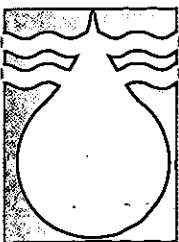


**The Economic Cost Effects of Salinity
INDUSTRIAL SECTOR**

VOLUME V

Urban - Econ

WRC Report No 634/4/00



Water Research Commission 

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VOLUME V
The Economic Cost Effects of Salinity
INDUSTRIAL SECTOR

by

Urban-Econ

Report to the Water Research Commission and
the Department of Water Affairs and Forestry
on the project
*Determining the impact of the salinisation of
South Africa's water resources
with respect to economic effects*

Project Leader: Urban-Econ

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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)

SECTOR \ SALINITY	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 <i>mg/l</i>	R101.5m	R402.6m
1200 <i>mg/l</i>	R647.5m	R2623.4m
Regional increase		
600 <i>mg/l</i>	R7.4m	R18.0m
1200 <i>mg/l</i>	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.

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

Dr D van Driel	Department of Water Affairs & Forestry
Dr G C Green	Water Research Commission
Mr C Swiegers	Department of Water Affairs & Forestry
Mr F C van Zyl	Department of Water Affairs & Forestry
Mr F X Jurgens	Development Bank of South Africa
Mr H M du Plessis	Water Research Commission
Mr J A van Rooyen	Department of Water Affairs & Forestry
Mr P H van Niekerk	Department of Water Affairs & Forestry
Ms A Belcher	Department of Water Affairs & Forestry

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Annexure A

1. INTRODUCTION

1.1. PURPOSE

The purpose of this report is to develop a generalised methodology for the determination of the generic cost impact of salinity and applying this in a case study in the Middle Vaal River Area for the industrial sector. This report (Volume V) and analysis form part of a larger study to determine the total cost impact of salinity of the Middle Vaal River Area. The main findings of the study are presented in an integrated report (Volume V).

This report contains all the detail information related to the integrated model and study approach for the industrial sector in developing conceptual formulae to determine the economic costs of salinity.

The study consists of two distinct phases, although the results have been integrated into a single report. The first component refers to the conceptualisation of the costs and behaviour with respect to salinity, whereas the second component tests the formulae in the Middle Vaal River Area.

1.2. IDENTIFICATION OF SECTORS

The industrial sector is a major water using sector, and for purposes of this study includes manufacturing, power generation and construction. Extensive research has been carried out in the past on industrial effluent and the treatment thereof. This situation is, however, totally the reverse with respect to the water quality requirements for water intake. As a result relatively little information can be obtained from literature on the water quality requirements of the industrial sector. This information can, however, be obtained by means of industrial surveys.

A survey undertaken in the Middle Vaal and the Vaal Barrage catchment areas on effluent discharges, determined the volume of water intake for a total of 248 industries (refer to Table 1.1). This information is provided for orientation purposes only, thereby serving as an example. Although the information in Table 1.1 gives an indication of significant water users, no data was obtained on water quality requirements. Based on the specific processes of industrial subsectors, many industries follow a policy of in-house pollution management. The element of relevance to this study, is that industries treat their intake water to reach a level of quality suitable for each process. In many cases water is recycled in the production process for which in-house treatment facilities are required. Information on production processes of industries and water intake has been obtained from two main sources namely the Natsurv studies (1987, 1988, 1989, 1990, 1991) and the South African Water Quality Guidelines (1993).

On account of the diversity of the industrial sector, the variations in water using processes and process-specific water quality requirements, the reference framework and model are based on general assumptions for the industrial subsectors.

1.3. CONTENTS OF THE REPORT

Apart from this introductory section, the rest of the report consists of the following sections :

2	:	Conceptual Framework
3	:	Case Study
4	:	Data Analysis
5	:	Input Data for Modelling
6	:	Conclusion

TABLE 1.1 : INDUSTRIAL WATER INTAKE (JAN 1990 - DEC 1991)

No. of Industries	Industry	Water Intake (m ³ /d)	Water Intake (million m ³ /a)
33	Chemicals	38 862	14.18
51	Plating	7 260	2.65
5	Printing and publishing	191	0.07
7	Baking	511	0.19
1	Photographic	150	0.05
9	Soft drinks	4 494	1.64
10	Sorghum brewing	2 606	0.95
18	Motor trade	1 037	0.38
3	Malt brewing	12 265	4.48
5	Tanning and leather	1 000	0.37
11	Food miscellaneous	4 121	1.50
6	Rubber and plastic	1 027	0.37
7	Dairy	930	0.34
9	Laundries	2 675	0.98
4	Vegetable oils	4 180	1.53
7	Paper products	5 510	2.01
4	Glass and glass products	1 027	0.37
4	Fruit and vegetable	3 595	1.31
1	Synthetic diamonds	148	0.05
2	Pulp and paper	678	0.25
7	Concrete	403	0.15
9	Iron and steel	3 687	1.35
1	Motor vehicles	138	0.05
3	Grain	760	0.28
3	Pottery	318	0.12
1	Non-ferrous metals	118	0.04
1	Gas	229	0.08
2	Vehicle depots	181	0.07
12	Meat	6 786	2.48
2	Tobacco products	717	0.26
4	Bricks, tiles, clay pipes	743	0.27
2	Textiles	545	0.20
2	Wood and cork products	392	0.14
245	Subtotal	107 427	39.21
3	Superfactory 1	32 000	11.68
	Superfactory 2	68 000	24.82
	Superfactory 3	95 000	3.47
248	Total	302 472	110.39

Source : Natsurv, 1991

Note: The figures are average values based on records of measurements, verified wherever possible by actual flow measurement.

2. CONCEPTUAL FRAMEWORK

2.1. ORIENTATION

The purpose of this section is to formulate a conceptual framework which can be used to model the cost implications of increased levels of salinity in water. In doing so, it is necessary to review existing literature as well as to apply and utilise specialised expertise in conceptualising the industrial sector's behaviour due to increased salinity.

This approach suggests that cost formulae are constructed which take cognisance of all quantifiable items as well as behavioural aspects related to salinity. As with any other modelling process, assumptions have to be made and conditions be specified.

2.2. IMPACT OF WATER QUALITY CONSTITUENTS

This section aims at summarising the potential role of salinity and specific water constituents related to salinity.

A wide variety of industries use water in many different processes for various purposes. There is an extensive number of water quality constituents with potential to affect the functioning of these processes and thus cause problems. Only those water quality constituents were considered which are fundamental to the main water-related problems experienced in industry (South African Water Quality Guidelines, 1993). These are subsequently discussed.

2.2.1. Electrical Conductivity

The Total Dissolved Solids (TDS) concentration is a key water quality constituent for many industries. It gives an indication of the concentration levels of a number of important constituents and properties. These are intimately involved with water quality related problems such as scaling, corrosion and sedimentation. Since electrical conductivity is a measure of the concentration of the TDS of a water, it is a rapid and convenient method to monitor TDS levels in the water supply. Such monitoring allows industries to control their water conditioning processes in order to keep scale and corrosion problems to a minimum more efficiently. TDS is also a key factor in steam purity generated in high pressure boilers. Increasing TDS makes it more difficult to treat the water supply to meet the requirements for boiler-feed water.

As a general rule for most South African fresh waters, the approximate TDS can be calculated from electrical conductivity according to the following formula:

$$\text{TDS (mg/l)} = \text{electrical conductivity (mS/m)} \times 6.5$$

To remove excessive salt content, and thus reduce the electrical conductivity of a water source, several treatment options are available. These depend on what salts must be removed and the degree of purity required. Some of the more common methods of demineralising or desalinating water are distillation, ion exchange, electrodialysis and reverse osmosis.

2.2.2. pH

Although pH is one of the most frequently measured water quality properties, pH on its own is seldom a problem to most industries. However, pH is involved in nearly every phase of water supply and waste water treatment, and is often a vital factor in various industrial processes.

pH gives an indication of the acidic ($\text{pH} < 7$) or basic ($\text{pH} > 7$) nature of the water.

The pH of the incoming water is normally adjusted to the required pH by dosing the process water with acid or alkali, whichever is appropriate.

2.2.3. Suspended Solids

Suspended solids (or total suspended matter) are a measure of the organic and inorganic particulate matter in water. These may cause a number of problems in different industries. It contributes to the formation of sediment deposits commonly found in boilers, heat exchange systems, on cooling tower packing and in pipelines.

Removal of suspended solids from water is conventionally achieved through coagulation and flocculation with mixing, followed by sedimentation and filtration. Various designs of mixing basins, sedimentation tanks and filter beds are available to clarify the water supply.

2.2.4. Total Hardness

Wherever water is heated in industry, either for heating purposes, steam production or in the cooling process, scaling is one of the major problems. The main source of scaling in heat exchange equipment is hardness. Scaling is, however, not the only problem associated with hardness.

A certain degree of calcium hardness may inhibit corrosion by forming a thin protective layer on the metal surface and water with a hardness concentration greater than 50 mg/l prevents concrete dissolution.

Calcium and magnesium are regarded as the principal components of hardness. Other metals making a minor contribution to hardness include iron, strontium and manganese. Scale forming from temporary hard waters, when the alkalinity is greater than or equal to the concentration of calcium and magnesium, is primarily calcium carbonate and magnesium hydroxide, while scale forming from permanently hard water low in alkalinity is primarily sulphates and chlorides.

Two modern techniques are applied to hard waters in order to soften them. In the lime-soda process, both lime and soda are added to the water to remove the calcium and magnesium salts. The second technique uses ion exchange principles to soften the water. Calcium and magnesium ions are exchanged for sodium in cation exchange columns. Boiling can soften temporary hardness, while both temporary and permanently hard water can be softened by the addition of sodium carbonate.

2.2.5. Alkalinity

Alkalinity is an important consideration for many industries, as it has a number of undesirable consequences in many industrial processes. High alkalinity values increase the scaling tendency of water. The severity of scaling depends on the bicarbonate alkalinity and the calcium hardness of the water, while the rate of scaling is dependant on the temperature and pH of the water.

