta_{LS}| \left(WI \cdot R_{HLSj}\right) * NH_{LS}$$

$$K_{HD} = \sum_{LS,j} |\Delta_{LS}| \left(UI * D_{HLSj}\right) * NH_{LS}$$

where:

$$UI = Usage\ Index = \left(Usage_{new} - Usage_{current}\right)$$

$$WI = Wear\ Index = \left(\frac{\text{Current life - Expected life at new S}}{\text{Current life}}\right)$$

S = current or anticipated salinity (TDS)
TDS_{thres} = salinity threshold where expenditure pattern changes

$$\left|\Delta\bar{S}_{ij}\right| = \left(\mathrm{TDS} - \mathrm{TDS}_{\mathrm{thres}}\right)_{\text{for all LS}}$$

$$\left|\Delta\vec{S}_{ij}\right| = \left(\mathrm{TDS}_{\mathrm{thres}} - \mathrm{TDS}\right)_{\text{for all LS}}$$

$$Rs = \left(\frac{S_{new}}{S_{curr}}\right)_{\text{for all LS}}$$

M	=	maintenance costs, and covers geysers and plumbing
R	=	accelerated replacement costs, including geysers, anodes, piping, fabrics and appliances.
D	=	costs of soaps and detergents
LS	=	living standard, comprising high, medium and low
N	=	number of households
PDj	=	probability of distribution arises due to uncertainty of behaviour

4.2.2 Agriculture

4.2.2.1 Description

The agricultural sector can be broadly divided in terms of its water usage and water requirements, into :

- irrigated agriculture/crop farming
- livestock agriculture
- aquaculture.

These categories are further subdivided on the basis of economic return, intensity of production and water usage.

(i) Irrigated Agriculture

The water requirements of agriculture vary in terms of:

- water quality requirements - vary with crop, soil and socio-economic circumstances
- water quantity requirements - vary with crop and cultural practice
- volume of water required - varies with irrigation method.

Water quality and water quantity cannot entirely be separated. To some extent poor water quality can be mitigated against, under certain circumstances, without reduction in crop yield, by increasing the amount of water used in irrigation.

(ii) Livestock Agriculture

Livestock agriculture is generally less sensitive to water chemistry than crop agriculture. However, some plants can accumulate elements which are toxic to animals while remaining unaffected themselves.

Livestock differ in their ability to use water of poor quality. Further, the ability to use poor water with no ill effects also varies with life cycle. Livestock which are not accustomed to poor water quality will suffer ill effects from water, which other animals, accustomed to such water, drink with no apparent ill effect.

(iii) Aquaculture

Aquaculture responds to the same chemical parameters as do crop and livestock agriculture. However, aquaculture is generally more sensitive to sudden changes in quality than to extremes in quality, up to those levels tolerated by livestock. Aquaculture is, however, not included in the model, since the cost elements of desalination within the specified parameters of this study are not relevant.

4.2.2.2 Conditions

The agricultural sector is a supply-driven sector. This implies that profit maximisation behaviour may not be comparable to that of other sectors. The agricultural sector may continue to produce, even when decreased income and yield are obtained. The effect of water quality on product quality has been disregarded.

The production function is either mathematically intractable, discontinuous, non-linear or a mix of these. Data in such cases would normally be presented in tabular or matrix format. Linear programming analyses could be conducted to determine the most probable optimal substitution crops for different salinity levels.

4.2.2.3 Equations

The total cost of salinity in the agricultural sector is determined by the average costs and the variable costs. The former consists of corrosion, fixed costs and the cost of replacing plant and buildings. The latter consists of the cost of water supply, maintenance costs, plant and chemicals. All these costs are determined by the specific level of salinity and the tolerance levels of different crops.

$$K_{ATot} = f\left(K_{AC}, K_{AVar}\right)$$

where

$$K_{AC} = f(\text{corrosion, fixed costs, plant \& buildings})$$

$$K_{AVar} = f(\mathrm{M, C, V, P})$$

and

$$K_{AVarj} = \sum_{i}\left[\left|\Delta\vec{S}_{AVj}\right|\left(Rs*V_{AVj}\right)+\left|\Delta\vec{S}_{AVj}\right|\left(Rs*M_{AVj}\right)+\left(Rs*C_{AVj}\right)+\left|\Delta\bar{S}_{AVj}\right|*P_{AVj}\right]_{PDj}$$

$$K_{ACj} = \sum_{i}\left[\left|\Delta\bar{S}_{ACj}\right|*P_{ACj}+Rs*C_{ACj}\right]_{PDj}$$

where

V	=	cost of water supply
M	=	maintenance costs
P	=	plant
C	=	chemicals

S	=	current or anticipated salinity (TDS)
TDS_{thres}	=	salinity threshold where expenditure pattern changes
T	=	crop tolerance band, comprising Hi+, Hi, Lo and Lo-.

$$\left|\Delta\bar{S}_{Aij}\right| = \left(\mathrm{TDS} - \mathrm{TDS}_{\mathrm{thres}}\right)$$

$$\left|\Delta\vec{S}_{Aij}\right| = \left(\mathrm{TDS}_{\mathrm{thres}} - \mathrm{TDS}\right)$$

$$Rs = \left(\frac{S_{new}}{S_{curr}}\right)_{\text{for all sectors}}$$

$$V_j = \sum_{i=1}^{j} \Delta X_{ij} \qquad M_j = \sum_{i=1}^{j} \Delta X_{ij}$$

$$C_j = \sum_{i=1}^{j} \Delta X_{ij} \qquad P_j = \sum_{i=1}^{j} \Delta X_{ij}$$

ΔX_{ij} = contribution to direct costs of sector *i* by sector *j*.
H, A, M, I, S, F as defined under generalised model formulation.
PDj = probabilistic distribution arises due to uncertainty of management behaviour.

Furthermore, income reduction, which is incorporated in the model as an exogenous variable rather than as a cost, is expressed as:

$$I_{redn} = \sum_{T} \left[I_{thres} * Z_T \cdot |\Delta S_i| \right]_{PDi}$$

Where

I_{thres} = income level when reduction commences
Z_T = income reduction ratio
D_{Si} = threshold at which income reduction begins.
Note that both $\mathbf{D_{Si}}$ and $\mathbf{I_{redn}}$ = 0 for all values <= 0.

4.2.3 *Mining*

4.2.3.1 Description

The general classification of mining activities and the number of operations in South Africa are as follows:

Mining Activity	No. of Operations
• Precious metals and minerals	174
• Coal	76
• Base metals and industrial minerals	418
• Aggregate and sand	374
• Processed minerals	31
TOTAL	1073

The mining sector within South Africa is diverse and a large number of minerals are mined. Water usage patterns and the impacts of increased salinity will vary significantly throughout the mining sector and therefore any attempt to conceptualise this diverse behaviour within a model will necessitate a model which is so broad and generalised that it will have limited practical use. For this reason and due to the almost total lack of information on water usage and quality effects within the other mining sectors, this study will focus on gold mining operations. Gold mining is also the dominant mining activity within the study area, namely the Middle Vaal River area.

4.2.3.2 Conditions

Four major water use areas were considered, namely:

- Mine services water circuit
- Evaporative cooling circuit
- Metallurgical plant water circuit
- Irrigation water circuit.

Secondary water requirements including gland water, carbon elution and regeneration, etc. are excluded at this stage. Water plant circuits, with the exception of flotation and electrolytic processes are not sensitive to salinity and are not considered. Mine service water is only significant with respect to scaling.

4.2.3.3 Equations

The total cost of salinity to the mining sector consists of the costs incurred in the various water use areas in the mine, i.e. evaporative cooling circuits, service water circuits, metallurgical plant circuits (flotation circuits and electrolytic processes) and irrigation water circuits. Each of these is affected in varying degrees by the cost of water supply, chemicals, discharge water, scaling and water treatment for different levels of salinity. The formula for the mining sector is as follows:

$$K_{MTot} = f(EC, SW, FC, EP, IW, PD)$$
$$K_{MEC} = (Rs*V_{EC} + Rs*C_{EC} + Rs*B_{EC})$$
$$K_{MSW} = f(SC, DC)$$
$$K_{MFC} = (Rs*C_{FC})$$
$$K_{MEP} = f(V, WT, DC)$$
$$K_{MIW} = |\Delta S_{MIW}|*V_{MSIW}$$

where :

EC	=	evaporative cooling circuits
SW	=	service water circuits
MP	=	metallurgical plant circuits
FC	=	flotation circuit
EP	=	electrolytic processes
IW	=	irrigation water circuits
PDj	=	probabilistic distribution of management behaviour
V	=	cost of water supply
C	=	cost of chemicals
WT	=	cost of water treatment
DC	=	cost of discharge water
SC	=	cost due to scaling
Rs	=	salinity ratio

4.2.4 Industry

4.2.4.1 Description

Industry is classified into three subgroups, namely:

* Manufacturing
* Electricity
* Construction.

The three subgroups are discussed separately.

(i) Manufacturing

Water has many functions in manufacturing in general. A number of these functions are common to nearly all concerns, while others are specific to a particular process or concern. The most common purposes for which water is used in manufacturing include:

- steam generation and/or heating
- cooling
- constituent of the product, product dilution, or product conditioning
- reagent make-up
- product or surface washing
- transport of materials or wastes.

Water of almost any quality can be used for some purposes. On the other hand, water quality is critical for many other purposes, where it can either interfere with the proper functioning of processes, thereby impairing the quality of the product, or it can hinder the efficient operation of or cause damage to equipment and machinery. Water quality criteria are therefore usually set by the manufacturers of equipment or the designers of processes to ensure that problems do not arise.

The problems experienced by manufacturing, which are related to water quality, are diverse. Some are common to most plants, others more specific to a particular concern. The types of potential problems that may arise as a result of a change in water quality are :

- scaling of hydraulic systems and process equipment
- corrosion of hydraulic systems and process equipment
- formation or presence of suspended solids which may-
  - interfere chemically with the process
  - adversely affect the quality of the product
  - deposit sediments within the hydraulic system and process equipment
  - cause erosion of pumping systems
  - generate sludge.
- discoloration or staining of the product
- interference with or inhibition of one or more stages of production
- development of organic growths in hydraulic systems, process equipment or material under production.

Scaling and corrosion are widespread problems and are not limited to industrial operations. The water quality requirements of a manufacturing concern are dependent not only on the nature of the product, but also on the technology used in the manufacture of the product.

The selection of manufacturing industries included in the model are the following:

- leather and tanning industry
- iron and steel industry
- pulp and paper industry
- petrochemical industry
- textile industry
- other industries.

Manufacturing industries accept that, whatever the source of water supply, some water treatment or conditioning will generally have to be carried out on their own premises to render it fit for its designated use. Conversely, concerns expect that the quality of water supply should remain relatively constant. Therefore in-house treatment facilities take into account the quality of the water supply received. Subsequent changes to this quality may have highly detrimental consequences for a concern.

The manufacturing concerns had been aggregated into two subsectors, namely treatment and non-treatment industries. This was on account of the undiversified manufacturing profile of the study area, since only a few of the abovementioned industries occur in the study area. This can be considered a limitation of the case study area.

(ii) Electricity

Electrical power in South Africa is predominantly supplied by Eskom. Eskom supplies most of the country's electrical power, and a substantial amount of the electricity generated in Africa. The balance of the electrical power generated in South Africa is produced mainly by municipally owned power stations and by some industries which generate their own electricity. The municipally owned power stations are generally small power stations, some of which are only commissioned during emergency situations. These facilities normally obtain treated water supplies from the local municipality or water board for steam production, and often use treated sewage effluent for cooling water purposes.

The principal functions of water in the power generation industry are:

- production of steam to drive the turbine
- cooling water, mainly to condense the spent steam.

To a much smaller extent, water is used for the provision of auxiliary equipment cooling systems.

(iii) Construction

Construction can be classified into three categories, namely :

- building construction - primarily engaged in construction of buildings

- civil engineering - primarily construction of civil engineering projects such as bridges, roads, canals, dams, etc.
- other construction, such as erection of steel structures, drilling of water boreholes, etc.

Water is used for general purposes such as cleaning as well as for end-product purposes. Water quality for the latter category is relatively important. For example, the effect of salinity may have cost implications in terms of material inputs, concrete preparation, life expectancy of structures, etc.

4.2.4.2 Conditions

Industries have profit functions and therefore production functions will be adjusted to ensure profit maximisation.

The industrial sector utilises water in three ways, namely:

- Process water: Water is used as transport reaction medium. The composition of the water is not critical, as process conditions are prevalent.
- Water for end product: Composition is critical as it affects the process and quality of the end product.
- Utility water: Generally used for cooling processes. Corrosivity and scaling properties are important particularly with high concentration ratios in recirculating systems.

4.2.4.3 Equations

The total cost of salinity to the industrial sector consists of the costs incurred in the utility, process and end-product water components. This costs is thus determined by the cost of water supply, maintenance costs, cost of chemicals and cost of replacing plant and buildings for various levels of salinity. The equation for the industrial sector is as follows:

$$K_{Uj} = \left|\Delta\bar{S}_{Uj}\right|\left(Rs_{Uj} * V_j\right) + \left|\Delta\bar{S}_{Uj}\right|\left(Rs_{Uj} * M_j\right) + \left(Rs_{Uj} * C_j\right) + \left|\Delta\bar{S}_{Uj}\right| * P_j$$

$$K_{Pj} = \left|\Delta\bar{S}_{Pj}\right| * P_j + \left(Rs_{Pj} * C_j\right)$$

$$K_{Ej} = \left|\Delta\bar{S}_{Ej}\right| * P_j + \left(Rs_{Ej} * C_j\right)$$

and:

$$K_{Tot\,j} = \left[K_{Uj} + K_{Pj} + K_{Ej}\right]_{PDj}$$

where:

V	=	cost of water supply
M	=	maintenance costs
C	=	cost of chemicals
P	=	cost of replacing plant (equipment) and buildings
S	=	current or anticipated salinity (TDS)
TDS_{thres}	=	salinity threshold where expenditure pattern changes

$$\left|\Delta\bar{S}_{ij}\right| = \left(\mathrm{TDS} - \mathrm{TDS}_{\mathrm{thres}}\right)_{\text{for all sectors}}$$

$$\left|\Delta\vec{S}_{ij}\right| = \left(\mathrm{TDS}_{\mathrm{thres}} - \mathrm{TDS}\right)_{\text{for all sectors}}$$

$$Rs = \left(\frac{S_{new}}{S_{curr}}\right)_{\text{for all sectors}}$$

$$V_j = \sum_{i=1}^{j} \Delta X_{ij} \qquad M_j = \sum_{i=1}^{j} \Delta X_{ij}$$

$$C_j = \sum_{i=1}^{j} \Delta X_{ij} \qquad P_j = \sum_{i=1}^{j} \Delta X_{ij}$$

$K_{Tot\,j}$ = total salinity costs of sector j $\quad$ K_{Uj} = salinity costs of utility water

K_{Pj} = salinity costs of process water $\quad$ K_{Ej} = salinity costs of end - product water

U, P and *E* represent *utility water, process water* and *end-product water* respectively

ΔX_{ij} = contribution to direct costs of sector *i* by sector *j*.

PDj = probability distribution due to management behaviour

H, A, M, I, S, F as defined under generalised model formulation.

4.2.5 Services

4.2.5.1 Description

For the purpose of this study, services were disaggregated into two major groups, namely recreation and commercial services.

(i) Recreation

Recreational use of water bodies is impacted by changes in water quality. For the purpose of this study, recreational water use applies to freshwater bodies only. This incorporates natural water bodies, such as rivers, and man-made impoundments such as dams. Swimming pools receiving continuous maintenance are not included, nor is recreational water used in marine or estuarine environments. Businesses and concerns such as resorts, hotels, etc. are included under commercial activities owing to their profit-induced production functions.

Water quality for recreation depends largely on ambient water quality, since no water treatment or maintenance is practised. Since contact with water is generally infrequent and of limited duration, this use has less stringent quality requirements than other water contact use, such as domestic use. However, certain broad limits are necessary to protect the well-being and enjoyment of recreational water users. The extent of such limits is variable, since water contact can range from full immersion, as in swimming and diving, to minimal contact, as in paddling.

Recreational water use was classified as follows :

- full contact
- intermediate contact recreation
- non-contact recreation.

An important component of recreational water use is the enjoyment derived from viewing water in a natural or near-natural state. Many recreational users derive most of their pleasure from the scenic aspect of water bodies and their environment, with the associated fauna and flora. This aspect also carries economic value since it is intrinsic to the value of waterfront properties and resorts. Aesthetic enjoyment of water poses quality requirements, but these are more difficult to define than those arising from water contact, since they pertain to a subjective, holistic impression. Perception of aesthetic quality cannot be easily represented as numbers of objective, quantifiable water quality constituents or properties. The levels of salinity of the current study would not directly impact on the said economic value. Salinity in combination with other water quality constituents may impact on the economic value of properties and the aesthetic enjoyment of water. Furthermore, salinity levels above the range specified for the study may have impacts.

(ii) Commercial

Commercial services refer mainly to offices and retail sectors. These can be associated to some extent, with the behavioural patterns of households with respect to water usage trends, since their minimum requirement is that water should be potable. The aspect that needs to be determined within commercial services is the cost implication of increased salinity with respect to the profit function of firms. The profit function is based on the profit maximisation motivation. Two elements with respect to the effect of salinity are thus important, namely level of water usage and behavioural or social effects of the quality of water.

4.2.5.2 Conditions

The recreational sector has not been included in the equation system since the costs associated with increased salinity of water are of an indirect nature. Recreational business concerns, however, are included under the commercial sector.

The commercial sector's behaviour is based on profit maximisation and therefore the equation is similar to that of the utility function of industry as discussed in subsection 4.2.4. Health and aesthetic aspects are indirect costs based on behaviour and could become important at very high salinity levels.

