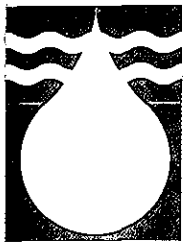


**The Economic Cost Effects of Salinity
MINING SECTOR**

VOLUME IV

Pulles Howard & De Lange Inc

WRC Report No 634/3/00



Water Research Commission 

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VOLUME IV
The Economic Cost Effects of Salinity
MINING SECTOR

by

Pulles, Howard and de Lange Inc

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

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Appendix A: Example of a Mine Survey Questionnaire

Appendix B: Example of Boiler and Demineralisation Plant Information Sheet

Appendix C: Site Reports and Survey Questionnaire Results

**Appendix D: Results of Cost Formula Applications for Evaporative
Cooling Circuits and Demineralisation plants**

1. INTRODUCTION

1.1 PURPOSE

The aim of the study is 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 in financial, economic and social terms.

The research product will be a generic model that makes provision for all possible conceptual elements applicable to salinisation. The model consists of separate equations for the different sectors of the economy. It will be a generalised model and as such applicable to any salinisation problem situation in South Africa.

The purpose of the study is to develop cost equations for sectors of the economy which will reflect the cost of increased salinity levels in water. The economy can be broadly categorised into sectors based on the Standard Industrial Classification of Economic Activities. Since water use is the important aspect in this study, the sectoral disaggregation was modified to include the following sectors:

- Households
- Agriculture
- Industry
- Services
- Feeder Systems
- Natural Environment
- Mining

The mining sector within South Africa is very diverse and a large number of minerals are mined. Water usage patterns and impacts of increased salinity will vary so tremendously throughout the mining sector, that any attempt to conceptualise this diverse behaviour within a model will necessitate a model which is so broad and generalised that it has limited practical utility. For this reason, and due to the almost total lack of information on water usage and quality effects within the other mining sectors, this study focused on gold mining operations only.

2. CONCEPTUAL FRAMEWORK

2.1 ORIENTATION

According to Heynike (1987) there has been a steady increase in salinity of the Vaal River since 1935. This increase in salt content affects the consumer of this water by affecting all components exposed to such water. Therefore, it became necessary to quantify the cost effect of the increase in salinity for the various economic sectors.

The focus of the study is on economic theory which implies that the approach is not aimed at the scientific analysis of issues but rather at conceptualising sectoral behaviour of the economy. The study incorporates the conceptualising of the problems by means of a generalised conceptual model and the application of the model to a specific geographic area, namely the Middle Vaal River area.

Heynike (1987) found that the gold mines experience high costs in replacing damaged and corroded pipelines and fittings caused mainly by circulating mixtures of underground, surface and Vaal River water. It was therefore difficult to differentiate between costs for each water type. However, an attempt

was made to give a cost where Vaal River water was used exclusively. The total cost experienced by the mines is probably much higher than that indicated in his report viz. R10,4 million per annum. Although the overall project concentrates on behavioural aspects, it must be noted that water quality related decisions in the mining industry are technologically and economically driven. In other words, the water management practised in the gold mining industry is dependent on the available technology and whether it is economically viable.

2.2 MAIN ELEMENT OF REFERENCE FRAMEWORK

The general economic reference framework of the integrated model is the input-output (IO) matrix. By applying the input-output matrix approach, both direct and indirect cost effects to the economy are accounted for.

A major salinity problem exists in the Middle Vaal area, between the Barrage and the 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.

2.3 VERIFICATION WITH EXPERTS

A workshop was held with various specialists in the fields present to compile applicable cost formulae in order to quantify the cost implications if the TDS increased for each water circuit on the mines. The results after the application of the cost formulae were validated in a second workshop. The possibility of double-billing needed to be eliminated by reviewing the cost formulae. The cost formulae, after reviewing, follow.

2.4 COMPILATION OF FORMULAE

Conceptual formulae were developed to cover all possible cost elements and did not attempt to distinguish between major and minor costs - as a result, a large number of potential variables were taken into account. These formulae were developed in a workshop with mine water specialists from within the mining industry and corrosion/scaling specialists.

2.4.1 Evaporative Cooling Water Circuits

The evaporative cooling circuits are sensitive to the quality of the make up water introduced to the circuit. Scaling inhibition programmes are currently under way in all the cooling circuits. Biocides and antiscalants are added to the water to control the scaling potential.

As a result of increased make-up water requirements, the blow down volumes would also increase, which may lead to increased disposal costs. The following conceptual cost formula was developed for the evaporative cooling water circuits:

$$EC = f(WSC; TC; DC; WM)$$

where WSC = water supply cost; TC = treatment chemical cost;
DC = discharge cost; WM = water management cost.

The water supply cost is expected to increase significantly as the TDS in the make-up water increases. The make-up volumes in the evaporative cooling circuits will increase due to fewer cycles being run as the TDS in the water increases. The number of cycles of concentration is the main parameter influencing the cost in the evaporative cooling circuits. The revised formula takes the cycles of concentration into account by including the TDS of the system in the formula. The fewer cycles of

concentration obtained in an evaporative cooling circuit, the more make-up water is required. The cost is therefore related to the make-up volumes and the water unit cost. If the water unit cost increases, the costs calculated for the mining sector would need to be modified accordingly as current calculations have assumed that the raw water cost will remain unchanged if the TDS increases. The formula for the water supply cost is as follows:

$$\Delta WSC = \left(\frac{(TDS_s - TDS_o)}{(TDS_s - TDS_n)} \times MV_o \times WC_n \right) - MV_o \times WC_o$$

where TDS_s = TDS system
 MV_o = Make-up volume old
 WC_o = Water unit cost old

TDS_n = TDS new
 WC_n = Water unit cost new
 TDS_o = TDS old

The treatment chemical cost will increase with the increased TDS in the make-up water. The treatment chemical cost is directly affected by volume of make up water and the revised incremental treatment chemical cost formula is therefore similar to the revised incremental water supply cost formula. The revised treatment chemical cost formula includes the TDS of the system. The mines use chemical treatment consulting companies to treat the water in the cooling circuits. The management cost of the water treatment companies is built into the chemical cost. The formula used to calculate the incremental treatment chemical cost is as follows:

$$\Delta TC = \left(\frac{(TDS_s - TDS_o)}{(TDS_s - TDS_n)} \times TC_o \right) - TC_o$$

where TDS_s = TDS system
 TC_o = treatment chemical cost

TDS_n = TDS new
 TDS_o = TDS old

The discharge cost (DC) was found to be a function of the blow down volume together with a site specific discharge cost (X_{DC}). The blow down volume, in essence, is governed by the TDS of the system which directly affects the number of cycles, thereby controlling the volumes of make up water required and the resulting blow down. The revised formula takes the TDS of the system and the make up volumes into account. The site specific discharge cost (X_{DC}) also depends on the regulations which the mine needs to comply with, the treatment or disposal technology employed and the ability of the system in use to accommodate the increased blow down volume. The effluents are discharged into evaporation pans and storage dams via storm drains. Currently, no costs can be ascribed to the discharge of effluents. The capacities of these systems can comfortably accommodate the resulting increased blow down volumes if the TDS increases. A discharge cost can however result in the future due to the possible imposition of stricter legislation. The discharge cost formula is as follows:

$$\Delta DC = \left(\frac{(TDS_s - TDS_o)}{(TDS_s - TDS_n)} - 1 \right) \times MV_o \times X_{DC}$$

where TDS_s = TDS system
 TDS_o = TDS old
 X_{DC} = site specific discharge cost

TDS_n = TDS new

MV_o = make up volume old

The water management cost on the mines is the sum of the maintenance chemicals cost, the management staff cost and control equipment cost. The maintenance chemical cost is calculated at approximately R 1 000 per fridge plant (or spray pond) per annum. The control equipment costs are minimal in the fridge plants and spray ponds. The management staff cost at each mine was calculated

using the average 1995/1996 values of the salary packages offered at the mines for each level of the Patterson Grading System. The percentage of time spent on water management in the cooling circuits was used in the above calculation. The management staff cost is considered to be constant as the TDS increases. Therefore, no incremental costs are associated with management. The increased cost of the water treatment consultants is built into the chemical costs.

The data for the total water supply cost and treatment chemical cost in each cooling circuit on each mine were totalled per annum for each TDS level and divided by the tonnage mined per annum. The average was calculated and multiplied by the total tons mined for all mines in the Middle Vaal Area to obtain a total cost per annum.

2.4.2 Mine Service Water Circuits

The chilled and unchilled water circuits are combined under the heading of mine service water circuits and most cases management options C and D would apply in this situation. However, mines would keep close control on the health related aspects and would modify water treatment systems if required TDS would probably not have a major effect on health related parameters.

Due to the very high TDS levels currently found in mine service water circuits, the TDS increases in the supply water being considered for this project would have no significant effect on corrosion rates within the reticulation system. The more important components affecting corrosion in these waters would be dissolved oxygen and pH.

The only significant cost components would be those related to scaling and discharge of excess water. With regard to the scaling, the more important consideration was the scaling potential for calcium sulphate and not calcium carbonate.

The following conceptual formula applies:

$$SW = f(SC; DC)$$

2.4.2.1 Scaling Cost

The following conceptual formula applies to the scaling cost:

$$SC = f(WQ; TDS; Ca; SO_4)$$

The main complicating factor in defining a universal cost formula is the fact that the existing mine service water systems have highly variable qualities (e.g. TDS ranges from 200 mg/l- 10 000 mg/l). The water quality (WQ) is affected by various factors on a site specific basis as follows:

$$WQ = f(WS; RF; GL; MT; MA; FI)$$

In an attempt to address the variable and site specific water quality, use is made of the calcium sulphate precipitation potential (PPS) which reflects and incorporates a number of water quality parameters. A negative PPS indicates a water which is not scaling with regard to calcium sulphate while a positive PPS indicates a scaling water. The PPS value indicates the mass of calcium sulphate in mg which will precipitate per litre of water. The following four potential scenarios are possible:

$$PPS_o < 0 \text{ and } PPS_n < 0 \quad \text{No scaling problem exists}$$

PPS _o < 0 and PPS _n > 0	Water system converts from non-scaling to scaling regime and a change in management approach and possibly treatment will be required - probable cost increase.
PPS _o > 0 and PPS _n < 0	Water system converts from scaling to non-scaling and a change in management approach will be required - probable cost saving.
PPS _o > 0 and PPS _n > 0	Increased scale formation with increased associated cost, or increased purchase of make-up water (reduced RF) to get PPS _n ≈ PPS _o .

2.4.2.2 Discharge Costs

The following conceptual formula was developed for the discharge costs:

$$DC = f(DV; WQ; WMP; WLA)$$

The impacts of the applicable water management plan (WMP) and the mine's waste load allocation (WLA), besides being the most significant, are also extremely site specific. The relationship with WLA is shown below.

$$\text{Is } DV \times WQ_n > WLA? \quad \text{If yes, } \Delta DC > 0; \quad \text{If no, } \Delta DC = 0$$

The following relationship can also be defined:

$$DV = f(PPS), \text{ where PPS is a function of TDS for a given study area}$$

2.4.3 **Metallurgical Plant Water Circuits**

The water quality in most of the plant water circuits already has a very high TDS and the water quality is closely related to the mine service water circuit quality. As a result, an increase in supply water TDS will have no significant effects on the mill circuits (milling, screening, crushing, ore transport and thickening). It may even be possible that increased TDS will have a beneficial effect on filtration processes.

Specific circuits where problems may arise are discussed below.

2.4.3.1 Flotation Circuits

Increased TDS will result in an increase in the cost of treatment chemicals and the following formula applies:

$$\Delta TC = \frac{TDS_n \times TC_o}{TDS_o} - TC_o$$

TC_o is site specific and will be a function of the concentration factor and the metallurgical process.

2.4.3.2 Electrolytic Processes

Electrolytic processes tend to be sensitive to water quality and typically to very specific ions such as chloride or fluoride. In some cases the negative reaction may be very severe.

The negative effects are very site and ion specific and cannot be modelled or predicted on the basis of TDS. Where such severe reactions occur, either or both of management options A and B will be applied in order to maintain an acceptable system water quality. Accordingly, the following conceptual formula can be developed for the electrolytic processes affected by increased TDS:

$$\sum_1^t DEP = \sum_1^t DWSC + \sum_1^t DWT + \sum_1^t DDC$$

This conceptual formula was further refined to produce a composite cost formula as follows:

$$\sum_1^t \Delta EP = \sum_1^t \left\{ \left[\left(MV_o + \left(\frac{MV_o \times (TDS_n - TDS_o)}{SR} \right) \times \left(\frac{(1 - WR)}{WR} \right) \right) \times WC_n - (MV_o \times WC_o) \right] + \left[\frac{MV_o \times (TDS_n - TDS_o) \times XWT}{SR} \right] + \left[\left(MV_o + \left(\frac{MV_o \times (TDS_n - TDS_o)}{SR} \right) \times \left(\frac{(1 - WR)}{WR} \right) \right) \times \frac{XDC}{MV_o} \right] \right\}$$

2.4.3.3 Other Processes

A number of specific users within the metallurgical plants can be expected to be sensitive to increased TDS. These users include gland service water, carbon elution and regeneration, reticulation piping, furnace cooling jackets and steam generation. These processes and the necessary formulae are being looked at and developed within other sectors.

2.4.4 **Slimes/Discard Irrigation Water Circuits**

In irrigating vegetation which has been or is being established on slimes dams or discard dumps, there is a general need to maintain the TDS below 1500 mg/l. This is typically done by diluting the source water (such as mine service water) with RWB. Therefore, if the RWB TDS increases, then additional volumes will need to be purchased to maintain the irrigation water TDS below 1500 mg/l, i.e. management option A will be applied. Minor additional scaling problems may be experienced with the microjets which are used in the irrigation system. The applicable conceptual formula is therefore as follows:

$$IW = f(MV; WC)$$

The overall cost formula for the irrigation water circuit has been defined as an incremental cost resulting from an increased TDS as follows:

$$\Delta IW = \frac{WC_n \times MV_o (TDS_{sw} - TDS_o)}{(TDS_{sw} - TDS_n)} - (WC_o \times MV_o)$$

2.4.5 Boiler and Demineralisation Plants

The contributing factors to the cost of the boiler system are:

- increased water volume used due to increased blowdown at increased TDS
- increased chemical dosing

The boilers generally operate to a maximum of 3 000 - 3 500 TDS. Thus, the relationship can be calculated that at 2 000 ppm starting TDS, 15 cycles can be used, whereas at 500 ppm, this is reduced to 6 cycles and at 1 200 ppm, only 2,5 cycles can be employed. The increased water cost will be significant.

On the chemical dosing front, there will be an increase in the amount of softeners and other chemicals required. The increase should be linear over the range of the study, although the linearity is dependent on the actual chemical mixtures used. It is expected that the increased cost in the water will be of greater significance than of the increased chemical requirements.

The incremental boiler cost is in essence the same as the evaporative cooling cost formula. Therefore, the data was applied to the evaporative cooling circuit cost to obtain an incremental cost for the boilers.

Therefore, the following cost formulae apply:

Boiler Cost = f(WSC; TC) where WSC = water supply cost; and
TC = treatment chemical cost;

$$\Delta WSC = \left(\frac{(TDS_s - TDS_o)}{(TDS_s - TDS_n)} \times MV_o \times WC_n \right) - MV_o \times WC_o$$

where TDS_s = TDS system TDS_n = TDS new
 MV_o = Make-up volume old WC_n = Water unit cost new
 WC_o = Water unit cost old TDS_o = TDS old

$$\Delta TC = \left(\frac{(TDS_s - TDS_o)}{(TDS_s - TDS_n)} \times TC_o \right) - TC_o$$

where TDS_s = TDS system TDS_n = TDS new
 TC_o = treatment chemical cost TDS_o = TDS old

The capital cost component for new plant can be disregarded as it will be highly unlikely to occur. The chemical cost may be fixed if overdosing is currently employed. It is expected that the major cost component will be the water costs. This is linear to the ratio between the total volume of water required and the number of cycles for which the water can be used. The formula essentially becomes the same as that for the evaporative cooling water circuits for the mines.

The conceptual formulae presented have been rationalised and simplified to the point where they have been transformed into useful formulae which can be incorporated into an economic model.

3. CASE STUDY AREA

3.1 INTERPRETATION OF STUDY AREA

The study area encompasses 80 to 90 percent of South Africa's gold mining industry. The study area is not homogenous in terms of the supply water quality and three different Water Boards are involved. At the upper end of the study area, the gold mines in the Carletonville area are supplied by Rand Water with water abstracted from the Vaal Dam, Vaal River and Vaal Barrage, i.e. water from outside the study area. In the Stilfontein, Klerksdorp, Orkney area, the gold mines are supplied by the Western Transvaal Regional Water Company with water abstracted from the Vaal River near Stilfontein. In the Welkom area (which lies outside the catchment boundaries of the study area) the gold mines are supplied by Goudveld Water with water abstracted from the Vaal River near Bothaville.

For the purposes of the study, mines in the following areas were surveyed:

- Klerksdorp/Orkney/Stilfontein
- Welkom/Virginia/Allanridge

The gold mines within the study area differ substantially with regard to the following important factors:

- ore / reef type mined
- age of mine
- quantity and quality of fissure water entering mine water circuits
- mine service water quality
- Board water supply quality
- effluent management and treatment strategies
- water quality related problems
- type of water circuits (open, closed or complex)

3.2 PROFILE OF GOLD MINING IN MIDDLE VAAL AREA

The gold mining industry is a relatively small user of water in South Africa and only uses about 1 percent of the total water supplies - this proportion is obviously substantially larger within the gold mining regions. The overall water balance for the gold mining industry is summarised in Figure 1 below. This balance, derived by Pulles (1992), differs substantially from that reported and used by Heynike (1987).

The information shown in Figure 1 indicates that the gold mining industry uses large volumes of water in its operations (73 800 l/s) which is equivalent to approximately three times the total volume of water sold by the Rand Water Board (25 300 l/s) in 1990. However, of this total water, only 6 600 l/s, or 9 percent, of the water is brought into the mine water circuits from Water Boards, rivers and boreholes. Five percent of the water requirement is supplied by underground fissures while 86 percent is water which is reused (with or without treatment).