On the other hand, a certain degree of alkalinity is desirable in many industrial waters since, under the right conditions, calcium carbonate acts as a corrosion protector by forming a thin layer that shields metal surfaces.

The alkalinity of a water supply is adjusted by chemical dosage, either by adding lime or sodium carbonate to raise the alkalinity, or by bubbling carbon dioxide into the water to reduce the alkalinity.

2.2.6. Summary

The various water quality constituents mentioned here are considered to be the most significant with respect to the modelling of costs of salinity (or total dissolved solids). Other water quality constituents such as organic matter and bacteria may have more profound cost implications in terms of treatment but the focus of this study is on total dissolved solids (TDS), i.e. salinity.

2.3. COMPILATION OF FORMULAE

The purpose of this section is to compile cost formulae for the industrial sector. Each subsector will be discussed separately in terms of assumptions and cost formulae.

2.3.1. Manufacturing Formulae

Manufacturing is an important user of water and in many cases have stringent requirements with respect to water quality. Manufacturing concerns can obtain water from various sources, namely raw water sources (rivers), treated sewage effluent, water from municipalities and groundwater sources.

The process in which water is used, determines the quality of the intake water and as a result many industries have to purify, treat or demineralise its water to render it fit for use. These water treatments imply specific costs. Changes in water quality may be absorbed up to a certain stage,

depending on the design and sensitivity of treatment works, machinery and product requirements, after which capital costs have to be incurred to replace equipment. This suggests that the cost of salinisation may constitute two broad issues, namely capital cost and maintenance or other costs.

The purpose of this section is to provide the general manufacturing formula that can be applied to each industry with the necessary adaptations for unique circumstances. The formulae contained in this section are conceptualising the production processes and typical behaviour of the manufacturing sector.

2.3.1.1. Assumptions

The manufacturing sector refers to profit motivation concerns and therefore behaviour will be profit driven. This implies that the behaviour of industrialists is based on profit maximisation.

The manufacturing sector produces countless products by means of a variety of processes. The practical approach in this regard would be to assume that industries use water for essentially three purposes. These three processes can then be described as a general production process with related water quality requirements and are the following:

- Utility water: Generally used for cooling processes. Corrosivity and scaling properties are important particularly with high concentration ratios in recirculating systems.
- 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.

2.3.1.2. Formula

The general formula for the manufacturing sector is provided here.

I	=	f(P)
P	=	f(W; B)
W	=	f(p)
p	=	f(p ₁ ; p ₂ ; p ₃)
p ₁₋₃	=	f(H; Q)
(H _{p1} Q _{p1})	=	f(water use, treatment, capital equipment, maintenance)
(H _{p2} Q _{p2})	=	f(ion removal treatment)
	=	f(plant, chemicals, technology)
(H _{p3} Q _{p3})	=	f(plant, chemicals, technology)
B	=	f(M)

Where

I	=	manufacturing industries	
P	=	production cost	
W	=	total water use	
B	=	behaviour	
p	=	processes	
H	=	amount of water	
Q	=	quality of water, (TDS)	
M	=	management decisions	
p ₁	=	utility water	use 50% water; moderately sensitive
p ₂	=	process	use 20% water; not sensitive
p ₃	=	end product	use 30% water; highly sensitive

Application

Each process requires a specific water quality which implies a specific cost to attain these specifications. Any change in water quality implies that additional costs will be incurred, based on the sensitivity of the process to water quality changes, to reach the given water quality levels. These variables represent the starting point of the formula.

Specification

The functional relationship is specified in this section by using parameters and proxies. The functional relationship is based on the water quality requirements of the various processes.

The causality of the functional relationship leads from subelements to the cost of water expressed in Rands. The subelements are the following:

H	=	amount of water used : m ³ water per process
	=	cost of water in Rand
Q	=	quality of water : mg/l TDS per process
	=	minimum quality requirements for process water intake
	=	inhouse treatment cost to maintain or reach quality level
	=	Rand
M	=	management decisions : a quantifiable proxy that can be used in the capital return rate of management
	=	bench-mark where quality of product becomes evident to consumer as a result of undesirable water constituents
	=	probabilistic interval

The cost of increased salinity for the **utility water (process 1)** is as follows :

$$\text{Cost} = \left| \text{TDS}_{\text{thres}} - \text{TDS} \right| \left(\frac{\text{TDS}}{\text{TDS}_{\text{curr}}} \times V \right) + \left| \text{TDS}_{\text{thres}} - \text{TDS} \right| \left(\frac{\text{TDS}}{\text{TDS}_{\text{curr}}} \times M \right) + \left(\frac{\text{TDS}}{\text{TDS}_{\text{curr}}} \times C \right) + \left| \text{TDS} - \text{TDS}_{\text{thres}} \right| P$$

where : TDS_{thres} = threshold where capital expenditure would be required for larger or altered plant
 TDS = new /anticipated TDS conditions
 TDS_{curr} = currently acceptable TDS conditions
 V = volume of water currently used
 C = cost of treatment chemicals currently incurred
 M = current costs of maintenance and replacement
 P = capital cost for plant, dependent on size, site etc.

Note : $| TDS - TDS_{thres} | = \text{modular function} = 0 \text{ if } < 0 \text{ and } 1 \text{ if } 0$

The cost of increased salinity for the **process water (process 2)** is as follows:

$$\text{Cost} = | TDS - TDS_{thres} | P + (TDS/TDS_{curr} \times C)$$

where: TDS = new /anticipated TDS concentration
 TDS_{curr} = currently acceptable TDS concentration
 TDS_{thres} = threshold TDS where capital expenditure would be required for larger or altered plant
 V = volume of water currently used
 P = capital cost for plant, dependant on size, site etc.
 C = chemical cost for treatment

Note : $| TDS - TDS_{thres} | = \text{modular function} = 0 \text{ if } < 0 \text{ and } 1 \text{ if } 0$

The cost of increased salinity for **end product water (process 3)** is as follows:

$$\text{Cost} = | TDS - TDS_{thres} | P + (TDS/TDS_{curr} \times C)$$

where: TDS = new /anticipated TDS conditions
 TDS_{curr} = currently acceptable TDS concentration
 TDS_{thres} = threshold where capital expenditure would be required for larger or altered plant
 P = capital cost for plant, dependant on size, site etc.
 C = chemical cost for treatment

Note : $| TDS - TDS_{thres} | = \text{modular function} = 0 \text{ if } < 0 \text{ and } 1 \text{ if } 0$

The formulae as presented here, can be applied to each of the manufacturing sectors. The parameters which will change for each subsector refer to the types of processes.

PROCESS			% of total water use	Sensitivity to water quality
NO	ACTIVITY	TYPE		
1.	Beamhouse soaking	U	14% water;	not sensitive
2.	Beamhouse dehairing	U	8% water	not sensitive
3.	Beamhouse fleshing	U	none	not relevant
4.	Beamhouse washing	U	18% water	mildly sensitive
5.	Tanhouse washing	U	36% water	moderately sensitive
6.	Tanhouse deliming and bating	P	7% water	mildly sensitive
7.	Tanhouse tanning	P	2% water	mildly sensitive
8.	Finishing : neutralising/retanning	P	x/15% water	mildly sensitive
9.	Finishing dyeing/fat liquoring	P	x/15% water	highly sensitive
10.	Finishing	P	x/15% water	mildly sensitive

NOTE: U = utility
P = process

Water quality requirements

Electrical conductivity represents a measure of the TDS content and gives an indication of the concentration level of the major anions and cations in solution, which in turn may influence efficient tanning and leather finishing processes. Problems that may be experienced are precipitation of insoluble salts that may cause hide abrasion.

The water quality requirements of the leather and tanning industry with respect to salinity are the following:

TDS mg/l	Electrical conductivity (mS/m)	Increase in water costs
Target range 65 - 455	Target range 10 - 70	None (0%)
455 - 975	70 - 150	Moderate (21 - 50%)
975 - 1950	150 - 300	Substantial (> 50%)

Source : SAWQG, 1993

ii. Iron and Steel

Definition and conditions

- * Manufacture basic or primary iron and steel products
- * Smelting and refining are done to produce rolled, drawn or forged steel.
- * Three major companies are located in South Africa.
- * Various operations - iron from iron ore

- coke from coal
- reduction of iron to make steel
- rolling, drawing, casting, forging primary steel products.

- * Role of water is important in cooling and quenching.
- * Anti-pollution control is necessary.
- * Water quality requirements vary from process to process.
- * Water use amounts to about 46 000 M³/pa.
- * Obtain water from rivers and local authorities

Assumptions

- * Draw water from raw sources as well as local authorities, ground water supplies and treated sewage effluent.
- * Water should have low corrosion and scaling potential in cooling of furnaces, cooling of motors and machinery and cooling of steelmill rollers.
- * Demineralised water is used for steam generation, finishing processes.
- * Water of nearly any quality is used for cooling of products, quenching of coke and slag.

Processes

The following processes are important in the iron and steel industry.

PROCESS			% of total water use	Sensitivity to water quality
NO	ACTIVITY	TYPE		
1.	steam generation	U	8% water	highly sensitive
2.	furnace cooling	U	x/70% water	moderately sensitive
3.	motor cooling	U	x/70% water	moderately sensitive
4.	mill roller cooling	U	x/70% water	moderately sensitive
5.	product cooling	U	x/70% water	moderately sensitive
6.	coke quenching	-	recovered water	not relevant
7.	slag quenching	-	recovered water	not relevant
8.	gas scrubbing	U	5% water	moderately sensitive
9.	finishing process	E	17% water	highly sensitive

Note : E = end product
U = utility

Water quality requirements

Electrical conductivity *per se* has no direct effect on any of the processes involved in steel making. However, electrical conductivity measurements reflect the TDS in the water supply. While TDS levels may not be critical for many of the processes in the iron and steel industry, water for steam generation must be demineralised or softened to electrical conductivity levels stipulated by the manufacturer of the type of boiler and the operating pressure used by the facility. High TDS levels

in water used for cooling rollers may cause embrittlement of the rollers. Problems experienced include corrosion, scaling, fouling.