4.2.5.3 Equations

The cost of salinity in the services sector is determined by the cost of water supply, maintenance costs, chemical costs, and cost of replacing plant (equipment and buildings) for a specific level of salinity. The equation is as follows:

$$K_j = \left[\left|\Delta\bar{S}_j\right| \left(Rs_j * V_j\right) + \left|\Delta\bar{S}_j\right| \left(Rs_j * M_j\right) + \left(Rs_j * C_j\right) + \left|\Delta\bar{S}_j\right| * P_j \right]_{PDj}$$

Where

V = cost of water supply
M = maintenance costs
C = cost of chemicals

P = cost of replacing plant (equipment and building)
S = current or anticipated salinity (TDS)
TDS_{thres} = salinity threshold where expenditure pattern changes

$$\left|\Delta \bar{S}_{ij}\right| = \left(\mathrm{TDS} - \mathrm{TDS}_{\mathrm{thres}}\right)_{\text{for all sectors}}$$

$$\left|\Delta \vec{S}_{ij}\right| = \left(\mathrm{TDS}_{\mathrm{thres}} - \mathrm{TDS}\right)_{\text{for all sectors}}$$

$$Rs = \left(\frac{S_{new}}{S_{curr}}\right)_{\text{for all sectors}}$$

$$V_j = \sum_{i=1}^{j} \Delta X_{ij} \qquad M_j = \sum_{i=1}^{j} \Delta X_{ij}$$

$$C_j = \sum_{i=1}^{j} \Delta X_{ij} \qquad P_j = \sum_{i=1}^{j} \Delta X_{ij}$$

ΔX_{ij} = contribution to direct costs of sector *i* by sector *j*.
H, A, M, I, S, F as defined under generalised model formulation above
PDj = probability distribution due to managerial behaviour

4.2.6 Feeder systems

4.2.6.1 Description

By definition, the impact of salinity on feeder systems includes the following:

- Incremental treatment costs to purify water from a eutrophic source
- Costs associated with either corrosion or scale effects on all pipes between the point of abstraction of raw water to the point of delivery to the individual consumer (individual households, industrial consumers, etc.). The costs that are the direct responsibility of the individual consumer are excluded. This refers to on-site plumbing and costs associated with scaling of hot-water systems or corrosion of pipes.

As a general rule it can be assumed that a water supply authority is required to supply water for domestic purposes and industrial activities that conforms to prescribed standards. The total dissolved solids within the range of this study (200-1200 mg/ℓ) also falls within the range set in SABS 241 with ±450 mg/ℓ as preferred maximum level and ±1950 mg/ℓ as allowable maximum level. These standards were compiled primarily with human health in mind and do not necessarily indicate a safe water from a corrosion/scale-formation point of view. These problems still have to be addressed separately in the design of infrastructure by providing appropriate corrosion protection. The incremental cost of more sophisticated corrosion protection due to increased corrosiveness of a water with a higher salinity is deemed to be the cost of salinisation in this case.

4.2.6.2 Conditions

No attempt is made to reduce salinity levels during water handling, since it is accepted that only the cost to revert the water back to its previous (original) salinity will be relevant.

By-products of salinity (eutrophication) are not included although these represent indirect costs. Labour costs, maintenance costs and energy costs are assumed to be incorporated in capital costs (as these are a function of capital).

4.2.6.3 Equations

The total cost of salinity for feeder systems is determined by capital costs, chemical costs, pipe maintenance and reticulation costs, as well as the specific level of salinity. These costs relate to the provision of conventional plant, air flotation plant, activated carbon plant and ozone plant. The formula is as follows:

$$K_{FTot} = f(P, C, Y, S)$$

$$K_{FP} = \sum_j \left[K_{FP1j} + \left|\Delta S_{FP2j}\right| * K_{FP2j} + \left|\Delta S_{FP3j}\right| * K_{FP3j} + \left|\Delta S_{FP4j}\right| * K_{FP4j} \right]$$

$$K_{FC} = \sum_j \left[K_{FC1j} + \left|\Delta S_{FC2j}\right| * K_{FC2j} + \left|\Delta S_{FC3j}\right| * K_{FC3j} + \left|\Delta S_{FC4j}\right| * K_{FC4j} \right]$$

$$K_{FY} = \sum_j \left[K_{FY1j} + \left|\Delta S_{FY2j}\right| * K_{FY2j} \right]$$

$$K_{FTot} = \left[K_{FP} + K_{FC} + K_{FY} \right]_{PDj}$$

where

P = related to capital costs
C = related to chemical costs
Y = related to pipe maintenance and reticulation costs
1 = related to provision of conventional plant
2 = related to provision of air flotation plant
3 = related to provision of activated carbon plant
4 = related to provision of ozone plant
S = current or anticipated salinity (TDS)
TDS_{thres} = slinity threshold where expenditure pattern changes

$$\left|\Delta \overleftarrow{S}_{Fij}\right| = \left(\mathrm{TDS} - \mathrm{TDS}_{\mathrm{thres}}\right)$$

$$\left|\Delta \vec{S}_{Fij}\right| = \left(\mathrm{TDS}_{\mathrm{thres}} - \mathrm{TDS}\right)$$

$$Rs = \left(\frac{S_{new}}{S_{curr}}\right)_{\text{for all sectors}}$$

K_{FTot} = Total salinity costs K_{FP} = Capital costs of salinity

K_{FC} = costs of chemicals K_{FY} = costs of pipe maintenance

PDj= probability distribution due to managerial behaviour
H, A, M, I, S, F as defined under generalised model formulation

4.2.7 *Natural environment*

4.2.7.1 Description

The economic sectors for the natural environment have been defined in terms of use of the natural environment, the role of aquatic organisms in relation to man and the impact of salinity on those components of the natural environment (mainly algae), whose presence in raw water supplies would affect the cost of purifying water.

The economic sectors are as follows :

- *Drinking water for wild-life:* Where water becomes too "salty" for wild-life, the wild-life will either die or move away.
- *Maintenance of the river channel:* Salinity may reach levels where the riparian vegetation, which is important in maintaining the stability of the banks of the river, dies. Costs may be incurred through this.
- *Water for domestic and industrial use - purification costs:* At least in the Middle Vaal River, salinity has resulted in the precipitation of colloidal material. As this settles, the water clears and more light becomes available for algal growth, algal populations increase and the cost of water treatment rises.
- *Angling recreation:* Salinity could cause changes in fish populations and their resultant abundance to fishermen. This may be beneficial or costly.
- *Aquatic wild life:* Salinity may have impacts on aquatic wildlife such as crocodiles, hippos and aquatic birds.
- *Aesthetics:* Salinity may affect the aesthetic value of rivers.
- *Disease vectors:* Salinity may affect the species composition and abundance of communities of aquatic animals important as intermediate hosts of various human and veterinary disease organisms. Snails, mosquitoes and blackfly must be considered.

4.2.7.2 Conditions

The natural environment *per se* is not an economic sector which can be included in the integrated IO model. As a result, the following important cost aspects are included in the cost equations of other sectors:

- angling revenue: recreation
- algal bloom: feeder systems

4.3 SUMMARY

This section was used to provide the sectoral framework for conducting surveys in the case study area. The framework consists of conceptual formulae which include all aspects that may have impacts. In obtaining information from primary research, the postulations can be verified.

SECTION 5: APPLICATION OF MODEL

The IO technique which is used as integrated model is discussed in this section. The specific applications and extensions used in the research are elaborated on.

5.1 CLASSICAL INPUT-OUTPUT MODELLING

The classical IO model is a linear model and any development of this technique will also be linear. Techniques are available for non-linearising IO analysis, but these are complex, and beyond the scope of this exercise. This need not necessarily be seen as a disadvantage, as IO analysis is at its strongest when trying to get a "first look" at the impact of any economic activity. Results are fairly readily obtained, and are often the only alternative to an "educated guess". Under these circumstances, the confidence created by the methodology underlying the technique easily outweighs the inherent linearity.

5.1.1 Assumptions

The IO model is based on simplified assumptions, which can also be considered restrictions of the model.

Classical IO models are linear and are based on fixed commodity prices. IO analysis assumes that the output value will be directly proportional to demand, allowing for no economies of scale. Similarly, production functions (the mix of inputs relative to outputs) are fixed for all output ranges. This effect is inherent in the use of production coefficients.

The classical IO model formulation thus provides the framework demanded by considerations such as inter-industrial linkages and economic interdependence. An IO model allows the estimation of the changes in output production and pricing, as well as the value added from a given change in the final demand for the goods and services produced. While some sectors of the economy produce mainly for final demand, other sectors produce goods which serve as intermediate inputs to yet other sectors within the area. The strength of an IO analysis is its empirical recognition of these inter-industrial linkages for each of the sectors of the economy.

IO tables contain information which was relevant at a particular stage, when the data was collected. Furthermore, some time has to pass before the data can be processed into viable IO tables, therefore the IO tables do not reflect current data. Any inferences which are made using such tables, therefore assume that the economic structures, which were in place at the time the IO data was assembled, have not changed significantly.

The analysis based on IO tables makes use of linear relationships between the monetary values in the tables. Although absolute monetary values can change quite significantly over the short term due to inflation and other economic effects, these faster moving economic effects can be easily adjusted. The complex inter-industry relationships which underpin the IO tables are retained, since the industry structures which underlie IO tables are usually much slower to change. However, substitution effects, which result from changing levels of production, are not taken into account. Use of IO tables, which may be some years old, is therefore rarely a problem, unless it is known that drastic changes have taken place in the relevant industry structures in the region.

5.1.2 Input-output tables

IO tables represent a picture of the economy at a specific stage. This implies that the analyses are static rather than dynamic, but can still be used effectively for forecasting.

IO tables are initially compiled at national level. Exercises are often undertaken to regionalise these tables when it is desired to determine the economic impacts of any specific action on a single region alone. This exercise would normally exclude the effects of both regional and national imports, and would thus only be undertaken when it was desired to isolate the region from all outside effects for analysis purposes. It would not be necessary, or even desirable, to undertake a regional analysis simply because the data had been collected in a single region, unless it was desired to examine only the effects on that particular region. In this instance it is assumed that it is desired to determine the effect on the national economy of activities which are being researched in a specific region, and therefore national IO tables were used.

5.2 INPUT-OUTPUT APPLICATIONS

The IO technique has many applications and with appropriate extensions and manipulations, can address many economic problems. This was also the case with current research requiring a method of determining the cost of salinity to a specific economy.

In the first instance the difference between open and closed tables is discussed, since both had been used. The value in conducting a multiplier analysis is elaborated on after which the pricing model used to generate the main results of the research, is discussed. The last application refers to an augmented IO table or hybrid model, based on the introduction of a new industry to the existing IO table; implying the creation of a new row and column in the inter-industry quadrant. Both national and regional tables were used to compare the results obtained in a national and regional economy.

5.2.1 Open and close tables

Households are usually represented in IO tables by salaries and wages as well as private consumption expenditure. With conventional tables or open tables these are regarded as exogenous variables.

Closing IO tables with respect to households involves regarding households as endogenous sectors (similar to industries, agriculture, mining, etc.) and incorporating them in the first quadrant of the IO table.

It is often desired to estimate the indirect and induced effects of any particular economic stimulation. The inputs demanded by any sector to affect a given increase in output are the direct inputs (or effects). The indirect effects arise from the fact that in supplying these direct inputs to the demanding sector, other sectors will, in turn, demand their own inputs from other sectors, and so on. Induced effects stem from the assumption that as a result of the increase in output, the wage bill will also rise to allow for the additional labour inputs necessary. This will put more disposable income in the pockets of workers and there will be a concomitant rise in the final demand for goods from consumers.

IO tables are normally open with respect to households, i.e. wages and salaries. Private consumption expenditure is kept as exogenous variables and as such not included in the analysis. In other words, all changes in output are assumed to have occurred without any increased labour inputs. To estimate the induced effects it is necessary to close the tables with respect to households to enable the impact of labour to be captured by the analysis.

5.2.2 Salinity multiplier analysis

An approach to determine indirect and induced effects is to take the direct cost data collected in the field and to consider this as an exogenous factor in the IO analysis. It is then used to calculate so-called salinity multipliers which would indicate the impact of additional production on the costs of combating salinity. Both open and closed models can be used and indirect and induced effects would be estimated. Multipliers by virtue of the fact that they derive from the classical IO equation, relate various effects such as salinity costs, to changes in final demand.

These salinity multipliers are calculated in the same manner as that in which classical GDP or employment multipliers would be calculated, and they are used in exactly the same way. In the case of salinity multipliers, they would indicate, in rands, the increase in salinity combating costs which would arise as a result of each additional Rand of final demand being supplied from any given sector of the economy. These multipliers are particularly useful for estimating the impact of expansion of any given sector on salinity combating costs throughout the economy.

5.2.3 Pricing model

In order to better understand the total impact of increases in salinity abatement costs arising in any given sector of the economy, use is made of an IO pricing model. Classical IO modelling, which forecasts increases in output, assumes fixed prices and in cases where cost increases are being dealt with, this approach is not readily seen to be applicable. The IO pricing model, on the other hand, takes direct salinity cost increases in any sector and passes them on as percentage price increases to all users. Indirect and induced effects are estimated using open and closed models in a manner exactly analogous to other IO modelling. The final percentage rise in price thus calculated, captures all the impacts of combating salinity, taking the direct, indirect and induced effects into account.

The equations governing the pricing model are set out below :

$P= [(I-A)^{-1}]^T[\pi(a_{mj})]^T$

where:

P	=	column vector of output price change
(a_{mj})	=	vector of direct output coefficients for sector
π	=	percentage changes (external shocks) postulated in the output price for sector
$(A-I)^{-1}$	=	vector of Leontief inverse coefficients, and
T	=	represents the transpose of a matrix or vector.

It is important to note that this model passes on all additional costs as a price increases. No allowance is made for substitution effects or increases in efficiency as prices rise.

The individual price increases in different sectors as a result of a price increase in a given sector are combined to predict an increase in both Consumer Price Index (CPI) and Producer Price Index (PPI) by means of appropriate weighting factors. These factors are derived in the case of CPI framework from private consumption expenditure and PPI from the sum of intermediate output, gross domestic fixed capital formation and exports.

A pricing model implemented using an open model would quantify only direct and indirect increases in CPI and PPI. The closed pricing model would take into account the induced household effects empirically. These effects can be applied to the industrial sector alone, or can be used to quantify the impact when all household expenditure is taken into account. Both of these approached were taken.

5.2.4 Augmented input-output model

As an alternative approach to expand on the understanding of the costs, an augmented IO model can be used to estimate total additional resource usage as salinity rises. In IO modelling terms, changing concentrations of salinity in the water cannot be represented as an input (or an input coefficient) into any cell of the appropriate IO matrix. This so, since salinity, *per se*, is neither a cost nor an inter-industry transfer. However, changing salinity does in fact change the production functions of the various sectors, enabling the effects of changing salinity to be accommodated. Thus, in effect, the input structure of the table changes with every change in salinity.

To actually do this in practice would be a time-consuming and exacting procedure and would not be practically viable. In seeking an alternative, a new industry was postulated to have entered the economy. The purpose of this industry was to buy of all the commodities (plant, labour, materials, services, etc.) needed to combat a given level of salinity in the system and to re-sell them, at no profit, to all sectors requiring them. This method of assembling direct costs allowed a new row and a new column representative of this new industry to be readily calculated and inserted into a standard IO table. The overall effect of this approach was to introduce into the IO structure, the inter-industry linkages necessary to generate indirect costs, without having to interfere with the existing industry structures.

Whilst perhaps seeming a somewhat artificial procedure, this process rather elegantly overcame the need to restructure IO tables for each change in salinity. Furthermore, the necessary IO methodologies for analysing the impact of a new industry are well documented and can be readily implemented. This methodology is based upon a modified IO analysis where a new row and column are inserted into the IO matrix to represent the new industry and a mixture of exogenous and endogenous variables are used (Miller and Blair, 1985). This approach is used as a control against which to evaluate the performance of the pricing model.

5.3 DEALING WITH BEHAVIOURAL STOCHASTICITY

Management behaviour is, in general, unpredictable. Nevertheless, it does impact on the total costs arising from salinity. The effect of the inclusion of management behaviour in the model would be to introduce an element of uncertainty, since these decisions defy formal calculation. Although these effects are difficult to quantify and the costs of management decisions cannot be readily calculated, they will usually yield to a probabilistic approach. This would require inputs to allocated probabilistic upper and lower bounds.

Two possibilities exist for dealing with these – either to:

- collect all figures associated with an upper bound and those associated with a lower bound, thus obtaining absolute highs and absolute lows between which the results must lie.
- associate probabilities with all costs which appear in the cost collection matrix, and to derive an overall probability distribution for the final cost.

5.3.1 Probabilistic distribution of behaviour

The impacts of management behaviour should be taken into account. Probabilistic analyses and techniques, such as those used in risk analysis, are considered the better approach to employ. Such analyses would provide a probabilistic distribution of expected costs arising from each cost calculation.

When costs arising from different calculations are summed to provide a single overall cost, the individual probability distributions could be combined using Monte-Carlo methods, to provide a probability distribution representative of the overall cost. To implement this methodology, it would be necessary to collect data relating to the expected values of each cost calculation. This would relate management behaviour to the expected outcome of cost calculations in a probabilistic fashion. The overall cost is the simple arithmetic sum of the individual costs, whilst the overall probabilistic distribution is a combination of the individual distributions, generated by a Monte-Carlo approach.

The probability distribution mentioned here can also be used to calculate the standard deviation of the results. The standard deviation provides a confidence band for each result. The probabilistic distribution of management behaviour is represented in the sectoral equations as PD.

5.3.2 Limitations in the case study

While it was anticipated that the probability option should be pursued, provided that the research results could render the probability inputs, this proved not to be practical. Several outcomes emerged after data collection was completed.

In some sectors behavioural aspects were considered not to influence the outcome of the cost forecasts in any significant way. These sectors are essentially "bottom-line" driven and decisions are made in the light of the effect upon the balance sheets and not according to management behavioural patterns. This was the case for the services, industrial, feeder and mining sectors. Decision-making is therefore strongly determined by technology and cost elements, thus minimising behavioural influences.

In some sectors, it was clear that behavioural aspects had an influence on the forecasts of costs. This was the case in the household and agricultural sectors. However, in order to be able to apply the preferred approach of quantifying the effect of these behavioural patterns, it would be necessary to:

- have a sufficiently large sample of respondents; and
- have respondents in the sample who were sufficiently enlightened and informed to be able to respond accurately to searching questions relating to cost data.

These criteria could not all be met in the field.

Although probability distributions for individual responses in the household sector could not be obtained, sufficient data was collected to enable the variance of the overall cost estimates to be calculated, without rigorously combining the probability distributions.

In the case of the agricultural sector, the sample was not large enough to confirm expected behavioural patterns in operation. The results generated did allow upper and lower bounds of possible outcomes to be obtained, based upon one or other extremes of management behaviour.

5.4 SECTORAL DISAGGREGATION

As the main purpose of this study was to develop cost equations for the various sectors of the economy, these had to reflect the costs due to increased salinity levels in water. The economy can be broadly categorised into sectors, based on the Standard Industrial Classification of Economic Activities (SIC). Since water use is the important aspect in this study, the sectoral disaggregation was modified to include the following seven sectors:

* Household
* Agriculture
* Mining
* Industry
* Services
* Feeder systems
* Natural environment.