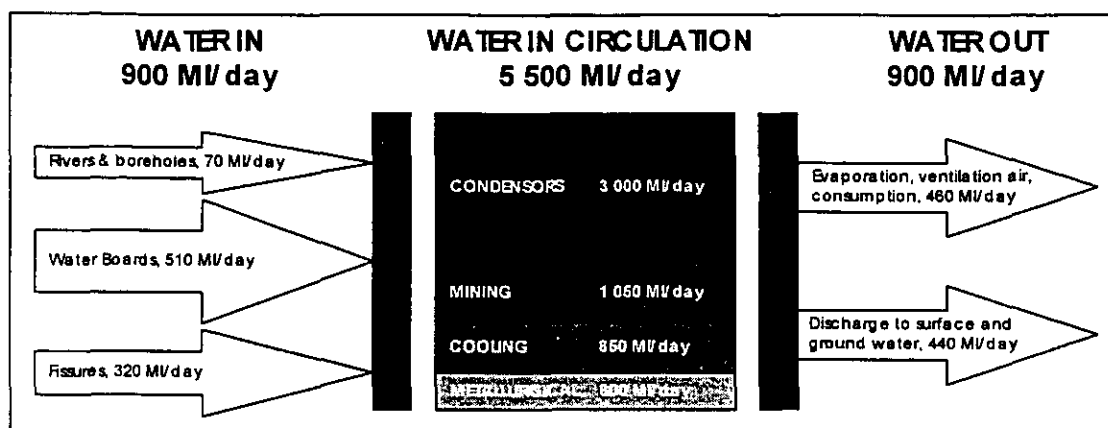


Figure 1 : Summary Water Balance for the Gold Mining Industry - 1990

The water used in the different water circuits in a gold mine can be assessed in terms of volume of water used per ton of rock mined. Gold mining encompasses 80 to 90 percent of the mining activity in the area. The increase in salinity in the Vaal River has certain cost implications for the gold mining industry which relies on the river as a source of water. Basic water usage in gold mining can be categorised as follows:

- condensor and evaporative circuits for surface and underground fridge plants, compressors, etc.
- chilled water for cooling of ventilation air through bulk air coolers and spray chambers
- chilled, or unchilled water for mining purposes (conventional stoping, hydropower, mechanised mining) for lubrication, cooling, cleaning and dust suppression
- metallurgical operations (primarily as a carrier and transport medium for ore, chemicals, gold and waste materials) in gold, uranium and acid plants
- steam generation (demineralised water for boilers)
- engineering and general maintenance/housekeeping purposes (gland service water, workshops, washing down, cleaning)
- irrigation of slimes dam vegetation, gardens, sports facilities, etc.
- domestic use (underground, surface offices, hostels, mine villages, etc.)
- recreational use

The increased salinity in the water supplied and the reticulation systems causes significant scaling, which can affect the operation and some of the processes in the plants.

The quality of water used for domestic purposes and the resultant effects of increased salinity will be as determined for the Domestic sector in another component of this project.

The quality of water used for recreational purposes varies widely within the mining industry. Recreational facilities are provided on different water bodies which can vary from relatively uncontaminated natural surface water impoundments to pollution control dams containing highly contaminated effluents. The effects of increased salinity will obviously differ, depending on the nature of the impoundment and the type of recreational activities practised. This aspect is also being addressed in the Services sector of the project.

For the purpose of this study four water circuits were identified, namely; evaporative cooling, mine service water; metallurgical plant water and irrigation water circuits.

4. DATA GATHERING

4.1 METHODOLOGY

Water use in the gold mining industry was divided into the four water circuits. The variables determining the total cost of the increased TDS in the water to the mining industry were identified in terms of formulae and was quantified by extracting information from specially developed survey questionnaires. An example of the survey questionnaire is shown in Appendix A. The data from the survey questionnaires were transformed into a format that could be applied to the cost formulae. The results were validated in a workshop and the cost formulae reviewed. The second set of results were revalidated and taken as a true representation of the expected costs that will be incurred to the gold mining industry due to an increase in TDS in the Board Water. Subsequent to the completion of the survey questionnaires, a data sheet was compiled regarding the boiler and demineralisation plants on the mines surveyed previously, as shown in Appendix B.

4.2 SAMPLING METHOD

The survey questionnaires were designed in order to obtain information pertaining to the four water circuits. Six mines were identified according to their water supply and geographic areas. Two of the larger mines sampled are supplied water by Western Transvaal Regional Water Company and the remaining four by Goudveld Water. The six mines surveyed are indicated in Table 1.

Data for the water volumes, water quality and the discharge paths and sinks were collected. Data on water quality related problems experienced in the circuits and treatment were collected.

Table 1: Mines surveyed within study area

MINE	SHAFTS	PLANTS	TONS MINED / ANNUM
Hartebeestfontein	6	4	4 933 000
President Steyn	4	2	3 600 000
Vaal Reefs	10	5	12 704 000
Harmony	7	3	6 572 000
Western Holdings	8	1	3 360 000
Beatrix	2	1	2 364 000
TOTAL	37	16	33 533 000

The mines surveyed represent 57,15 % of the total tonnage mined per annum in the area.

The current water management and the future water management at various TDS scenarios were identified. The following management options are available to the mines and were incorporated in the survey questionnaire:

- Option A: Purchase increased supplies of fresh water in order to control the water to a constant salinity;
- Option B: Treat the water in order to control the water to a constant salinity and hold the volumes input water constant;
- Option C: Allow the water quality to deteriorate and manage the secondary problems which will be manifested as corrosion, scaling and process inefficiencies;
- Option D: Treat the effluents to meet discharge limits.

4.3 FIELD REPORT

The survey questionnaire revealed an important aspect where the management of the water circuit is concerned. The management and treatment of the water in the various circuits is generally optimised in terms of available technology, cost effectiveness and availability of water. The water restrictions which were in place at the time of the study were found to place considerable restraints on the volumes of the make-up water that could be purchased. The water restrictions are however a temporary measure and were therefore disregarded in the study.

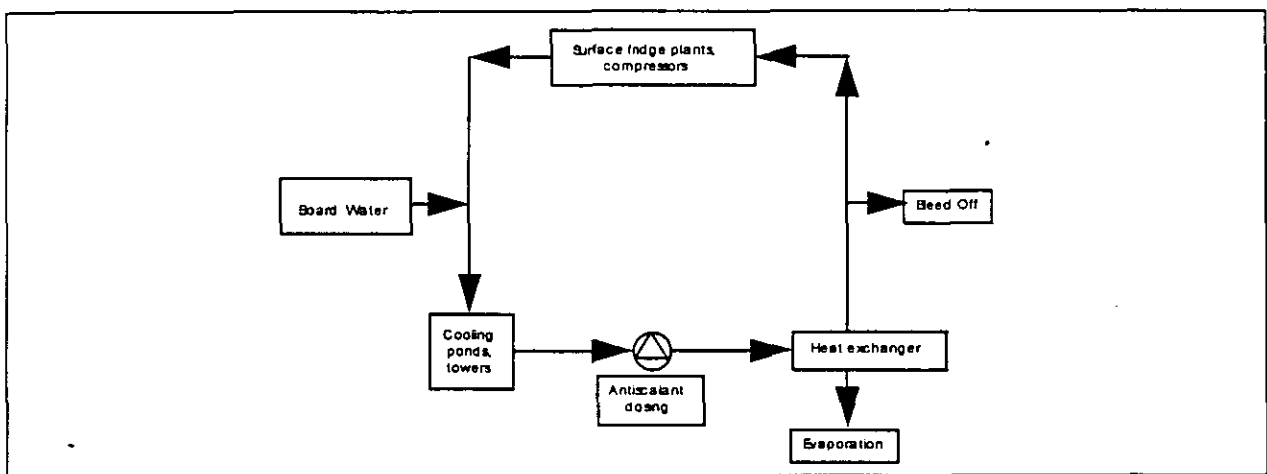
The results of the survey questionnaire are summarised below. The detailed results of individual survey questionnaires are shown in Appendix C.

Due to the nature of the boilers on the mines and the extensive network of people involved, further data is being awaited. As the available results show, the water and chemical treatment costs can have high incremental costs.

4.3.1 Evaporative Cooling Water Circuits

The cooling circuits include surface and underground fridge plants. The evaporative cooling circuits were found to be sensitive to the quality of the make-up water introduced to the cooling circuit. All the mines surveyed experience scaling, fouling and, to a lesser degree, corrosion in the boilers, fridge plants and compressors. Scaling inhibition programmes are currently under way in all the cooling circuits. Biocides and antiscalants are added to the water to control the scaling potential. All the mines surveyed use Water Board water, either Goudveld Water or Western Transvaal Regional Water, as make-up water. The mines discharge the effluents from the cooling circuits to evaporation pans or to the metallurgical plants. Possible costs associated with the discharge are the pumping costs, however, according to the survey, the discharge is bled off into storm water drains or directly into the evaporation pans or storage dams and no pumping costs are incurred. The water management practice that will be employed if the TDS level of the Board water increases, is to purchase increased supplies of fresh water in order to control the water in the circuit to a constant salinity.

A simplified typical water reticulation diagram of the cooling systems is shown below.

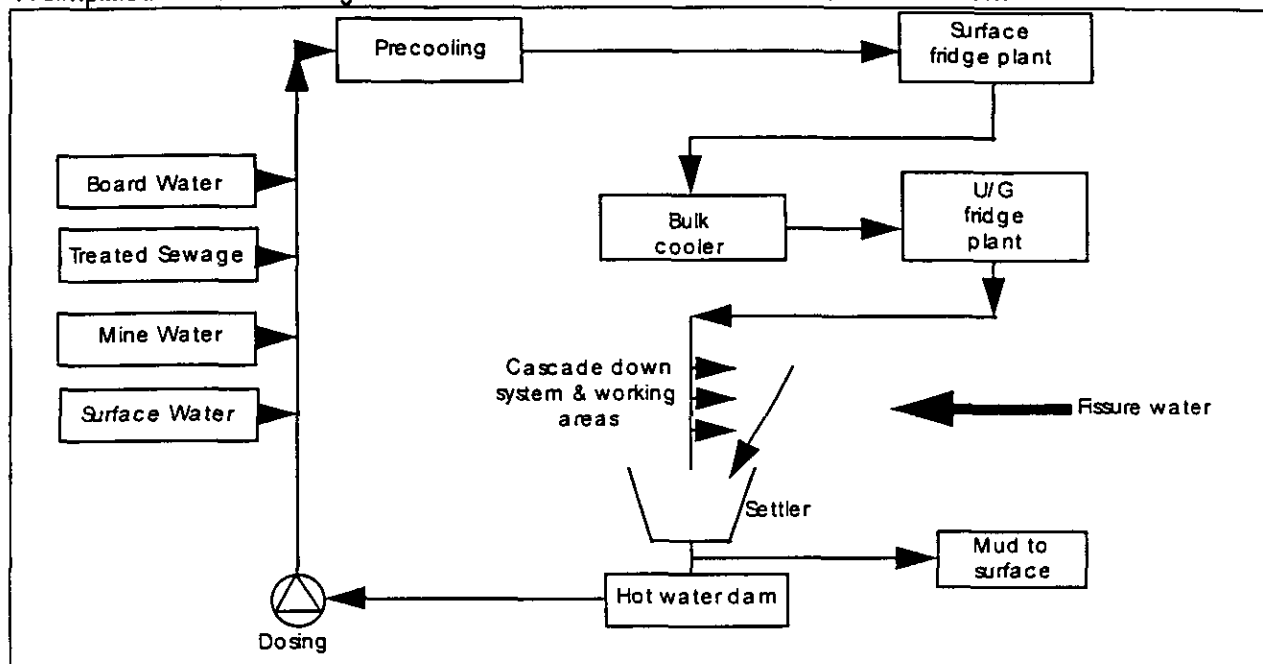


4.3.2 Mine Service Water Circuits

Water quality related problems experienced in the mine service water circuits are scaling, corrosion, erosion and, in some mines, high amounts of chlorides. The mines treat the service water by flocculating and settling out the suspended solids to prevent severe erosion in the circuits. Liming is

used to control the pH and so doing control the potential for scaling and corrosion. In addition, the mine service water requires disinfecting. Although the chemical treatment costs of the mine service water are high, the make-up water used is not only Board water. The make-up water in the service water circuits is a combination of Board water, treated sewage water, mine water, fissure water and water from surface storage dams.

A simplified reticulation diagram for the mine service water circuits is shown below.



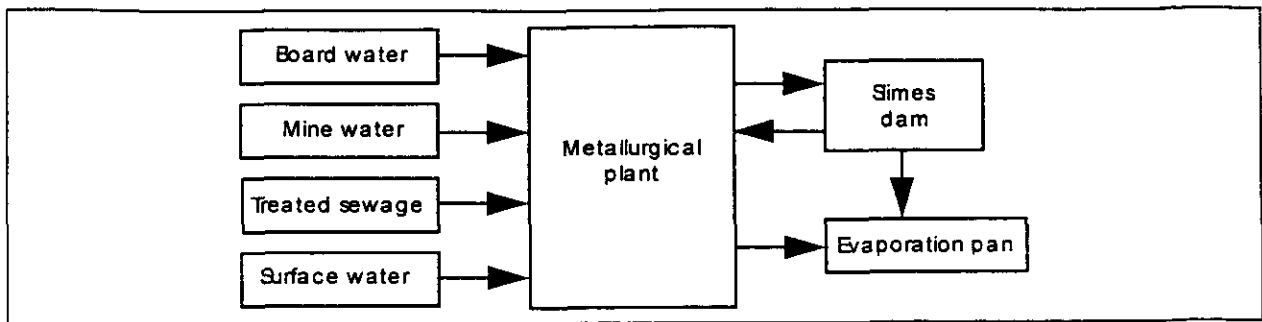
The effluent or bleed off service water is discharged to surface dams, evaporation pans, to the plants as process water or to slimes dams. Therefore the incremental discharge cost for the excess mine service water is currently regarded as zero. The possibility of an increase in the discharge cost has not been ruled out. New and stricter legislation governing the discharge quantities and quality may result in costly effluent discharge treatment systems. The current storage capacities of the evaporation pans are believed to be sufficient for current effluent discharge.

The salinity of the water is currently controlled by purchasing increased supplies of fresh water (Board water, water from surface storage dams or elsewhere on the mine).

4.3.3 Metallurgical Plant Water Circuits

The process plant water circuits in the metallurgical plants and the relevant water quality management problems depend on the different process stages which are used. No sensitive water users were identified in the plants during the mine surveys. The metallurgical plants receive a combination of Board water, mine water, treated sewage, slimes dam return water, and water from surface storage dams. The water is not treated in the metallurgical plants to prevent scaling or corrosion. The metallurgical plant effluent is discharged to slimes dams and evaporation pans. The costs that can be ascribed to the discharge of the effluents are the pumping costs.

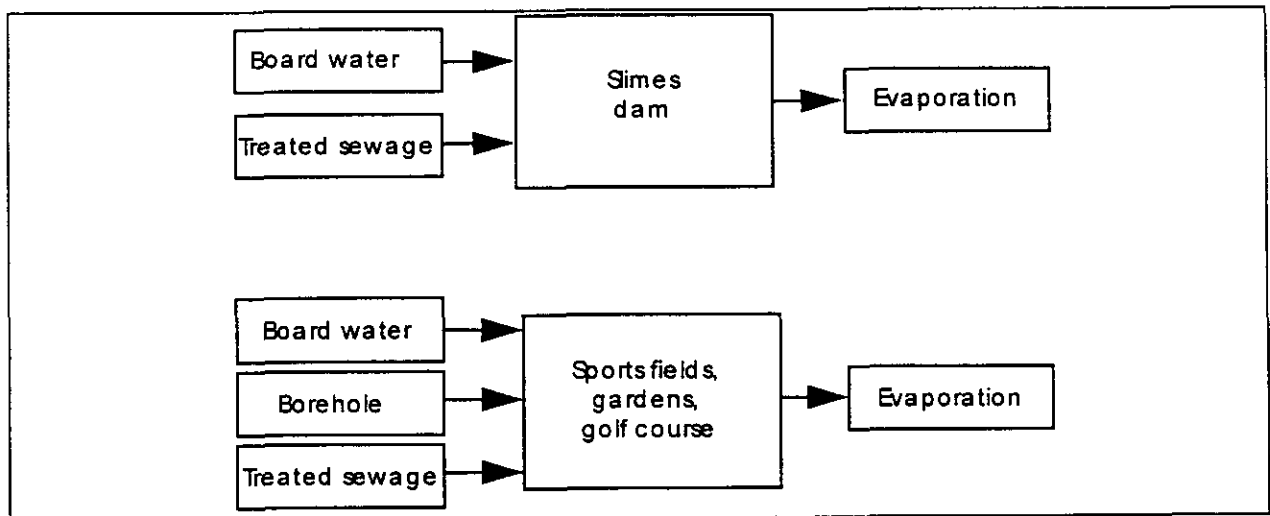
A schematic of the basic water balance of a metallurgical plant, representing all the mines surveyed, is shown below.



4.3.4 Irrigation Water Circuits

The irrigation water circuits on the mines surveyed can be divided into two main categories. These are irrigation circuits on the slimes dams and irrigation circuits for various sports fields, gardens and golf courses. The water used in the irrigation circuits on the slimes dams is Board water and treated sewage in some instances. The sports fields and gardens are irrigated with treated sewage, borehole water and Board water. No water output occurs due to consumption and the evaporative water loss in the irrigation circuits. The water is not treated in the irrigation circuits in any way.

Simplified reticulation diagrams of the two irrigation circuits are shown below:



4.3.5 Boiler and Demineralisation Plants

The data obtained at this stage from the mines show that a large variety of demineralisation and softening plants are in use. The make up water used in these circuits is Board water. The effluent or spent regenerant are discharged to evaporation dams, sewage plants or used around the boiler areas for cleaning purposes. No costs are associated with the discharged effluents. The capital cost of a new demineralisation or softening plant was excluded due to the very small probability of a new plant being built.

4.4 ANALYSIS OF SALIENT FEATURES

The water quality problems which result from the increased dissolved salts depend on the nature of the salts and the subsequent usage of the water. In general terms, an increase in dissolved salts may lead to corrosion problems, depending on the materials used in the particular water reticulation system. In cases where the dissolved salts may include high levels of calcium, significant problems may be experienced as a result of scaling of pipelines and heat exchanger tubes. Bosman and Britz (1984)

reported that a scale deposit of only 0,3 millimetres in depth in a heat exchanger could result in a 10 percent increase in power consumption by a refrigeration plant for the same output.