The water quality requirements of the iron and steel industry with respect to salinity are the following :

TDS mg/l	Electrical conductivity (mS/m)	Increase in water costs
Target range 0 - 650	Target guideline range 0 - 100	None (0%)
650 - 1 300	100 - 200	Moderate (1 - 20%)
1300 - 2 600	200 - 400	Substantial (21 - 50%)

Source : SAWQG, 1993

iii. Pulp and Paper

Definition and conditions

- * Twenty pulp and paper mills are located in South Africa
- * Integrated mills produce pulp and paper products
- * Non-integrated mills produce paper and paperboard products
- * Industry uses about 130 000M Λ water pa
- * Recover and recycle process water
- * Methods : mechanical pulping
- : thermomechanical pulping
- : chemical pulping (kraft process)
- * Many processes use recycled water, of interest is only those using clean/fresh water
- * Clean water is used for make-up, blow-down, dilution, solvent for bleaching chemicals, additives and finishing materials and washing water.

Assumptions

- * Many processes use recycled water
- * Only processes using clean or fresh water are included.

Processes

The following processes are important in the pulp and paper industry.

PROCESS			% of total water use	Sensitivity to water quality
NO	ACTIVITY	TYPE		
1.	debarking	U	5% water;	not sensitive
2.	steam generation	U	5% water	highly sensitive
3.	cooling water	U	30% water	mildly sensitive
4.	crude pulp washing	P	10% water	mildly sensitive
5.	bleaching	P	25% water	moderately sensitive
6.	stock production	E	5% water	moderately sensitive
7.	paper machine	E/P	20% water	highly sensitive

Note : U = utility

P = process

E = end product

Water quality requirements

Electrical conductivity is a relatively easy and convenient method to obtain an indication of the (TDS) content of water supply. Specifications for demineralisation plants, required for boiler make-up water preparation, are based on TDS. High TDS contents may enhance the potential for scaling and corrosion problems. Problems encountered include scaling, corrosion and fouling.

The water quality requirements of the pulp and paper industry with respect to salinity are the following:

TDS mg/l	Electrical conductivity (mS/m)	Increase in water costs
Target range 65 - 455	Target range 10 - 70	None (0%)
455 - 975	70 - 150	Moderate (21 - 50%)
975 - 1950	150 - 300	Substantial (> 50%)

Source : SAWQG, 1993

iv. Petrochemical industry

Definition and conditions

- * Produce petrol, fuel oils, illuminating oils, lubricating oils and greases and other products from crude petroleum, coal or other raw materials.
- * Two types : conventional oil refineries using crude oil
: installations, synthesising petroleum products from coal
- * Four conventional, industries use about 10 500M³/ which is supplied by municipalities.
- * Conventional refining : separation, conversion, treating.

- * Synthetic oils from coal : gasification, purification, synthesising, fractionation, refinement.

Assumptions

- * Raw water extracted from Vaal River is used.
- * Municipal water, water from boreholes and treated waste process water.

Processes

The following processes are important in the petrochemicals industry.

PROCESS			% of total water use	Sensitivity to water quality
NO	ACTIVITY	TYPE		
1	steam generation	U	60% water;	highly sensitive
2	cooling water	U	25% water	moderately sensitive
3	utility water	U	15% water	mildly sensitive
4	hydraulic transport	-	recycled effluent	not relevant
5	product water	E	<1% water	moderately sensitive

Note: U = utility E = end product

Water quality requirements

Electrical conductivity is a crucial water quality constituent for steam generation, as it gives an indication of the (TDS). Design and operational specifications of demineralising plants are based on the TDS concentration of the water supply. Problems include chemical fouling, scaling and corrosion. The water quality requirements of the petroleum industry with respect to salinity are the following :

Steam generation			Cooling/other		
TDS mg/l	Electrical conductivity (mS/m)	Increase in water costs	TDS mg/l	Electrical conductivity (mS/m)	Increase in water costs
Target range 0 - 195	Target range 0 - 30	None (0%)	65 - 455	10 - 70	None (0%)
195 - 455	30 - 70	Substantial (> 50%)	455 - 975	70 - 150	Mild (1 - 20%)
> 455	> 70	Substantial (> 50%)	975 - 1950	150 - 300	Moderate (21 - 50%)

Source : SAWQG, 1993

v. Textiles

Definition and conditions

- * The textile industry refers to a wide range of activities.
- * Preparing fibres for spinning, spinning and weaving, bleaching and dyeing, printing and finishing, manufacturing of narrow fabrics and small wares, braids and other primary textiles, yarn, fabric and jute mills.
- * Typical textile processing plant uses 150-1 400 litres per kilogram of manufactured product.
- * Water is required for processing, steam generation, product washing, plant and equipment washing, air conditioning, transport material, cooling systems, personnel consumption and sanitation.
- * Type of raw fibre determines processes.

Assumptions

- * Textile manufacturers are typified.
- * Manufacture of wool, cotton and synthetic textiles requires either wet or dry process for similar stages in processing.

Processes

The following processes are important in the textile industry.

PROCESS			% of total water use	Sensitivity to water quality
NO	ACTIVITY	TYPE		
1.	steam generation	U	10% water;	moderately sensitive
2.	cooling water	U	4% water	mildly sensitive
3.	air humidification	P	2% water	mildly sensitive
4.	wool scouring	P	1% water	mildly sensitive
5.	filling	-	none/recycled	mildly sensitive
6.	carbonising	-	none/recycled	mildly sensitive
7.	neutralising	-	none/recycled	mildly sensitive
8.	carding	-	none/recycled	not relevant
9.	sizing	P	5% water	mildly sensitive
10.	spinning	-	none/recycled	not relevant
11.	weaving	-	none/recycled	not relevant
12.	singeing	-	none/recycled	not relevant
13.	desizing	P	6% water	mildly sensitive
14.	kiering/open boiling	E	7% water	mildly sensitive
15.	bleaching	P	10% water	moderately sensitive
16.	mercerising	P	10% water	mildly sensitive
17.	dyeing	E	40% water	highly sensitive
18.	printing	-	none/recycled	not relevant
19.	finishing	E/P	5% water	moderately sensitive

Note : U = utility P = process E = end product

Water quality requirements

High TDS may cause problems in ion exchange columns used to demineralise water for steam generation. Where the concentration of dissolved salts in wash waters is excessive, the salts may precipitate out during drying processes and adhere to the fibres. Contamination in this manner may impair products such as cotton wools used for medical purposes. Problems include chemical fouling, scaling and corrosion.

The water quality requirements of the textile industry with respect to salinity are the following:

TDS mg/l	Electrical conductivity (mS/m)	Increase in water costs
Target range 65 - 455	Target range 10 - 70	None (0%)
455 - 975	70 - 150	Substantial (21 - 50%)
975 - 1950	150 - 300	Substantial (> 50%)

Source : SAWQG, 1993

vi. Conclusion

All manufacturing sectors not addressed in the preceding sections, can be classified under other industries. This category will, similar to the manufacturing formulae, refer to three water using processes in general, namely water for utility, process and end product purpose.

2.3.2. POWER GENERATION FORMULAE

Definition and conditions

The waters used in the electricity industry are generally for cooling water and boiler water. The latter will be affected by increased TDS with a resultant increase in chemical consumption. Regarding cooling water, increased TDS may result in increased water consumption as water is dumped more rapidly due to increased salt levels. In addition, water treatment processes may have to change, possibly resulting in capital outlay as well as increased running costs. An increased throughput of the water and a change in its composition would result in increased chemical consumption and an allied increase in cost. Although in theory piping and plant should not be affected, if no change in water treatment occurs, there will probably be an increased maintenance cost.

- * Eskom is the main producer of energy in the country, providing, 98% of electricity.
- * 17 coal-fired thermal, 3 gas turbine and diesel, 2 hydro-electric, 2 pumped storage dams, 1 nuclear power station.
- * Rest of power - municipality owned stations.

M = management decisions

Processes

The following processes are important in the power generation industry.

PROCESS			% of total water use	Sensitivity to water quality
NO	ACTIVITY	TYPE		
1	demineralisation	U	X/3% water;	highly sensitive
2	steam generation	U	X/3% water;	moderately sensitive
3	condenser cooling	U	90% water	moderately sensitive
4	production of potable water	U	7% water	sensitive

Note: U = utility

Application

Each process requires a specific water quality (TDS, pH, hardness, etc) which implies a specific cost to attain these specifications. Any change in water quality implies that additional costs will be incurred, based on the sensitivity of the process to water quality changes, to reach the given water quality levels. These variables represent the starting point of the formula.

Specification

The causality of the functional relationship leads from subelements to the cost of water expressed in Rands. The subelements are the following:

- H = amount of water used : m³ water per process
 = cost of water in Rands
- M = management decisions : a quantifiable proxy that can be used is the capital return rate of management
 = bench-mark where quality of product becomes evident to consumer as a result of undesirable water constituents
 = probabilistic interval
- Q = quality of water : mg/l/TDS per process
 = minimum quality requirements for process water intake
 = in-house treatment cost to maintain or reach quality level
 = Rands

The cost of increased salinity of water for **utility processes** is as follows :

$$\text{Cost} = \left| \text{TDS}_{\text{thres}} - \text{TDS} \right| \left(\frac{\text{TDS}}{\text{TDS}_{\text{curr}}} \times V \right) + \left| \text{TDS}_{\text{thres}} - \text{TDS} \right| \left(\frac{\text{TDS}}{\text{TDS}_{\text{curr}}} \times M \right) \\ \left(\frac{\text{TDS}}{\text{TDS}_{\text{curr}}} \times C \right) + \left| \text{TDS} - \text{TDS}_{\text{thres}} \right| P$$

where: TDS = new /anticipated TDS conditions

TDS_{surr} = currently acceptable TDS conditions
 TDS_{thres} = threshold where capital expenditure would be required for larger or altered plant
 V = volume of water currently used
 C = cost of treatment chemicals currently incurred
 M = current costs of maintenance and replacement
 P = capital cost for plant, dependant on size, site etc.