The application of the sectoral models to a well-defined case study area, specifically the Middle Vaal River area, required some changes to the structure of the generic sectoral equations originally postulated. These changes arose largely from the need to tailor the model to the specific needs and economic structure of the study area. The changes involved aggregating subsectors of the economy to arrive at an economic structure suited to the case study area, since not every aspect catered for in the sectoral equations features in every area. Further, some sectors were not adequately represented in the study area and were therefore excluded from the study at this point. Specifically, the Natural Environment and Feeder Systems were excluded, allowing for some simplification of the original approach. These modifications can be studied in the individual specialist reports included in the associated reports.

5.5 RATIONALE FOR CHOSEN INPUT-OUTPUT TABLES

IO tables are produced in a variety of configurations, depending on the level of detail required in the analysis. Generally speaking the following configurations are conventional :

- 9 sector tables
- 22 sector tables
- 93 sector tables

The sectors included in a conventional 9 sector IO table are the following:

- Agriculture
- Mining
- Manufacturing
- Electricity and water
- Construction
- Trade
- Transport
- Finance
- Services.

With each increasing level of detail, different sectors are disaggregated namely manufacturing, agriculture, services, etc. These sectors were refined and the actual level of disaggregation of the IO tables was dependent upon the economically active segments in the region, as well as the detail with which the field workers were able to gather data.

Although seven sectors were studied, the IO table of choice was a 9-sector table. The following additional disaggregation was used.

- Mining

Gold-mining was explicitly disaggregated from the mining sector, as it is the only mining activity appropriately represented by the field research.

- Manufacturing

Originally the manufacturing sector has been disaggregated into six sectors namely leather and tanning, iron and steel, pulp and paper, petrochemical, textile and other industries. This, however, proved to be unsuitable for the local conditions of the study area and the manufacturing sector was aggregated into two sectors. Manufacturing was thus disaggregated into processes which made use of water treatment in their production function (manufacturing 2) and those which made no use of water processing in their production function (manufacturing 1) in the ratio of 20% to 80% respectively.

- Water and Electricity

Water and electricity have been disaggregated according to their respective outputs as given in the 93-sector national IO tables.

- Households

Households were disaggregated into three separate sectors, in accordance with their income, classifying the households as high, medium and low. This was adapted to suburban, township and informal households in the study area.

- Natural environment

The effects of salinity on the natural environment were incorporated within the agricultural, services and feeder systems sectors, and thus did not feature as an individual sector in the model.

- Feeder systems

The effects of salinity on feeder systems are generally incremental, and based on the given salinity range, no additional costs are incurred. As a result this sector was excluded.

5.6 MODEL CONSTRUCTION

The construction of the model is based on the integration of direct cost equations in the IO framework. In simulating the total effects of increased levels of salinity, the following approach was followed :

- ***Closing the table***

The IO table was closed with respect households. The wages and salaries row was moved from the "value added" quadrant of the matrix, into quadrant 1, the "technical coefficient" quadrant. The consumer expenditure column was moved from the "final demand" quadrant, into quadrant 1.

The table was re-balanced by adjusting the intermediate inputs to match the intermediate demand. This was achieved by moving amounts from government surplus into the households row (previously the wages and salaries row).

- ***Calculating salinity multipliers***

In calculating salinity multipliers a 1993 aggregated National table, consisting of 11 sectors for the open table and of 12 sectors for the closed table, was used.

Salinity multipliers, which relate the increases in salinity costs to an increase in final demand in any sector at any given salinity level, were calculated in the classical manner by converting salinity coefficients (rands of salinity costs per rands of gross input) into a matrix of salinity multipliers (rands of salinity costs per million rands of additional final demand). This was done by multiplying a row vector of salinity coefficients firstly by the open Leontief inverse matrix to get the direct and indirect multipliers, and then by the first (n-1) rows and columns of the closed Leontief inverse matrix to get the direct, indirect and induced multipliers. In both cases, only the impact on the production sectors is calculated.

* ***Pricing model***

An open-pricing model would quantify only the direct and indirect increases in CPI and PPI. The closed-pricing model would take into account the induced household effects empirically. These effects can be applied to the industrial sector alone, or can be used to quantify the impact when all household expenditure is taken into account. As described above, both of these approaches were taken.

The same tables applied to calculate the multipliers, were used for the pricing model. The pricing model was exercised according to the classical equations by postulating a price increase for each of the researched sectors individually. Since it was assumed that all salinity-combating costs would be passed on as price increases, the price increase for each sector was found by dividing its direct salinity costs by its total output and expressing the result as a percentage. The pricing model was then used to calculated the direct, indirect and induced changes in total price for each sector arising from these price shocks. These individual price increases were integrated into effective changes in CPI and PPI by combining them using weights derived from the IO tables. This procedure was repeated for each level of salinity being evaluated.

The impacts brought about by the combating of salinity by production sectors and by households have been handled separately, to be able to highlight more effectively the problems which face householders.

In dealing with the production sector impacts, the effects of householders' direct salinity abatement costs have been excluded, although the induced effects associated with industries' abatements costs have also been captured.

A separate closed model was set up to enable the direct costs of salinity abatement faced by householders to be brought into the integrated picture. This model presupposes that householders are operating in a manner analogous to that of the other industries. They have their direct salinity costs, and they will pass these on as "price increases" (effectively demands for higher wages). As a result, in IO terms, they will demand more inputs (i.e., they will indulge in greater consumer spending) and since their new inputs will be more costly, they will demand more wage increases, until equilibrium is reached.

* ***Augmented IO Model***

The augmented model was used as a control case and consisted of 14 sectors. The model was exercised in discrete steps and proceeded as described below:

- Discrete intervals of salinity in the range 200 mg/ℓ TDS and 1200 mg/ℓ TDS were selected. The TDS interval selected was 200 mg/ℓ.
- For each value of salinity, the direct costs were calculated using the direct cost equations. These costs embodied separate input cost- attributable to each industry sector and were most easily assembled in matrix format.
- The row and column representing the total inputs and outputs of the "new industry" (salinity) were then readily assembled and inserted into the IO table prior to the analysis being performed. By taking account of all the inter-industry linkages embodied in the IO table,

this analysis revealed all of the direct and indirect costs associated with the level of salinity chosen.

The above procedure was repeated for each level of salinity being evaluated and for both a regional and a national table. This resulted in a set of economic scenarios, each representing the impact of a given level of salinity in the system, for regional and national situations.

- ***Spreadsheet***

The use of the stated models pointed strongly towards employing a spreadsheet approach to implement the model, as this could be efficiently implemented and would remain flexible, while changing scenarios could easily be incorporated. Spreadsheets are easily able to cope with the matrix algebra required for IO analysis and on modern computers the models run extremely quickly.

Use was made of scenario-generating techniques within the spreadsheet, to allow relatively large quantities of data to be readily manipulated.

5.7 SUMMARY

This section discussed the model framework which provided parameters to obtain data to be integrated into the chosen models. The data collected and the transformations required for use in the integrated models are discussed in Section 6.

SECTION 6: DATA COLLECTION, TRANSFORMATION AND MODEL USE

6.1 DATA COLLECTION

The availability of data was a consideration in the modification of the model in order to successfully apply it to the case study region. An overview of the approaches used within each sector, in compiling its sectoral formula and obtaining suitable information to input into the modified generalised model, is discussed.

6.1.1 Household sector

The data collection for the household sector was conducted in two phases.

Initially, data was collected in the Welkom region. The sample comprised households which had recently moved to Welkom, a high salinity area, from relatively lower salinity areas. This rationale allowed comparisons of the induced changes resulting from higher salinities, isolating the direct costs of salinity.

This rationale was found acceptable. The sample was then enlarged, following the same procedure in another town within the study area, namely the Klerksdorp–Orkney–Stilfontein complex. This extension of the survey ensured that an acceptable level of confidence was obtained. It also served to verify the preliminary results of the Welkom survey.

The household surveys conducted in the two areas were based on the following objectives:

* to determine whether households incur additional costs due to increased salinity of water,
* to determine if household behaviour is significantly modified in response to increased water salinity.

The sample of households was stratified according to area of residence which serves as proxy for levels of income. The following stratification was used:

* Households from suburban areas
* Households from formal housing in townships
* Households from informal settlements.

Only households which had recently moved to the survey areas were included in the survey, to allow the effects of changes in salinity to be observed. In-depth qualitative interviews were held with these newcomers, to identify changes in costs which could be attributed to salinity.

Data has also been generated from a comparable statistically representative probability survey in Klerksdorp to provide a typical household profile in accordance with the three household categories.

Both quantifiable, perceptive and behavioural data was obtained by using a structured questionnaire during the interviews.

6.1.2 Agricultural sector

An agricultural model postulating agricultural production relationships was developed, based on the sectoral generic model. This model required data from conventional agricultural data sources which formed the basis of the model. The behavioural responses of the farmers were tested and verified by means of selected interviews.

Behavioural responses were mainly related to the availability of management options, determined by financial returns. The four management options are:

* yield reduction
* additional (leaching) water
* adapted planted area
* adapted crops.

These options were tested and the responses of farmers therefore represent the behavioural costs of salinity to the agricultural sector.

Eight farms in the study area were taken as a representative sample. Sufficient quantitative and qualitative data was obtained from these farmers to determine the cost of salinity in the agricultural sector. Structured questionnaires were used during the interviews to obtain information on the production environment of the farmers, as well as behavioural or management options which would be followed if the farms were subjected to conditions of deteriorating irrigation water.

6.1.3 Mining

Gold-mining encompasses between 80% and 90% of the mining sector in the study area. As a result, surveys were conducted in the gold-mining sector only. Survey questionnaires were designed to obtain information pertaining to the four main water circuits, namely evaporative cooling water, mine service water, metallurgical plant water and irrigation water.

Six mines were surveyed, providing information for 37 shafts and 16 metallurgical plants. This survey represents nearly 60% of the total mining activity in the study area.

Information on management options was identified:

* purchasing increased supplies of fresh water
* treating water to maintain constant volumes of input water
* allowing water quality to deteriorate
* treating effluents to meet discharge limits.

Data on water usage, water quality and related problems was also obtained.

6.1.4 Industry and services

The industry and services surveys were conducted in Welkom and Klerksdorp and discussed together. Due to similarities in the sectoral formulae, one questionnaire was used for both these sectors.

The survey was preceded by a pilot survey to test the suitability of the questionnaire as well as the level of general awareness of salinity. Although the questionnaire was found to be suitable, the general ignorance about salinity and costs thereof, confirmed earlier predictions.

The sampling of these two sectors was determined by the relatively undiversified economic base of both Welkom and Klerksdorp. A total of 110 interviews were conducted and categorised as follows:

* services
* manufacturing
* treatment manufacturing.

This categorisation is mainly due to the undiversified manufacturing base of the economy of the study area.

The information obtained by means of the survey related to general background data for classification purposes, production information, water usage data, purification data, as well as information on maintenance and replacement costs. Attempts were also made to obtain data regarding management options related to salinity increases as well as behavioural aspects. Limited information could be obtained in this regard, since behaviour is generally determined by technological options.

6.1.5 Feeder system

The survey of feeder systems was necessary to determine the costs which were found to be insignificant in the salinity range provided. As a result this sector was not included in further modelling.

Interviews with water supply authorities were undertaken and inputs from specialists were obtained. These have also been augmented by literature reviews.

The following institutions were interviewed:

* Umgeni Water
* Rand Water
* Western Transvaal Water Corporation
* Goldfields Water.

Information was obtained on the salinity levels affecting treatment costs, treatment processes and costs thereof.

Since no incremental costs are anticipated in the feeder systems sector, despite increases in TDS levels from the current to 1200 mg/ℓ levels, no data was obtained to be used in the model. Thus, the entire sector was excluded for the purposes of cost calculations in the case study.

6.2 TRANSFORMATION

Much of the data collected within each sector had to be transformed. These data transformations ensured that the input data for the model was usable and consistent as well as being in line with the model parameters.

The current salinity level in the study area is approximately 500 mg/ℓ and this has therefore been used as the reference point for all the calculations, i.e. the cost of combating salinity at the various salinity levels has been calculated as an incremental cost with reference to the 500 mg/ℓ salinity level.

All the data was provided in 1995 values. This required de-escalation to 1993 values using the relevant PPI for the years 1993 to 1995, before being input into the model.

6.2.1 Sector selection

To calculate the effects of changing salinity on the economy for the purposes of the IO model, the data contributions to each economic sector were re-allocated to the following sectors, as shown in Table 6.2.1 (refer to Annexure A):

- Trade: covers the retail sales of items such as household cleaners and toiletries, white goods (including kettles, geysers and other bathroom fittings) and chemicals for use in the treatment of water.

- Water: includes all additional water used to combat the effects of salinity in the manufacturing, mining and households sectors of the economy.

- Services: includes the maintenance and repairs of items such as car batteries, radiators, white goods (kettles, geysers, etc.) as well as replacement and repairs of industrial equipment, including pipework.

- Construction: includes the costs of civil engineering drainage work in the agricultural sector.

- Electricity: includes the costs of electricity used for irrigation purposes, such as running pumps and sprinklers.

- Finance: the interest payments required for loans for pre-harvest production costs.

- Manufacturing: covers the wholesale trade costs for items such as piping, equipment and machinery, manufactured by non-water treatment industries (Manufacturing 1).

- Households: includes the cost of labour used by the producers of goods, who treat water in their production processes (Manufacturing 2).

A summary of the data collected and transformed, for each individual sector, is presented in Tables 6.2.2 to 6.2.5 (refer to Annexure A).

6.2.2 Household sector data

The data obtained with the surveys provided the direct costs for the household sector at the 500 mg/ℓ level and the costs at the 200 mg/ℓ level were assumed to be zero. In order to calculate values for the other levels, a linear relationship between these two points was assumed.

The incremental costs for combating salinity were classified as "trade," "manufacturing" and "services" costs and were derived from the suburban, township and informal sectors, and are presented in Table 6.2.2 (refer to Annexure A).

6.2.3 Agricultural sector data

The data supplied falls into two distinct categories, based on management behavioural responses. These categories or scenarios are defined as a "best case" scenario where yield maintenance would occur (scenario 1), and a "worst case" scenario (scenario 2) where yield reduction and loss of income would be accepted.

The data provided for this sector was given for the range of salinity levels under consideration i.e. 200 mg/ℓ to 1200 mg/ℓ and is presented in Table 6.2.3 (refer to Annexure A).

In the first scenario, the incremental costs for combating salinity could be derived from the following input sectors:

- Construction (artificial drainage)
- Electricity
- Services
- Finance.

For the second scenario, the loss of income to the agricultural sector was calculated on the basis that no action would be taken to combat salinity, i.e. a reduced yield in crop production. The loss of income was calculated and was used as a cost to the agriculture sector.

6.2.4 Mining sector data

The data provided for this sector was given for the range of salinity levels under consideration i.e. 200 mg/ℓ to 1200 mg/ℓ, and the incremental cost for combating salinity was allocated to the following sectors (refer to Table 6.2.4, Annexure A) :

- Manufacturing (cost of chemicals)
- Water (cost of water supply)

6.2.5 Manufacturing sector data

The data obtained for this sector was provided for three salinity levels as follows:

- Manufacturing 1 (no water treatment sector): 200 mg/ℓ, 500 mg/ℓ and 1200 mg/ℓ
- Manufacturing 2 (water treatment sector): 200 mg/ℓ, 500 mg/ℓ and 1000 mg/ℓ.

In order to calculate the values for the other salinity levels, it was assumed that linear relationships existed between the 200 mg/ℓ and 500 mg/ℓ points and between the 500 mg/ℓ and 1000 mg/ℓ or 1200 mg/ℓpoints. The incremental costs for combating salinity were further allocated to the following input sectors, as presented in Table 6.2.5 (refer to Annexure A) :

- Trade (chemicals and replacement costs for kettles, urns, geysers etc.)
- Manufacturing 1 & 2 (chemicals and replacement costs for pipes, other equipment and plant etc.)
- Services (maintenance costs for equipment)
- Household (labour costs)
- Water (increased water usage).

The information relates to differential costs, i.e. the constant basic cost of water was removed to ensure that incremental costs are used in to the model.

6.2.6 Services sector data

The data obtained for this sector is provided for three salinity levels namely: 200 mg/ℓ, 500 mg/ℓ and 1200 mg/ℓ. In order to calculate the values for the other levels, it was assumed that linear relationships existed between the 200 mg/ℓ and 500 mg/\ℓ points and between the 500 mg/ℓ and 1200 mg/ℓ points. The incremental costs for combating salinity were further allocated to the following input sectors, as presented in Table 6.2.5 (refer to Annexure A) :

- Manufacturing 1 & 2 (cost of chemicals)
- Trade (chemicals and replacement costs for kettles, urns, geysers etc.)
- Services (maintenance costs for equipment)
- Water (increased water usage).

The information relates to differential costs, i.e. constant basic cost of water was removed to ensure that incremental costs are used in to the model.

6.3 USING THE MODEL

The integrated model was exercised in discrete steps, and proceeded as follows:

- The data was centred around 500 ℓ /1, which is the salinity level presently experienced in the study area. Thus input data below 500 mg/ℓ implied a corresponding saving if salinity drops.
- For each value of salinity, direct costs were used after transforming the direct costs obtained from the individual sectoral models. These costs embodied separate input costs attributable to each industry sector and were assembled in matrix format.

- The direct cost data was used in the three applications of the IO model previously discussed. By taking account of all the inter-industry linkages embodied in the IO table, the analysis revealed all direct, indirect and induced costs associated with the level of salinity chosen.
- Discrete intervals of salinity of 200 mg /ℓ were selected, in the range 200 mg/ℓ to 1200 mg/ℓ. The procedure was repeated for each level of salinity, giving rise to a set of economic scenarios, each representing the impact of a given level of salinity in the system.

Table 6.3.1 presents a ranking of the annual direct cost data (in 1995 values) at a salinity level of 600 mg/ℓ. The detailed information for the two scenarios is contained in Annexure B for each salinity level (Tables 6.3.2 to 6.3.7).

Table 6.3.1: Total direct costs of salinity, ranked at the 600 mg/ℓ level (1995 values in millions of SA rands)

Salinity	200	400	600	800	1000	1 200
SECTOR						
Households (suburban)	-35.121	-11.707	11.707	35.121	58.535	81.949
Households (township)	-27.927	-9.309	9.309	27.927	46.544	65.162
Households (informal)	-5.081	-1.694	1.694	5.081	8.468	11.855
Manufacturing 2	-2.825	0.294	1.351	1.993	2.635	3.278
Business and services	-1.843	0.487	1.211	1.707	2.202	2.697
Mining	-7.309	-2.212	0.844	4.863	10.209	17.816
Agriculture	0	0	0.439	0.439	0.472	0.503
Manufacturing 1	-0.145	0.028	0.086	0.123	0.16	0.198
TOTALS	**-80.251**	**-24.113**	**26.64**	**77.253**	**129.225**	**183.457**

6.4 MODEL OUTPUT

The model used in determining the total economic costs of salinity is the IO technique and in building up towards an answer, the three applications as discussed before were used. The value and expected output are discussed after which the relation between the three sets of results is indicated.