Based on the field report, it can be concluded that the only water circuits that will be significantly influenced by the increasing TDS of the Board water are the evaporative cooling water circuits. The evaporative cooling water circuits are dependent on good quality make-up water to function efficiently. The boiler and demineralisation plants, although relying on good quality Board Water, do not have such a significant incremental cost.

5. TRANSFORMATION OF DATA

The costs that can be applied to the Cost Accumulation Matrix are the water supply cost (as water), treatment chemical cost (as chemicals) and the labour or management cost (as labour) for each TDS level as shown in the table below.

5.1 RESULTS OF THE COST FORMULAE APPLICATION

5.1.1 Evaporative Cooling Circuits

Appendix D shows the results obtained after application of the cost formulae.

The first set of calculations assume a standard optimal functioning evaporative cooling circuit with a TDS in the system of 3 000 mg/l . A standard TDS in the system of 3 000 mg/l will be used as well as the actual TDS of the system to illustrate the sensitivity of the evaporative cooling circuits to the number of cycles of concentration. However, it is possible that this underestimates the total cost in the evaporation systems. Therefore, the actual TDS of the system is applied to the cost formula in a second round of calculations.

The total incremental cost to the mining sector, representing the mining industry in the study area, was calculated in two ways. Firstly, the average total cost per ton mined is multiplied with the total tons mined in the area to obtain a total cost for the industry. The second method takes the factored approach. The total of the mines surveyed produced 57, 15 percent of the total tons mined in the area. The total incremental cost for the mines surveyed is multiplied by a factor of 1.7497 ($1/0,5715$) to obtain a total cost for the whole mining industry in the study area.

The water supply cost depends on the water unit cost. The new water unit cost (WC_n) is however unknown and the cost used in the formula is that of the current water unit cost (or old water unit cost, WC_o). The make up volumes in the evaporative cooling circuits will increase due to fewer cycles being run as the TDS in the water increases. The cost is therefore related to the make-up volumes, TDS of the system and the water unit cost. (NOTE: If the unit cost does indeed increase, then the costs calculated for the mining sector would need to be modified accordingly, as the calculations in this report have assumed that the raw water cost is unchanged).

The chemical treatment cost increases with the increased TDS in the make-up water. However, it must be noted that the chemical treatment cannot control the salinity or TDS of the water, but controls the secondary problems which manifest as corrosion, scaling and erosion. The chemical treatment cost is directly affected by the TDS in the water. The water can, however, only be treated effectively up to a certain level of TDS. The TDS of the system (TDS_s) was averaged at 3 000 mg/l . The treatment chemical cost (TC_o) is the current total cost of the chemical treatment in the evaporative cooling circuits. The mines use chemical treatment consulting companies to treat the water in the cooling circuits. The

management cost of the water treatment companies is built into the chemical cost and is therefore excluded from the water management cost calculations.

The discharge cost (DC) is considered to be a function of the make up volume, TDS of the system together with a site specific discharge cost (X_{DC}). The discharge cost depends on the regulations which the mine needs to comply with, the treatment or disposal technology employed and the ability of the system in use to accommodate the increased blow down volume. The only costs that are associated with the discharge of effluents are the pumping costs. The mines surveyed, however, do not pump the effluents from the evaporative cooling water circuits. Therefore no costs can be ascribed to the discharge. The effluents are discharged into evaporation pans and storage dams via storm drains. The capacities of these systems can comfortably accommodate the resulting increased blow down volumes resulting from the increased TDS.

The water management cost on the mines is the sum of the maintenance chemicals cost, the management staff cost and control equipment cost. The control equipment costs are minimal in the fridge plants and spray ponds in comparison to the operating costs. The management staff cost at each mine was calculated using the average 1995/1996 values of the salary packages offered at the mines for each level of the Patterson Grading System. The percentage of time spent on water management in the cooling circuits was used in the above calculation. The management staff cost is considered to be constant as the TDS increases. Therefore, no incremental costs are associated with management. The increased cost of the water treatment consultants is built into the chemical costs.

Table 2 shows a comparison of the results of the calculations for each TDS scenario using the different calculation techniques.

The average current TDS of the Board water is between 400 mg/l - 600 mg/l . This implies that a TDS lower than 600 mg/l in the make up water can result in a cost saving. The negative incremental costs shown in Table 2 can be regarded as a cost saving in Rands for the mining industry.

Figure 2 presents the results of the different calculation methods in Table 2. Figure 2 shows how similar the results are and that the average can be used to estimate the total incremental cost incurred to the mining industry. This takes into account the actual TDS of the evaporative cooling systems as they are currently operating as well as the costs of cooling systems when functioning optimally.

Table 2: Comparison of the total cost for the mining sector using the different calculation techniques.

TDS (mg/l)	200	400	600	800	1000	1200
TDS OF 3000 IN SYSTEM						
Revised formula @ $TDS_S = 3000$ (R/t basis)	-3 422 650	-1 564 640	86 740	3 324 860	6 649 720	10 365 740
Revised formula @ $TDS_S = 3000$ (factor basis)	-3 181 488	-1 535 014	383 837	2 651 560	5 372 835	8 698 835
Average for industry @ TDS 3000	-3 302 069	-1 549 827	485 289	2 988 210	6 011 278	9 532 288
ACTUAL TDS IN SYSTEMS						
Revised formula @ TDS_S actual (R/t basis)	-5 182 870	-2 542 540	782 320	5 574 030	12 223 750	22 002 750
Revised formula @ TDS_S actual (factor basis)	-5 152 646	-2 640 904	626 639	5 087 244	11 642 100	22 618 524
Average for industry @ TDS actual	-5 167 758	-2 591 722	704 480	5 330 637	11 932 925	22 310 637

The total incremental cost for the water supply and chemicals at each TDS scenario is shown below and can be applied to the cost accumulation matrix. The value represents the incremental total in Rands for all the gold mines in the Middle Vaal area per year.

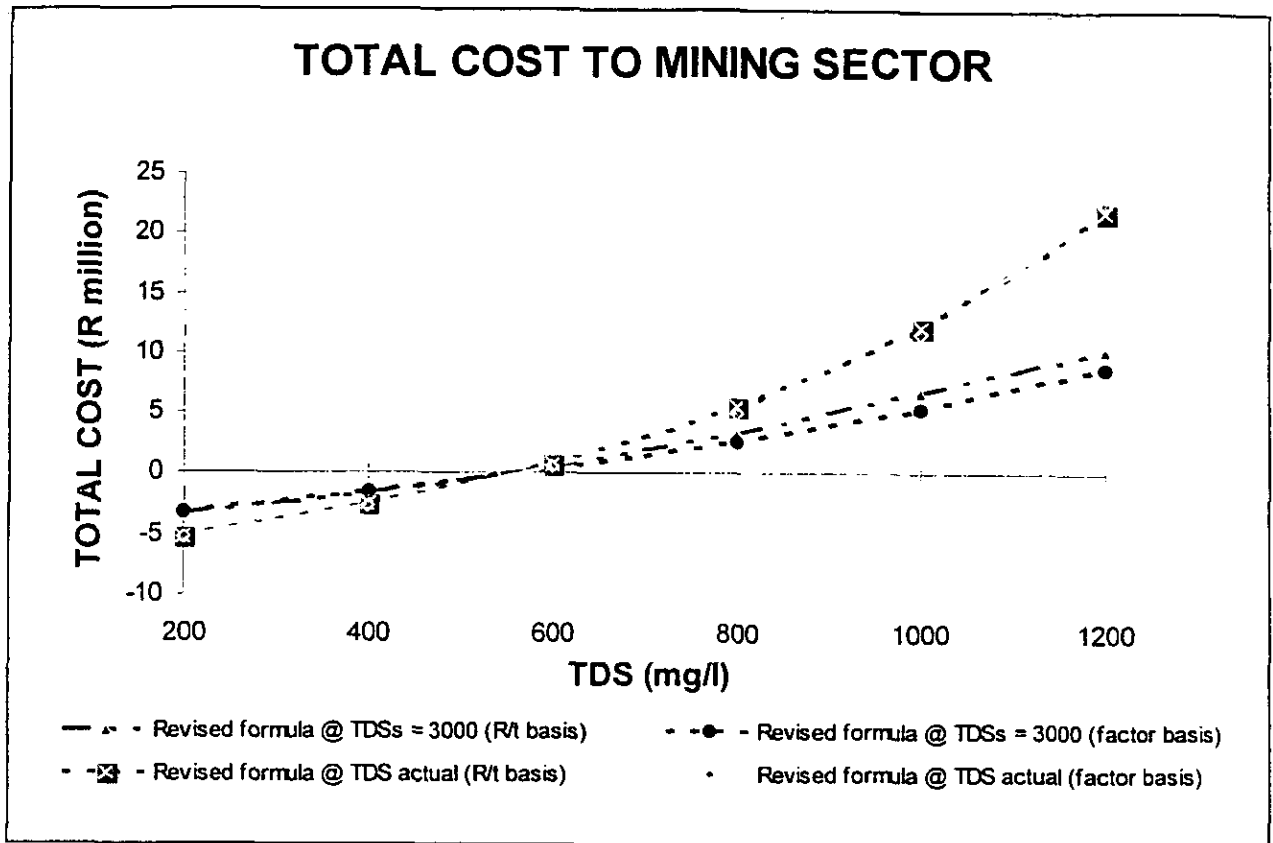


Figure 2: Total cost in Rands for the mining sector using the different calculation techniques for each TDS scenario

5.1.2 Mine Service Water Circuits

The only significant cost components would be those related to scaling and discharge of excess water. Corrosion in these systems is not a cost factor that needed to be considered in this exercise. The scaling cost (SC) is realistically the cost of the resultant increase in make up water volumes that may be required to keep the circuit TDS constant.

The incremental discharge cost for the excess mine service water is currently zero. The possibility of an increase in the discharge cost has not been ruled out. New and stricter legislation governing the discharge quantities and quality may result in costly effluent discharge treatment systems. The current storage capacities of the evaporation pans are believed to be sufficient for current effluent discharge. As a result, no incremental cost can be associated with the service water due to an increase in the TDS of the Board water.

5.1.3 Metallurgical Plant Water Circuits

The water quality in the metallurgical plant water circuits already has such a high TDS that the increase in TDS of the Board water and the small volumes of Board water used in the plants will have a minimal effect in the metallurgical plants. Therefore, no incremental cost will be incurred by the metallurgical plants due to an increase in TDS in the Board water.

5.1.4 Irrigation Water Circuits

The only cost associated with the increase in TDS is that of scaling costs. Minor additional scaling problems may be experienced with the microjets which are used in the irrigation system. If these costs can be identified, they will be very small. The irrigation water circuits will therefore be omitted in the total incremental cost calculations for the mining sector.

5.1.5 Boiler and Demineralisation Plants

The boiler water data was applied to the cost formulae of the evaporative cooling circuits due to the similar nature of the two water circuits. The boilers and demineralisation plants usually operate at a TDS of 3 000 mg/l to 3 500 mg/l. For the purpose of calculating the average cost for the mining industry, a TDS of 3 000 mg/l was used. Two techniques were used to obtain a figure representative of the mining industry in the Middle Vaal area, namely; per ton mined per annum basis and a factored basis. The tonnage mined of the mines surveyed represented 50,87 percent of the total tonnage mined in the area. Table 3 shows the incremental cost of the boiler and demineralisation for each TDS scenario.

Table 3: Comparison of total costs to the boilers in the mining industry.

	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1000 mg/l	1200 mg/l
Chemical Cost (R/t basis)	-475064	-141209	268688	742422	1298651	1991004
Chemical Cost (factor basis)	-209354	-60934	112222	316859	562423	862558
Average Chemical Cost	-342209	-101072	190455	529641	930537	1426781
Water Supply Cost (R/t basis)	-164874	-60043	85077	251125	438882	668101
Water Supply Cost (factor basis)	-66867	-20688	33187	96855	173258	266641
Average Water Supply Cost	-115871	-40366	59132	173990	306070	467371
Total average cost to mining industry	-458080	-141437	249587	703631	1236607	1894152

The total average cost indicated in Table 3 is the average between the two calculation techniques mentioned above.

5.2 UNDERLYING ASSUMPTIONS

The incremental discharge cost for the excess mine service water is currently zero. The possibility of an increase in the discharge cost has not been ruled out. New and stricter legislation governing the discharge quantities and quality may result in costly effluent discharge treatment systems. The current storage capacities of the evaporation pans are believed to be sufficient for current effluent discharge. The site specific discharge costs are assumed to be zero for the purpose of this study.

The water unit cost was taken as constant. It is evident that an increase in water unit cost will have a drastic effect on the management of the evaporation systems and total incremental cost.

It is possible that the management costs on the mines may increase due to the increased attention required to manage the water circuits more effectively. However, it is assumed that the water treatment consultants dedication will increase and in so doing, the service fees will remain being built into the chemical costs, resulting in an increase in chemical costs. Therefore, the incremental management cost is regarded as zero.

The assumption was made that the construction of a new demineralisation and softening plant is very unlikely to occur. The capital cost component of the new plant has not been taken into account.

5.3 INPUT DATA FOR MODELLING

The total incremental cost for the water supply and chemicals at each TDS scenario is shown in Table 4 and can be applied to the cost accumulation matrix. The value represents the total in Rands for all the gold mines in the Middle Vaal area per annum. The cost indicated below excludes the total capital cost of a new demineralisation plants.

Table 4: Sectoral input cost components in Rands for the mining industry

SECTORAL INPUT COST COMPONENTS IN RANDS			
	chemicals, plastics and rubber	electricity, gas and water	TOTALS
200 mg/l	-10 610 159	-13 024 151	-23 634 310
400 mg/l	-4 306 042	-12 166 326	-16 472 368
600 mg/l	2 146 255	2 503 882	4 650 137
800 mg/l	8 548 421	10 148 570	18 696 991
1000 mg/l	15 207 877	17 614 900	32 822 777
1200 mg/l	21 864 891	25 403 821	47 268 712

6. CONCLUSION

The data applied to the IO Matrix will present a cost analysis of salinisation of the Middle Vaal River area as a specific area. This will, amongst others, give an indication of the cost of salinisation for the mining sector, the direct effect, as well as the total cost to the economy, incorporating the indirect effects as well. The results of IO model are presented in the main report.

It must be noted that the application of the IO model presents a current situation analysis only. This is due to many variables such as the current water unit costs, the development of industry and other economic sectors are excluded, the increased demands of water supply to new areas and the improvement of technology as well as the application of water restrictions.

Management behaviour in general is unpredictable, however, the mining industry relies on available technology and the economic feasibility thereof when making decisions regarding the management of water.

Appendix A: Example of Mine Survey Questionnaire

DRAFT MINE SURVEY QUESTIONNAIRE

Version 1

MINE :

SHAFT/S :

GENERAL INFORMATION

1. Name of mine
2. Name of project person/s completing questionnaire.....
3. Name of mine person/s completing questionnaire.....
4. Position of mine person completing questionnaire.....
5. Current monthly tonnages mined.....
6. Current Monthly tonnages milled.....
7. Type of reef being mined?.....
8. Current age of mine.....
9. Expected remaining life of mine.....
10. Current mining methods.....
11. Who supplies the mine with potable water.....
12. What is the cost of potable water.....
13. Does the mine have a waste load allocation or effluent quality standard specified & spelt out.....
14. What products are produced in the met plant?.....
.....
15. What processes are used in the met plant?.....
.....



MINE :

SHAFT/S :

A. EVAPORATIVE COOLING WATER CIRCUITS

1. Water Reticulation and Flow Diagram

Produce a schematic water reticulation flow diagram for the evaporative cooling water circuits. Show flows and TDS to give a flow and TDS balance.



4. Water management structure and personnel

4.1 Produce a schematic line diagram of the mine's evaporative cooling water circuit management structure with responsibilities.

4.2 Based on the average costs of these personnel and the percentage of their time spent on managing the evaporative cooling water circuits, what is the average monthly management cost?

.....
.....
.....



5. Management Options

The costs associated with increased salinity of surface water resources may be realised in the mining industry by applying one or more of the following management options:

1. **OPTION A** : Purchase increased supplies of fresh water in order to control the water to a constant salinity;
2. **OPTION B** : Treat the water in order to control the water to a constant salinity and hold the volumes of input water constant;
3. **OPTION C** : Allow the water quality to deteriorate and manage the secondary problems which will be manifested as corrosion, scaling and process inefficiencies;
4. **OPTION D** : Treat effluents to meet discharge limits.

Which option will be chosen to manage the evaporative cooling water circuits for the scenarios in the Table below?

TDS INCREASE	OPTION CHOSEN	REASON
200 mg/l		
400 mg/l		
600 mg/l		
800 mg/l		
1000 mg/l		
1200 mg/l		



MINE :

SHAFT/S :

B. MINE SERVICE WATER CIRCUITS

1. Water Reticulation and Flow Diagram

Produce a schematic water reticulation flow diagram for the underground mine service water circuits. Show flows to give a flow balance.



4. Water management structure and personnel

4.1 Produce a schematic line diagram of the mine's service water circuit management structure with responsibilities.

4.2 Based on the average costs of these personnel and the percentage of their time spent on managing the mine service water circuits, what is the average monthly management cost?

.....
.....
.....



5. Management Options

The costs associated with increased salinity of surface water resources may be realised in the mining industry by applying one or more of the following management options:

1. **OPTION A** : Purchase increased supplies of fresh water in order to control the water to a constant salinity;
2. **OPTION B** : Treat the water in order to control the water to a constant salinity and hold the volumes of input water constant;
3. **OPTION C** : Allow the water quality to deteriorate and manage the secondary problems which will be manifested as corrosion, scaling and process inefficiencies;
4. **OPTION D** : Treat effluents to meet discharge limits.

Which option will be chosen to manage the mine service water circuits for the scenarios in the Table below?