Note : $\left| \text{TDS} - \text{TDS thres} \right| = \text{modular function} = 0 \text{ if } < 0 \text{ and } 1 \text{ if } 0$

Water Quality requirements

Electrical conductivity gives an indication of the TDS and is a critical water quality constituent / property in the power generation industry. Design specifications for demineralising plants are based to a large extent on the TDS of the water supply. Hence, electrical conductivity measurements will give a warning of any changes in the quality of the water supply which may need urgent corrective action. Rising salt contents can result in the uncontrollable build-up of calcium and alkalinity, resulting in calcium carbonate scale and the consequent loss of heat transfer efficiency in cooling systems. Problems include chemical fouling, scaling and corrosion.

The water quality requirements of the power generation industry with respect to salinity are the following :

Steam generation			Cooling/other		
TDS mg/l	Electrical conductivity (mS/m)	Increase in water costs	TDS mg/l	Electrical conductivity (mS/m)	Increase in water costs
Target range 0 - 130	Target range 0 - 20	None (0%)	Target range 65 - 455	Target range 10 - 70	None (0%)
130 - 293	20 - 45	Substantial (> 50%)	455 - 975	70 - 150	Mild (21 - 50%)
> 293	> 45	Substantial (> 50%)	975 - 1 950	150 - 300	Moderate (> 50%)

Source : SAWQG, 1993

2.3.3. Construction Formulae

Definition and conditions

- * Construction refers to the assembly and installation on site of prefabricated, integral parts into bridges, water tanks, storage and warehousing facilities, railway and systems for buildings and structures. Also includes installation of permanent fixtures.
- * Construction can be categorised as follows :

- building construction
 - civil engineering (i.e. bridges, roads, canals, dam)
 - other construction (i.e. erection of steel structure, drilling, etc.).
- * Water is used for
- utility : water quality has very little effects
 - end product : constitution of mixing water for concrete is important especially with regard to sulphate and chloride.

Assumptions

- * Water is obtained on site for building and other construction.
- * Water for civil engineering can be obtained from raw water sources and groundwater sources.

Formula : Construction

I	=	f(P)
P	=	f(W; B)
W	=	f(p)
p	=	f(p ₁ ; p ₂ ; p ₃)
p ₁₋₃	=	f(H; Q)
H _{1,3} Q _{1,3}	=	f(water use, treatment, capital equipment, maintenance)
H ₂ Q ₂	=	f(plant, chemicals, technology)
Behaviour	=	f(M)

Where

I	=	industry - Construction
P	=	production cost
W	=	total water use
B	=	behaviour
p	=	processes
H	=	amount of water
Q	=	quality of water, namely TDS, electrical conductivity, pH, hardness
M	=	management decisions

Processes

The following processes are important in construction.

PROCESS			% of total water use	Sensitivity to water quality
NO	ACTIVITY	TYPE		
p1	washing	U	50% water;	not sensitive
p2	mixing concrete products	E	40% water;	mildly sensitive
p3	potable water	U	10% water	sensitive

Note: U = utility E = end product

Application

Each process requires a specific water quality (TDS, pH, hardness, etc.) which implies a specific cost to attain these specifications. Any change in water quality implies that additional costs will be incurred, based on the sensitivity of the process to water quality changes, to reach the given water quality levels. These variables represent the starting point of the formula.

Specification

The functional relationship of this industry is based on the water quality requirements of the various processes.

The causality of the functional relationship leads from four subelements to the cost of water expressed in Rand. The four subelements are the following:

- H = amount of water used : m³ water per process
- = cost of water in Rand
- Q = quality of water : mg/l TDS per process
- = minimum quality requirements for process water intake
- = inhouse treatment cost to maintain or reach quality level
- = Rand
- M = management decisions : a quantifiable proxy that can be used is the capital return rate of management
- = bench-mark where quality of product becomes evident to consumer as a result of undesirable water constituents
- = probabilistic interval

The cost of increased salinity of water for utility water (processes 1,3) is as follows:

$$\text{Cost} = |TDS_{\text{thres}} - TDS| (TDS/TDS_{\text{curr}} \times V) + |TDS_{\text{thres}} - TDS| (TDS/TDS_{\text{curr}} \times M) + (TDS/TDS_{\text{curr}} \times C) + |TDS - TDS_{\text{thres}}| P$$

where : TDS = new /anticipated TDS conditions
TDS_{curr} = currently acceptable TDS conditions

TDS_{thres} = threshold where capital expenditure would be required for larger or altered plant

V = volume of water currently used

C = cost of treatment chemicals currently incurred

M = current costs of maintenance and replacement

P = capital cost for plant, dependant on size, site etc.

Note : $|TDS_{thres} - TDS| = \text{modular function} = 0 \text{ if } < 0 \text{ and } 1 \text{ if } 0$

The cost of increased salinity end product water (process 2) is as follows:

$$\text{Cost} = |TDS - TDS_{thres}| P + (TDS/TDS_{curr.} \times C)$$

where:

TDS = new /anticipated TDS conditions

TDS_{curr} = currently acceptable TDS concentration

TDS_{thres} = threshold where capital expenditure would be required for larger or altered plant

TDS = currently acceptable TDS conditions

P = capital cost for plant, dependant on size, site etc.

C = chemical cost of treatment

Note : $TDS - TDS_{thres} = \text{modular function} = 0 \text{ if } < 0 \text{ and } 1 \text{ if } 0$

Water quality requirements

[C1-] is the most likely to cause effects. The threshold value is 300 mg/l in concrete. Using standard concrete, the maximum acceptable chlorine value is 0.4% C1- in the water. This is higher than ever likely to be experienced with the defined limits of 200 mg/l to 1200 mg/l TDS. It is therefore unlikely that there will be major cost implications.

The water quality requirements of the construction industry with respect to salinity are the following:

TDS mg/l	Electrical conductivity (mS/m)	Increase in water costs
65 - 455	10 - 70	None (0%)
455 - 975	70 - 150	Mild (21 - 50%)
975 - 1950	150 - 300	Moderate (> 50%)

Source : SAWQG, 1993

2.4. CONCLUSION

The industrial sector is a relatively important water using sector. The direct cost of increased salinity have been addressed by means of conceptual equations. The indirect costs will be addressed in the integrated model.

The behavioural costs for the manufacturing, power generation and construction sectors are similar in nature since production is based on profit maximisation. The costs can be generated by assuming that managers/owners will, within a given range of salinity, behave in a certain way. The probability of this range can be determined by testing the conceptual formulae in a case study.

Based on the conceptualisation of the costs of salinity done in this section, the formulae are tested in the Middle Vaal River Area by conducting surveys. This process is subsequently discussed.

3. CASE STUDY

3.1. INTRODUCTION

The purpose of this section is to discuss the methodology followed with surveying the industrial sectors in the Middle Vaal River Area. The reason for conducting surveys is to obtain information on the effect of salinity on the industrial sector. This information has been analysed and transformed to be inputted to an integrated model to determine the total costs of combating salinity and relate the findings to the conceptualisation of costs.

The results of the surveys are discussed to identify the important cost factors of concerns using saline water in their production processes.

3.2. STUDY AREA

The area identified for the case study refers to the Middle Vaal River Area which stretches from the Barrage to the Bloemhof Dam. The following magisterial districts are included :

- * Klerksdorp (Orkney, Stilfontein)
- * Odendaalsrus (Allanridge)
- * Virginia
- * Welkom
- * Bothaville
- * Hennenman
- * Ventersburg
- * Parys
- * Viljoenskroon
- * Wesselsbron
- * Theunissen

A sample of industrial concerns in the study area will be included in the survey. Table 3.1 contains the total number of industrial concerns in the Middle Vaal River Area.

Table 3.1: Total number of industrial concerns in Middle Vaal River Area.

MAGISTERIAL DISTRICT	PERCENTAGE DISTRIBUTION	
	INDUSTRIAL	CONSTRUCTION
Klerksdorp	37,7	65,9
Odendaalsrus	2,5	2,4
Welkom	30,5	21,0
Virginia	6,4	1,2
Ventersburg	1,7	0
Hennenman	3,4	1,2
Parys	8,5	7,2
Viljoenskroon	2,1	1,2
Bothaville	4,7	0
Wesselsbron	1,7	0
Theunissen	0,9	0
TOTAL	236	167

Source: BMR, 1993

Based on the table, it is evident that Klerksdorp and Welkom are the two major towns in the study area in terms of concentration of economic activities. Despite this, the economic structures of these areas are rather undiversified, focusing on supporting the mining and agricultural activities of the region. The manufacturing sector, is not well represented in the Middle Vaal River Area. This has a direct bearing on the results of the study, since the various types of industries demarcated in the preceding section will not form the basis of the analysis. The following industries are for instance not represented in the study area:

- leather and tanning
- pulp and paper
- petrochemical
- textile manufacturers

Some small iron and steel industries are located in the study area, but are not using water intensively for processing purposes. The important subsectors in the study area are the food manufacturers and beverage industries which are relatively intensive water users. In relation to the conceptual formulae the majority of the manufacturing concerns interviewed in the study area relates to the general manufacturing formula.

3.3. SURVEY METHODOLOGY

The industrial surveys were conducted in Klerksdorp and Welkom based on the existing profile of the study area. A structured questionnaire has been compiled which was used to obtain the relevant information from the industrial sector (refer to Annexure A). The process that was followed in undertaking the surveys is discussed.

3.3.1. Pilot Survey

The questionnaire was piloted to test the suitability of the questionnaire and whether industrialists can actually provide the information. The results of the pilot survey indicated that not all the industrialists are informed about the technical aspects of salinity. It was, however, established that the questionnaire was suitable.

3.3.2. Sample

Due to the specific nature of the data required as well as the conditions prevailing in the study area, it was decided that a limited sample of industries will generate adequate data to meet the requirements of the model. The focus is therefore not on the representivity of the sample, but rather the quality of the information.

The sampling was strongly influenced by the local conditions of the study area. This means that the industrial profile of each town in the study area was evaluated in terms of the diversity and number of concerns. Based on this, it was determined that a total of about 55 interviews were to be held in Klerksdorp and Welkom.

3.3.3. Field Report

The purpose of this section is to provide some feedback on the main findings observed during the survey. These observations provide valuable insight to the results of the surveys.