6.4.1 Salinity multipliers

The calculation of salinity multipliers is useful for ranking sectoral sensitivities with respect to the impact of salinity. Direct, indirect and induced multipliers are determined (refer to Table 6.4.1). These multipliers are useful in decision-making in that they relate salinity costs to expansion potential in each sector at any given salinity level.

Table 6.4.1. Salinity multipliers (R of salinity costs per R 000 000 of additional final demand)

Salinity level 600 mg/ℓ TDS	Direct & Indirect	Direct, Indirect & Induced	Ranking
Community and other services	36.30	47.54	1
Gold-mining	33.43	44.00	2
Agriculture, forestry and fishing	17.39	24.59	3
Manufacturing 1	10.52	18.62	4
Manufacturing 2	2.63	4.66	5
Salinity level 1200	**Direct & Indirect**	**Direct, Indirect & Induced**	**Ranking**
Gold-mining	649.92	672.86	1
Community and other services	80.82	105.21	2
Agriculture, forestry and fishing	25.34	40.98	3
Manufacturing 1	23.51	41.09	3
Manufacturing 2	5.88	10.27	5

The multipliers which have been ranked in the abovementioned table are those relating to the sectors which were researched. However, the model has produced multipliers for all sectors in the IO table used (refer to Table 6.4.2).

Even those sectors with no direct costs, can still have indirect and induced costs. The production of an extra Rand's worth of final demand requires additional input which could come from industries who have salinity combating costs. These can be used to generate an impact on households when they implement their own programmes.

All input purchased by households represents additional final demand on some or other economic activity, and the salinity costs brought about by this additional final demand are given by the appropriate multipliers. The additional direct, indirect and induced effects of households combating salinity can thus be calculated (refer to Table 6.4.3).

6.4.2 Pricing model

The pricing model is required to estimate the total effects of salinity in monetary values. This model operates by passing on all costs associated with salinity as price increases.

All costs are passed on and therefore no substitution effects are postulated. The model was run to simulate these sectoral actions and both indirect and induced effects were taken into account (refer to Table 6.4.4). In estimating the induced effects, the tables were closed with respect to households, but only the labour provision activities of households were taken into account. In considering the salinity costs of households, the pricing model is based on a closed IO table. This assumes that household salinity costs would be "passed on" in the form of additional wage requirements. In this model, not only is the additional labour which is required to meet sectoral salinity combating activities considered, but it is also assumed that labour costs rise as households implement their own salinity combating effects (refer to Table 6.4.5).

Table 6.4.2: Additional salinity costs per R000 000 of final demand salinity multipliers

Salinity Level: 200	Agriculture, forestry and fishing	Goldmining	Other mining	Manufacturing 1	Manufacturing 2	Electricity, gas & steam	Water	Construction	Trade, catering and accommodation	Transport, storage and communication	Finance, insurance and business services	Community and other services
	1	2	3	4	4	5	6	7	8	9	10	11
Direct	0.00	-263.95	0.00	-8.04	-2.01	0.00	0.00	0.00	0.00	0.00	0.00	-44.97
Direct & indirect	-6.29	-267.36	-7.47	-14.70	-3.68	-2.60	-6.83	-7.92	-3.37	-4.25	-2.06	-53.52
Indirect	-6.29	-3.41	-7.47	-6.66	-1.67	-2.60	-6.83	-7.92	-3.37	-4.25	-2.06	-8.55
Direct, indirect & induced	-12.46	-277.27	-14.68	-21.22	-5.31	-8.74	-13.83	-18.43	-14.03	-13.89	-9.88	-63.56
Induced	-6.17	-9.91	-7.21	-6.52	-1.63	-6.14	-7.00	-10.51	-10.66	-9.65	-7.82	-10.04

Salinity Level: 400	Agriculture, forestry and fishing	Goldmining	Other mining	Manufacturing 1	Manufacturing 2	Electricity, gas & steam	Water	Construction	Trade, catering and accommodation	Transport, storage and communication	Finance, insurance and business services	Community and other services
	1	2	3	4	4	5	6	7	8	9	10	11
Direct	0.00	-79.89	0.00	0.87	0.22	0.00	0.00	0.00	0.00	0.00	0.00	11.87
Direct & indirect	0.98	-79.24	1.53	2.01	0.50	0.48	1.32	1.28	0.57	0.76	0.43	13.68
Indirect	0.98	0.65	1.53	1.14	0.28	0.48	1.32	1.28	0.57	0.76	0.43	1.81
Direct, indirect & induced	2.10	-77.44	2.84	3.19	0.80	1.59	2.59	3.19	2.51	2.51	1.84	15.50
Induced	1.12	1.80	1.31	1.18	0.30	1.11	1.27	1.91	1.93	1.75	1.42	1.82

Salinity Level: 600	Agriculture, forestry and fishing	Goldmining	Other mining	Manufacturing 1	Manufacturing 2	Electricity, gas & steam	Water	Construction	Trade, catering and accommodation	Transport, storage and communication	Finance, insurance and business services	Community and other services
	1	2	3	4	4	5	6	7	8	9	10	11
Direct	11.54	30.50	0.00	3.89	0.97	0.00	0.00	0.00	0.00	0.00	0.00	29.55
Direct & indirect	16.14	32.61	4.68	8.65	2.16	1.61	4.24	4.77	2.10	2.62	1.30	34.96
Indirect	4.61	2.12	4.68	4.76	1.19	1.61	4.24	4.77	2.10	2.62	1.30	5.42
Direct, indirect & induced	20.21	39.15	9.44	12.94	3.24	5.66	8.85	11.70	9.13	8.98	6.46	41.58
Induced	4.07	6.53	4.76	4.30	1.07	4.05	4.61	6.93	7.03	6.36	5.15	6.62

Table 6.4.2: continued

Salinity Level: 800	Agriculture, forestry and fishing	Goldmining	Other mining	Manufacturing 1	Manufacturing 2	Electricity, gas & steam	Water	Construction	Trade, catering and accommodation	Transport, storage and communication	Finance, insurance and business services	Community and other services
	1	2	3	4	4	5	6	7	8	9	10	11
Direct	11.54	175.62	0.00	5.73	1.43	0.00	0.00	0.00	0.00	0.00	0.00	41.63
Direct & indirect	17.67	178.59	6.58	12.15	3.04	2.26	5.96	6.71	2.93	3.67	1.83	49.24
Indirect	6.13	2.97	6.58	6.42	1.61	2.26	5.96	6.71	2.93	3.67	1.83	7.61
Direct, indirect & induced	23.27	187.59	13.13	18.07	4.52	7.84	12.31	16.25	12.62	12.44	8.93	58.36
Induced	5.60	9.00	6.55	5.92	1.48	5.58	6.36	9.54	9.68	8.76	7.10	9.12

Salinity Level: 1000	Agriculture, forestry and fishing	Goldmining	Other mining	Manufacturing 1	Manufacturing 2	Electricity, gas & steam	Water	Construction	Trade, catering and accommodation	Transport, storage and communication	Finance, insurance and business services	Community and other services
	1	2	3	4	4	5	6	7	8	9	10	11
Direct	12.39	368.67	0.00	7.57	1.89	0.00	0.00	0.00	0.00	0.00	0.00	53.72
Direct & indirect	20.15	372.51	8.51	15.75	3.94	2.92	7.70	8.68	3.78	4.75	2.36	63.54
Indirect	7.76	3.84	8.51	8.18	2.04	2.92	7.70	8.68	3.78	4.75	2.36	9.82
Direct, indirect & induced	27.34	384.06	16.91	23.34	5.83	10.07	15.85	20.92	16.20	15.99	11.47	75.24
Induced	7.18	11.54	8.40	7.59	1.90	7.15	8.15	12.24	12.42	11.24	9.11	11.70

Salinity Level: 1200	Agriculture, forestry and fishing	Goldmining	Other mining	Manufacturing 1	Manufacturing 2	Electricity, gas & steam	Water	Construction	Trade, catering and accommodation	Transport, storage and communication	Finance, insurance and business services	Community and other services
	1	2	3	4	5	6	7	8	9	10	11	12
Direct	13.21	643.38	0.00	9.41	2.35	0.00	0.00	0.00	0.00	0.00	0.00	65.80
Direct & indirect	22.60	648.10	10.44	19.37	4.84	3.58	9.45	10.67	4.64	5.82	2.89	77.85
Indirect	9.39	4.71	10.44	9.96	2.49	3.58	9.45	10.67	4.64	5.82	2.89	12.04
Direct, indirect & induced	31.38	662.19	20.69	28.64	7.16	12.32	19.41	25.61	19.80	19.55	14.01	92.13
Induced	8.77	14.10	10.26	9.27	2.32	8.73	9.95	14.95	15.16	13.72	11.12	14.28

Table 6.4.2: continued

Ratios	Agriculture, forestry and fishing	Goldmining	Manufacturing 1	Manufacturing 2	Community and other services
Salinity level: 200					
Direct, indirect	-	1.0129	1.8284	1.8284	1.1901
Direct, indirect & induced	-	1.0505	2.6389	2.6389	1.4134
Salinity level: 400					
Direct, indirect	-	0.9918	2.3049	2.3049	1.1525
Direct, indirect & induced	-	0.9693	3.6628	3.6628	1.3059
Salinity level: 600					
Direct, indirect	1.3992	1.0694	2.2238	2.2238	1.1833
Direct, indirect & induced	1.7516	1.2836	3.3291	3.3291	1.4074
Salinity level: 800					
Direct, indirect	1.5318	1.0169	2.1212	2.1212	1.1827
Direct, indirect & induced	2.0173	1.0682	3.1548	3.1548	1.4018
Salinity level: 1000					
Direct, indirect	1.6262	1.0104	2.0808	2.0808	1.1829
Direct, indirect & induced	2.2061	1.0417	3.0841	3.0841	1.4006
Salinity level: 1200					
Direct, indirect	1.7107	1.0073	2.0585	2.0585	1.1830
Direct, indirect & induced	2.3745	1.0292	3.0439	3.0439	1.4001

Table 6.4.3: Additional salinity costs due to additional final demand from households (1995 Rand p.a. values)

Additional Salinity Costs	200	400	600	800	1000	1200
Household (Suburban):						
Direct	-496.57	36.68	100.93	430.84	931.47	1602.83
Direct & Indirect	-430.13	43.30	147.22	621.35	1338.26	2298.30
Household (Township):						
Direct	-219.72	11.92	39.86	172.92	377.11	652.42
Direct & Indirect	-91.59	14.37	74.84	315.58	680.74	1170.67
Household (Informal):						
Direct	-42.61	2.41	7.84	33.95	73.95	127.85
Direct & Indirect	-20.08	2.89	14.25	60.11	129.65	222.93
Total Direct Additional Costs	**-758.90**	**51.02**	**148.64**	**637.72**	**1382.54**	**2383.11**
Total Direct & Indirect Additional Costs	**-541.81**	**60.56**	**236.32**	**997.04**	**2148.65**	**3691.90**

NOTE: Based on the Salinity Multipliers

In running the pricing model, the increased sectoral prices are combined to calculate the percentage change in the CPI. The modelling essentially comprised a means to collate and transform the data, identifying the annual direct costs to the sectors as well as the annual total direct costs to the economy. The data was then incorporated into the IO table in order to generate the annual indirect and induced costs, and the output, re-escalated to 1995 levels, is presented as annual increases in prices or output from all sectors required to combat the given level of salinity in each scenario. As this output is used solely to combat salinity, and does not contribute to final demand, it is to be interpreted as a cost to the economy. In relating this to Private Consumption Expenditure, the annual price changes in rands were calculated (refer to Table 6.4.6).

6.4.3 Augmented IO model

The augmented IO model was originally executed as main model but subsequent to using the pricing model, it has been utilised as control case and to incorporate behavioural costs. The augmented IO model is used to determine the Direct Cost Multipliers (DCM) which indicate the ratio of direct to direct, indirect and induced costs. It also assigns values to the annual sectoral impacts of salinity increases (refer to Table 6.4.7). The total impacts refer to the combined direct, indirect and induced costs and represent typical costs per annum.

6.4.4 Relation between models

The multiplier analysis is directly comparable to that of the augmented IO model. The salinity multipliers provide insight into the sectoral cost changes due to a stimulation of the economy, such as that experienced as a result of increased salinity levels. The sectoral salinity multiplier ratios range from 1 to 3.37 whereas the DCMs calculated with the augmented IO model amount to 2.6 and 3.0.

The pricing model expresses the multiplier analysis results in terms of price changes which are effectively representing forward linkages. This then means that the pricing model, using the same data, tables and equations, is a transpose of the multiplier analysis and thus the "other side of the same coin." The multipliers express backward linkages based on classical IO manipulations.

Given this information the results are discussed and interpreted in Section 7.

Table 6.4.4: Percentage impact of salinity abatement by industry on CPI and PPI

SALINITY LEVEL: 1200	Direct change in		Direct & indirect change in		Direct, indirect & induced change in	
Sector	CPI	PPI	CPI	PPI	CPI	PPI
Agriculture, forestry and fishing	0.0000921	0.0001047	0.0001919	0.0002163	0.0003747	0.0003917
Goldmining	0.0000077	0.0047335	0.0000285	0.0047571	0.0000493	0.0047771
Manufacturing 1	0.0000318	0.0000360	0.0000588	0.0000666	0.0001180	0.0001235
Manufacturing 2	0.0019028	0.0021339	0.0035104	0.0039683	0.0063512	0.0066935
Community and other services	0.0009315	0.0007742	0.0016787	0.0016122	0.0034273	0.0032896
Total % increase	0.0029660	0.0077826	0.0054683	0.0106209	0.0103207	0.0152761

SALINITY LEVEL: 1000	Direct change in		Direct & indirect change in		Direct, indirect & induced change in	
Sector	CPI	PPI	CPI	PPI	CPI	PPI
Agriculture, forestry and fishing	0.0000862	0.0000981	0.0001797	0.0002026	0.0003510	0.0003669
Goldmining	0.0000044	0.0027124	0.0000163	0.0027259	0.0000283	0.0027374
Manufacturing 1	0.0000258	0.0000292	0.0000477	0.0000540	0.0000957	0.0001001
Manufacturing 2	0.0015299	0.0017157	0.0028225	0.0031907	0.0051066	0.0053817
Community and other services	0.0007605	0.0006320	0.0013704	0.0013161	0.0027979	0.0026854
Total % increase	0.0024069	0.0051876	0.0044366	0.0074895	0.0083795	0.0112720

Table 6.4.4: continued

SALINITY LEVEL: 800	Direct change in		Direct & indirect change in		Direct, indirect & induced change in	
Sector	CPI	PPI	CPI	PPI	CPI	PPI
Agriculture, forestry and fishing	0.0000804	0.0000915	0.0001675	0.0001889	0.0003272	0.0003420
Goldmining	0.0000021	0.0012921	0.0000078	0.0012985	0.0000135	0.0013040
Manufacturing 1	0.0000198	0.0000224	0.0000366	0.0000414	0.0000734	0.0000768
Manufacturing 2	0.0011164	0.0012520	0.0020596	0.0023282	0.0037263	0.0039271
Community and other services	0.0005894	0.0004898	0.0010621	0.0010200	0.0021684	0.0020813
Total % increase	0.0018081	0.0031478	0.0033335	0.0048771	0.0063088	0.0077313

SALINITY LEVEL: 600	Direct change in		Direct & indirect change in		Direct, indirect & induced change in	
Sector	CPI	PPI	CPI	PPI	CPI	PPI
Agriculture, forestry and fishing	0.0000804	0.0000915	0.0001675	0.0001889	0.0003272	0.0003420
Goldmining	0.0000004	0.0002244	0.0000013	0.0002255	0.0000023	0.0002264
Manufacturing 1	0.0000138	0.0000156	0.0000254	0.0000288	0.0000511	0.0000534
Manufacturing 2	0.0007841	0.0008794	0.0014466	0.0016353	0.0026173	0.0027583
Community and other services	0.0004183	0.0003477	0.0007538	0.0007239	0.0015390	0.0014771
Total % increase	0.0012970	0.0015584	0.0023947	0.0028024	0.0045369	0.0048574

Table 6.4.4: continued

SALINITY LEVEL: 400	Direct change in		Direct & indirect change in		Direct, indirect & induced change in	
Sector	CPI	PPI	CPI	PPI	CPI	PPI
Agriculture, forestry and fishing	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Goldmining	-0.0000010	-0.0005878	-0.0000035	-0.0005907	-0.0000061	-0.0005932
Manufacturing 1	0.0000045	0.0000051	0.0000083	0.0000094	0.0000167	0.0000175
Manufacturing 2	0.0001705	0.0001912	0.0003145	0.0003555	0.0005690	0.0005997
Community and other services	-0.0001681	-0.0001397	-0.0003029	-0.0002909	-0.0006184	-0.0005935
Total % increase	0.0000059	-0.0005312	0.0000164	-0.0005166	-0.0000388	-0.0005696

SALINITY LEVEL: 200	Direct change in		Direct & indirect change in		Direct, indirect & induced change in	
Sector	CPI	PPI	CPI	PPI	CPI	PPI
Agriculture, forestry and fishing	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
Goldmining	-0.0000032	-0.0019419	-0.0000117	-0.0019516	-0.0000202	-0.0019598
Manufacturing 1	-0.0000234	-0.0000265	-0.0000432	-0.0000490	-0.0000869	-0.0000909
Manufacturing 2	-0.0016402	-0.0018395	-0.0030260	-0.0034208	-0.0054749	-0.0057699
Community and other services	-0.0006366	-0.0005291	-0.0011473	-0.0011018	-0.0023424	-0.0022482
Total % increase	-0.0023035	-0.0043370	-0.0042282	-0.0065231	-0.0079243	-0.0100685

Table 6.4.5: Percentage impact of salinity abatement by industry and households on CPI and PPI taking all household costs into account