TDS INCREASE	OPTION CHOSEN	REASON
200 mg/l		
400 mg/l		
600 mg/l		
800 mg/l		
1000 mg/l		
1200 mg/l		



MINE :

SHAFT/S :

C. METALLURGICAL PLANT WATER CIRCUITS

1. Water Reticulation and Flow Diagram

Produce a schematic water reticulation flow diagram for the metallurgical plant water circuits. Show flows to give a flow balance.



4. Water management structure and personnel

4.1 Produce a schematic line diagram of the mine's metallurgical plant water circuit management structure with responsibilities.

4.2 Based on the average costs of these personnel and the percentage of their time spent on managing the metallurgical plant water circuits, what is the average monthly management cost?

.....
.....
.....



5. Management Options

The costs associated with increased salinity of surface water resources may be realised in the mining industry by applying one or more of the following management options:

1. **OPTION A** : Purchase increased supplies of fresh water in order to control the water to a constant salinity;
2. **OPTION B** : Treat the water in order to control the water to a constant salinity and hold the volumes of input water constant;
3. **OPTION C** : Allow the water quality to deteriorate and manage the secondary problems which will be manifested as corrosion, scaling and process inefficiencies;
4. **OPTION D** : Treat effluents to meet discharge limits.

Which option will be chosen to manage the metallurgical plant water circuits for the scenarios in the Table below?

TDS INCREASE	OPTION CHOSEN	REASON
200 mg/l		
400 mg/l		
600 mg/l		
800 mg/l		
1000 mg/l		
1200 mg/l		



MINE :

SHAFT/S :

D. IRRIGATION WATER CIRCUITS

1. Water Reticulation and Flow Diagram

Produce a schematic water reticulation flow diagram for the irrigation water circuits. Show flows to give a flow balance.



2. Water Quality Aspects

2.1 Provide water quality and flow data for streams indicated in the reticulation diagram.

No	Source description (refer to reticulation diagram in 1)	Quality					Flow	
		Ca	Mg	Na	SO4	Cl		TDS

2.2 Are current water sources adequate for present and future water requirements , if not, what plans have been made for new sources?

.....

.....

.....

2.3 What water quality-related problems are being experienced in the irrigation water circuits? Quantify if possible.

.....

.....

.....

.....

.....



3. Water management structure and personnel

3.1 Produce a schematic line diagram of the mine's irrigation water circuits management structure with responsibilities.

3.2 Based on the average costs of these personnel and the percentage of their time spent on managing the irrigation water circuits, what is the average monthly management cost?

.....
.....
.....



5. Management Options

The costs associated with increased salinity of surface water resources may be realised in the mining industry by applying one or more of the following management options:

1. **OPTION A** : Purchase increased supplies of fresh water in order to control the water to a constant salinity;
2. **OPTION B** : Treat the water in order to control the water to a constant salinity and hold the volumes of input water constant;
3. **OPTION C** : Allow the water quality to deteriorate and manage the secondary problems which will be manifested as corrosion, scaling and process inefficiencies;
4. **OPTION D** : Treat effluents to meet discharge limits.

Which option will be chosen to manage the irrigation water circuits for the scenarios in the Table below?

TDS INCREASE	OPTION CHOSEN	REASON
200 mg/l		
400 mg/l		
600 mg/l		
800 mg/l		
1000 mg/l		
1200 mg/l		



Management Options

The costs associated with increased salinity of these water circuits may be realised in the mining industry by applying one or more of the following management options:

1. **OPTION A** : Purchase increased supplies of fresh water in order to control the water to a constant salinity;
2. **OPTION B** : Treat the water in order to control the water to a constant salinity and hold the volumes of input water constant;
3. **OPTION C** : Allow the water quality to deteriorate and manage the secondary problems which will be manifested as corrosion, scaling and process inefficiencies;
4. **OPTION D** : Treat effluents to meet discharge limits.

Which option will be chosen to manage these water circuits for the scenarios in the Table below?

TDS INCREASE	WATER CIRCUIT	OPTION CHOSEN	REASON
200 mg/l			
400 mg/l			
600 mg/l			
800 mg/l			
1000 mg/l			
1200 mg/l			



F. OTHER INFORMATION

1. List effluent standards; flows; describe effluent treatment systems; spare capacity and costs.

EFFLUENT STANDARDS	FLOW	EFFLUENT TREATMENT SYSTEM	SPARE CAPACITY	COST

G. GENERAL INFORMATION

1. What job grading system is used at the mine?

2. Provide a guideline salary structure for job grading at the mine

3. Provide the following information in the table below on personnel housed on mine:

	No. of people	Total water used	Per capita consumption (l/d)
Hostels			
Houses			
Other:			

**MINE:
SHAFT/S:**

	VARIABLE	FUNCTION	1	2	3	4	OTHER
BV	Blowdown volume						
CE	Control equip. maint. cost						
EC	Evap. cooling circuit cost						
MC	Maintenance chemicals cost						
MS	Maintenance staff cost						
MV	Make -up volume						
TC	Treatment chemical cost						
WC	Water unit cost						
WM	Water management cost	MC+MS+CE					
X _{DC}	Site specific discharge cost						
Ca	Calcium concentration						
DC	Discharge cost	DV, WQ, WMP, WLA					
DV	Discharge volume						
FI	Fissure volume & quality						
GL	Geographic location of mine						
MA	Mine age						
MT	Type of mining practised						
PPS	Precipitation potential (Ca ₃ SO ₄)						
RF	Recirculation factor						
SC	Scaling cost	WQ, TDS, Ca, SO ₄					
SO ₄	Sulphate concentration						
SW	Mine service water circuit cost	SC, DC					
WLA	Waste load allocation						
WMP	Water management plan						
WQ	Water quality within system						
WS	Water sources						
FC	Flotation circuits	$\frac{TDS_n \times TC_o}{TDS_o} - TC_o$					
MP	Met plant circuits cost						
SR	Water treatment plant salt rejection						
WR	Water treatment plant water recovery						
X _{WT}	Site specific treatment cost incl. operating, capital & brine disposal costs						
IW	Slimes irrigation water cost						

- 1 - Evaporative cooling water circuits
- 2 - Mine service water circuits
- 3 - Metallurgical plant water circuits
- 4 - Irrigation water circuits

Other - Domestic, sewage, engineering and maintenance, recreation, gland service water etc.

Appendix B: Example of Boiler and Demineralisation Plant Information Sheet

INFORMATION SHEET

BOILER AND DEMINERALISATION PLANT DATA

NAME OF MINE:

BOILER DESCRIPTION:

DEMINERALISATION PLANT DESCRIPTION:

NAME OF PERSON COMPLETING SHEET:

POSITION HELD:

1. What will the capital cost component be if a new demin plant is to be built equivalent to the existing plant?.....
.....
2. What are the current chemical (treatment and regeneration) costs for the demin plant and boilers?
3. What are the current volumes of water used in boilers per month?
.....
4. What are the current maintenance costs for demin plants per annum?.....
5. What is the average water quality of the demin plant feed and product water ?

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Demin plant feed water						
Demin plant product water						

6. What volumes of effluent/spent regenerant are discharged?
.....
7. Where are the effluents/spent regenerant discharged to?
.....
8. What are the associated discharge costs?.....
.....

Appendix C: Site Reports and Survey Questionnaire Results

QUANTIFYING THE IMPACT OF THE SALINISATION OF SOUTH AFRICA'S WATER RESOURCES WITH SPECIAL REFERENCE TO ECONOMIC EFFECTS

Name of mine: Beatrix Gold Mine

Geographical location: Central Northern Free State

Water supplier: Goudveld Water Board

1. INTRODUCTION

The salinity of the Vaal River has been increasing steadily over the last few years. This increase in salinity has certain cost implications on the gold mining industry which relies on the river as a source of water. In order to quantify these cost implications, the water circuits affected by an increase in the TDS of the river or Board water can be classified into four circuits: namely, evaporative cooling water circuits, mine service water circuits, metallurgical plant water circuits and irrigation water circuits. The variables determining the total cost of the increased TDS in the water to the mining industry have been identified in terms of formulae developed in Phase 1 of the project and can be quantified by extracting information from the survey questionnaire. See Appendix 1 for detailed information as collected in the questionnaire.

2. EVAPORATIVE COOLING WATER CIRCUITS

Water quality related problems experienced in the cooling water circuits at Beatrix include scaling in the boilers, fridge plants and compressors. The make-up water used in the cooling circuits is Goudveld Water Board water and treated sewage. The treatment of the sewage includes the removal of phosphates. Effluents arising from the evaporative cooling circuits are bled off into small ponds and evaporation dams on the surface at no operational cost other than pumping. The effluent is not treated in any way. The current management of the evaporative cooling water circuits at Beatrix is to treat the water in the cooling water circuit in order to control the water to a constant salinity and hold the volumes of input water constant. However, if the TDS in the make-up water increases to 1 000 mg/l and above, the mine will purchase increased supplies of fresh water in order to control the water to a constant salinity. This management option will be chosen if the water restrictions permit. Beatrix Gold Mine is using biocides and antiscalants in the evaporative cooling circuits to prevent scale formation and biological fouling as well as to minimise corrosion. The following determinants and associated costs, where applicable, can be identified:

	VARIABLE	FUNCTION	QUANTITY
BV	Blow down volume		*12 000 kl/month
CE	Control equipment maintenance cost		-
EC	Evaporative cooling circuit cost		Will be calculated
MC	Maintenance chemicals		R1 000/ year
MS	Maintenance staff cost		-
MV	Make-up volume		**47 700 kl/month
TC	Treatment chemical cost		R20 675/month
WC	Water unit cost		R1, 30 /kl
WM	Water management cost	MC+MS+CE	R53 344/ annum
XDC	Site specific discharge cost		-

* Calculated blow down volume using figures from the water balance dated March 1995.

** Figure obtained from water balance dated 31 March 1995.

The blow down volume in the cooling circuits operates automatically. Bleed off occurs between the TDS levels of 1 800 mg/l and 2 100 mg/l. The blow down was calculated to be 400 kl/day in a water and salt balance where blow down + evaporative losses = make-up.

The incremental cost due to increased TDS will be calculated using the cost formula designed in Phase 1 of the salinity modelling project.

3. MINE SERVICE WATER CIRCUITS

Water quality related problems experienced with mine service water at Beatrix include high amounts of chlorides in the system, corrosion, scaling and erosion. In order to minimise the erosion problems, the mine flocculates and settles out suspended solids. The water is kept within reasonable limits by bleeding off saline water and introducing Goudveld water as make-up. Water from surface dams is used as make-up water in the service water circuits. The saline bleed off is sent to the plant where it is used for processing or to evaporation dams for storage or disposal. Large quantities of fissure water enter the service water circuits and are pumped to other mines in the area to be used as process water. A total of 5 910 kl/month of water is purchased from Goudveld Water for the service water circuits. The bleed off (210 000 kl/month) from the service water circuit is sent to Unisel, President Brand and St Helena Gold Mines and the remainder to Wolwepan to evaporate. The remaining (235 200 kl/month) is sent to evaporation dams (25 200 kl/month) and to the plant (210 000 kl/month). The following are determinants of the total costs and quantities associated with the TDS of the water:



	VARIABLE	FUNCTION	QUANTITY
Ca	Calcium concentration		*265 mg/l
DC	Discharge cost	f(DV;WQ;WMP;WLA)	
DV	Discharge volume		445 200 kl/month
FI	Fissure water quality & quantity		474 270 kl/month
GL	Geographic location		Central N.Free State
MA	Mine age		13 years
MT	Type of mining practised		Conventional
PPS	Precipitation potential (CaSO ₄)		**1# -1059 mg/l 2#-1229 mg/l
RF	Recirculation factor		
SC	Scaling costs	f(WQ;TDS;Ca;SO ₄)	N/A
SO ₄	Sulphate concentration		*254 mg/l
SW	Service water recirculated	f(SC;DC)	*** 126 000 kl/month
WLA	Waste load allocation		None yet
WMP	Water management plan		None yet
WQ	Water quality within system	f(W;RF;GL;MT;MA;FI)	

* The sulphate concentration is a calculated value based on the assumption that the water balance obtained from Beatrix is accurate.

** The precipitation potential was calculated using AQUACHEM and indicates non-scaling conditions with regard to CaSO₄.

*** The figure was obtained from the water balance dated March 1995.

4. METALLURGICAL PLANT WATER CIRCUITS

The process water circuits and the relevant water quality management problems depend on the different process stages which are used. The plant at Beatrix Gold Mine is supplied with Goudveld Water and mine water from a surface dam. The plant discharges effluents to the sewage plant and to the slimes dams. The problem experienced in the metallurgical plants is that the pipes corrode from the outside before they corrode or scale up on the inside. It is therefore felt that the increased TDS of the water has no effect in the metallurgical plant.

	VARIABLE	FUNCTION	QUANTITY
FC	Flotation circuits cost	$\frac{TDS_N \times TC_o}{TDS_o} - TC_o$	None
MP	Metallurgical plant circuits cost		Will be calculated
MV	Make-up volume		222 630 kl/month
SR	Water treatment plant salt rejection		-
TC	Treatment chemical cost		-
WC	Water unit cost		R 1,30 / kl
WR	Water treatment plant recovery		-
X _{DC}	Site specific discharge cost		0
X _{WT}	Site specific treatment cost, include. operating, capital & brine disposal		0

No actions are currently being taken to manage the quality of the water circulated in the metallurgical plant water circuits. Effluent from the metallurgical plant is sent to the slimes dams and evaporation dams and the

sewage goes to the sewage plant. The following determinants have been identified within the metallurgical plant which have cost implications due to TDS in the water. No specific sensitive water users were identified in the metallurgical plant at Beatrix Gold Mine.

The make-up water is made up of 12 630 kl/month Goudveld water and 210 000 kl/month return underground water which is withdrawn from a surface dam. Beatrix Gold Mine does not treat the water in the metallurgical plant in any way, therefore, no values can be obtained for the water treatment plant salt rejection, treatment chemical cost or the site specific treatment cost, including operating, capital and brine disposal. The discharge of the effluents and the saline bleed off is considered to be nil, as it is merely pumped to the slimes dams. The mine is unable to isolate costs associated with this pumping. Water management in the metallurgical plants concentrates on the required quantities of water being supplied, and not specifically, if at all, on the quality of the water.

5. IRRIGATION WATER CIRCUITS

The irrigation at Beatrix Gold Mine is divided into two circuits. Firstly, the sports fields and gardens and secondly, the slimes dams. The sports fields and gardens are irrigated with sewage water (16 350 kl/month) and brothel water (2 250 kl/month). The slimes dams are irrigated with Goudveld water (1 200 kl/month). The sewage water cost is nil, as it is recycled water and provides water to the Theronspruit. The irrigation water circuit costs due to the TDS can be calculated using the following determinants:

	VARIABLE	FUNCTION	QUANTITY
IW	Slimes irrigation water circuit cost		Will be calculated
MV	Make-up volume (Goudveld)		1 200 kl/month
WC _o	Water unit cost (old) (Goudveld)		R1,30 /kl
TDS	Total dissolved solids (Goudveld)		393 mg/l
WC _N	Water unit cost (new) (sewage)		0
MV	Make-up volume (sewage)		16 350 kl/month
TDS	Total dissolved solids of sewage water		614 mg/l

The slimes irrigation water circuit cost will be calculated in the formula designed in Phase 1. The current cost is R130,00/day. No water quality related problems are experienced in the irrigation water circuits.

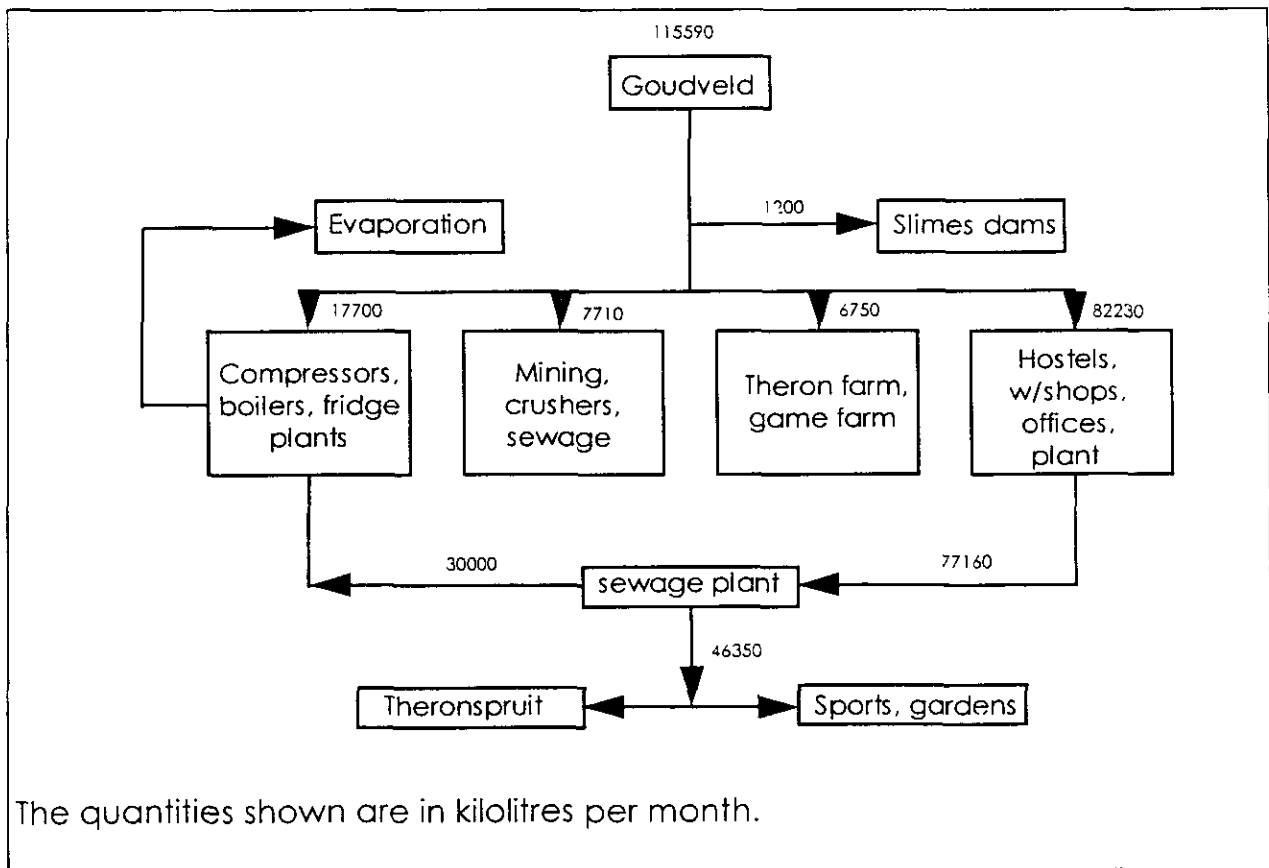
6. CONCLUSION

In conclusion, the increased TDS in the Vaal River has cost implications on Beatrix Gold Mine. The largest cost implications are in the evaporative cooling circuits. The water restrictions do not allow the mines to optimise the processes used in mining and the resultant cost of the treatment of the water is increasing. The water treatment can only be effective to a certain degree, after which good quality make-up water is required in larger quantities.