3.3.3.1. Klerksdorp

The industrial surveys were undertaken during October 1995. The total number of concerns interviewed amounted to 25 and these were situated in the industrial areas of the Vraniaville and Klerkindustria. In most cases the interviews were held with the business manager, production manager or other relevant persons in the industry. Some of the salient features of the survey include the following :

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- * Very few of the industries interviewed were found to regularly test the salinity or the quality levels of water intake. The concerns testing their water intake included abattoirs, food and beverage manufacturers. In most cases water testing is undertaken by private companies.
 - * Very few concerns ever test the quality of their water intake and only a small number of people understand or have any knowledge of what TDS levels or salinity are.
 - * The overwhelming majority of respondents complained that their drinking water often has a bad smell or taste. Many also complained of water being milky and having a chlorine taste.
 - * Many respondents complained that their geysers, kettles and urns do not last very long due to corrosion and scaling.
 - * Of the larger industries, which use water for cooling and/or heating purposes often have problems related to corrosion and scaling in pipes, boilers or cooling systems.
 - * A few respondents complained about the high costs of replacing blocked water pipes.
 - * A relatively large number of industries make use of borehole water. The reason being that borehole water is apparently cheaper and of higher quality than the municipal water.
 - * A few of the smaller industries have specific complaints of how the water quality affects their businesses. An example is a printing works that has to filter its water before mixing it with ink.

3.3.3.2. Welkom

The Welkom industrial surveys were undertaken during October and November 1995. A total of 30 interviews were held with heavy and light industries and where possible, concerns were sought which have water-intensive production processes. The industries interviewed are mostly situated in Voorspoed and Voorspoed-East industrial areas.

The main findings of the survey are as follows:

- Very few industries were found which regularly test the TDS levels of their water intake. The concerns use water either in their end-product i.e. the dairy and cooldrink manufacturers or use water in large boilers or cooling systems i.e. frozen food distributors, breweries, abattoir, etc.
- As in the case of Klerksdorp, the water tests in Welkom are undertaken by private companies and the industries themselves are relatively ignorant about the technical details of the water quality.
- Apart from the above mentioned companies, very few companies are concerned about testing their water and few people understand or have any knowledge of what TDS levels in their water are.

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- Relatively fewer people complained about bad tasting or smelling water as was the case in Klerksdorp.
 - Many respondents complained of the high costs of replacing water pipes that often corrode or scale to the point that they are no longer serviceable.
 - The most prominent problems related to TDS levels in water appears to be high maintenance and service costs on boilers, followed by cost of replacing water pipes.
 - It appears that relatively fewer concerns in Welkom make use of borehole water than in Klerksdorp.
 - Very few specific complaints with respect to the costs of salinity were received from the respondents.
 - A general perception exists that the water in Welkom is of a low quality since it is transported from the Vaal River to Welkom over a distance of more than 100km.

3.3.4. Summary

The methodology used in the survey ensured that the best possible information was obtained from the sample of industries in the study area. Upon completing the surveys, the results were computerised and analysed to extract data to be related to the conceptual cost formulae.

Before providing the results it is, however, necessary to discuss the assumptions of the study as well as conditions impacting on the results of the surveys.

3.4. ASSUMPTIONS AND CONDITIONS

Since the purpose of the study is to verify and test a conceptual model, it is imperative to discuss how the assumptions of the model impact on the fieldwork, as well as to set out the specific conditions relating to the survey and analysis of results.

3.4.1. General Conditions

The following general conditions apply:

- The average TDS for the study area varies between 300 mg/l and 600 mg/l . The average TDS has been accepted as 470 mg/l – 500 mg/l .
- The 1995/6 rain season has had limited impact on the survey results since it can be considered as a deviation from the norm and does not influence average trends.

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- The behavioural aspects obtained from the survey are mainly technology-driven where water is used as process or end product water.
 - Compensatory behaviour or related changes in water use, treatment, etc. only becomes relevant at TDS ranges with potential negative health effects, e.g. TDS of 1100 mg/l and more.
 - Scaling of heating surfaces is one of the main problems experienced in the study area due to relatively high levels of TDS.
 - Obtaining information on the cost of salinity is greatly influenced by the general lack of knowledge on the issue.
 - The responsibility of supplying water with an acceptable level of TDS is considered to be that of the water supply authorities, e.g. the municipalities and water boards.

It is evident from the preceding discussion that determining the cost of salinity on the various sectors is not a simplistic matter due to the variety of factors influencing production, water usage and management decisions relating to combating salinity.

3.4.2. Sectoral Conditions

The issues relating to the industrial sector include the following:

- Subsectors included under the industrial sector are manufacturing, construction and electricity.
- Due to the manner in which water is applied in industry, the industrial sector has been aggregated into *non-treatment industries* and *treatment manufacturing*. The former group of industries does not use water in their production processes or has to obtain specific levels of TDS. The treatment manufacturing group has to treat water to a certain extent or has to incur maintenance costs to adhere to the technical standards of equipment.
- The behavioural information on especially treatment manufacturing is confined to parameters provided by the technology of processes and equipment. This means that if a certain process requires water which is of a lower TDS value than the intake water, choice in behaviour is limited to what technology prescribes.
- Behaviour of the manufacturing group is limited to water used for human consumption. This implies that, depending on the cost of installing purification systems, for example, the management may consider incurring costs to treat water to ensure that the water will have no adverse health effects.

In general, industry may consider treatment plants and equipment only if the water reaches unmanageable levels of salinity, both in terms of technology and human consumption.

4. DATA ANALYSIS

The purpose of this section is to discuss the results of the industrial surveys. Some general information is provided which is useful for classification of activities after which specific data on water usage and costs of salinity are discussed. The results are discussed for the non-treatment industries and treatment manufacturing.

4.1. NON-TREATMENT INDUSTRIES

This section discusses the survey results relating to concerns classified under the industrial sector and which do not treat water. The subsectors included in this category are mainly manufacturing concerns which are not very intensive water users or do not use water for processing products.

Approximately 346 concerns are located in the study area and 16 concerns have been interviewed. This accounts for a sample size of 4,6%.

4.4.1. General Information

The types of manufacturing concerns that could be located for inclusion in the survey are indicated in Table 4.1.

TABLE 4.1. : TYPE OF INDUSTRIES INTERVIEWED

CLASSIFICATION	PERCENTAGE
Food products and beverages	25,0
Products of wood, cork, straw and plaiting material	6,3
Printing and related services	12,5
Plastic products	6,3
Non-metallic products	12,5
Structural metal products	6,3
General purpose machinery	12,5
Special purpose machinery	18,7
TOTAL	100,0

It is evident from the table that the manufacturing sector is largely focused on providing inputs and services to the mining sector in the study area. These types of concerns do not rely on water as an important input to the production process, but use water mainly for human consumption. The average employment figures for this sector amounts to 50 workers suggesting the manufacturing concerns are mainly medium concerns.

The annual turnover of the manufacturing sector can also be used as an indicative parameter of the size of the company. Table 4.2. provides the average annual turnover distribution.

TABLE 4.2. : AVERAGE ANNUAL TURNOVER

CATEGORY (R'000)	PERCENTAGE
0 - 100	0
100 - 500	23,1
500 - 1 000	30,7
1 000 - 5 000	7,7
5 000 - 10 000	7,7
10 000 - 50 000	23,1
50 000 - 100 000	7,7
100 000 +	0
TOTAL	100,0

The turnover distribution confirms that the manufacturing concerns are of a medium size. The average turnover amounts to R13,8m per annum.

4.1.2. Water Usage

The non-treatment manufacturing sector is a relatively large water user although not an intensive water user. The non-treatment manufacturing sector uses on average approximately 1545,72 k/ of water per annum at a cost of approximately R3 090 per annum and the manner in which it is applied is indicated in Table 4.3.

TABLE 4.3. : WATER USAGE

PURPOSE	PERCENTAGE
Human consumption	50,0
Washing (cleaning, vehicles)	16,7
Cooling	6,7
Gardening	3,3
Treatment	3,3
Process	6,7
Product	13,3
TOTAL	100,0

Water is predominantly used for human consumption, as well as for washing purposes. An important application of water is to use water as input to the final products. In most cases this refers to the food manufacturers. Cases that may indicate problems in terms of dealing with increased salinity can be where water is used for cooling and processing. The respondents indicated these applications did not, however, respond in any way as to how salinity is currently influencing cost or to what extent it may impact on costs with higher levels of salinity.

The respondents were asked what their perceptions on the current water quality are (refer to Table 4.4).

TABLE 4.4. : QUALITY OF WATER

QUALITY OF WATER	PERCENTAGES
Lime	16,7
Bad taste/smell	25,0
Milky	16,7
Chlorine	8,3
Bad quality	16,7
Pipes chalk up	16,7
TOTAL	100,00

Respondents complained mostly that the water tasted bad whereas the rest of the responses were mainly referring to mineral content of water (lime, milky, chlorine). Some respondents observed that the bad quality of the water caused pipes to chalk up.

4.1.3. Purification

The manufacturing sector does not treat water to obtain or attain lower levels of salinity, but the inclination of these concerns to introduce mitigating actions to purify for human consumption needs to be tested.

The respondents were asked if any form of drinking water purification are currently used or may be considered. Approximately 94% indicated they are not using any form of water purification system. The positive responses were related to water purification for machinery but no costs were provided.

In consequence to this, it was requested if the concerns would consider introducing purification systems and the following responses were recorded :

- will consider : 31%
- will not consider : 69%

The respondents who indicated that the concern will consider such a system stated that it will be subject to necessity. This means that they will only consider it when the water cannot be used for human consumption.

The respondents replied unanimously that they will consider alternatives such as boiling water or using purification pills as alternatives to unpalatable water.

4.1.4. Maintenance and Replacement

Total costs of combating salinity include maintenance and replacement costs. In the case of the manufacturing sector no maintenance costs have been recorded. Replacement of mainly appliances used for heating water for human consumption and washing purposes has been

recorded. The average annual replacement costs for the manufacturing sector are indicated in Table 4.5.