SALINITY LEVEL: 1200 Sector	Direct, indirect & induced change in	
	CPI	PPI
Agriculture, forestry and fishing	0.0003746	0.0003845
Goldmining	0.0000492	0.0034059
Manufacturing 1	0.0001181	0.0001221
Manufacturing 2	0.0063380	0.0064046
Community and other services	0.0034289	0.0033522
Household (Suburban)	0.0616631	0.0689255
Household (Township)	0.0927400	0.1088754
Household (Informal)	0.0548442	0.0667806
Total % increase	0.2197198	0.2584788

SALINITY LEVEL: 1000 Sector	Direct, indirect & induced change in	
	CPI	PPI
Agriculture, forestry and fishing	0.0003508	0.0003601
Goldmining	0.0000282	0.0019517
Manufacturing 1	0.0000957	0.0000990
Manufacturing 2	0.0050959	0.0051495
Community and other services	0.0027992	0.0027366
Household (Suburban)	0.0440451	0.0492325
Household (Township)	0.0662429	0.0777681
Household (Informal)	0.0391744	0.0477004
Total % increase	0.1579173	0.1851152

SALINITY LEVEL: 800 Sector	Direct, indirect & induced change in	
	CPI	PPI
Agriculture, forestry and fishing	0.0003270	0.0003357
Goldmining	0.0000134	0.0009297
Manufacturing 1	0.0000734	0.0000760
Manufacturing 2	0.0037185	0.0037576
Community and other services	0.0021694	0.0021209
Household (Suburban)	0.0264270	0.0295395
Household (Township)	0.0397457	0.0466609
Household (Informal)	0.0235047	0.0286203
Total % increase	0.0960111	0.1120838

Table 6.4.5: continued

SALINITY LEVEL: 600 Sector	Direct, indirect & induced change in	
	CPI	PPI
Agriculture, forestry and fishing	0.0003270	0.0003357
Goldmining	0.0000023	0.0001614
Manufacturing 1	0.0000511	0.0000529
Manufacturing 2	0.0026118	0.0026393
Community and other services	0.0015397	0.0015053
Household (Suburban)	0.0088090	0.0098465
Household (Township)	0.0132486	0.0155536
Household (Informal)	0.0078349	0.0095401
Total % increase	0.0344288	0.0396404

SALINITY LEVEL: 400 Sector	Direct, indirect & induced change in	
	CPI	PPI
Agriculture, forestry and fishing	0.0000000	0.0000000
Goldmining	-0.0000061	-0.0004229
Manufacturing 1	0.0000167	0.0000173
Manufacturing 2	0.0005678	0.0005738
Community and other services	-0.0006187	-0.0006048
Household (Suburban)	-0.0088090	-0.0098465
Household (Township)	-0.0132486	-0.0155536
Household (Informal)	-0.0078349	-0.0095401
Total % increase	-0.0299298	-0.0353728

SALINITY LEVEL: 200 Sector	Direct, indirect & induced change in	
	CPI	PPI
Agriculture, forestry and fishing	0.0000000	0.0000000
Goldmining	-0.0000202	-0.0013973
Manufacturing 1	-0.0000869	-0.0000899
Manufacturing 2	-0.0054635	-0.0055209
Community and other services	-0.0023434	-0.0022911
Household (Suburban)	-0.0264270	-0.0295395
Household (Township)	-0.0397457	-0.0466609
Household (Informal)	-0.0235047	-0.0286203
Total % increase	-0.0975581	-0.1140742

Table 6.4.6: National and regional CPI impact expressed in R000 000 taking all industry and household salinity abatement costs into account

SALINITY LEVEL: 1200	Direct, indirect & induced change in CPI		Direct, indirect & induced change in PPI	
Sector	National	Region C	National	Region C
Agriculture, forestry and fishing	1.104607	0.080335	3.905412	0.17459927
Goldmining	0.145064	0.010550	34598483	1.546794397
Manufacturing 1	0.348141	0.025319	1.240646	0.055465558
Manufacturing 2	18.690449	1.359300	65.059862	2.908631264
Community and other services	10.1116657	0.735390	34.053048	1.522409633
Household (Suburban)	181.841350	13.224775	700.165274	31.30228892
Household (Township)	273.485642	19.889790	1105.987962	49.44540383
Household (Informal)	161.732767	11.762339	678.37676	30.32818982
Total increase	647.459677	47.087799	2623.387449	117.283783

SALINITY LEVEL: 1200	Direct, indirect & induced change in CPI		Direct, indirect & induced change in PPI	
Sector	National	Region C	National	Region C
Agriculture, forestry and fishing	0.964401	0.070138	3.409703	0.152438
Goldmining	0.006876	0.000500	1.639991	0.073319
Manufacturing 1	0.150684	0.010959	0.536982	0.024007
Manufacturing 2	7.702177	0.560156	26.810622	1.198622
Community and other services	4.540478	0.330215	15.290976	0.683614
Household (Suburban)	25.977336	1.889254	100.023611	4.471756
Household (Township)	39.069377	2.841399	157.99828	7.063629
Household (Informal)	23.104681	1.680334	96.910966	4.332599
Total increase	101.516009	7.382955	402.621131	17.999983

Table 6.4.7: Salinity costs per annum for Scenario 1 – Base model (National table)

DIRECT SALINITY COSTS				1995 VALUES – R1 000 000		
SECTOR \ SALINITY	200	400	600	800	1000	1200
Mining	(7.309)	(2.212)	0.844	4.863	10.209	17.816
Business and services	(1.843)	0.487	1.211	1.707	2.202	2.697
Manufacturing 1	(0.145)	0.028	0.086	0.123	0.160	0.198
Manufacturing 2	(2.825)	0.294	1.351	1.993	2.635	3.278
Agriculture	0.000	0.000	0.439	0.439	0.472	0.503
Households (suburban)	(35.121)	(11.707)	11.707	35.121	58.535	81.949
Households (township)	(27.927)	(9.309)	9.309	27.927	46.544	65.162
Households (informal)	(5.081)	(1.694)	1.694	5.081	8.468	11.855
TOTALS	**(80.251)**	**(24.113)**	**26.640**	**77.253**	**129.225**	**183.457**

OVERALL SALINITY COSTS				1995 VALUES – R1 000 000		
SECTOR \ SALINITY	200	400	600	800	1000	1200
Agriculture	(1.39)	(0.46)	0.45	1.36	2.28	3.22
Mining	(2.37)	(0.20)	0.85	2.01	3.39	5.12
Manufacturing (w/o water)	(98.77)	(33.64)	31.89	97.33	163.46	230.84
Manufacturing (with water)	(3.22)	(1.07)	1.06	3.17	5.30	7.48
Water	(18.52)	0.20	6.73	14.68	24.79	38.52
Electricity	(2.04)	(0.21)	0.78	1.81	3.06	4.60
Construction	(0.20)	(0.06)	1.02	1.16	1.28	1.41
Trade	(36.03)	(12.13)	11.65	35.09	58.52	81.95
Transport	(1.94)	(0.63)	0.64	1.88	3.14	4.41
Finance	(4.53)	(1.49)	1.49	4.41	7.37	10.38
Business and services	(26.55)	(8.95)	8.53	25.71	42.89	60.07
Households (informal)	(3.05)	(0.94)	1.00	2.93	4.89	6.92
Households (township)	(11.66)	(3.59)	3.84	11.19	18.69	26.46
Households (suburban)	(28.65)	(8.83)	9.43	27.49	45.93	65.00
Direct, indirect and induced	(238.93)	(71.99)	79.37	230.21	385.01	546.38
Direct costs	(80.25)	(24.11)	26.64	77.25	129.22	183.46
Indirect and induced costs	(158.68)	(47.88)	52.73	152.96	255.79	362.93
Direct Cost Multiplier	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**

NOTE: The direct cost multiplier is the ration of direct, indirect and induced costs to direct costs. The National IO table has been used. Cost allocations are based on all sectors.

Table 6.4.7: *(continued) Salinity costs per annum for Scenario 1 – Base model (Regional Table)*

DIRECT SALINITY COSTS				1995 VALUES – R1 000 000		
SECTOR \ SALINITY	200	400	600	800	1000	1200
Mining	(7.309)	(2.212)	0.844	4.863	10.209	17.816
Business and services	(1.843)	0.487	1.211	1.707	2.202	2.697
Manufacturing 1	(0.145)	0.028	0.086	0.123	0.160	0.198
Manufacturing 2	(2.825)	0.294	1.351	1.993	2.635	3.278
Agriculture	0.000	0.000	0.439	0.439	0.472	0.503
Households (suburban)	(35.121)	(11.707)	11.707	35.121	58.535	81.949
Households (township)	(27.927)	(9.309)	9.309	27.927	46.544	65.162
Households (informal)	(5.081)	(1.694)	1.694	5.081	8.468	11.855
TOTALS	**(80.254)**	**(24.113)**	**26.640**	**77.253**	**129.225**	**183.457**

OVERALL SALINITY COSTS				1995 VALUES – R1 000 000		
SECTOR \ SALINITY	200	400	600	800	1000	1200
Agriculture	(4.600	(1.56)	1.49	4.54	7.63	10.78
Mining	(0.04)	(0.01)	0.02	0.04	0.06	0.09
Manufacturing (w/o water)	(88.03)	(30.11)	28.39	87.01	146.33	206.86
Manufacturing (with water)	(0.57)	(0.19)	0.19	0.56	0.94	1.33
Water	(18.21)	0.23	6.63	14.46	24.44	38.02
Electricity	(0.10)	(0.02)	0.10	0.15	0.28	0.42
Construction	(0.03)	(0.01)	0.94	0.97	0.99	1.01
Trade	(32.80)	(11.10)	10.61	32.04	53.49	74.92
Transport	(0.50)	(0.16)	0.16	0.49	0.81	1.14
Finance	(0.55)	(0.18)	0.19	0.55	0.92	1.29
Business and services	(24.29)	(8.23)	7.81	23.59	39.38	55.15
Households (informal)	(2.58)	(0.78)	0.86	2.48	4.14	5.86
Households (township)	(9.89)	(2.99)	3.27	9.47	15.82	22.43
Households (suburban)	(24.29)	(7.35)	8.04	23.27	38.88	55.10
Direct, indirect and induced	(206.49)	(62.47)	68.69	199.60	334.10	474.41
Direct costs	(80.25)	(24.11)	26.64	77.25	129.22	183.46
Indirect and induced costs	(126.24)	(38.35)	42.05	122.35	204.88	290.96
Direct Cost Multiplier	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**

NOTE: The direct cost multiplier is the ration of direct, indirect and induced costs to direct costs. A Regional C IO table has been used. Cost allocations are based on all sectors in the region.

Table 6.4.7: (continued) Salinity costs per annum for Scenario 2 – Reduced crop yield (Regional Table)

DIRECT SALINITY COSTS				1995 VALUES – R1 000 000		
SECTOR \ SALINITY	200	400	600	800	1000	1200
Mining	(7.309)	(2.212)	0.844	4.863	10.209	17.816
Business and services	(1.843)	0.487	1.211	1.707	2.202	2.697
Manufacturing 1	(0.145)	0.028	0.086	0.123	0.160	0.198
Manufacturing 2	(2.825)	0.294	1.351	1.993	2.635	3.278
Agriculture	0.000	0.000	0.076	0.355	0.681	1.025
Households (suburban)	(35.121)	(11.707)	11.707	35.121	58.535	81.949
Households (township)	(27.927)	(9.309)	9.309	27.927	46.544	65.162
Households (informal)	(5.081)	(1.694)	1.694	5.081	8.468	11.855
TOTALS	**(80.251)**	**(24.113)**	**26.277**	**77.168**	**129.434**	**183.979**

OVERALL SALINITY COSTS				1995 VALUES – R1 000 000		
SECTOR \ SALINITY	200	400	600	800	1000	1200
Agriculture	(4.60)	(1.56)	1.51	4.56	7.67	10.84
Mining	(0.04)	(0.01)	001	0.04	0.06	0.09
Manufacturing (w/o water)	(88.03)	(30.11)	28.83	87.47	147.17	208.08
Manufacturing (with water)	(0.57)	(0.19)	0.19	0.56	0.94	1.33
Water	(18.21)	0.23	6.74	14.53	24.58	38.25
Electricity	(0.10)	(0.02)	0.04	0.09	0.16	0.23
Construction	(0.03)	(0.01)	0.01	0.03	0.05	0.07
Trade	(32.80)	(11.10)	10.77	32.21	53.79	75.37
Transport	(0.50)	(0.16)	0.16	0.49	0.81	1.15
Finance	(0.55)	(0.18)	0.18	0.54	0.91	1.28
Business and services	(24.29)	(8.23)	7.93	23.72	39.60	55.48
Households (informal)	(2.58)	(0.78)	0.85	2.47	4.14	5.88
Households (township)	(9.89)	(2.99)	3.25	9.45	15.84	22.48
Households (suburban)	(24.29)	(7.35)	7.99	23.22	38.92	55.23
Direct, indirect and induced	(206.49)	(62.47)	68.46	199.37	334.64	475.76
Direct costs	(80.25)	(24.11)	26.28	77.17	129.43	183.98
Indirect and induced costs	(126.24)	(38.35)	42.19	122.21	205.20	291.78
Direct Cost Multiplier	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**	**2.6**

NOTE: The direct cost multiplier is the ration of direct, indirect and induced costs to direct costs. A Regional C IO table has been used. Cost allocations are based on all sectors in the region.

Table 6.4.7: (continued) Salinity costs per annum for Scenario 2 – Reduced crop model (National Table)

DIRECT SALINITY COSTS				1995 VALUES – R1 000 000		
SECTOR \ SALINITY	200	400	600	800	1000	1200
Mining	(7.309)	(2.212)	0.844	4.863	10.209	17.816
Business and services	(1.843)	0.487	1.211	1.707	2.202	2.697
Manufacturing 1	(0.145)	0.028	0.086	0.123	0.160	0.198
Manufacturing 2	(2.825)	0.294	1.351	1.993	2.635	3.278
Agriculture	0.000	0.000	0.076	0.355	0.681	1.025
Households (suburban)	(35.1210	(11.707)	11.707	35.121	58.535	81.949
Households (township)	(27.927)	(9.309)	9.309	27.927	46.544	65.162
Households (informal)	(5.081)	(1.694)	1.694	5.081	8.468	11.855
TOTALS	**(80.251)**	**(24.113)**	**26.277**	**77.168**	**129.434**	**183.979**

OVERALL SALINITY COSTS				1995 VALUES – R1 000 000		
SECTOR \ SALINITY	200	400	600	800	1000	1200
Agriculture	(1.39)	(0.46)	0.45	1.36	2.29	3.24
Mining	(2.37)	(0.20)	0.85	2.01	3.39	5.12
Manufacturing (w/o water)	(98.77)	(33.64)	32.29	97.76	164.31	232.11
Manufacturing (with water)	(3.22)	(1.07)	1.06	3.16	5.31	7.50
Water	(18.52)	0.20	6.84	14.76	24.93	38.75
Electricity	(2.04)	(0.21)	0.72	1.75	2.95	4.42
Construction	(0.20)	(0.06)	0.06	0.19	0.32	0.45
Trade	(36.03)	(12.13)	11.81	35.25	58.84	82.42
Transport	(1.94)	(0.63)	0.64	1.88	3.14	4.43
Finance	(4.53)	(1.49)	1.48	4.41	7.38	10.39
Business and services	(26.55)	(8.95)	8.65	25.84	43.13	60.42
Households (informal)	(3.05)	(0.94)	1.00	2.92	4.89	6.94
Households (township)	(11.66)	(3.59)	3.82	11.17	18.72	26.53
Households (suburban)	(28.65)	(8.83)	9.40	27.45	46.00	65.19
Direct, indirect and induced	(238.93)	(71.99)	79.08	229.92	385.60	547.90
Direct costs	(80.25)	(24.11)	26.28	77.17	129.43	183.98
Indirect and induced costs	(158.68)	(47.88)	52.80	152.75	256.17	363.92
Direct Cost Multiplier	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**

NOTE: The direct cost multiplier is the ratio of direct, indirect and induced costs to direct costs. The National IO table has been used. Cost allocations are based on all sectors.

SECTION 7: INTERPRETATION OF RESULTS

The results generated from the case study of the Middle Vaal River area provided typical annual cost information regarding both the direct economic impact anticipated for changes in salinity as well as the indirect and induced economic effects anticipated for changing salinity. These effects are discussed for the economy as a whole as well as for each of the individual economic sectors examined.

7.1 DIRECT COST EFFECTS OF SALINITY

The direct costs of salinity to the entire economy of the case study area can be established from the mathematical combination of the survey data collected within each individual sector. There are constraints with much of the data, since most interviewees were unable to supply data for any conditions other than those currently being experienced. Thus, the data was collected for a single salinity (500 mg/ℓ) in many of the sectors. A few of the sectors were, however, able to provide postulated costs at higher and lower salinities.

For the data to be useful in establishing the effects of salinity, information at the lower and upper limits of the study profile is required. In most cases, the data was linearly extrapolated to provide annual information for the higher salinity levels. While it is true that the relationships may well not be linear, the lack of information prevented any other mathematical relationships between the data points from being established.

Despite the drawbacks, the data provided some indication of the direct economic effects of increased salinity. At 600 mg/ℓ, a 100 mg/ℓ increase in the TDS is anticipated to effect a R26 million increase in direct costs in the study area (refer to Table 7.1.1).

Table 7.1.1. Annual direct costs of salinity (1995 values in millions of rands)

SALINITY / SECTOR	mg/ℓ TDS						% Contribution at 600 mg/ℓ
	200	400	600	800	1000	1200	
Mining	(7.309)	(2.212)	0.844	4.863	10.209	17.816	3.17
Business and Services	(1.843)	0.487	1.211	1.707	2.209	2.697	4.55
Manufacturing 1	(0.145)	0.028	0.086	0.123	0.160	0.198	0.32
Manufacturing 2	(2.825)	0.294	1.351	1.993	2.635	3.278	5.07
Agriculture	0.000	0.000	0.439	0.439	0.427	0.503	1.65
Households (suburban)	(35.121)	(11.707)	11.707	35.121	58.535	81.949	43.94
Households (township)	(27.927)	(9.309)	9.309	27.927	46.544	65.162	34.94
Households (informal)	(5.081)	(1.694)	1.694	5.081	8.469	11.855	6.36
TOTALS	(80.251)	(24.113)	26.640	77.253	129.225	183.457	100.00

Increasing the TDS to the highest limit, (1200 mg/ℓ) is expected to result in a direct cost of R183 million to the region. Conversely, a saving of R80 million is anticipated should the salinity drop from current levels to 200 mg/ℓ.

In considering these direct cost changes the effects can be equated to changes in prices in the economy. The percentage direct impact of salinity abatement on CPI and PPI at a salinity level of 600 mg/ℓ TDS, amounts to 0.0013% and 0.0016% respectively. In effect, this implies a relatively small change in these indices which can be equated to changes in inflation.