APPENDIX 1

I GENERAL INFORMATION

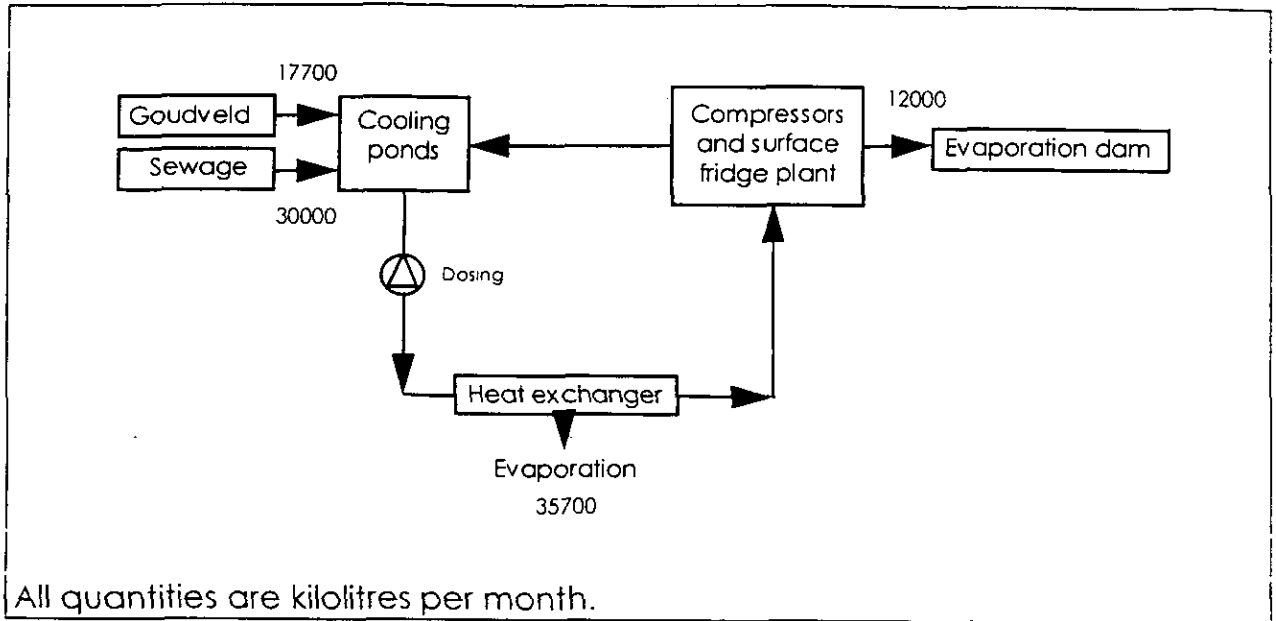
Brain Pedersen, the Outside Section Foreman and Environmental Programmer at Beatrix Gold Mine was visited on 17 October 1995. Beatrix Gold Mine's current monthly tonnage mined is 197 000 tons and 195 000 tons milled. The Beatrix Reef is being mined with an expected life of mine of 20 years. The mine is 13 years old. The mining and cleaning methods are conventional. The mine purchases potable water from Goudveld Water Board at R1,30 / kl. Beatrix has 2 shafts and 1 metallurgical plant. The metallurgical plant uses the carbon-in-pulp process (electro-winning). A simplified reticulation diagram of the distribution of Goudveld water at Beatrix Gold Mine is shown below:



II EVAPORATIVE COOLING WATER CIRCUITS

1. Water Reticulation and Flow Diagram

A simplified water reticulation of the cooling systems at Beatrix Gold Mine is shown below:



All quantities are kilolitres per month.

Note: Treated sewage TDS will increase as the Goudveld Water TDS increases.

2. Water Quality Aspects

2.1 Water quality

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Sewage (final)	68	33	95	162	152	614
Goudveld water make-up	65	26	52	109	75	393
Cooling tower 1 #	108	38	213	198	160	1084

2.2 Water sources

The current water sources are adequate for present requirements. Future water requirements will result in purchasing more water from Goudveld Water Board or increasing the intake of treated sewage water. Presently, 1MI/day of treated sewage water is available. This figure will improve in the near future with the planned upgrading of the sewage plant.

2.3 Water quality problems

Water quality related problems experienced in the evaporative cooling water circuits are calcification (scaling) in the boilers, fridge plants and compressors due to the treated sewage water being used in these circuits. A small amount of biological fouling occurs.

2.4 Water quality management

Sewage water is used extensively in the cooling water circuits. Phosphates are removed and the water is treated in the circuit with biocides and antiscalants. The sewage plant on the mine uses extended aeration and activated sludge methods. The sewage plant total costs, including engineering and maintenance, are R13 000 per month. A consulting water treatment company treats the water in the cooling circuits. Treatment chemical consumption figures have been recorded and the costs are shown in the table below:

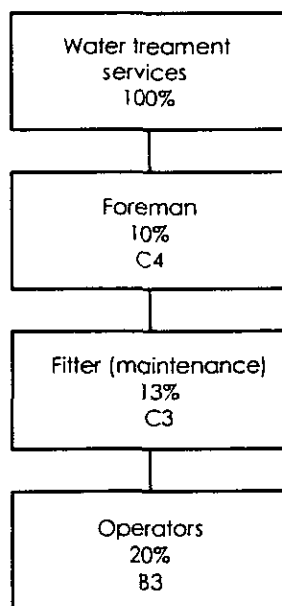
	Treatment	Consumption/month	Cost/month
Compressor:	Antiscalant & biocide	250 kg	R4 500
Boilers:	Antiscalant	400 kg	R7 200
	Oxygen scavenger	80 kg	R 650
	Condensate inhibitor	200 kg	R 2 100
Fridge plant:	Antiscalant	300 kg	R 3615
	Biocide	300 kg	R 2700
	TOTAL		R 20 675

3. Effluent Systems

Effluents arising from the cooling circuits are sent to evaporation dams and small ponds. No costs other than pumping are associated with the discharge of these effluents or bleed off from the cooling circuits. The effluents are not treated in any way.

4. Water Management Structure and Personnel

Below is the basic management structure at Beatrix and the average time spent on the water management in the cooling circuits and the grading on the Patterson scale.



The water treatment services are done by Anikem, a water and chemical treatment consulting company. The average total package value at each

level was determined using the 1995/1996 salary scale. The total cost of the water management in the cooling water circuit is approximately R53 344 per year. The main cost is that of the water treatment services where the service fee is included in the price of the chemical cost.

5. Management Options

The Goudveld water has a TDS of between 300 mg/l and 600 mg/l. The current management is (Option B) to treat the water in circulation in order to control the water to a constant salinity and hold the volumes of input water constant. However, if the TDS is to increase to 1000 mg/l and above, the management option would need to change to Option A which is to increase the purchase of fresh make-up water to control the salinity. This option is expensive, but is the only viable option. The cost of desalination of the raw water would far exceed these costs.

III MINE SERVICE WATER CIRCUITS

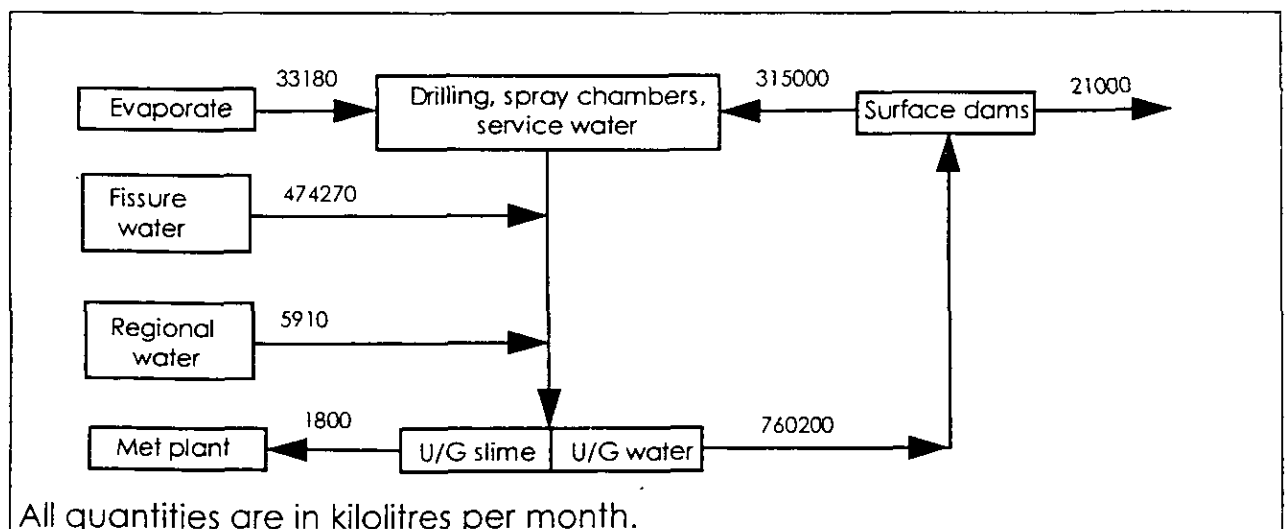
1. Water Reticulation and Flow Diagram

The following volumes of water are sent down and pumped up the shafts as service water:

1# Pumped up 246 990 kl/month
Sent down 177 000 kl/month

2# Pumped up 513 210 kl/month
Sent down 138 000 kl/month

A simplified reticulation diagram of the mine service water is shown below:



2. Water Quality Aspects

2.1 Water quality in service water circuits

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Goudveld water make-up	65	26	51	109	75	393
U/G to surface water	166	16	1071	159	1785	3479
1# surface	880	12	90	106	1530	2752
2# clear water dam	870	8	82	110	1550	3031

2.2 Water sources

The current water sources are adequate for the service water. The evaporation dams store large amounts of water, and these will be tapped to a larger extent if a water shortage occurs.

2.3 Water quality problems

The problems experienced in the mine service water are high chlorides. The scaling and corrosion are currently under control.

2.4 Water quality management

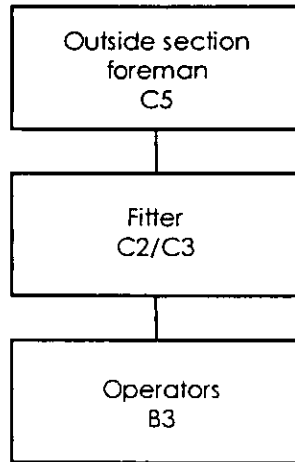
Liming is practised to control the pH of the water and prevent scaling and corrosion. The water sent to the plant is not treated. The monthly cost to flocculate the water is approximately R5 500. The service water is disinfected as required.

3. Effluent systems

The effluents from the service water circuits are sent to the evaporation dams. The effluents are not treated.

4. Water management structure

The outside section foreman is responsible for these circuits. The basic management structure and the grading on the Patterson Scale is shown below:



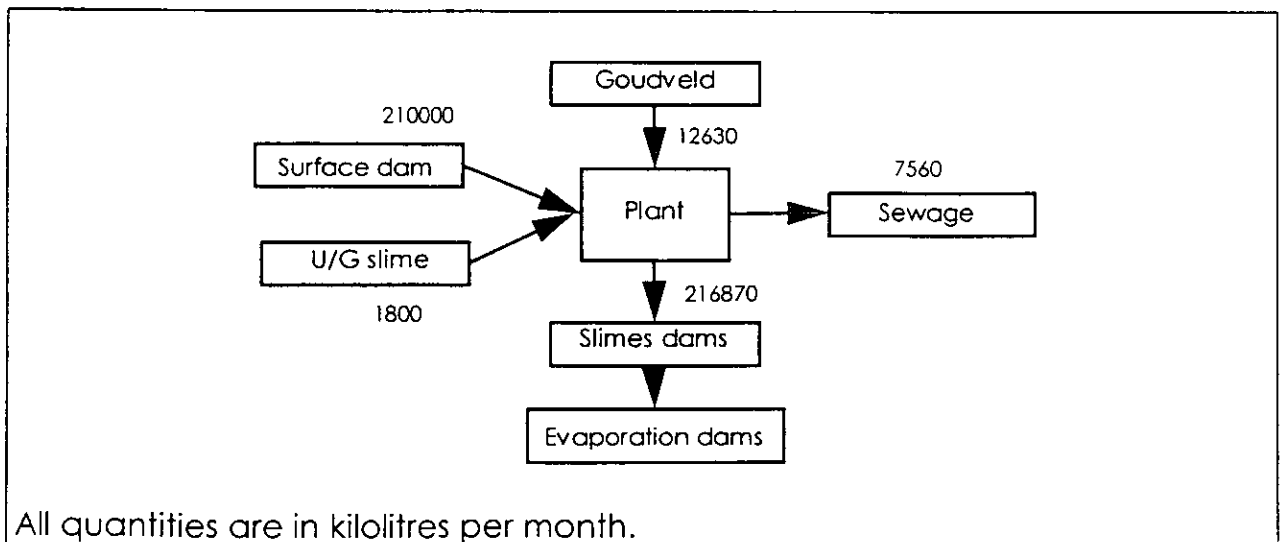
5. Management Options

Option A is currently being used which is purchasing increased supplies of fresh water in order to control the water to a constant salinity. This management option will change to Option B if the TDS increases, in other words treating the water in order to control the water to a constant salinity and hold the volumes of input water constant. The main driving force behind this choice is that the current water restrictions do not allow the increased volumes of water in Option A.

IV METALLURGICAL PLANT WATER CIRCUITS

1. Water Reticulation Diagram

A simplified water reticulation diagram of the input and output of the metallurgical plant is shown below:





2. Water Quality Aspects

2.1 Water quality in metallurgical plant water circuits

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Goudveld water make-up	65	26	51	109	75	393
Underground water	166	16	1071	159	1785	3479
Electro-winning enter	0.4	5	22794	1704	1934	5248
Electro-winning leaving	13	5	22651	1669	1993	53114
C.I.P residue *	538	7	1127	503	2036	4640
U/G slime water	199	19	1089	246	1802	3665

* C.I.P. residue is pumped to the slimes dams.

Electrowinning enter and electrowinning leaving is one of process in the plant.

2.2 Water sources

The current water sources are adequate for present and future water requirements.

2.3 Water quality problems

The water used in the metallurgical plant is not treated. It has been observed in the metallurgical plant that the pipes corrode from the outside before they corrode from the inside. No scaling problem is being experienced.

2.4 Water management

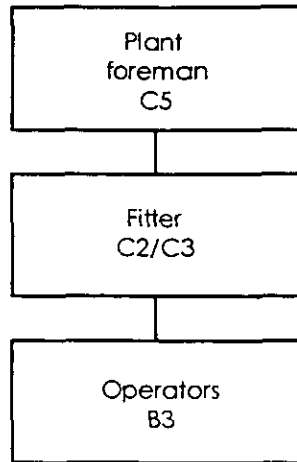
No actions are currently being undertaken to manage the quality of the water circulated in the metallurgical plant.

3. Effluent systems

Effluent sources arising from the metallurgical plant water circuits are sent to the slimes dams and evaporation dams. Some of the effluent, mainly from the change house, is sent to the sewage plant.

4. Water management structure

The management structure for the water management at the plant can be schematically represented, with the level on the Patterson Grading System, as follows:



The total management cost of the metallurgical plant water circuits is averaged at R9 000/month. The water management concentrates on the quantity of water required, and not on the quality of water.

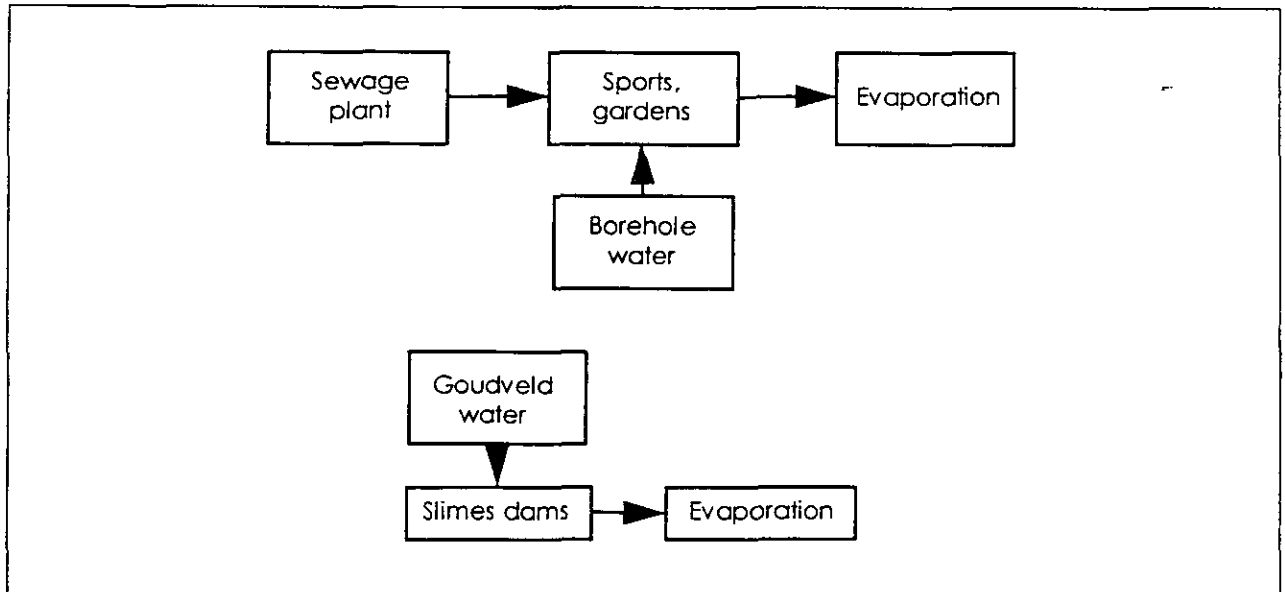
5. Management Options

No water treatment is practised in the plant. The increased TDS is considered to have no effect in the plant. No specific sensitive users are in use at the plant. The make-up water in the metallurgical plant is reticulated water from the mine.