TABLE 4.5. : REPLACEMENT COSTS

COST ITEM	OCCURRENCE PER YEAR	AVERAGE ANNUAL COSTS (R)
Kettle	0,38	21,89
Urns	0,07	13,33
Geysers	0,07	186,30
TOTAL REPLACEMENT		221,52

The total average annual costs per concern to combat salinity amounts to R221,52. This can typically be related to roughly one replacement every two years per concern if all three appliances are considered.

The total number of non-treatment manufacturing concerns in the study area amounts to about 346 and the total costs to the industry are as follows:

- Total water costs R1 069 638 p.a.
- Total replacement costs R 76 646 p.a.

4.1.5. Conclusion

Water usage in the non-treatment manufacturing sector is mainly applied for human consumption and washing purposes. Since very little water is used for processing where specific TDS levels are required, the costs of combating salinity are relatively low. The costs are mainly aimed at replacing household-type appliances when necessary.

The behavioural component relating to salinity is limited to considering mitigating actions when water for human consumption becomes unacceptable. Since this would in all probability occur at TDS levels above the 1 200 mg/l level, costing of behaviour is not realistic.

4.2. TREATMENT MANUFACTURING

The purpose of this section is to discuss the results obtained from the manufacturing concerns treating water to obtain appropriate levels of TDS to meet standards required by technology. The treatment manufacturing sector is estimated to represent about 15% of the total industrial sector in the study area, amounting to 57 concerns. The survey included 11 concerns representing a sample of more than 19%.

4.2.1. General Information

More than 54% of the concerns interviewed are manufacturers of food products and beverages, generally being medium or large concerns. The average number of employees amounts to 95 workers per factory. This is significantly more than the non-treatment industries.

The annual turnover of a concern is also indicative of the size of the concern. The average figure for the treatment manufacturers amounts to R15,015 million per annum.

The distribution of the turnover is provided in Table 4.6.

TABLE 4.6: AVERAGE ANNUAL TURNOVER

CATEGORY (R'000)	PERCENTAGE
0 - 500	0
500 - 1 000	20,0
1 000 - 5 000	50,0
5 000 - 10 000	0
10 000 - 50 000	20,0
50 000 - 100 000	10
100 000 +	0
TOTAL	100,00

Most of the concerns have an annual turnover of between R500 000 and R5 000 000, whereas other mainly fall in the R10 million to R100 million categories.

4.2.2. Water Usage

The treatment manufacturing sector is a relatively intensive water user since water is either an input to the final product or an important component of processing. The average water used per annum amounts to about 64 304 kilolitres per concern, costing between R8 625 and R10 900 per month.

The purposes for which water is used, are provided in Table 4.7

Table 4.7. : APPLICATION OF WATER

PURPOSE	PERCENTAGES
Human consumption	34,3
Washing (cleaning)	12,5
Cooling	12,5
Boilers / heating / steam generation	15,7
End product	15,6
Processing	9,4
TOTAL	100,0

Water is mostly used for processing products and utility water. Important applications are, however, also for human consumption and washing purposes.

4.2.3. Purification

The purpose of this section is to discuss the possibility of concerns considering to take measures to purify water for human consumption with increased levels of salinity. More than 90% indicated that they do not currently make use of any purification. The concerns providing purification use sand filters and in all probability this actually refers to product water.

The treatment manufacturing sector was asked to indicate whether any systems may be considered in future and the response were as follows:

- will consider : 45,4%
- will not consider : 54,5%

The concerns who responded positively indicated that mitigating actions will be taken when it becomes necessary.

The concerns were also prompted to indicate whether any alternatives would be provided if water becomes unpalatable or undrinkable. Approximately 91% of the respondents were in favour of introducing alternatives. Examples of alternatives would be to obtain water from other sources than from the current suppliers.

4.2.4. Treatment Costs

The treatment manufacturing sector was requested to indicate their costs in terms of treating water to obtain the required levels of TDS. Each process requires a different level of TDS which means that the costs of treating water to obtain specific levels of TDS will be different from process to process.

The respondents were asked to provide the average costs for the industry to obtain the appropriate levels of TDS. On average annual costs reported, amount to about R23 600 per concern. This figure mainly represents chemical costs of treatment as well as other maintenance costs related to treatment.

An important distinction can be made between the treatment costs for the different processes and this information is presented in Table 4.8.

TABLE 4.8. : TREATMENT COST PER PROCESS

PROCESS	PERCENTAGE
Human consumption	2,7
Washing (products)	39,5
Cooling	13,8
Heating	24,0
Products	20,0
TOTAL	100,0
Average cost per industry	R21 700 to R23 600

It is evident from the information contained in the table that most of the costs of treating water are related to water used for washing products. The costs related to this can be due to, for example, the need to remove solids and organic components from wash water to ensure that effluent would be of an acceptable standard.

The water used for heating purposes, such as for boilers, followed by water used as input to products, are other treatment categories with significant costs.

4.2.5. Maintenance and Replacement

In the previous section the treatment costs were provided whereas this section aimed at providing the total costs to combat salinity. This means that both maintenance and replacement costs are recorded here. The average annual maintenance and replacement costs for the treatment manufacturing sector are provided in Table 4.9.

TABLE 4.9. : REPLACEMENT AND MAINTENANCE COSTS

COST ITEM	OCCURRENCE PER YEAR	AVERAGE ANNUAL COSTS (R)
REPLACEMENT		2 139,8
Kettles	0,48	55,6
Urns	0,41	13,0
Geysers	0,17	200,0
Piping	0,14	1 409,1
Equipment	0,18	462,1
MAINTENANCE		30 115,9
Piping	3,99	3 393,0
Chemicals	9,2	18 360,0
Equipment		453,8
Labour	3,6	3 545,5
Fines	1,2	4 363,6
TOTAL		32 255,7

The information in the table indicates that the total maintenance and replacement costs of the treatment industries are relatively high. The maintenance costs represent the largest component of total costs, namely 93%.

The maintenance costs constitute chemicals, piping, equipment, labour and fines for effluent. The maintenance in terms of chemicals represents the majority of the costs, namely 57%. This suggests that most of the concerns use chemicals to treat water for the various processes to obtain appropriate levels of TDS.

The information shows that substantial amount of effort goes into maintenance of piping due to clogging and scaling. This must be done at least three times a year to ensure optimal operation.

The fines for effluent also constitute an important cost component and relate to concerns not currently treating effluent adequately to meet discharge standards. The quality of intake water plays a role in this instance, since higher TDS levels contribute to the TDS values of effluent quality.

Labour cost refers to the labour used in treatment of water such as cleaning equipment. Equipment maintenance costs refer to instances where equipment must be treated and cleaned by treatment and servicing companies.

Apart from maintenance costs, costs are incurred to replace capital goods such as piping and equipment due to the secondary effects of waters with high levels of TDS. The largest cost component is piping which needs replacement as many as four times a year. The piping includes pipes for internal reticulation as well as piping in equipment and machinery. The most common problems include scaling due to the high levels of lime in the water.

Equipment refers to costs which are incurred on account equipment and machinery becoming inoperable due to predominately scaling problems.

The total number of treatment manufacturing concerns amounts to 57 and based on this, the annual costs to the industry, due to the salinity of water, are as follows:

• Total water cost	R5 899 910 p.a.
• Replacement	R 121 970 p.a.
• Maintenance	R1 716 610 p.a.
• TOTAL	R1 838 580 p.a.

The total water cost includes base line water usage (i.e. water usage under low salinity conditions) plus additional water usage due to salinity.

4.2.6. Summary

The treatment manufacturing sector is a relatively intensive water user and on account of the technologies used, forced to incur relatively high costs to treat water to reach appropriate levels of TDS. Apart from this, the situation also necessitates relatively high replacement costs due to high levels of TDS.

5. INPUT DATA FOR MODELLING

The purpose of this section is to interpret the data obtained through the surveys in a format to be inputted to the interactive model.

5.1. INCREMENTAL COST CHANGES

The changes in cost, related to increased salinity levels of water, may be in terms of the overall cost of water, the complexity and level of water treatment technology, the level and intensity of supervision as well as the complexity of water handling. The effect of any of these will be in terms of increased costs as a result of any of the following :

- paying more for in-house treatment of the water to attain the required standard
- change the level or complexity of technology used in water treatment
- increase the level or intensity of supervision of water treatment facilities
- handle additional wastes resulting from the water treatment process.

Changes in salinity do not imply that all the above will be done, but mean that costs will increase. The specific actions taken and resultant cost increases will be influenced by the severity of the salinity changes.

Actions in any or all of the mentioned aspects would lead to additional costs and the sum of these will give rise to increased water treatment costs. Any water using concern (business services and manufacturing) has a "baseline" cost for its water usage. This refers to the basic cost of water purchased, capital costs for equipment and facilities, costs for chemicals for treatment and costs for handling wastes. Changes in salinity will be reflected in the increases above this cost.

The costs recorded during the surveys indicate the total current costs related to treatment, which means that the costs represent baseline cost plus incremental costs due to a salinity level of 500 mg/l.

Total water costs have been obtained, which represent typical water usage as part of the production process as well as additional water usage to compensate for higher levels of salinity.

5.2. NON-TREATMENT INDUSTRIES

This sector consists of manufacturing concerns not treating water. Water quality is generally not an important consideration in production and therefore salinity in water will only have an impact on household-type of appliances. As a result, the costs of salinity will be related to the maintenance costs of water mainly used for human consumption.

The costs of salinity to the manufacturing sector are indicated in Table 5.1.

TABLE 5.1 : COST OF SALINITY TO NON-TREATMENT MANUFACTURING (RAND PER YEAR.)

COST ITEM	INPUT SECTOR	AVERAGE COST PER CONCERN	TOTAL	COST AT
			500 mg/l	1200 mg/l
Kettle	Trade	21,89	7574	11361
Urn	Trade	13,33	4612	5765
Geyser	Trade	186,30	64460	96690
TOTAL		221,52	76646	113816
Water cost	Government	3091,44	1069638	1230084

Since adverse health effects may occur above 1200 mg/l it is expected that increases may be substantial at this level. The cost of replacement may increase by 49%, i.e. R113 816 and the water cost by 15% i.e. R1 230 084 i.e. R1 230 084 at 1200 mg/l. The incremental cost is about R37 170 whereas the incremental water cost will amount to R160 446 p.a.