From Table 7.1.1, it is clearly seen that the greatest direct cost implications occur to the household sector. These direct costs to the households comprise approximately 85% of the total direct costs within the economy under investigation. This is not unexpected, since the household sector comprises the largest group of treated water users in the economy even though the per capita cost increases are not the highest. Conversely, the sectors which use very little water and those using predominantly untreated water are expected to have lower direct cost effects.

Manufacturing 1, where water requires no treatment, has a relatively low water consumption and experiences less than 0.5% of the direct cost of salinisation increases at 600 mg/ℓ.

By way of contrast, business and services, a relatively large sector within the economy, can be attributed with 4.5% of the total direct costs, while Manufacturing 2 (which treats its water) will face cost increases owing to the costs of treatment. Thus, unsurprisingly, this latter sector experiences 5% of the direct costs to the economy.

Although the mining sector uses large volumes of water in terms of production, much of the water employed is used in re-circulating circuits. Further, this water does not, in general, require a high degree of purification and thus the costs are lower than might otherwise be expected (3%).

Similarly, most of the water employed in the agricultural sector is drawn directly from the river itself. The water costs to agriculture are low and agriculture is a small sector, occupying a fairly narrow band along the Vaal River. Thus, agriculture occupies a small niche in the economy and its contribution of 1.5% of the total direct costs of the study region, is not unexpected.

7.2 INDIRECT AND INDUCED COST EFFECTS OF SALINITY

While the direct costs to the economy are relatively easily identified, they alone do not depict the total effect on the economy. The indirect and the induced costs borne by the economy, as a result of the interactions and relationships between the various sectors of the economy, could be considerable.

By way of definition, "indirect costs" are attributed to the knock-on effect between sectors, whenever there is stimulation to the economy. The induced effects arise from having closed the table with respect to households, and thus having taken increased spending power into account. Although technically different, the indirect and induced costs are considered together for the purposes of this discussion.
The models employed for the case study calculated the annual direct, indirect and induced costs to the economy. Since the IO table was closed with respect to households, an allowance was made for the reciprocal relationships between income and consumption, as well as the impact on the economy, resulting from the interdependence of industries in their production process and the behaviour of households. The closing of the IO table effectively added another

industry to the economy. Households have a large impact on the economic processes in the study region and wider, resulting in the expectation of larger impacts than would have been anticipated if the table had been in its open format, considering direct and indirect effects alone.

The indirect and induced effects have been determined by means of the three model applications of the IO technique as indicated before. Ratios of the direct, indirect and induced cost to the direct costs (Direct Cost Multipliers, DCM) were calculated and range from 1 to about 3.3. This implies that the spin-off effects of increased salinity are significant and the direct costs alone are then a poor reflection of the cost impacts of salinity.

7.3 BEHAVIOURAL EFFECTS ON TOTAL COSTS

The impact of human behaviour on the resultant total cost effects of salinisation should not be ignored. However, human behaviour is not easily quantified nor, in some cases, identified. It is worth noting, that the different sectors have a different degree of behavioural impact associated with them.

The decisions regarding salinity changes made in the mining, business, services and the manufacturing sectors tend to be "bottom-line" driven. These sectors are likely to make changes to combat the effects of salinity, based purely on the financial implications to the concern. As a result, there are few, if any, unexpected responses to salinity effects and the calculated costs can be accepted as reliable.

There is, however, one instance in which the costs in the mining, business, services, and the manufacturing sectors may be affected by a behavioural response. The sectors may receive an option of treating water further, or alternatively, of paying a municipal or government fine, should their effluent exceed accepted standards of TDS. Some concerns may decide to treat their water, whilst others may consider it more economically viable to maintain the *status quo* and pay any fines owing. Although this could change the cost implications, the differences are expected to be slight and the effects of introducing new technology to treat effluent discharge was not taken into account during this study.

During the data collection in the agricultural sector, the cost effects of two possible scenarios, based on management decisions or behaviour, were established. These included a "best case" scenario, where the farmer would maintain the current levels of production, regardless of cost. The data for this scenario was used in calculating a Base Model (Scenario 1) output. However, a second response, wherein the farmer could choose to allow the crop yields to be reduced, was also predicted. The data for this scenario was also used in the model (Reduced Crop Yield, Scenario 2). This was only done for the hybrid model, and the overall costs to the economy were hardly affected by the changed response (refer to Tables 6.4.7. and 6.4.8). At the 600 mg/ℓ level, the total costs decreased by less than R0.3 million. The variations were found to be between 0.1% and 0.3% of the overall costs, which is less significant than the probable errors in the data. Thus, the different behavioural responses available in the agricultural sector are unlikely to impact on the total costs to the economy.

The most significant behavioural effects are, however, likely to arise from the household sector. The responses to increased salinity, while to some extent determined by the need to adapt to the changes, will largely be driven by the availability of finances to maintain the *status quo* and overcome the problems arising from increased salinity. These behavioural responses are more likely to appear in those sectors of lower earning potential, and the informal household sector is far less likely to effect changes arising from increased salinity than suburban households. This is borne out by the variance in the data collected and will be discussed in a subsequent subsection (refer to Table 7.3.1).

Table 7.3.1. Variance in the household cost data

Sector	No of Households	Range for Variance Calculations			Percentage within range	Percentage outside range
		0	x	2x		
		(500 mg/ℓ value)				
Suburban	59 270	0	49.38	92.76	94	6
Township	63 952	0	36.39	72.78	85	15
Informal	30 070	0	14.08	28.16	78	22

Although a Monte-Carlo approach could be used to model the effects of varying behaviour on the model output, the difficulty in obtaining suitable data for this approach has precluded its use in this study. Rather, the effects of increased costs to the households in terms of monthly costs has been calculated from the model output (refer to Table 7.3.2). It may be able to predict behavioural responses (refer to discussion on household sector).

Table 7.3.2. Anticipated monthly costs to the household sectors (R)

Sector	No of households	Monthly Costs at TDS Levels				
		500 mg/ℓ	600 mg/ℓ	800 mg/ℓ	1000 mg/ℓ	1200 mg/ℓ
Suburban	59 270	49.38	65.84	98.76	131.68	164.60
Township	63 952	36.39	48.52	72.78	97.04	121.30
Informal	30 070	14.08	18.77	28.16	37.55	46.93

7.4 DISCUSSION OF TOTAL COST EFFECTS

This section is used to interpret the results obtained with the multiplier analysis, the pricing model and the hybrid model.

7.4.1 Multiplier analysis

The multiplier analysis produces results in terms of additional salinity costs per million rands of final demand.

The ranking of the sectors researched, based on the salinity multipliers, indicates that at relative low levels of salinity the community and other services sectors will be most adversely affected (refer to Table 6.4.1). The manufacturing sectors will have the lowest salinity costs for the entire range of salinity levels. At high levels of salinity the gold-mining sector will have to incur the highest cost to combat salinity.

These multipliers are useful for ranking industry sensitivities to the impact of salinity costs. This is demonstrated by comparing the 600 and 1200 mg/ℓ salinity level cases (refer to Table 6.4.1). At the extreme case (1200 mg/ℓ TDS) gold mining is the most affected in terms of salinity costs per million rands of final demand delivered. At the 600 mg/ℓ TDS level this effect is not so obvious as far as gold-mining is concerned, although the rankings otherwise remain the same. The difference between the direct and the direct, indirect and induced multipliers is due to the fact that the direct effects tend to swamp the indirect and induced effects, as a result of limited linkage of gold-mining with other industries.

To provide a link with the augmented model, the DCMs can be calculated using salinity multipliers. Looking at the direct and indirect DCM at salinity levels of 600 and 1200 mg/ℓTDS, the range over the different sectors varies from approximately 0.99 to 2.3 and the direct, indirect and induced DCM ranges from approximately 0.97 to 3.7 (refer to Table 6.4.2). These multipliers are not readily come by, nor would they necessarily be too meaningful. It is better to use the multiplier results, as mentioned before, to compare impacts between sectors. The higher multipliers indicate strong intersectoral linkages, whilst the lower ones indicate weak linkages. Note particularly the cases of gold-mining (very low) and manufacturing (very high), which is consistent with expectations.

Similarly, the household direct and indirect DCMs (Table 6.4.3.) are around the 1.6 mark. These could be expected to be of comparable order with the direct, indirect and induced DCMs, and as such are on the low side, considering the high household linkages.

7.4.2 Pricing model results

The results of the pricing model are expressed in terms of percentage changes in the consumer and producer price indices and essentially represent forward linkages. The impacts have been determined in terms of regional and national impacts.

Considering only the impact on the industrial sectors, results of the same order as the multipliers provided are found, but with less spread. The direct and indirect DCMs for PPI and CPI are found to lie between 1.36 and 1.84, whilst the direct, indirect and induced DCMs are is found to lie between 1.96 and 3.5. The percentage total increases in CPI and PPI for salinity levels 600 and 1200 mg/ℓ can be summarised as indicated in Table 7.4.1:

Table 7.4.1. Percentage increases in CPI and PPI

Salinity abatement by :	CPI: % change	PPI: % change
Industry*	-0.008 to 0.01	-0.01 to 0.015
Industry* and households	-0.1. to 0.22	-0.11 to 0.26

NOTE: *Refers to economic sectors

These changes seem to be small but are significant when related to Rand values in regional and national context. This had been done (refer to Table 6.4.6) and the regional and national impacts are summarised as indicated in Table 7.4.2:

Table 7.4.2. Regional and National Impacts

IMPACTS	CPI	PPI
National increase		
600 mg/ℓ	R101.5m	R402.6m
1200 mg/ℓ	R647.5m	R2623.4m
Regional increase		
600 mg/ℓ	R7.4m	R18.0m
1200 mg/ℓ	R47.1m	R117.3m

The larger effects on the national economy are due to the inclusion of interregional imports and exports. These are internalised in a national model, whereas in a regional model they are externalised and thus are exogenous to the productive quadrant.

7.4.3. Augmented input-output model

The augmented IO model was executed using both regional and national IO tables to determine the total annual cost effects of salinity abatement. Multipliers were calculated for comparison with the other model applications. The study area falls mainly in the Free State area for which a Region C IO table was used.

The chief outcome was that the DCM was 3.0 for the national case, and 2.6 for the regional case. These figures did not change significantly over the salinity range of 600 to 1200 mg/ℓ TDS.

The conclusions which flow from these findings are as follows :

* There is a (relatively small) difference between Direct Cost Multiplier (DCM) in the national and the regional cases. This is to be expected and it represents the differences in structure between the national and the regional economies. Since the IO analysis is based upon coefficients, the actual size of the economies has no influence on the DCMs. Only changes in the size of the input (or technical) coefficients (which in turn reflects a change in the structure of the tables) would influence the outcome. Although the structures of individual sectors might be considered to be similar, whether viewed nationally or regionally, there would certainly be a difference with regards to imports. In the regional case, inter-regional imports can play a big part in the input structure of the table. The IO tables used have imports in the row, which means that as the imported content rises, the import row increases and the technical coefficients decrease as a consequence. As a result, the DCM could be expected to be smaller in the regional case than in the national case. This is consistent with findings.
* A very rough "rule-of-thumb" regarding the relationship between direct, indirect and induced effects is that for each unit of direct effect a further unit of indirect effect and two of induced effects can be expected. The findings fall well within this framework. Whilst this does not in any way validate the findings, it should help to give confidence in them.

7.5 INDIVIDUAL SECTORAL EFFECTS

Interpretation of the sectoral outputs is important, to make comparisons regarding the cost implications and the impact of salinity on the different economic sectors.

Table 6.4.2 indicates the DCMs that can be established for each of the sectors under investigation. The constraints experienced in the availability of data have provided a consistent error throughout the range of outputs calculated and therefore can be assumed to have been cancelled out.

7.5.1 Households

The surveys in Welkom and Klerksdorp indicated that increased salinity in water is associated with behavioural adjustments as well as specific costs to the household sector of the economy. The costs incurred extend beyond expenditure on consumable, durable or capital goods. They also involve social costs, such as appreciable increases in the time and effort spent on maintenance and repair of goods damaged or affected by mineral deposits. Additional effort and energy are also expended on cleaning activities such as scrubbing tiles, de-scaling utensils, washing cars, lamps and windows. A hidden cost, determined by behaviour, is the option of not replacing damaged items.

The effects of salinity on households are mainly the following :

* impact on palatability of water
* impact on effectiveness of soap and detergents.

Certain perceptions exist that the quality of the water poses health risks. The most common practise employed to overcome this, is the boiling of water. Further, a marked trend observed, is the change in water-drinking habits. This is expressed in the avoidance of drinking the water and the preferential use of substitutes.

The effect of the water on consumables, such as soaps and detergents, is a reduction in foaming. Since the presence of foam is perceived as an indicator of cleansing power, adaptive behaviour is experienced, including the use of different brands as well as increased consumption.

Adaptive behaviour was also marked in the use of water for personal and hygienic purposes. Notably, an increase in the consumption of skin softeners, including creams and oils, was established.

The effect of salinity on durable goods lies in a shortened lifespan as well as increased maintenance costs. Replacement of appliances is, however, largely determined by the socio-economic profile of the household, where non-replacement may be practised.

The average monthly increase in the cost of consumable, durable and capital goods due to changes in salinity is presented in Table 6.3.4. It is likely that while the three household sectors are prepared to absorb the cost implications due to salinity at the current 500 mg/ℓ level, there may be a point at which the availability of disposable income within the sector will override any other behavioural responses. This may prevent the sector from effectively dealing with the costs of increased salinity and may have further financial implications for the economy.

The DCM for the three household sectors based on the multiplier analysis amounts to 1.6. The multiplier indicates that the "hidden" costs, namely, the indirect and induced costs, are expected to be significant with regard to the overall economic implications of increased salinity.

The total impact of salinity abatement by households on CPI and PPI for salinity levels 600 and 1200 mg/ℓ is estimated as indicated in Table 7.5.1:

Table 7.5.1. Impacts on Salinity Abatement

HOUSEHOLDS	Percentage change in			
	CPI		*PPI*	
TDS	**600 mg/ℓ**	**1200 mg/ℓ**	**600 mg/ℓ**	**1200 mg/ℓ**
Suburban	0.0088	0.0617	0.0099	0.0689
Township	0.03132	0.0927	0.0156	0.1089
Informal	0.0078	0.0548	0.0095	0.0668

The relatively more significant impacts are related to the township households. This may be influenced by the number of households as well as the magnitude of direct costs. In relating these percentages to National Consumer Expenditure, the total impacts of salinity can be expressed in monetary values. These changes are as indicated in Table 7.5.2.

Table 7.5.2. Total Monetary Changes

HOUSEHOLDS	Total impact expressed in R million			
	CPI		*PPI*	
TDS	**600 mg/ℓ**	**1200 mg/ℓ**	**600 mg/ℓ**	**1200 mg/ℓ**
Suburban	26	182	100	200
Township	39	274	158	1106
Informal	23	162	97	678

The regional changes are approximately 7.3% of CPI and 4.5% of PPI. These changes all relate to the forward linkages, since any costs incurred due to salinity are passed on as price increases (including increased labour bills).

In relating the impacts of salinity to costs, the augmented model results express the costs of salinity based on backward linkages. The total costs for households range between R1 million and R9.43 million/a, with suburban households incurring the latter higher costs at 600 mg/ℓ. At 1200 mg/ℓ TDS these costs increase to between R6.92 million and R65.00 million respectively.

7.5.2 Agriculture

The impact of increased salinity has been related to crop yields. Management options, which include the acceptance of reduced yields due to increases in the salinity, have been taken as a proxy for behaviour. These can be presented in terms of reduced yields. The following reactions, based on pre-calculated reductions/increases in yield, have been recorded:

- Soil that will allow unrestricted drainage
  - Apply a leaching fraction to maintain yield.
  - If the crop yield deteriorates to the degree that crop production is unprofitable, crop selection will be adapted.
  - If additional water is unavailable poorer quality land will be withdrawn from use and its water used to apply a leaching fraction.

- Soil that has restricted drainage
  - Installation of artificial drainage.
  - Change to less salt-sensitive crops first and later install drains. This behaviour was anticipated by 50% of respondents.

However, comparison of the base scenario (no reduction in yield) and the second scenario (yield reduction accepted) in the augmented model, demonstrates that the direct costs do not differ very much. Up to the current levels of salinity (500 mg/ℓ) there is in fact no change at all. Thereafter, costs initially fall slightly before increasing. The changes between the second scenario and the base scenario are not sufficiently significant for the multipliers to change. Thus, in the case of agriculture, it can be deduced that behavioural patterns are likely to have little effect on the costs of salinity, since there are only small cost differences between the two extremes.

A third behavioural response, that of changing crop selection, is less likely to impact on the total costs as the change in costs will be small and will vary for each specific new crop selected.

Thus, when increased leaching fractions are applied, to maintain yield, the gross margin is expected to decrease from R3644,07/ha at 200 mg/ℓ to R3594,80/ha at 1200 mg/ℓ. Where reduced yield for the current crop selection is accepted, there are indications that the gross margin will decrease from R3645,10/ha at 200 mg/ℓ to R2957,72/ha at 1200 mg/ℓ. The decrease in the gross margin, when a change in the crop selection is effected, is expected to be from R3746,17/ha at 200 mg/ℓ to R3142,31/ha at 1200 mg/ℓ.

Once again, the changes are fairly small across the salinity range examined, confirming the low impact on the total economy of the region. This does not, however, discount the substantial impact on individual farmers, since high levels of salinity may in fact lead to non-viable situations.

Despite the low impact of the behavioural responses on the economic impact of salinity, the costs calculated across the range of salinities are affected by the indirect and induced costs. The effects of increases in salinity may result in the abandonment of farming in any marginally profitable situations. This impact, which cannot be quantified, should be considered.

The DCMs calculated for agriculture using the multiplier analysis range between 1.75 and 2.38. These DCMs are lower than the 2.6 and 3.0 calculated with the augmented model. The total impact of salinity abatement by agriculture in percentage changes on CPI and PPI for salinity levels 600 and 1200 mg/ℓ is estimated as indicated in Table 7.5.3:

Table 7.5.3: Percentage changes in price indices: Agriculture

TDS	CPI	TDS	PPI
600 mg/ℓ	0.00033%	600 mg/ℓ	0.00034%
1200 mg/ℓ	0.00038%	1200 mg/ℓ	0.00039%

The changes in CPI and PPI are relatively small compared to the other sectors. In relating these changes to national consumer expenditure, the monetary values are as indicated in Table 7.5.4 :

Table 7.5.4: Monetary changes in price indices: Agriculture

TDS	CPI	TDS	PPI
600 mg/ℓ	R0.964m	600 mg/ℓ	R3.410m
1200 mg/ℓ	R1.105m	1200 mg/ℓ	R3.905m

The regional changes represent approximately 7% of the National CPI and about 4.5% of the National PPI.