V IRRIGATION WATER CIRCUITS

1. Water Reticulation Diagram

The simplified reticulation diagram of two irrigation circuits at Beatrix can be seen below:



2. Water Quality Aspects

2.1 Water quality

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Goudveld water	65	26	51	109	75	393
Sewage water	68	33	95	162	152	614

2.2 Water sources

The current water sources are adequate. Sewage water can be planned for in the future if water shortages occur.

2.3 Water quality problems

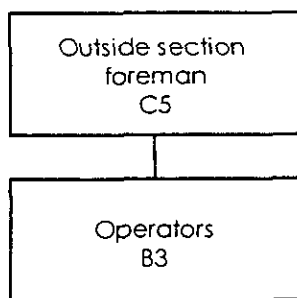
No water quality problems are being experienced.

2.4 Water management

The water is treated in the sewage plant. The slimes dams are being irrigated with Goudveld water.

3. Water Management and Structure

A schematic diagram of the management structure of the irrigation water circuits is shown below:



The average monthly management cost is estimated at R3 000/month.

4. Management Options

The current management of the irrigation water circuits is simply to treat the effluents or run-off to meet discharge limits. The Goudveld water is used on the slimes dam, however, if the water restrictions persist, sewage water will most likely be used.

QUANTIFYING THE IMPACT OF THE SALINISATION OF SOUTH AFRICA'S WATER RESOURCES WITH SPECIAL REFERENCE TO ECONOMIC EFFECTS

MINE SURVEY REPORT

Name of Mine : Harmony Gold Mine

Geographical location : Northern Free State

Water supplier : Gold Fields Water Board

1. INTRODUCTION

The salinity of the Vaal River has been increasing steadily over the last few years. This increase in salinity has certain cost implications on the gold mining industry which relies on the river as a source of water. In order to quantify these cost implications, the water circuits affected by an increase in the TDS of river or Board water can be classified into four circuits; namely, evaporative cooling water circuits, mine service water circuits, metallurgical plant water circuits and irrigation water circuits. The variables determining the total cost of the increased TDS in the water to the mining industry have been identified in terms of formulae developed in Phase 1 of the project and can be quantified by extracting information from the survey questionnaire. See Appendix 1 for detailed information as collected in the questionnaire.

2. EVAPORATIVE COOLING WATER CIRCUITS

Water quality related problems experienced in cooling water circuits at Harmony Gold Mine are scaling and corrosion. The make-up water used in the cooling circuits is Goudveld Water Board water. Effluents arising from the evaporative cooling circuits are bled off to the Virginia plants. The effluents are not treated in any way. The current management practice of the evaporative cooling water circuits at Harmony Gold Mine is to purchase increased supplies of fresh water in order to control the water in the circuit to a constant salinity. This management option will remain unchanged if the TDS increases to 1000 mg/l and above. Harmony Gold Mine is treating the water in the cooling circuits with biocides and antiscalants. The following determinants and associated costs, where applicable, can be identified:

	VARIABLE	FUNCTION	QUANTITY
BV	Blow down volume		8995 kl/month
CE	Control equipment maintenance cost		-
EC	Evaporative cooling circuit cost		We be calculated*
MC	Maintenance chemicals		R1000/fp/year
MS	Maintenance staff cost		-
MV	Make-up volume		32 769 kl/month
TC	Treatment chemical cost		R21 112/month
WC	Water unit cost		R1,13 /month
WM	Water management cost	MC+MS+CE	R187 920/an.
X _{pc}	Site specific discharge cost		nil

* The current evaporative cooling circuit cost (R103 041/month) is calculated as the sum of the total volume of water purchased from Goudveld Water, the maintenance staff cost, treatment cost and the water management cost.

The bleed off or blow down volumes are not measured due to automatic bleeding systems being used. However, these blow down volumes have been calculated using water and salt balances. The automatic bleeding system is set to blow down at a TDS of 3 000mg/l. The resultant blow down volume is 8 995 kl/month in total and an evaporative loss of 23 774 kl/month in total. The TDS value for the evaporative loss was taken as zero.

Control equipment maintenance cost and maintenance chemicals cost are combined in the water management cost.

The site specific discharge cost is considered to be nil (other than pumping costs) as the effluents arising from the cooling circuits are sent to Virginia plant, 4 Shaft and evaporation dams for storage or disposal.

The water management cost is estimated at R187 920 per annum. The water treatment services cost is included in the chemical cost.

3. MINE SERVICE WATER CIRCUITS

Water quality related problems experienced with mine service water at Harmony Gold Mine include high amount of chlorides in the circuits (due to the fissure water entering), corrosion, scaling and erosion. In order to minimise these problems, the mine neutralises acidic drainage by adding lime, flocculates and settles out suspended solids and disinfects the water. The water quality is kept within reasonable limits by bleeding off saline water and introducing Goudveld water and sewage water as make-up. The sewage comes from the Virginia sewage plant. The saline bleed-off is sent to the plants where it is used for processing or to evaporation dams for storage or disposal. The following are determinants of the total costs and quantities associated with the TDS of the water :

	VARIABLE	FUNCTION	QUANTITY
Ca	Calcium concentration		420 mg/l
DC	Discharge cost	$f(DV;WQ;WMP;WLA)$	-
DV	Discharge volume		8 524 kl/day
Fi	Fissure water quality & quantity		*458 478kl/month
GL	Geographic location		N. Free State
MA	Mine age		45 years
MT	Type of mining practised		Longwall scattered
PPS	Precipitation potential ($CaSO_4$)		** (i) -1615 (ii) - 1381
RF	Recirculation factor		
SC	Scaling costs	$f(WQ;TDS;Ca;SO_4)$	Non scaling
SO_4	Sulphate concentration		556 mg/l
SW	Service water recirculated	$f(SC;DC)$	
WLA	Waste load allocation		None yet
WMP	Water management plan		
WS	Water sources		Goudveld & sewage

* The fissure water quantity as indicted on the water balance dated February 1995 obtained from the mine.

** The precipitation potential of calcium sulphate was calculated using AQUACHEM. The make-up volume Goudveld water, (i), has a precipitation potential of -1615 and the mine water, indicated as (ii), -1381. This indicates non scaling conditions with regards to calcium sulphate.

No costs, other than perhaps pumping costs , can be associated with the discharge costs.

4. METALLURGICAL PLANT WATER CIRCUITS

The process plant water circuits and the relevant water quality management problems depend on the different process stages which are used. The plants at Harmony use sewage water, Goudveld water, slimes dam return water and underground water as make-up. The water used is not treated in any way in the plant prior to processing. The problem experienced in the metallurgical plant is scaling in some of the coolers and compressors that are housed in the plants, but is minimal. The scaling is overcome by using Goudveld water as make-up in these coolers and compressors. The increased TDS of the water has no effect in the metallurgical plant. No actions are currently being taken to manage the quality of the water circulated in the metallurgical plant water circuits. The current management option being practised is Option A which is to purchase increased supplies of fresh water in order to control the water in the circuit to a constant salinity. Effluent from the metallurgical plant is sent to the slimes dams and evaporation dams. The following determinants have been identified within the metallurgical plant which have cost implications due to TDS in the water. No specific sensitive water users are present in the metallurgical plants at Harmony Gold Mine.

	VARIABLE	FUNCTION	QUANTITY
FC	Flotation circuit costs	$\frac{TDS_N \times TCo - TCo}{TDS_0}$	None
MP	Met.plant circuits cost		Will be calculated
MV	Make-up volume		1 604 990kl/month*
SR	Water treatment plant salt rejection		-
TC	Treatment chemical cost		-
WC	Water unit cost	Goudveld Water	R1,13/kl
WR	Water treatment plant water recovery		-
X _{DC}	Site specific discharge cost		-
X _{WT}	Site specific treatment cost, including operating, capital & brine disposal		-

* The metallurgical plant circuit cost is based on the assumption that the water balances received from the mine are accurate.

The total volume of make-up water in the metallurgical plant is 1 604 990 kl/month of which the volume of Goudveld water purchased is 56 827 kl/month at a unit cost of R1,13 /kl.

5. IRRIGATION WATER CIRCUITS

The irrigation at Harmony is undertaken with sewage water, plant water from Harmony 3 plant and central plant. The current management cost of the irrigation water circuits is a total of R8 8000/month, being mainly labour. The irrigation water circuit costs due to the TDS can be calculated using the following determinants :

	VARIABLE	FUNCTION	QUANTITY
IW	Slimes irrigation water circuit cost		Will be calculated
MV	Make up volume		16 230 kl/month
WC _N	Water unit cost (new)		Unknown
WC _O	Water unit cost (old)		R1,13
TDS	Total dissolved solids	Goudveld Water	549 mg/l

6. CONCLUSION

In conclusion, the increased TDS in the Vaal River has cost implications on Harmony Gold Mine. The greatest cost implications found are in the evaporative cooling water circuits. The water restrictions however, do not allow the mines to optimise the processes used in mining and the cost of treatment of the water is increasing. The treatment is effective up to a certain degree, after which good quality make-up water is required in larger quantities.

APPENDIX 1

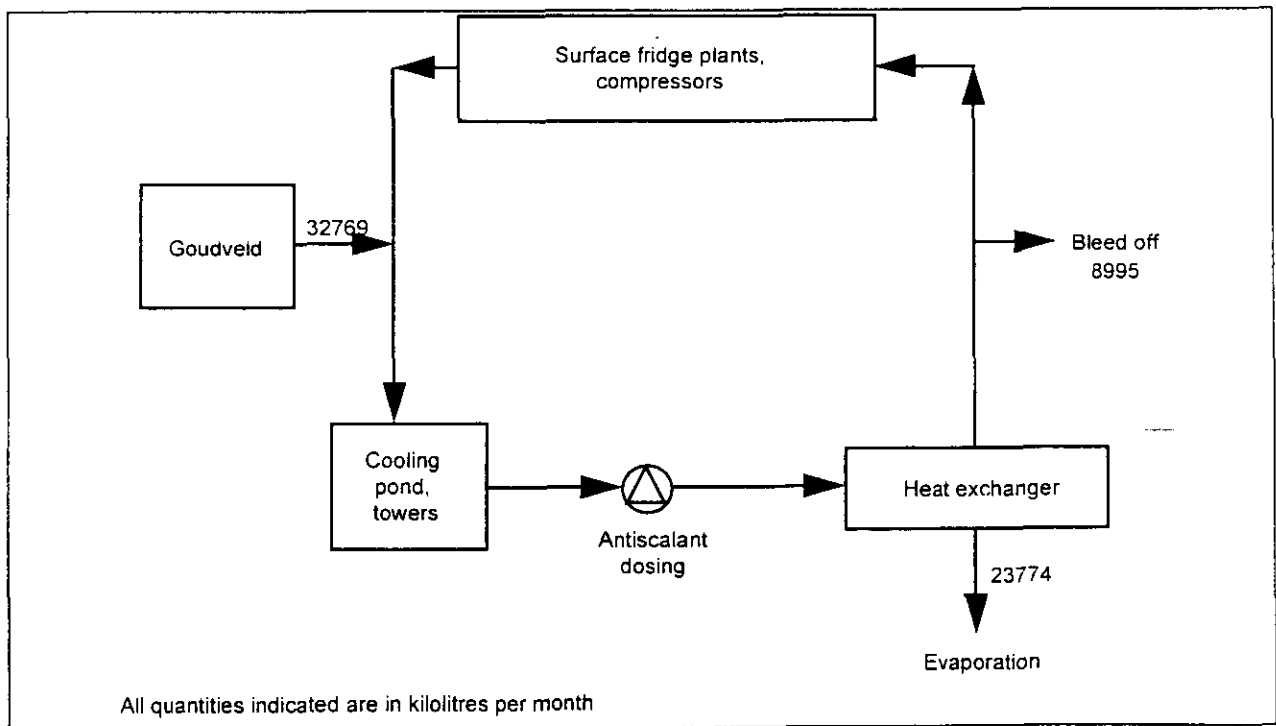
I. GENERAL INFORMATION

Rob Gilmour, the Manager of Environmental Control and Radiation was visited on 24 October 1995. The current monthly tonnages mined are 606 918 tons/month of which 511 540 tons/month are being milled. The type of reef being mined is the Leader Reef and A Reef. The current age of the mine is 45 years with a remaining life of mine of 20 years. The mining method used is the longwall scattered method. Harmony Gold Mine purchased water from Goudveld Water Board. The cost of the potable water is R1,13/kl. The metallurgical plants produce gold using the carbon in pulp process.

II. EVAPORATIVE COOLING WATER CIRCUITS

1. Water Reticulation and Flow Diagram

Harmony has six operational cooling circuits. Goudveld water is used as make-up water. A simplified water reticulation diagram, representing all the shafts, of the cooling systems is shown below:



The average volumes of water in the compressors in each shafts is as follows :

- Harmony 2# - Make-up water 7 032kl/month
- Bleed off 1 930 kl/month

- Harmony 3# - Make-up water 7 905kl/month
- Bleed off 2 169 kl/month
- Harmony 4# - Make-up water 5 009kl/month
- Bleed off 1 375 kl/month
- Virginia 1# - Make-up water 1 714 kl/month
- Bleed off nil
- Merriespruit 1# - Make-up water 3 850kl/month
- Bleed off 1 057 kl/month
- Merriespruit 3# - Make-up water 7 259 kl/month
- Bleed off 1 993 kl/month

The bleed off values are calculated values for an automatic bleeding system at a TDS level of 2 000 mg/l.

2. WATER QUALITY ASPECTS

2.1 Water quality

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Goudveld water make-up	71	27	74	183	88	549
**B" Dam average	342	-	1182	561	1891	4525

**B" Dam is a surface storage dam collecting the bleed-off.

2.2 Water sources

The current water sources are adequate for present water requirements. Future water requirements will result in purchasing more water from Goudveld Water Board. Another potential source of water is abstracting water from the subsurface canal which supplies water to the farmers in the area. The water originates from the Allemanskraal Dam, however, the low level of the water in Allemanskraal Dam does not allow for withdrawal at the moment. A permit has been granted to abstract up to 100 Ml/month at a price of R0,10/m³.

2.3 Water quality problems

Water quality related problems experienced in the evaporative cooling water circuits are scaling, corrosion and biological fouling. Water treatment consultants, Anikem, are treating the water with biocides and algicides as well as scale inhibitors.



2.4 Water quality management

The water treatment consultants treat the water in the cooling circuits with the following chemical costs :

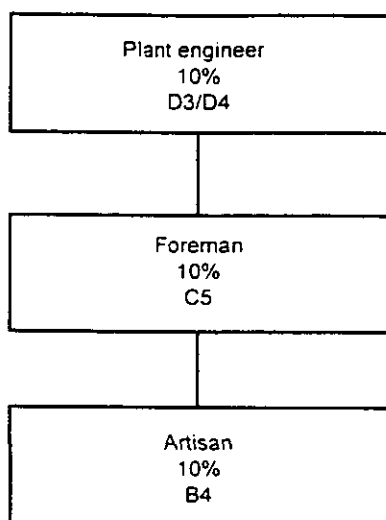
Harmony 2#	- Biocide dosing	R2 000,00/month
Harmony 3#	- No treatment	
Harmony 4#	- Acti-plus	R1 976,00/month
	- Antiscalant	R2 664,00/month
	- Dispersant	R 600,00/month
	- Biocide	R3 068,00/month
	Total	R8 308,00/month
Virginia 1#	- Antiscalant	R2 600,00/month
	- Biocide	R3 700,00/month
	Total	R6 300,00/month
Merriespruit 1#	-Biocide	R4 500,00/month
Merriespruit 2#	-Biocide	R4 000,00/month

3. Effluent Systems

Effluents arising from the cooling circuits are sent to evaporation dams as well as to Virginia plant and Harmony 4 shaft. No costs are associated with the discharge of these effluents. The effluents are not treated in any way.

4. Water Management Structure and Personnel

Below is the basic management structure at Harmony Gold Mine and the average time spent on the water management in the cooling circuits.