5.3. TREATMENT MANUFACTURING

The treatment manufacturing sector is characterised by intensive water usage for production purposes and as a result treating water to obtain appropriate levels of TDS for various processes. The formulae for the treatment manufacturing sector consist of three components, namely utility, process and end product water. The costs of treatment are distributed among the processes as follows:

- utility 40,5% (R753 733)
- process 39,5% (R720 190)
- end product 20,0% (R364 653)
- **TOTAL** **(R1 838 576)**

The water costs are distributed amongst the different processes as follows :

- utility : 62,5% (R3 687 444)
- process : 21,9% (R1 292 080)
- end product : : 15,6% (R 920 386)
- **TOTAL** : **(R5 899 910)**

The distribution of the treatment and water costs amongst the three processes form the basis for determining cost increases due to increased salinity levels.

5.3.1. Utility Water

The cost increases due to an increase in salinity from 500 mg/l to 1 000 mg/l are indicated in Table 5.2.

TABLE 5.2 : UTILITY COST INCREASES

COST ITEM	Cost in Rand at	
	500 mg/l	1000 mg/l
Replacement of appliances	15 310	22 780
Replacement of equipment	43 197	64 795
Maintenance	6 95 226	1 042 839
TOTAL	753 733	1 130 414
Percentage increase		50%
Water cost	3 687 444	5 366 527
Percentage increase		45,5%

The information in the table indicates that the cost to combat salinity increases by 50% and the water cost by about 46%.

5.3.2. Process Water

The cost increases due to an increase in salinity from 500 mg/l to 1000 mg/l are indicated in Table 4.12

TABLE 5.3 PROCESS COST INCREASE

COST ITEM	Cost in Rands at	
	500 mg/l	1000 mg/l
Replacement	42 130	52 663
Maintenance	678 060	8 47 575
Total	720 190	900 238
Percentage increase		25%
Water cost	1 292 080	1 485 892
Percentage increase		15%

The information in the table shows that the water cost will increase by 15% and the treatment cost will increase by 25%.

5.3.3. End Product

The cost increases due to an increase in salinity from 500 mg/l to 1000 mg/l are indicated in Table 5.4.

TABLE 5.4. END PRODUCT COST INCREASE

COST ITEM	Cost in Rands at	
	500 mg/l	1000 mg/l
Replacement	20 192	26 249
maintenance	343 321	446 318
Total	363 513	472 567
percentage increase		30%
Water cost	920 386	1 104 463
Percentage increase		20%

The data in the table reflects a water cost increase of 20% and a treatment cost of 30% between 500 mg/l and 1000 mg/l TDS.

5.4. TOTAL COSTS

Based on the disaggregated cost increases, it is evident that the highest cost increases will occur in the utility processes of the treatment manufacturing sector. This is mainly as a result of water quality sensitive equipment and machinery such as boilers. The total cost of salinity to be inputted to the model are provided in Table 5.5 The input sector refers to the sectors from which inputs are purchased to combat salinity.

TABLE 5.5 : COST OF SALINITY TO TREATMENT MANUFACTURING (RANDS PER YEAR)

COST ITEM	INPUT SECTOR	AVERAGE COST PER CONCERN	TOTAL COST AT	
			500 mg/l	1000 mg/l
REPLACEMENT				
Kettle	Trade	55,6	3 196	4 754
Urn	Trade	13,0	741	926
Geyser	Trade	200,0	11 400	17100
Pipes	Light Industry	1 409,1	80 319	109 334
Equipment	Light Industry	462,1	26 340	35 855
SUBTOTAL		2 139,8	121 969	167 972
MAINTENANCE				
Chemicals	Service	18 360,00	1 046 520	1 424 575

COST ITEM	INPUT SECTOR	AVERAGE COST PER CONCERN	TOTAL COST AT	
			500 mg/l	1000 mg/l
Piping	Light industry	3 393,00	193 401	263 268
Equipment	Service	453,81	25 867	35 211
Labour	Household	3 545,46	202 091	275 100
Fines	Government	4 363,63	248 727	338 577
SUBTOTAL		30 115,9	1 716 606	2 336 731
TOTAL		32 255,7	1 838 575	2 504 703
Water costs	Government	103 507	5 899 910	7 956 882

The total cost of salinity will increase from R1 838 575 at 500 mg/l to R2 504 703 at 1000 mg/l.

5.5. SUMMARY

The treatment manufacturing sector has to incur substantial costs to combat salinity. No behavioural information could be costed but this is in accordance with previous indications that the industrial sectors are mainly technology driven.

6. CONCLUSION

The results of the case study analysis indicate that treatment manufacturing concerns have to incur substantial costs to combat salinity at a TDS level of 500 mg/l and this will increase significantly at a TDS level of 100 mg/l. These findings are in line with the assumptions and relationships specified in the conceptual formulae. The non-treatment manufacturing concerns experience limited cost increases due to salinity, which implies that increased salinity levels will not impact significantly on production costs, although increased costs will be incurred.

The information obtained in the case study also shows that the applicability of conceptual formulae will increase largely if the study area has a more diversified economic base than the predominantly service-orientated economic structure of the Middle Vaal River Area. In applying the conceptual formulae in other areas, such as the Gauteng area, would in all probability render more significant results.

The conceptual formulae rely on complete and high quality information which is relatively difficult to obtain on account of the general ignorance on behalf of industrial concerns. Furthermore, the behavioural aspects are not easily quantifiable, since decisions are generally based on technical specifications. To some degree it may be inferred that the costs could be overstated since costs are attributed to be caused by salinity when in fact it could be due to other factors, such as replacement of piping and kettles, as a result of manufacturing or old age.

In conclusion it can be said that the study has produced valuable insight in the costs of salinity in the industrial sector.

REFERENCES

- BKS 1990 : *analysis of the integrated Vaal River system: Volume B: Water quality*", Vaal River System Analysis, Report P C000/00/7889, Directorate of Planning, Department of Water Affairs, Pretoria.
- Bureau of market Research, 1993. A guide to the BMR Industrial Registers.
- Department of Water Affairs and Forestry, 1993. South African Water Quality Guidelines. Volume 3: Industrial Use.
- Eskom Annual Report, 1991. Eskom.
- Binnie and Partners, 1987. A guide to waste-water management in the tanning and fellmongering industries. TT27/87
- Herold, CE. October 1983, SSO: *A preliminary investigation of the possible impact of power generation on the quality of the water resources of the Vaal Dam basin.*
- Heynike, (J.J.C.) WRC, 1985: *Economic effects of the increasing mineral content present in the Vaal River water on the community of the Pretoria-Witwatersrand-Vereeniging-Sasolburg and the Klerksdorp and OFS Goldfields complexes.* Water Research Commission.
- Heynike, J.J.C. 1987: "Salinisation of the Vaal River water : economic effects. Report KV 2-87, Water Research Commission, Pretoria, December 1987.
- Malan, G.J., 1988. Water consumption and possible water savings in apartment buildings. 177/1/88
- Netyzell-De Wilde, FG Orbin, A Solymosi, AM Simpson A, 1987. The Treatment of industrial effluent with high salinity and organic contents. 123/1/87
- Netyzell-De Wilde, FG Orbin, A Solymosi, AM Simpson, 1987. Supplement to : The treatment of industrial effluent with high salinity and organic contents. 123/2/87
- Schlemmer, L; Stewart, G; Whittles, J., 1989. The socio-economic effects of water restrictions on local authorities, selected industrial and commercial establishments and other private agencies. 168/1/89
-

Van Zyl, J.H.; Viljoen M.F, 1987. Die sosio-ekonomiese gevolge van watebeperkings op besproeiingsboerderye, mynbou, elektrisiteitsvoorsiening en die sentrale owerheid. 167/1/87

WRC, 1987. A guide for the planning, design and implementation of waste-water treatment plants in the textile industry (Part 2) 1987. TT26/87

WRC, 1987. Investigations into water management and effluent treatment in the processing of pulp and paper. 106/1/87

WRC, 1987. Investigations into water management and effluent treatment in the South African metal finishing industry. 106/2/87

WRC, 1987. Investigations into water management and effluent treatment in the fermentation industry. 106/3/87

WRC, 1987. Investigations into water management and effluent treatment in the pharmaceutical industry. 106/4/87

Binnies and Partners, 1987. A guide to water and waste-water management in the fruit and vegetable processing industry. TT30/87

Binnie and Partners 1987. Guide to water and waste-water management in the pelagic fishing industry. TT28/87

Binnie and Partners, 1987. Water and waste-water management in the fruit and vegetable processing industry. 96/1/87

Naturv 1 Binnie and Partners, 1987. Water and waste-water management in the malt brewing industry. TT29/87

Naturv 2 Binnie and Partners, 1987. Water and waste-water management in the metal finishing industry. TT34/87

Naturv 3 Binnie and Partners, 1987. Water and waste-water management in the soft drink industry. TT35/87

Binnie and Partners, 1988. Research on and investigation into the use of physical/chemical techniques of water and waste-water management in the meat processing industry - Volume 1. 127/1/88

Binnie and Partners, 1988. Research on and investigation into the use of physical/chemical techniques of water and waste-water management in the meat processing industry - Volume 2. 127/2/87

-
- Steffen, Robertson & Kirsten, Inc., 1988. Water and waste-water management in the dairy industry : Natsurv 4. TT38/89
- Steffen, Robertson & Kirsten Inc., 1989. Water and waste-water management in the sorghum, malt and beer industries : Natsurv 5. TT39/89
- Steffen, Robertson & Kirsten Inc., 1989. Water and waste-water management in the edible oil industry : Natsurv 6. TT40/89
- Steffen, Robertson & Kirsten Inc., 1989. Water and waste-water management in the red meat industry : Natsurv 7. TT41/89
- Steffen, Robertson & Kirsten Inc., 1989. Water and waste-water management in the laundry industry : Natsurv 8. TT42/89
- Steffen, Robertson & Kirsten Inc., 1989. Water and waste-water management in the poultry industry : Natsurv 9. TT43/89
- WRC, 1990. A guide for the planning, design and implementation of waste-water treatment plants in the textile industry, Part 3 : Closed-loop treatment/recycle options for textile scouring, bleaching and mercerising effluent. TT48/90
- WRC, 1990. Water management and effluent treatment in the textile industry : Scouring and bleaching effluent. 122/1/90
- Steffen, Robertson & Kirsten Inc., 1990. A guide to water and waste-water management in the red meat abattoir industry. TT45/90
- Steffen, Robertson & Kirsten Inc., 1990. Water and waste-water management in the tanning and leather finishing industry : Natsurv 10. TT44/90
- Steffen, Robertson & Kirsten Inc., 1990. A guide to water and waste-water management in the poultry abattoir industry. TT46/90
- Steffen, Robertson & Kirsten Inc., 1990. Water and waste-water management in the sugar industry : Natsurv 11. TT47/90
- Steffen, Robertson & Kirsten Inc., 1991. National industrial water and waste-water survey (NATSURV). 145/1/91
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ANNEXURE A

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INDUSTRIAL AND BUSINESS QUESTIONNAIRE

A. BACKGROUND INFORMATION

1. Name of concern: _____

2. Town/Address: _____

3. Contact person _____

4. Telephone no: _____

5. Give a short but complete description of what the company manufactures and the main activities the company is involved in.