Based on the DCM of the augmented IO model, the direct cost of R0.439 million at 600 mg/ℓ could increase to R1.317 million when considering the indirect and induced costs as well.

7.5.3 Mining

The results of the mining surveys indicate that the evaporative cooling water circuits of mines and the boilers in the metallurgical plants will be significantly affected by increases in salinity. This so, since evaporative cooling water circuits are dependent on good quality make-up water to function efficiently, and the build-up of scale from high TDS, causes boiler inefficiency.

Management behaviour is unlikely to impact on the costs in any significant way, since the mining sector is driven by profitability. However, salinity increases will affect the economics of the sector. At 600 mg/ℓ TDS, the direct costs to the sector are predicted to be R0.84 million/a. These costs increase to R2.52 million when the indirect and induced costs are also considered. The cost increases relate to increased water usage, chemical treatment cost, management cost, discharge cost and maintenance cost.

Based on the multiplier analysis the mining sector has been ranked as having the highest additional costs per unit final demand at high levels of salinity (e.g. 1200 mg/ℓ). This situation is mainly reliant on the significant size of direct costs. This is also reflected in the small DCMs for mining, ranging between 0.97 and 1.28. These low DCMs suggest that the mining sector has limited local backward inter-industrial linkages.

The pricing model results for the mining sector are indicated in Table 7.5.5:

Table 7.5.5: Monetary changes in prices indices: Mining

	CPI		PPI	
TDS	**PERCENTAGE**	**R million**	**PERCENTAGE**	**R million**
600 mg/ℓ	0.000002	R0.007	0.00016	R1.64
1200 mg/ℓ	0.00005	R0.145	0.0034	R34.599

The CPI changes for the mining sector are the smallest and second smallest for PPI at low salinity levels whereas mining is ranked the third smallest at high salinity levels for PPI.

Based on the total industry DCM calculated with the augmented IO model, the direct costs of R0.844m at 600 mg/ℓ could increase to R2.532m. At a salinity level of 1200 mg/ℓ these costs will increase significantly from R17.8m to R53.5 million.

Thus, although the mining costs only contribute a small proportion to the total economic effect, the costs are not insignificant, particularly at the higher salinities. It should be noted that in instances where mines currently operate at marginal profitability, dramatic increases in salinity could well result in mine closure. This would have a ripple effect on the other sectors within, and possibly beyond, the entire economic region.

7.5.4 Industry

When the Industry sectors consider the implications of increases in salinity, the cost effects vary, depending on whether the specific sector is Manufacturing 1 (with no water treatment) or Manufacturing 2 (where water treatment is required).

The Manufacturing 1 sector, which does not treat water for salinity, mainly incurs replacement costs. The direct costs amount to R86 000/a at 600 mg/ℓ and may increase to R198 000/a at 1200 mg/ℓ.The total costs can be calculated and are found to be R0.26 million/a at 600 mg/ℓ rising to R0.6 million/a at 1200 mg/ℓ. The Manufacturing 1 sector has a small influence in terms of salinity abatement on the total economy of the study area.

The treatment manufacturing sector, Manufacturing 2, incurs substantial costs due to the effects of salinity. The costs result mainly from the costs of replacement and maintenance, of which the latter is the largest.

The replacement costs in the treatment manufacturing sector, due to the effects of salinity, relate to household-type appliances such as kettles, urns and geysers, and also include costs of replacing production-related equipment, plant and piping.

Their maintenance costs are mainly incurred in the treatment of the water or in treating the secondary effects of salinity. The main components of the maintenance costs include purchase of chemicals for chemical treatment, cleaning and servicing equipment and labour employed, as well as fines paid due to effluent not meeting discharge standards.

The combined replacement and maintenance costs for the treatment manufacturing sector amount to R1.35 million/a at 600 mg/ℓ and will increase to R3.28 million/a at 1200 mg/ℓ. The total costs calculated are: R4.05 million/a at 600 mg/ℓ and R9.83 million/a at 1200 mg/ℓ.

The multiplier analysis conducted indicates that the manufacturing sectors will have the smallest relative salinity costs per additional unit of final demand. The DCMs range from 2,64 to 3,66 which is the highest, suggesting that the indirect and induced effects are considerably more significant than the direct costs. These findings are in line with *a priori* expectations that the linkages of the manufacturing sector with other sectors will lead to high indirect and induced effects.

The pricing model results for the manufacturing sector are indicated in Table 7.5.6:

Table 7.5.6: Changes in price indices: Manufacturing sector

	CPI		PPI	
TDS	PERCENTAGE	R million	PERCENTAGE	R million
Manufacturing 1:				
600 mg/ℓ	0.00005	0.151	0.00005	0.537
1200 mg/ℓ	0.000118	0.348	0.000122	1.241
Manufacturing 2:				
600 mg/ℓ	0.00261	7.702	0.00264	26.811
1200 mg/ℓ	0.00634	18.691	0.00641	65.060

Manufacturing 2 (treatment) will effect the largest changes in CPI and PPI of the economic sectors, which is a result of the strong inter-industrial linkages with the rest of the economy.

Given the total industry DCM of the augmented IO model, the direct costs of salinity at a 600 mg/ℓ TDS will increase when indirect and induced costs are considered as indicated in Table 7.5.7:

Table 7.5.7: Cost of salinity in manufacturing sector

SECTOR	DIRECT EFFECTS	TOTAL EFFECTS
Manufacturing 1: (no treat)	R0.086m	R0.258m
Manufacturing 2 :(treat)	R1.35m	R4.053m

Although behaviour is not easily quantified in these industries, probabilities of certain behavioural responses can be predicted when water quality deteriorates below acceptable levels and management action is required. However, the management responses are mainly production options, determined by technology and cost efficiency.

7.5.5 Services

Within the business and services sector, the costs of salinity arise mainly from replacement and maintenance costs. The replacement costs are incurred when replacing durable and capital goods such as kettles, urns, geysers and piping. The maintenance costs refer to the cleaning and maintenance of pumps, filters and equipment.

The total direct costs, arising from increased salinity, amount to R1.2 million at 600 mg/ℓ and will increase to R2.7 million/a, at 1200 mg/ℓ. Based on the DCM the total costs attributable to salinity will rise from R3.63 million/a at 600 mg/ℓ to R8.09 million/a at 1200 mg/ℓ.

With the multiplier analysis the salinity costs of the services sector are ranked relatively high, especially at lower levels of salinity. The DCMs based on the Multiplier analysis, range from 1,31 to 1,41, indicating that fewer linkages exist than for the manufacturing sector.

The pricing model results are indicated in Table 7.5.8:

Table 7.5.8: Changes in price indices: Services Sector

	CPI		PPI	
TDS	PERCENTAGE	R million	PERCENTAGE	R million
600 mg/ℓ	0.00154	4.541	0.00151	15.291
1200 mg/ℓ	0.00343	10.112	0.00335	34.053

Given the total industry DCM of the augmented IO model, the direct costs of salinity of R1,21m at 600 mg/ℓ TDS will increase with indirect and induced effects to R3,633m.

Although behaviour is not easily quantified in this sector, probabilities of certain behavioural responses can be predicted when water quality deteriorates below acceptable levels and management action is required. However, the management responses are based mainly on production options, determined by technology and cost efficiency.

7.5.6 Feeder systems

Based on the processes used to purify the water, no incremental costs are expected to be experienced in the Feeder Systems sector, should TDS levels increase from its current levels to 1200 mg/ℓ. Since no data was contributed to the model from this sector, no multipliers had been calculated.

7.6. SUMMARY

The discussion of the results indicated that direct effects of salinity increases represent significant cost increases but are overshadowed by the indirect and induced cost effects throughout the economy. The value of utilising an integrated model is therefore extremely significant in identifying secondary effects on the economy which would not be observed in considering direct cost effects only.

SECTION 8: CONCLUSIONS

Based on the output from the model established for the Middle Vaal River region, the economic costs attributable to changing salinity, have been determined.

There exists an effective limit to the cost of salinisation. This is determined by the cost of desalinating the bulk water supply which would represent the most costly option of water treatment. Care must be taken not to allow the costs of salinisation to reach high levels. The viability of deslination may be increased if selective desalination is applied to the consumer sectors with the highest relative cost, although other options must be explored first.

This is obviously a simplistic first-line approach, but it highlights the need for consideration of bulk or partial treatment of the water supply in the Middle Vaal River area as the *status quo* is already 500 mg/ℓ. Behavioural response is particularly important as the quality of the water in the area is already perceived to be problematic.

The results of the study identified the total economic effects of increased salinity levels for the Middle Vaal River area. Based on these findings and the knowledge gained with respect to behaviour, the following observations are made :

- The application of the generic model in the Middle Vaal River area was influenced by some limitations, mainly on account of the undiversified economic structure. Undiversified in this regard refers to the strong reliance of the economy on the mining and services sectors. Despite this, very significant information could be obtained on the relative importance of cost effects between the various sectors. To validate these, the model should be applied in a diversified economy such as that of the Gauteng area. More insight in relative costs could be obtained on, for instance, the manufacturing sector.
- It has been stated above that differential desalination may be considered. The reason for this is that the household sector has been found to bear relatively high costs in terms of combating salinity, followed by the industrial and services sectors. It may be of value to motivate differential desalination of waters on a purely developmental base, that is, to consider the social and socio-economic benefits which may accrue to households if the costs of salinity are decreased. This also implies that sectors which experience relatively low salinity costs may have to continue bearing these.
- It may be beneficial to water users if a salinity awareness campaign could be introduced. If end users were made aware of the cost effects, they may choose to behave differently and therefore take informed decisions in lessening the costs of salinity.
- A specialised data base has been established. As part of an awareness campaign, users can contribute towards the refinement and extension of a more comprehensive data base which can be utilised when the model is applied elsewhere. Since the availability of the data determines to a large extent the robustness of the model, such a data base can contribute significantly to the ease of applying the model.

The interpretation of the findings of this study does not take into account alternative options with respect to water provision. This implies that the costs of salinity have not been related or compared to the situation of utilising transfer water and other allocation options.

SECTION 9 : FURTHER RESEARCH

The value of the study lies in the fact that a first approximation of the spin-off effects of salinity on the economy had been determined. Furthermore, an indication of the behavioural costs for specific sectors have been obtained. On account of the specific study area chosen and the difficulties encountered in applying an integrated economic cost model to specific circumstances, the following shortcomings may be addressed with further research:

- Application of the model in a relatively diversified economy such as that of Gauteng. In doing this, a more disaggregated model can be executed. Cost effects for more subsectors may then be identified, such as for the leather industry. Based on expectations the total costs of salinity may be higher.

- In applying the model to a chosen study area more significant costs may be identified if the study population is made aware of the problem in advance. The benefits arising from this approach, namely more accurate cost estimates and possibly more correct reporting of behaviour, could outweigh potentially over-reporting due to increased awareness of the problem.

REFERENCES

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Heynike, J.J.C, July 1987: Economic effects of the increasing mineral content in the Vaal River water on the community of the Pretoria-Witwatersrand-Vereeniging-Sasolburg and the Klerksdorp and OFS Goldfields complexes. W.R.C.

ANNEXURE A

Table 6.2.1: Summary of sectors used for the salinity tables

Industry	Term	Description	Sector
Households	Dishwashing	Scourers, cleaners, chemical descalers, Handy Andy, dishwashing liquid	Trade, Manufacturing 1 & Manufacturing 2
Households	Laundry & textiles	Detergents, bleach, fabric softner, omo, laundry bar soap	Trade, Manufacturing 1 & Manufacturing 2
Households	Personal care	Shampoo, bathfoam, vaseline, body soap, body creams, hair conditioner	Trade, Manufacturing 1 & Manufacturing 2
Households	Durable goods	Kettles, steam irons, water filters	Trade, Manufacturing 1 & Manufacturing 2
Households	Capital goods	Geysers, taps & tap washers, repairs to pools & pool filters	Trade, Manufacturing 1 & Manufacturing 2
Households	Vehicle maintenance	Vehicle repairs resulting from battery failure and calcification of radiators	Services
Agriculture	Artificial drainage	Cost p.a. for construction of artificial drainage	Construction
Agriculture	Electricity	Use of electricity for irrigation	Electricity
Agriculture	Finance	Interest on production loan	Finance
Agriculture	Electrical motor & pump	Repairs and maintenance	Services
Mining	Water	Incremental cost of water supply	Water
Mining	Chemicals	Incremental cost of chemical treatment	Manufacturing 1 & Manufacturing 2
Business & services	Kettles, urns, geysers	Replacement	Trade, Manufacturing 1 & Manufacturing 2
Business & services	Pipes	Replacement of piping for internal reticulation and piping in equipment and machinery	Services
Business & services	Pumps	Maintenance	Services
Business & services	Filters	Maintenance	Services
Business & services	Equipment	Equipment maintenance i.e. where equipment must be treated and cleaned by treatment and servicing companies	Services
Business & services	Water	Additional water usage due to salinity	Water
Manufacturing 1	Kettles, urns, geysers	Replacement	Trade
Manufacturing 1	Water	Additional water usage due to salinity	Water
Manufacturing 2	Kettles, urns, geysers	Replacement	Trade, Manufacturing 1 & Manufacturing 2
Manufacturing 2	Pipes	Replacement of piping of internal reticulation and piping in equipment and machinery	Manufacturing 1
Manufacturing 2	Equipment	Replacement of equipment and machinery which become inoperable	Manufacturing 1
Manufacturing 2	Chemicals	The use of chemicals to treat water to obtain appropriate levels of TDS	Trade, Manufacturing 1 & Manufacturing 2
Manufacturing 2	Piping	Maintenance of piping for due to clogging and scaling	Manufacturing 1
Manufacturing 2	Equipment	Equipment maintenance i.e. where equipment must be treated and cleaned by treatment and servicing companies	Services
Manufacturing 2	Labour	Labour used in treatment of water such as cleaning equipment	Households
Manufacturing 2	Fines	Fines for not treating effluent adequately to meet discharge standards	Government
Manufacturing 2	Water	Additional water usage due to salinity	Water

Table 6.2.2: Households sector data (1995 values in rand per annum)

Households

Estimated mark-up for dishwashing, laundry & textiles, and personal care:	25%
Estimated mark-up for durable and capital goods:	50%

Summary of Average Household Costs (per month per Household):

@ TDS = 500 mg/ℓ	**Suburban**	**Township**	**Informal**
Dishwashing	3.03	5.05	8.68
Laundry & textiles	4.57	16.08	1.99
Personal Care	10.46	12.17	2.37
Subtotal 1 (Trade & manufacturing costs per month per household)	**18.06**	**33.30**	**13.04**
Durable goods	1.99	0.86	0.00
Capital goods	18.03	0.00	0.00
Subtotal 2 (Trade & manufacturing costs per month per household)	**20.02**	**0.86**	**0.00**
Vehicle maintenance (Service costs per month per household)	**11.30**	**2.23**	**1.04**
Total Costs per month per household	**49.38**	**36.39**	**14.08**
No of Households	59,270	63,952	30,070
Total 1 Trade & manufacturing costs p.a. @ 500 mg/ℓ	**12,844,944**	**25,555,219**	**4,705,354**
Total 2 Trade & manufacturing costs p.a. @ 500 mg/ℓ	**14,239,025**	**659,985**	**0**
Total Trade & manufacturing costs p.a. @ 200 mg/ℓ	**0**	**0**	**0**
Total Service costs p.a. @ 500 mg/ℓ	**8,037,012**	**1,711,356**	**375,274**
Total Service costs p.a. @ 200 mg/ℓ	**0**	**0**	**0**

TDS	200 mg/ℓ	400 mg/ℓ	500 mg/ℓ	600 mg/ℓ	800 mg/ℓ	1 000 mg/ℓ	1 200 mg/ℓ
Trade (Suburban)	(7,315,340)	(2,438,447)	0	2,438,447	7,315,340	12,192,234	17,069,128
Trade (Township)	(5,331,039)	(1,777,013)	0	1,777,013	5,331,039	8,885,065	12,439,090
Trade (Informal)	(941,071)	(313,690)	0	313,690	941,071	1,568,451	2,195,832
Manufacture 1 (Suburban)	(15,814,943)	(5,271,648)	0	5,271,648	15,814,943	26,358,238	36,901,534
Manufacture 1 (Township)	(16,707,332)	(5,569,111)	0	5,569,111	16,707,332	27,845,553	38,983,775
Manufacture1 (Informal)	(3,011,426)	(1,003,809)	0	1,003,809	3,011,426	5,019,044	7,026,661
Manufacture 2 (Suburban)	(3,953,736)	(1,317,912)	0	1,317,912	3,953,736	6,589,560	9,225,383
Manufacture 2 (Township)	(4,176,833)	(1,392,278)	0	1,392,278	4,176,833	6,961,388	9,745,944
Manufacture 2 (Informal)	(752,857)	(250,952)	0	250,952	752,857	1,254,761	1,756,665
Service (Suburban)	(8,037,012)	(2,679,004)	0	2,679,004	8,037,012	13,395,020	18,753,028
Service (Township)	(1,711,356)	(570,452)	0	570,452	1,711,356	2,852,259	3,993,163
Service (Informal)	(375,274)	(125,091)	0	125,091	375,274	625,456	875,638

Table 6.2.3: Agricultural sector data (1995 values in rand per annum)

Agriculture

Land surveyed:		
Area of land	1,510.50	Hectares
Area irrigated	425.00	Hectares
%	0.28	
Total land:		
Area of land	6,259.00	Hectares
Area irrigated	1,761.06	Hectares

Land under different Crops		
Crop	%	Hectares
Lucerne	14%	247
Wheat	27%	475
Maize	36%	634
Potatoes	2%	35
Groundnuts	1%	18
Dry Beans	0%	0
Pastures	12%	211
Other (veg.)	7%	123

Artificial drainage (Once of cost):		
Area of land	352	Hectare
Cost per hectare	8,500	Rand
Total cost	2,933,795	Rand
Cost per year (at 15.25% interest over 25 years)	**407,878**	**Rand**

(1) Bestcase Scenario (Maintain Yield)

Incremental Total Costs:

TDS	200 mg/ℓ	400 mg/ℓ	600 mg/ℓ	800 mg/ℓ	1 000 mg/ℓ	1 200 mg/ℓ
Artificial drainage:						
Construction	0	0	407,878	407,878	407,878	407,878
Lucerne:			**9,786**	**9,786**	**19,572**	**29,358**
Electricity	0	0	8,823	8,823	17,646	26,470
Services	0	0	106	106	211	317
Finance	0	0	857	857	1,714	2,571
Total	0	0	9,786	9,786	19,572	29,358
Wheat	0	0	0	0	0	0
Maize:			21,524	21,524	43,048	64,571
Electricity	0	0	18,067	18,067	36,133	54,200
Services	0	0	1,036	1,036	2,072	3,107
Finance	0	0	2,421	2,421	4,843	7,264
Total	0	0	21,524	21,524	43,048	64,571
Pastures	0	0	0	0	0	0
Cabbage:			0	0	1,231	1,231
Electricity	0	0	0	0	1,216	1,216
Services	0	0	0	0	15	15
Finance	0	0	0	0	0	0
Total	0	0	0	0	1,231	1,231

TOTALS:

TDS	200 mg/ℓ	400 mg/ℓ	500 mg/ℓ	600 mg/ℓ	800 mg/ℓ	1 000 mg/ℓ	1 200 mg/ℓ
Construction	0	0	0	407,878	407,878	407,878	407,878
Electricity	0	0	0	26,890	26,890	54,996	81,885
Services	0	0	0	1,142	1,142	2,298	3,439
Finance	0	0	0	3,278	3,278	6,557	9,835

(2) Worstcase Scenario (Accept Yield Reduction)

Loss of Income (@ LF = 0.05):

TDS	200 mg/ℓ	400 mg/ℓ	500 mg/ℓ	600 mg/ℓ	800 mg/ℓ	1 000 mg/ℓ	1 200 mg/ℓ
Lucerne	0	0	0	15,286	118,343	221,400	324,210
Wheat	0	0	0	0	0	0	0
Maize	0	0	0	60,228	236,475	412,087	588,334
Pasture	0	0	0	0	0	0	0
Cabbage	0	0	0	0	0	47,070	112,919
Total	0	0	0	75,514	354,818	681,194	1,025,463

Table 6.2.4: Mining sector data (1995 values in rand per annum)

TOTAL FOR GOLD MINING INDUSTRY IN MIDDLE VAAL AREA
(Including Boiler Water Costs)

TDS	200 mg/	400 mg/ℓ	500 mg/	600 mg/	800 mg/	1 000 mg/	1 200 mg/
Labour cost per annum	2,933,700	2,933,700	2,933,700	2,933,700	2,933,700	2,933,700	2,933,700
Incremental Cost of Water Supply	(5,749,731)	(1,546,924)	0	461,457	3,046,846	6,548,252	11,711,715
Incremental Cost of Chemicals	(1,559,146)	(665,288)	0	383,015	1,816,209	3,622,457	6,103,899

TDS	200 mg/	400 mg/ℓ	500 mg/	600 mg/	800 mg/	1 000 mg/	1 200 mg/
Labour	0	0	0	0	0	0	0
Water	(5,749,731)	(1,546,924)	0	461,457	3,046,846	6,586,252	11,711,715
Manufacture 1	(1,247,317)	(532,230)	0	306,412	1,452,967	2,897,966	4,883,119
Manufacture 2	(311,829)	(133,058)	0	76,603	363,242	724,491	1,220,780

Table 6.2.5: Services and manufacturing sector data (1995 values in rand per annum)

Estimated mark-up for kettles, urns & geysers: 50%

Business and Services

TDS	200 mg/ℓ	500 mg/ℓ	1 200 mg/ℓ
Total Trade & Manufacturing Costs	0	421,729	623,972
Total Service Costs	0	430,679	613,349
Total (Diff.) Water Costs	(991,009)	0	2,312,355

TDS	200 mg/ℓ	400 mg/ℓ	500 mg/ℓ	600 mg/ℓ	800 mg/ℓ	1 000 mg/ℓ	1 200 mg/ℓ
Trade	(140,576)	(46,859)	0	9,631	28,892	48,153	67,414
Manufacture 1	(224,922)	(74,974)	0	15,409	46,227	77,045	107,863
Manufacture 2	(56,231)	(18,744)	0	3,852	11,557	19,261	26,966
Service	(430,679)	(143,560)	0	26,096	78,287	130,479	182,670
Water	(991,009)	770,785	0	1,156,178	1,541,570	1,926,963	2,312,355

Manufacturing 1 (No Water Treatment Sector):

TDS	200 mg/ℓ	500 mg/ℓ	1 200 mg/ℓ
Total Trade & Manufacturing Costs	0	76,646	113,816
Total (Diff.) Water Costs	(68,762)	0	160,446

TDS	200 mg/ℓ	400 mg/ℓ	500 mg/ℓ	600 mg/ℓ	800 mg/ℓ	1 000 mg/ℓ	1 200 mg/ℓ
Trade	(25,549)	(8,516)	0	1,770	5,310	8,850	12,390
Manufacture 1	(40,878)	(13,626)	0	2,832	8,496	14,160	19,824
Manufacture 2	(10,219)	(3,406)	0	708	2,124	3,540	4,956
Water	(68,762)	53,482	0	80,223	106,964	133,705	160,446

Manufacturing 2 (Water Treatment Sector):

TDS	200 mg/ℓ	500 mg/ℓ	1 200 mg/ℓ
Trade & Manufacturing Costs	0	1,061,865	1,447,355
Total Manufacturing 1 Costs	0	300,060	408,457
Total Services Costs	0	25,867	35,211
Total Households Costs	0	202,091	275,100
Total (Diff.) Water Costs	(1,235,383)	0	2,058,972

TDS	200 mg/ℓ	400 mg/ℓ	500 mg/ℓ	600 mg/ℓ	800 mg/ℓ	1 000 mg/ℓ	1 200 mg/ℓ
Trade	(353,955)	(117,985)	0	25,699	77,098	128,497	179,895
Manufacture 1	(866,388)	(288,796)	0	62,798	188,395	313,992	439,588
Manufacture 2	(141,582)	(47,194)	0	10,280	30,839	51,399	715,958
Services	(25,867)	(8,622)	0	1,869	5,606	9,344	13,082
Household	(202,091)	(67,364)	0	14,602	43,805	73,009	102,213
Water	(1,235,383)	823,589	0	1,235,383	1,647,178	2,058,972	2,470,766

ANNEXURE B

Table 6.3.2: Table of cost data at 200 mg/ℓ salinity (1995 Values of SA Rand)

Scenario 1 – Base Model	Mining	Business & Services	Manufacture 1	Manufacture 2	Agriculture	Household (Suburban)	Household (Township)	Household (Informal)	Total
Water	-5 749 731	-991 009	-68 762	-1 235 383					-8 044 885
Electricity					0				0
Trade		-140 576	-25 549	-353 955		-7 315 340	-5 331 039	-941 071	-14 107 530
Manufacturing 1	-1 247 317	-224 922	-40 878	-866 388	0	-15 814 943	-16 707 332	-3 011 426	-37 913 206
Manufacturing 2	-311 829	-56 231	-10 219	-141 582		-3 953 736	-4 176 833	-752 857	-9 403 287
Services		-430 679		-25 867		-8 037 012	-1 711 356	-375 274	-10 580 187
Household				-202 091					-202 091
Finance					0				0
Construction					0				0
Total	**-7 308 877**	**-1 843 417**	**-145 408**	**-2 825 266**	**0**	**-35 121 031**	**-27 926 559**	**-5 080 627**	**-80 251 186**

Scenario 2 – Reduced Crop Yield	Mining	Business & Services	Manufacture 1	Manufacture 2	Agriculture	Household (Suburban)	Household (Township)	Household (Informal)	Total
Water	-5 749 731	-991 009	-68 762	-1 235 383					-8 044 885
Electricity					0				
Trade		-140 576	-25 549	-353 955		-7 315 340	-5 331 039	-941 071	-14 107 530
Manufacturing 1	-1 247 317	-224 922	-40 878	-866 388	0	-15 814 943	-16 707 332	-3 011 426	-37 913 206
Manufacturing 2	-311 829	-56 231	-10 219	-141 582		-3 953 736	-4 176 833	-752 857	-9 403 287
Services		-430 679		-25 867		-8 037 012	-1 711 356	-375 274	-10 580 187
Household				-202 091					-202 091
Finance									
Construction									
Agriculture									
Total	**-7 308 877**	**-1 843 417**	**-145 408**	**-2 825 266**	**0**	**-35 121 031**	**-27 926 559**	**-5 080 627**	**-80 251 186**

Table 6.3.3: Table of cost data at 400 mg/ℓ salinity (1995 Values of SA Rand)

Scenario 1 – Base Model	Mining	Business & Services	Manufacture 1	Manufacture 2	Agriculture	Household (Suburban)	Household (Township)	Household (Informal)	Total
Water	-1 546 924	770 785	53 482	823 589					100 932
Electricity					0				0
Trade		-46 859	-8 516	-117 985		-2 438 447	-1 777 013	-313 690	-4 702 510
Manufacturing 1	-532 230	-74 974	-13 626	-288 796	0	-5 271 648	-5 569 111	-1 003 809	-12 754 194
Manufacturing 2	-133 058	-18 744	-3 406	-47 194		-1 317 912	-1 392 278	-250 952	-3 163 543
Services		-143 560		-8 622		-2 679 004	-570 452	-125 091	-3 526 729
Household				-67 364					-67 364
Finance					0				0
Construction					0				0
Total	**-2 212 212**	**486 649**	**27 933**	**293 628**	**0**	**-11 707 010**	**-9 308 853**	**-1 693 542**	**-24 113 408**

Scenario 2 – Reduced Crop Yield	Mining	Business & Services	Manufacture 1	Manufacture 2	Agriculture	Household (Suburban)	Household (Township)	Household (Informal)	Total
Water	-1 546 924	770 785	53 482	823 589					100 932
Electricity									0
Trade		-46 859	-8 516	-117 985		-2 438 447	-1 777 013	-313 690	-4 702 510
Manufacturing 1	-532 230	-74 974	-13 626	-288 796		-5 271 648	-5 569 111	-1 003 809	-12 754 194
Manufacturing 2	-133 058	-18 744	-3 406	-47 194		-1 317 912	-1 392 278	-250 952	-3 163 543
Services		-143 560	0	-8 622		-2 679 004	-570 452	-125 091	-3 526 729
Household				-67 364					-67 364
Finance									0
Construction									0
Agriculture					0				
Total	**-2 212 212**	**486 649**	**27 933**	**293 628**	**0**	**-11 707 010**	**-9 308 853**	**-1 693 542**	**-24 113 408**

Table 6.3.4: Table of cost data at 600 mg/ℓ salinity (1995 Values of SA Rand)

Scenario 1 – Base Model	Mining	Business & Services	Manufacture 1	Manufacture 2	Agriculture	Household (Suburban)	Household (Township)	Household (Informal)	Total
Water	461,457	1,156,178	80,223	1,235,383					2,933,241
Electricity					26,890				26,890
Trade		9,631	1,770	25,699		2,438,447	1,777,013	313,690	4566,250
Manufacturing 1	306,412	15,409	2,832	62,798	1,142	5,271,648	5,569,111	1,003,809	12,233,160
Manufacturing 2	76,603	3,852	708	10,280		1,317,912	1,392,278	250,952	3,052,585
Services		26,096		1,869		2,679,004	570,452	125,091	3,402,512
Household				14,602					14,602
Finance					3,278				3,278
Construction					407,878				407,878
Total	**844,472**	**1,211,165**	**85,533**	**1,350,631**	**439,188**	**11,707,010**	**9,308,853**	**1,693,542**	**26,640,395**

Scenario 2 – Reduced Crop Yield	Mining	Business & Services	Manufacture 1	Manufacture 2	Agriculture	Household (Suburban)	Household (Township)	Household (Informal)	Total
Water	461,457	1,156,178	80,223	1,235,383					2,933,241
Electricity									0
Trade		9,631	1,770	25,699		2,438,447	1,777,013	313,690	4,566,250
Manufacturing 1	306,412	15,409	2,832	62,798		5,271,648	5,569,111	1,003,809	12,232,018
Manufacturing 2	76,603	3,852	708	10,280		1,317,912	1,392,278	250,952	3,052,585
Services		26,096	0	1,869		2,679,004	570,452	125,091	3,402,512
Household				14,602					14,602
Finance									0
Construction									0
Agriculture					354,818				354,818
Total	**844,472**	**1,211,165**	**85,533**	**1,350,631**	**354,818**	**11,707,010**	**9,308,853**	**1,693,542**	**26,556,025**

Table 6.3.5: Table of cost data at 800 mg/ℓ salinity (1995 Values of SA Rand)

Scenario 1 – Base Model	Mining	Business & Services	Manufacture 1	Manufacture 2	Agriculture	Household (Suburban)	Household (Township)	Household (Informal)	Total
Water	3,046,846	1,541,570	106,964	1,647,178					6,342,558
Electricity					26,890				26,890
Trade		28,892	5,310	77,098		7,315,340	5,331,039	941,071	13,698,750
Manufacturing 1	1,452,967	46,227	8,496	188,395	1,142	15,814,943	16,707,332	3,011,426	37,230,928
Manufacturing 2	363,242	11,557	2,124	30,839		3,953,736	4,176,833	752,857	9,291,187
Services		78,287		5,606		8,037,012	1,711,356	375,274	10,207,535
Household				43,805					43,805
Finance					3,278				3,278
Construction					407,878				407,878
Total	**4,863,055**	**1,706,533**	**122,894**	**1,992,922**	**439,188**	**35,121,031**	**27,926,559**	**5,080,627**	**77,252,809**

Scenario 2 – Reduced Crop Yield	Mining	Business & Services	Manufacture 1	Manufacture 2	Agriculture	Household (Suburban)	Household (Township)	Household (Informal)	Total
Water	3,046,846	1,541,570	106,964	1,647,178					6,342,558
Electricity									0
Trade		28,892	5,310	77,098		7,315,340	5,331,039	941,071	13,698,750
Manufacturing 1	1,452,967	46,227	8,496	188,395		15,814,943	16,707,332	3,011,426	37,229,787
Manufacturing 2	363,242	11,557	2,124	30,839		3,953,736	4,176,833	752,857	9,291,187
Services		78,287	0	5,606		8,037,012	1,711,356	375,274	10,207,535
Household				43,805					43,805
Finance									0
Construction									0
Agriculture					354,818				354,818
Total	**4,863,055**	**1,706,533**	**122,894**	**1,992,922**	**354,818**	**35,121,031**	**27,926,559**	**5,080,627**	**77,168,439**

Table 6.3.6: Table of cost data at 1 00 mg/ℓ salinity (1995 Values of SA Rand)

Scenario 1 – Base Model	Mining	Business & Services	Manufacture 1	Manufacture 2	Agriculture	Household (Suburban)	Household (Township)	Household (Informal)	Total
Water	6,586,252	1,926,963	133,705	2,058,972					10,705,892
Electricity			8,850		54,996				54,996
Trade		48,153	14,160	128,497		12,192,234	8,885,065	1,568,451	22,831,250
Manufacturing 1	2,897,966	77,045	3,540	313,992	2,298	26,358,238	27,845,553	5,019,044	62,528,295
Manufacturing 2	724,491	19,261		51,399		6,589,560	6,691,388	1,254,761	15,604,400
Services		130,479		9,344		13,395,020	2,852,259	625,456	17,012,558
Household				73,009					73,009
Finance					6,557				6,557
Construction					407,878				407,878
Total	**10,208,709**	**2,201,900**	**160,255**	**2,635,212**	**471,728**	**58,535,052**	**46,544,266**	**8,467,712**	**129,224,834**

Scenario 2 – Reduced Crop Yield	Mining	Business & Services	Manufacture 1	Manufacture 2	Agriculture	Household (Suburban)	Household (Township)	Household (Informal)	Total
Water	6,586,252	1,926,963	133,705	2,058,972					10,705,892
Electricity									0
Trade		48,153	8,850	128,497		12,192,234	8,885,065	1,568,451	22,831,250
Manufacturing 1	2,897,966	77,045	14,160	313,992		26,358,238	27,845,553	5,019,044	62,525,993
Manufacturing 2	724,491	19,261	3,540	51,399		6,589,560	6,961,388	1,254,761	15,604,400
Services		130,479		9,344		13,395,020	2,852,259	625,456	17,012,558
Household				73,009					73,009
Finance									0
Construction									0
Agriculture					681,194				681,194
Total	**10,208,709**	**2,201,900**	**160,255**	**2,635,212**	**681,194**	**58,535,052**	**46,544,266**	**8,467,712**	**129,434,300**

Table 6.3.7: Table of cost data at 1 200 mg/ℓ salinity (1995 Values of SA Rand)

Scenario 1 – Base Model	Mining	Business & Services	Manufacture 1	Manufacture 2	Agriculture	Household (Suburban)	Household (Township)	Household (Informal)	Total
Water	11,711,715	2,312,355	160,446	2,470,766					16,655,282
Electricity					81,885				81,885
Trade		67,414	12,390	179,895		17,069,128	12,439,090	2,195,832	31,963,749
Manufacturing 1	4,883,119	107,863	19,824	439,588	3,439	36,901,534	38,983,775	7,026,661	88,365,803
Manufacturing 2	1,220,780	26,966	4,956	71,958		9,225,383	9,745,944	1,756,665	22,052,652
Services		182,670		13,082		18,753,028	3,993,163	875,638	23,817,581
Household				102,213					102,213
Finance					9,835				9,835
Construction					407,878				407,878
Total	**17,815,614**	**2,697,268**	**197,616**	**3,277,502**	**503,038**	**81,949,073**	**65,161,972**	**11,854,797**	**183,456,880**

Scenario 2 – Reduced Crop Yield	Mining	Business & Services	Manufacture 1	Manufacture 2	Agriculture	Household (Suburban)	Household (Township)	Household (Informal)	Total
Water	11,711,715	2,312,355	160,446	2,470,766					16,655,282
Electricity	0								0
Trade		67,414	12,390	179,895		17,069,128	12,439,090	2,195,832	31,963,749
Manufacturing 1	4,883,119	107,863	19,824	439,588		36,901,534	38,983,775	7,026,661	88,362,364
Manufacturing 2	1,220,780	26,966	4,956	71,958		9,225,383	9,745,944	1,756,665	22,052,652
Services		182,670		13,082		18,753,028	3,993,163	875,638	23,817,581
Household				102,213					102,213
Finance									0
Construction									0
Agriculture					1,025,463				1,025,463
Total	**17,815,614**	**2,697,268**	**197,616**	**3,277,502**	**1,025,463**	**81,949,073**	**65,161,972**	**11,854,797**	**183,979,305**