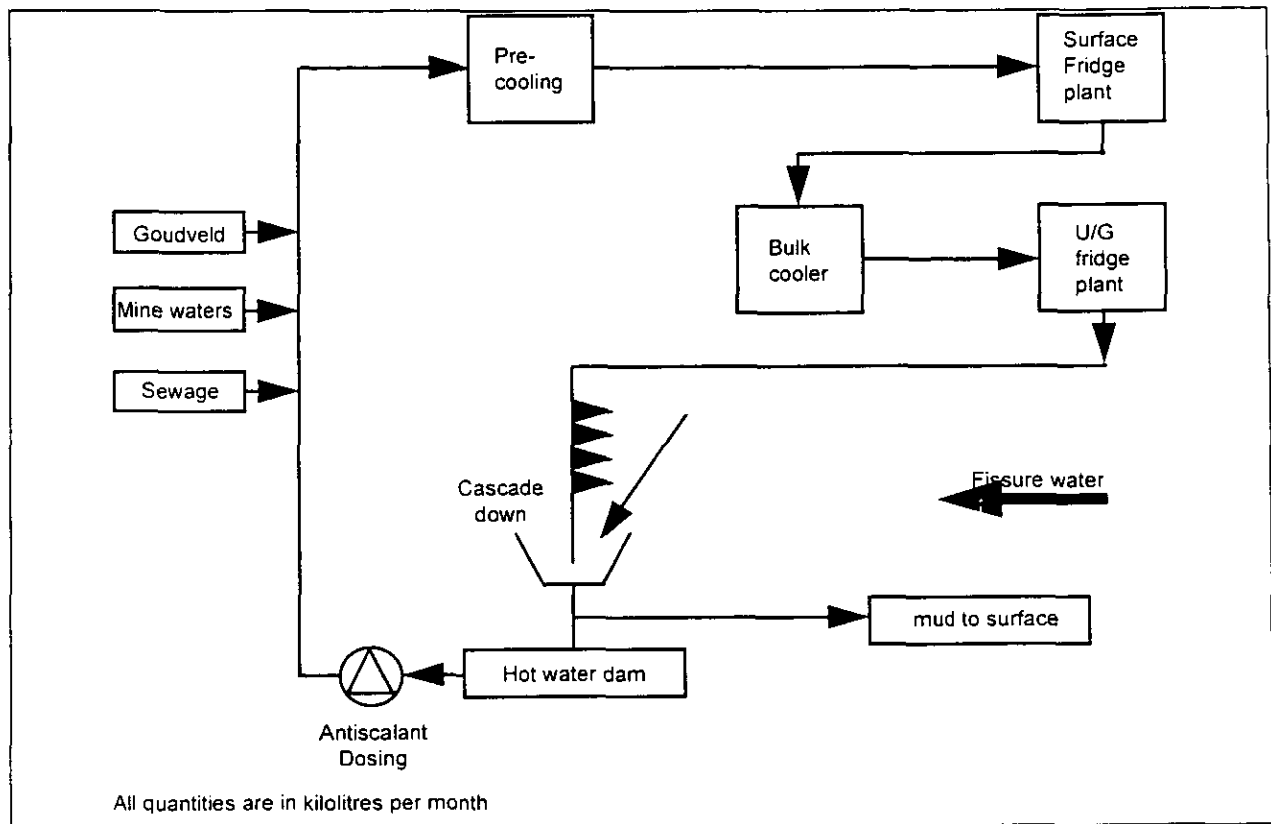
5. Management Options

The Goudveld water has a current TDS of between 300 mg/l and 600 mg/l. The current management is (Option A) to purchase increased supplies of fresh water in order to control the water in the circuit to a constant salinity. If the TDS is to increase to 1000 mg/l and above, the management option would remain the same. However, due to the water restrictions, option B would need to be applied, namely, treat the water in the circuit in order to control the water to a constant salinity and hold the volumes of input water constant. However, the water treatment becomes ineffective after a certain TDS level, resulting in more make-up water being required.

III MINE SERVICE WATER CIRCUITS

1. Water Reticulation and Flow Diagram

A simplified reticulation diagram, representing all the shafts at Harmony Gold Mine, service water circuits is shown below:



The quantities for the mine service water reticulation diagram are as follows:

SHAFT	WATER SOURCE	KILOLITRES/MONTH
V2#	Goudveld water	13059
	Mine water	77032
V1#	Goudveld water	1185
	Fissure water	93711
	U/G return water from M1# and M3#	253863
M3#	U/G return water from V2#	90091
	Goudveld water	22975
M1#	Mine water from Convent Dam	142471
	Goudveld Water	6124
H4#	Mine water from Convent Dam	33989
	Goudveld Water	8314
H2#	Sewage from H/Plant	114935
	Goudveld water	5920
H3#	Mine water Ex H3#	62442
	Goudveld water	18764
	U/G return water	143307
	Fissure water	364767

Goudveld water makes up 7.7% of the total water used in the service water circuits.

2. Quality Aspects

2.1 Water quality in service water circuits

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Virginia effluent	345	-	715	544	1099	3084
Virginia mine water	481	-	1367	561	2185	5289
Convent Dam	517	-	1357	579	2119	5324
Harmony mine water	338	-	1373	540	2458	5035
Goudveld water	71	27	74	183	88	549

2.2 Water sources

The current water sources are adequate for the mine service water. Another option is to abstract water from the subsurface canal from the Allemanskraal Dam. The possibility of abstracting water from evaporation pans to the north west of the mine will be studied for future water sources.

2.3 Water quality problems

The problems experienced in the mine service water are high chlorides due to the large amount of fissure water entering the underground water circuits.

2.4 Water quality management

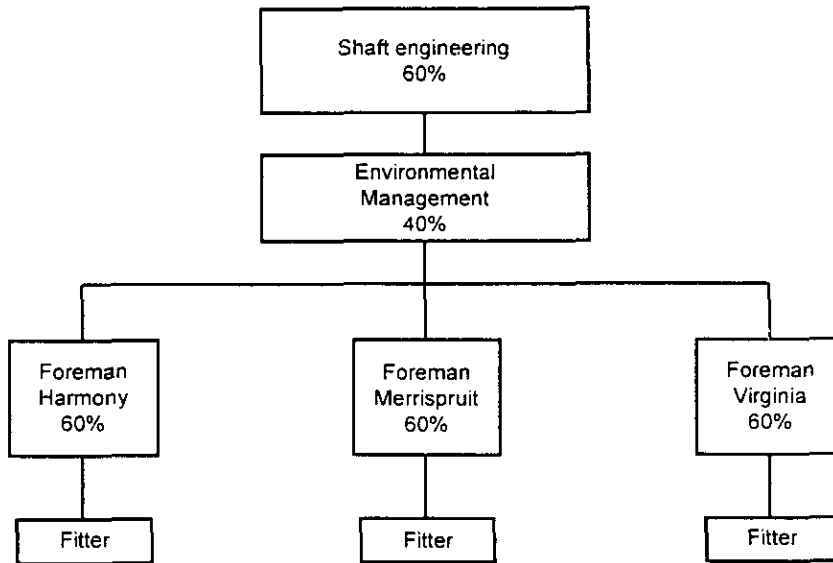
Liming is practised to control the pH of the water and to prevent scaling and corrosion. The water is flocculated and disinfected in the mine service water circuit. The water sent to the plant is not treated. The average cost for lime is R0,42/kg and the flocculants R0,10/kg.

3. Effluent systems

The effluents arising from the service water circuits are sent to the shafts as service water and to some of the plants. No treatment of these effluents takes place.

4. Water management structure

The water management of the mine service water is divided between the Harmony shafts, the Virginia shafts and the Merriespruit shafts. The figure below is a schematic diagram of the water management of the mine service water circuits and the percentage time spent on water management.



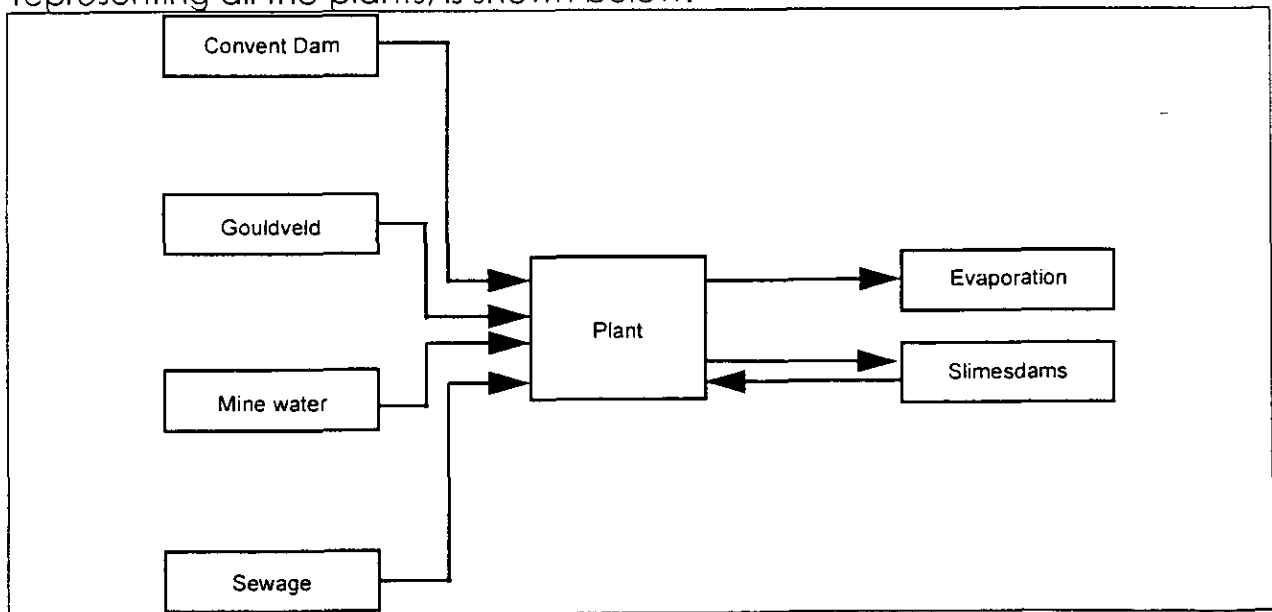
5. Management Options

Option A is currently being used which is to purchase increased supplies of fresh water in order to control the water in the circuit to a constant salinity. This management option will change to Option B as the TDS increases. Option B treats the water in order to control the water in the circuit to a constant salinity and hold the volumes of input water constant. The main driving force behind this choice is the water restrictions.

IV. METALLURGICAL PLANT WATER CIRCUITS

1. Water Reticulation Diagram

A schematic reticulation diagram of the metallurgical plant water circuits, representing all the plants, is shown below:



The quantities of make-up water and the source of the water is summarised in the table below :

PLANT	WATER SOURCE	KILOLITRES/MONTH
Central plant :	Goudveld water	23399
	Sewage from H/Plant	170527
	Slimes dam return	129284
Harmony plant :	Goudveld water	2346
	Mine water	464396
	Ex sewage	127001
Merriespruit plant :	Goudveld water	16900
	Convent Dam	234197
	Slimes dam return	115457
Virginia plant :	Goudveld water	14182
	Mine water	170613
	Sewage	136687

2. Water Quality Aspects

2.1 Water quality in metallurgical plant water circuits

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Plant return water	720	-	1181	525	2287	5599
Mine water	338	-	1373	540	2458	5035
Convent Dam	517	-	1357	579	2119	5324
Goudveld water	71	27	74	183	88	549

2.2 Water sources

The current water sources are adequate for present and future water requirements. The mine is currently investigating the possibilities of using evaporation dams as a source of water in the future.

2.3 Water quality problems

The water used in the metallurgical plant is not treated. The coolers and compressors in the metallurgical plants that have the potential problem of scaling use Goudveld water as make-up water.

2.4 Water management

No actions are currently being undertaken to manage the quality of the water circulated in the metallurgical plant.

3. Effluent Systems

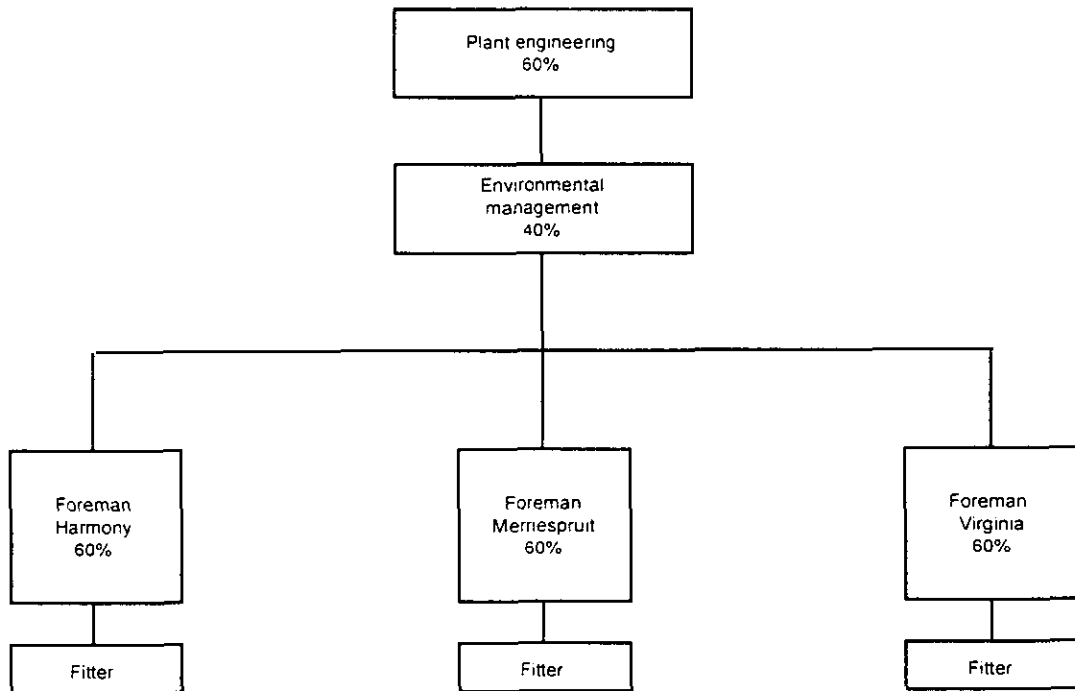
Effluent sources arising from the metallurgical plant water circuits are sent to the slimes dams and evaporation dams. Effluent from the change house is



sent to the sewage plant. No effluents are treated in the plant before discharge.

4. Water Management Structure

The management of the water in the plant concentrates on the volumes of water and not the treatment of water. The management structure for the water management at the plant and the percentage of their time on water management can be schematically shown as :-



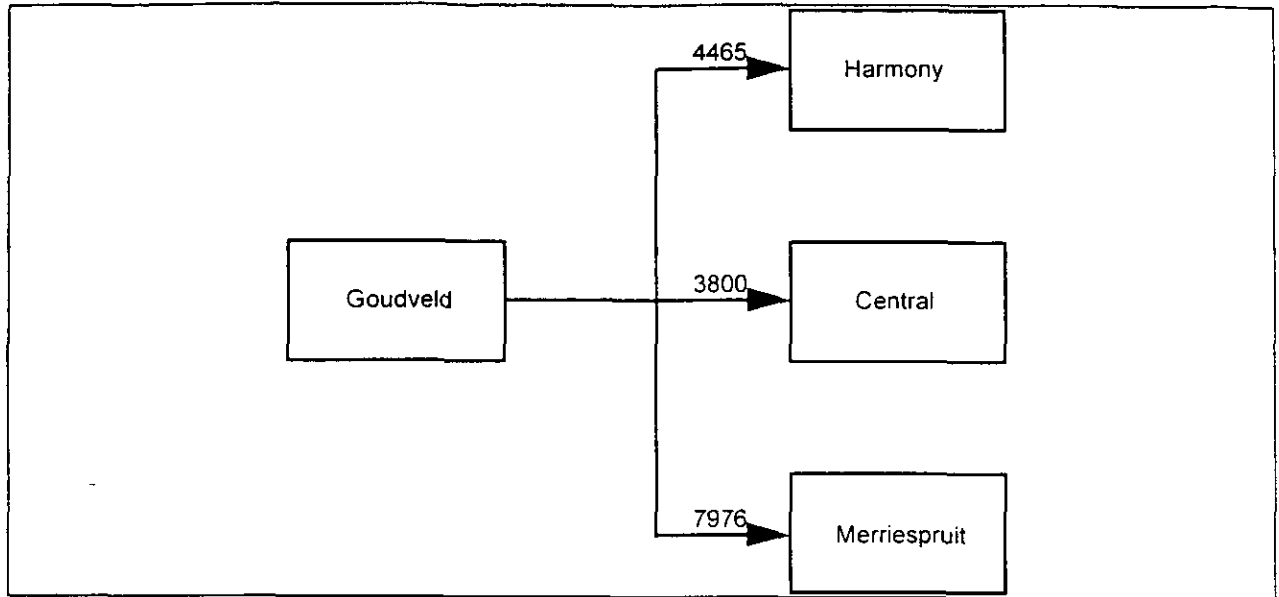
5. Management Options

No water treatment is practised in the plant. The increased TDS is considered to have no effect in the plant. No specific sensitive users are present in the plant.

V. IRRIGATION WATER CIRCUITS

1. Water Reticulation Diagram

The volume of Goudveld water distributed during September 1995 to irrigate three slimes dams that have been grassed is shown below:



All quantities indicated are in kilolitres/month.

2. Water Quality Aspects

2.1 Water quality

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Regional water	71	27	74	183	88	549

2.2 Water sources

The current water sources are adequate.

2.3 Water quality problems

No problems are being experienced

2.4 Water management

The slimes dams are being irrigated by untreated Goudveld water.

3. Water Management and Structure

The current average monthly management cost is R88 000/month which is mainly labour costs. The average cost of grassing the surface are is R7 000 per hectare and the sides R50 000 per hectare.

4. Management Options



The current management of the irrigation water circuits is simply to treat the effluents or run-off to meet discharge limits. The Goudveld water is used on the slimes dam, however, if the water restrictions persist, sewage water will most likely be used.

QUANTIFYING THE IMPACT OF THE SALINISATION OF SOUTH AFRICA'S WATER RESOURCES WITH SPECIAL REFERENCE TO ECONOMIC EFFECTS

MINE SURVEY REPORT

Name of mine : President Steyn Gold Mine

Geographical location : Central Northern Free State

Water supplier : Goudveld Water Board

1. INTRODUCTION

The salinity of the Vaal River has been increasing steadily over the last few years. This increase in salinity has certain cost implications on the gold mining industry which relies on the river as a source of water. In order to quantify these cost implications, the water circuits affected by an increase in the TDS of river or Board water can be classified into four circuits; namely, evaporative cooling water circuits, mine service water circuits, metallurgical plant water circuits and irrigation water circuits. The variables determining the total cost of the increased TDS in the water to the mining industry have been identified in terms of formulae developed in Phase 1 of the project and can be quantified by extracting information from the survey questionnaire. See Appendix 1 for detailed information as collected in the questionnaire.

2. EVAPORATIVE COOLING WATER CIRCUITS

Water quality related problems experienced in the cooling water circuits at President Steyn include scaling in the boilers, fridge plants and the compressors. The make-up water used in the cooling circuits is Goudveld Water Board water. The water in reticulation in the cooling circuits is treated to minimise corrosion and biological fouling and to prevent scale formation. The effluents arising in the cooling circuits are bled off to evaporation pans for storage or disposal. The effluents are not treated and the only cost associated with the discharge are pumping costs. However, the mine cannot quantify these pumping costs.