_____	SIC

6. Give a detailed list of the products and/or services that the company manufactures sells or provides and what percentage each represents of total production or turnover

Product/Service	Percentage of total
TOTAL	100

7. Please state the nature of ownership of firm

8. Does the firm own the premises it is occupying?
[]

9. What is the size of the premises ?

10. What is the average number of employees for the last financial year ?

11. What is the firm's average annual turnover ?

TURNOVER CATEGORY	"√"
R0 - R50 000	
R50 000 - R100 000	
R100 000 - R500 000	
R5 00 000 - R1 000 000	
R1 000 000 - R5 000 000	
R5 000 000 - R10 000 000	
R10 000 000 - R50 000 000	
R50 000 000 - R100 000 000	
R100 000 000 + MORE	

B. WATER RELATED INFORMATION

12. Please provide a breakdown of the company's cost structure according to the following elements:

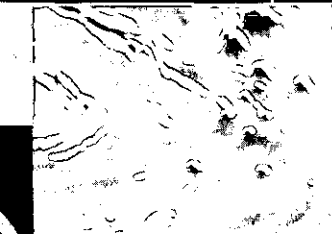
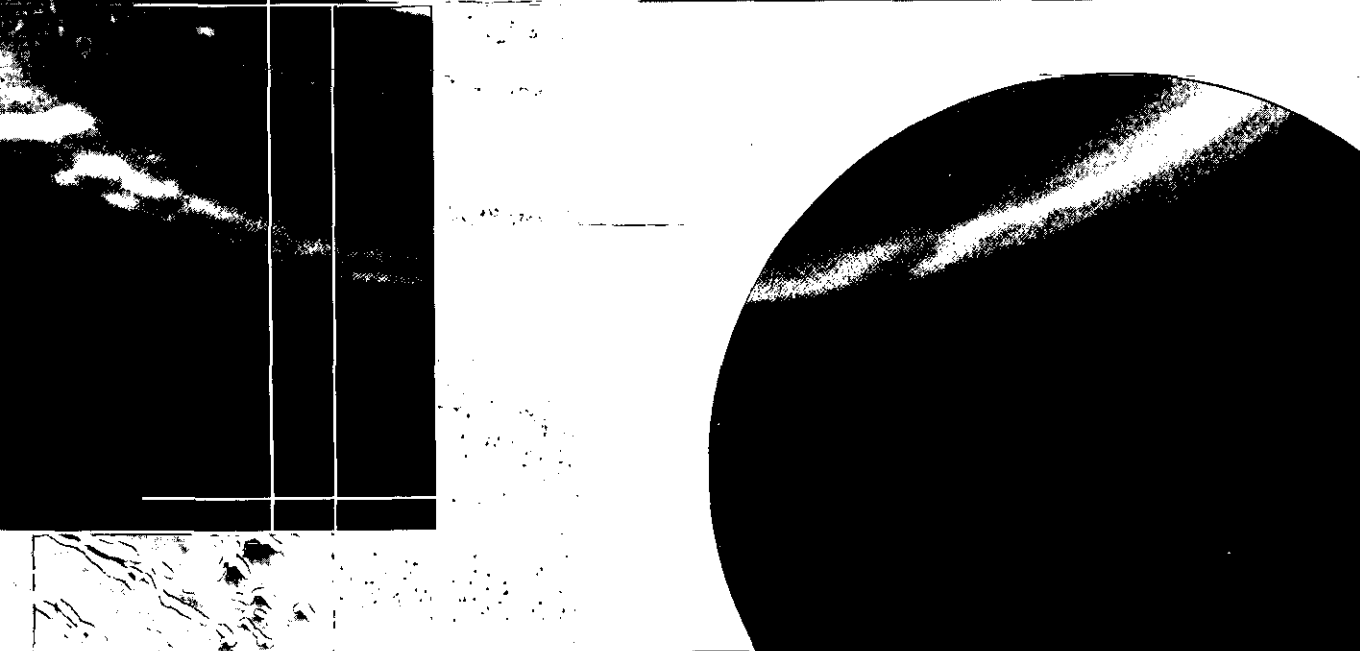
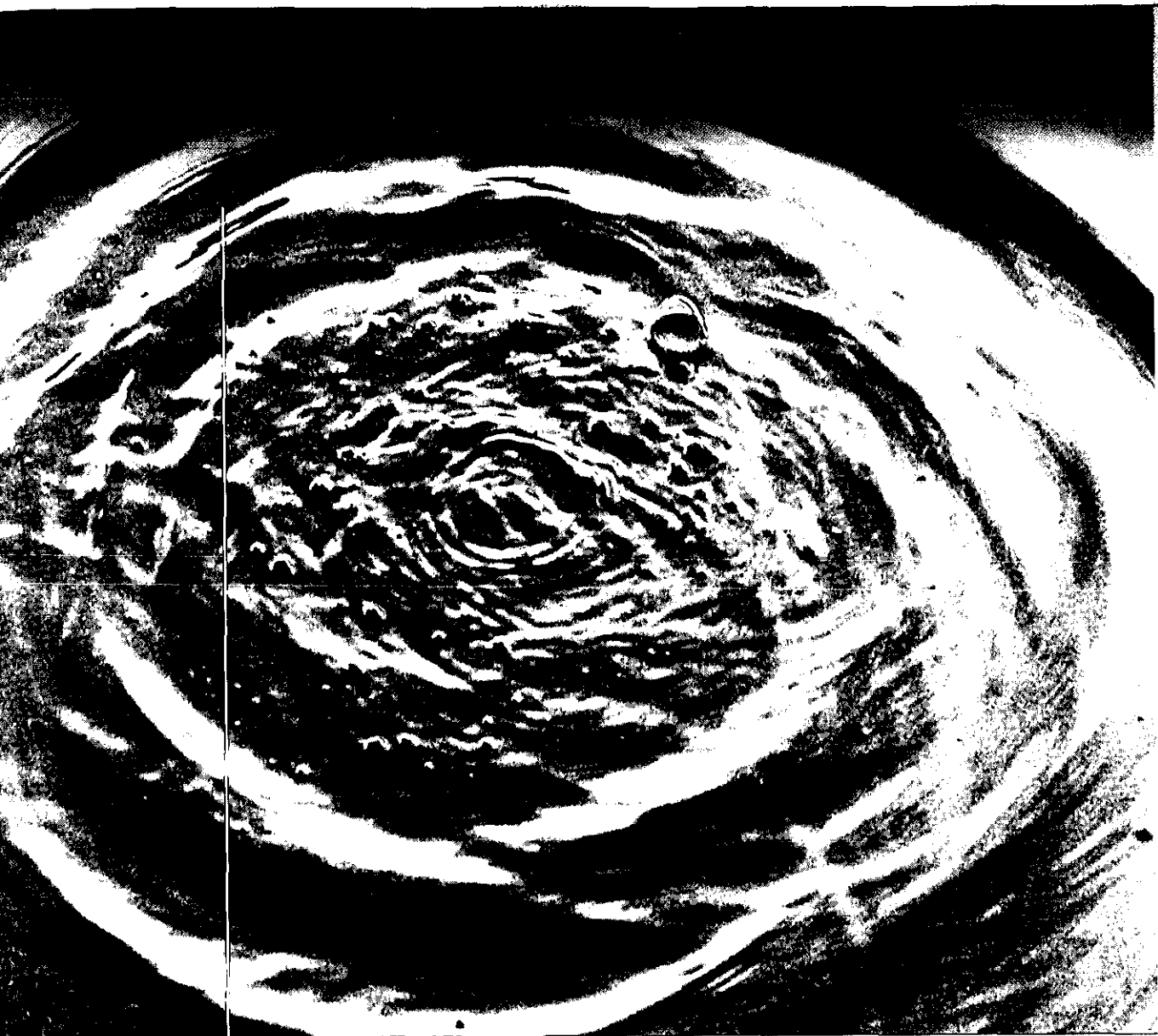
Cost element	%
Water	
Water treatment	
Material	
Stock	
Labour	
Energy	
Admin	
Maintenance	
Plant	
Transport	
Machinery	
Other	
Total	100%
	R

13. For what purposes is water used, i.e. human consumption, cooling, etc.

TDS mg/l		Process 2	decision	Cost
increase	desired level			
200				
400				
600				
800				
1000				
1200				

TDS mg/l		Process 3	decision	Cost
increase	desired level			
200				
400				
600				
800				
1000				
1200				

TDS mg/l		Process 4	decision	Cost
increase	desired level			
200				
400				
600				
800				
1000				
1200				



Water Research Commission

PO Box 824, Pretoria, 0001, South Africa

Tel: +27 12 330 0340, Fax: +27 12 331 2565

Web: <http://www.wrc.org.za>