The water management option currently in use at the mine is Option B, which is to treat the water in the circuit in order to control the water to a constant salinity. An increase in the TDS will result in a change in the management option. Option A would be the preferred management option. Option A is to increase the supply of fresh water in order to control the water in the circuit to a constant salinity. The reason for this choice is that currently the mine cannot increase their water consumption due to the water restrictions. The water used



as make-up can be chemically treated to control the scaling and corrosion potential. However, if the TDS increases to 1 000 mg/l and above, the treatment would not be effective, and the only viable option is to increase the make-up water volumes. The following determinants and associated costs, where applicable, have been identified :

	VARIABLE	FUNCTION	QUANTITY
BV	Blow down volume		43 036 kl/month
CE	Control equipment maintenance cost		
ED	Evaporative cooling circuit cost		Will be calculated
MC	Maintenance chemicals		R 1 000
MS	Maintenance staff cost		-
MV	Make-up volume		245 458 kl/month
TC	Treatment chemical cost		R 17 263 / month
WC	Water unit cost		R 1,15 /kl
WM	Water management cost	MS + CE	R 422 960
X _{DC}	Site specific discharge cost		0

* The value is the sum for all the cooling circuits per month.

** The maintenance chemicals is estimated as per fridge plant per year.

The chemical treatment cost is based on 4 cycles of concentration and a 28 day month. The evaporative cooling circuits are treated by water treatment consultants, BHT Chemicals.

The blow down volume and make-up data for each cooling circuit was supplied by BHT. The total blow down volume of 43 036 kl/month was calculated using a water balance.

The management cost is based on average salary packages offered on the mines for 1995/1996 and the percentage of time spent on water management in the cooling circuit.

3. MINE SERVICE WATER CIRCUITS

Water quality related problems experienced with mine service water at President Steyn are severe corrosion, erosion and some scaling. In order to minimise the erosion problems, the mine flocculates and settles out suspended solids. The mine neutralises the water with lime to reduce corrosion, and disinfects the water. The mine uses a blend of lime and soda ash to increase the pH buffer capacity of the water circulated. The water is kept within reasonable limits by bleeding off saline water and introducing Goudveld water as make-up. The bleed off is sent to evaporation dams for storage or disposal. Large quantities of fissure water enter the service water circuits.

The management option currently being used is Option B which is to treat the water in order to control the water in circulation to a constant salinity and

hold the volumes of input water constant. An increase in the TDS will result in larger volumes of make-up water being purchased as the treatment of the water in the circuit would be ineffective.

The following determinants of the total costs and quantities associated with the TDS of the water have been identified :

VARIABLE		FUNCTION	QUANTITY
Ca	Calcium concentration		547 mg/l**
DC	Discharge cost	f(DV;WQ;WMP;WLA)	
DV	Discharge volume		3 019kl/day*
FI	Fissure water quality & quantity		
GL	Geographic location		N. Free State
MA	Mine age		
MT	Type of mining practised		Open Stoping
PPS	Precipitation potential (CaSO ₄)		-529 mg/l***
RF	Recirculation factor		
SC	Scaling costs	f(WQ;TDS;Ca;SO ₄)	No Sealing
SO ₄	Sulphate concentration		737 mg/l
SW	Service water recirculated	f(SC;DC)	
WLA	Waste load allocation		None yet
WMP	Water management plan		
WQ	Water quality within system	f(WQ;RF;GL;MT;MA;FI)	
WS	Water sources (Goudveld)		Goudveld water

* Discharge volume is a value obtained from the water balance dated April 1994 to March 1995. The discharge is sent to the Dam 13 a process water (1 819 kl/day), gold plant (1 200kl/day) and 2 000 kl/day is lost due to evaporation.

** The concentrations are from the 73 level mains dam.

*** The precipitation potential of CaSO₄ was calculated using AQUACHEM and the same sample as above. The value of -529 indicates non scaling water with regards to CaSO₄.

4. METALLURGICAL PLANT WATER CIRCUITS

The process plant water circuits and the relevant water quality management problems depend on the different process stages which are used in the plants. The President Steyn gold plants receive underground water (1200 kl/day), Goudveld water (717 kl/day), slimes dam return water (3120 kl/day) and borehole water (400 kl/day). The gold plants discharge 7148 kl/day to Dam 13 as process water and lose 100 kl/day due to evaporation. It is felt that an increase in the TDS of the water will have little or no effect in the metallurgical plants. No actions are currently being taken to manage the quality of the water circulated in the metallurgical plant water circuits. The following determinants have been identified within the metallurgical plants which have cost implications due to TDS in the water.

	VARIABLE	FUNCTION	QUANTITY
FC	Flotation circuits cost	$\frac{TDS_N \cdot TCo - TCo}{TDS_0}$	N/A
MP	Met.plant circuits cost		Will be calculated
MV	Make-up volume		12 485 kl/day*
SR	Water treatment plant salt rejection		-
TC	Treatment chemical cost		-
WC	Water unit cost		R 1,15 /kl
WR	Water treatment plant water recovery		-
X _{DC}	Site specific discharge cost		0
X _{WT}	Site specific treatment cost,including operating, capital & brine disposal		0

*The value is a total as obtained from the water balance dated April '994 to March 1995.

Site specific discharge has no costs associated with it, except pumping costs, which cannot be isolated on the mine.

A flotation plant is in operation at President Steyn with a large make-up volume of 28 245 kl/day. The flotation plant receives water from Goudveld water (246 kl/day), slimes dam water (19 879 kl/day), process water from Dam 13 (6499 kl/day) and water from Witpan (1621 kl/day). The discharge (15 530 kl/day) is sent to slimes dams and to the President Brand Gold Mine metallurgical scheme (269 kl/day). A total of 12 715 kl/day is unspecified loss. These figures were obtained from the water balance dated April 1994 to March 1995.

5. IRRIGATION WATER CIRCUITS

Potable water, effluent water and borehole water is used in the irrigation circuits at President Steyn Gold Mine. The effluent water is received from the hostels, offices, work shops and other surface activities. The irrigation circuits indicated in the water balance dated April 1994 to March 1995 are for the purpose of providing water to the sports fields and the gardens. Grassing of slimes dams is not indicated and therefore taken as not currently being practised. No sewage water is used, but this is being considered as a potential water source. The irrigation water circuit costs due to the TDS increase can be calculated using the following determinants :

	VARIABLE	FUNCTION	QUANTITY
IW	Slimes irrigation water circuit cost		Will be calculated
MV	Make-up volume		1 368 kl/day
WC ₀	Water unit cost (Goudveld)		R 1,15 /kl
TDS	Total dissolved solids (Goudveld)		
WC _N	Water unit cost		
MV	Make-up volume (sewage)		
TDS	Total dissolved solids of sewage		

* Total make-up including Goudveld water (18 kl/day), borehole water (100 kl/day) and effluent water (1 250 kl/day).

APPENDIX 1

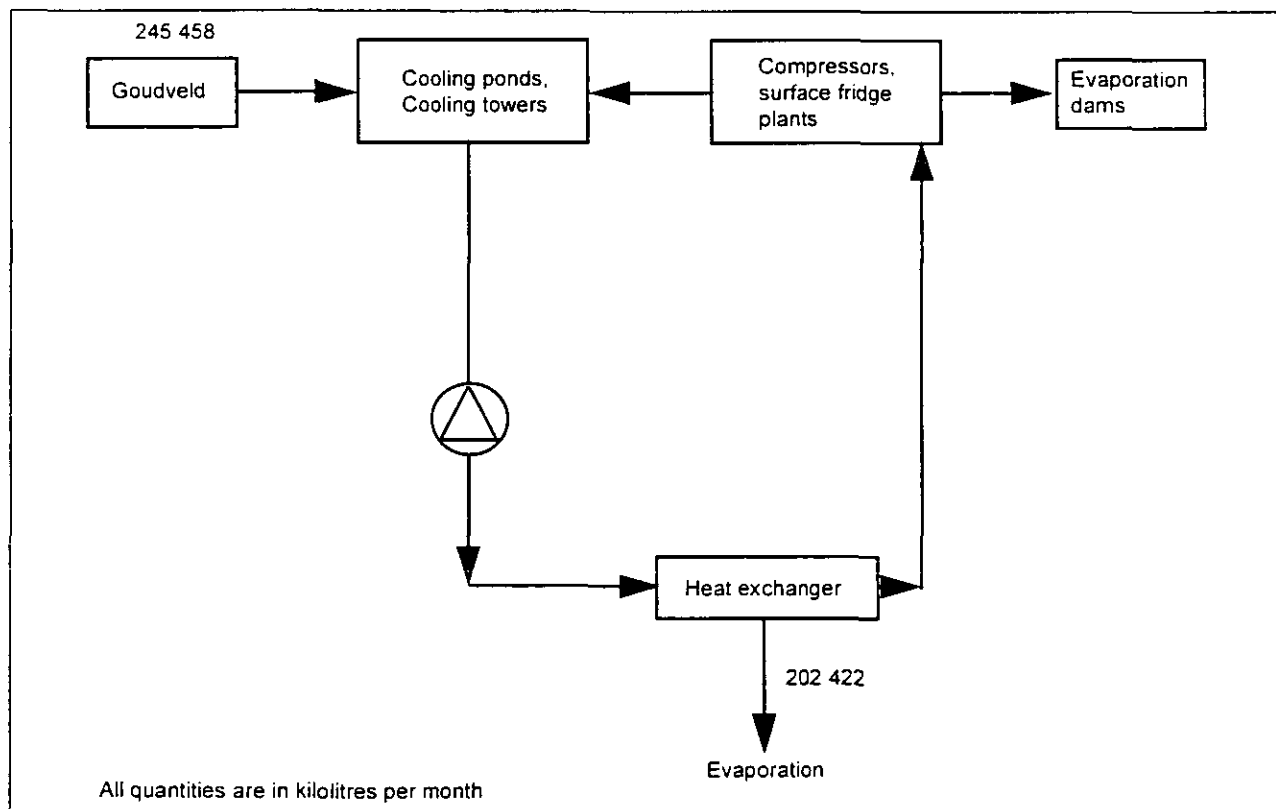
I INTRODUCTION

Theo Pieterse, the regional Water Technologist at President Steyn Gold Mine was visited on 25 October 1995. The mine purchases potable water from Goudveld Water Board at R 1,15/kl. The mining method used is standard open stoping layout. The mine has 4 operational shafts and 2 metallurgical plants.

II EVAPORATIVE COOLING WATER CIRCUITS

1. Water Reticulation and Flow Diagram

A simplified water reticulation diagram of the cooling systems at President Steyn Gold Mine is shown below :



2. Water Quality Aspects

2.1 Water quality

Description	Ca	Mg	Na	SO	Cl	TDS
Goudveld water	33	-	-	198	11	580
Bleed from fridge plant condenser south	285	-	-	939	383	2275
Sulzer compressor water 1 #	228	-	-	362	939	2002

2.2 Water sources

The current water sources are adequate for present requirements. Future water requirements will result in purchasing more water from Goudveld Water Board.

2.3 Water quality problems

Water quality related problems experienced in the evaporative cooling water circuits are calcification (scaling) in the boilers, fridge plants and compressors. Biological fouling is also a problem.

2.4 Water quality management

A consulting water treatment company, BHT, treats the water in the cooling water circuits with biocides and antiscalants. Treatment chemical costs are shown in the table below :

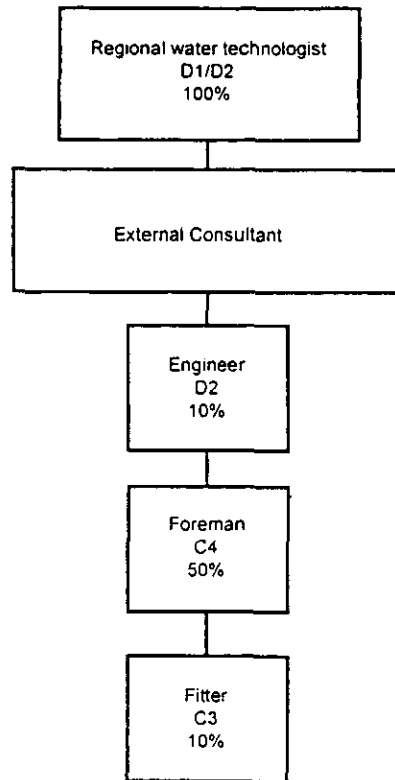
Total antiscalant	R72335
Biocide	8675
Algecide	13396
TOTAL PER MONTH	R94406

3. Effluent Systems

Effluent arising from the cooling circuits are sent to evaporation dams and small ponds. No costs are associated with the discharge of these effluents or bleed-off from the cooling circuits. The effluents are not treated in any way.

4. Water Management Structure and Personnel

Below is the basic management structure at President Steyn Gold Mine and the average time spent on the water management in the cooling circuits and the grading on the Patterson scale. The total cost of the water management in the cooling circuit is estimated at R 422 960 per annum. The costs of the external consultants service is included in the chemical costs. The 1995/1996 average salary package on each level was used to calculate the management cost.



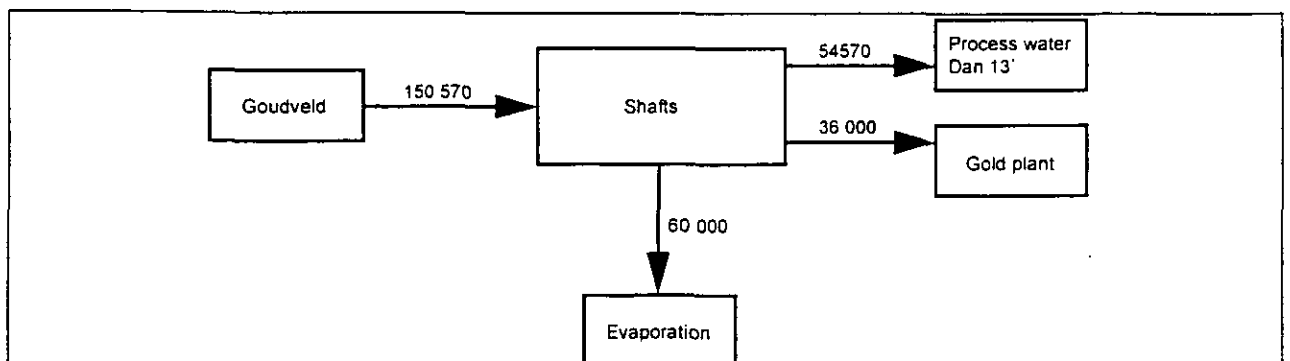
5. Management Options

The Goudveld water has a TDS of between 300 mg/l and 600 mg/l. The current management is (Option B) to treat the water in circulation in order to control the water to a constant salinity and hold the volumes of input water constant. However, if the TDS is to increase to 1 000 mg/l and above, the management would need to change to (Option A) which is to purchase increased supplies of fresh water in order to control the water in the circuit to a constant salinity. The water restrictions will however have a noticeable influence in this practice.

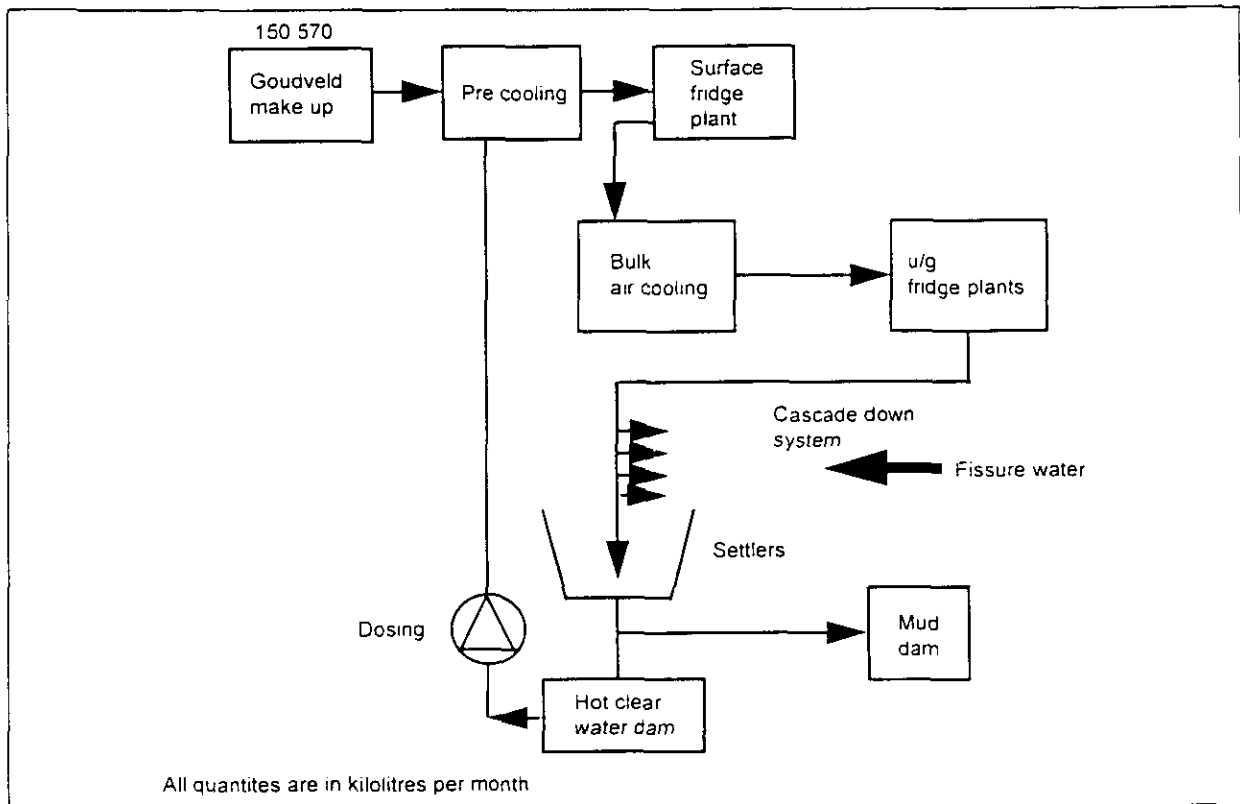
III MINE SERVICE WATER CIRCUITS

1. Water Reticulation and Flow Diagram

A simplified water balance of the mine service water is shown below :



A simplified reticulation diagram of the mine service water is shown below :



2. Water Quality Aspects

2.1 Water quality in service water circuits

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Goudveld water	33	-	-	198	111	581
40 level mains dam	539	-	-	1490	950	4123
50 level service water (hot)	181	-	-	820	489	2233
Chilled service water surface	71	-	-	342	227	1162

2.2 Water sources

The current water sources are adequate for the service water.

2.3 Water quality problems

The problems experienced in the mine service water service are CaSO₄ precipitation.

2.4 Water quality management

Liming is practised to control the pH of the water and prevent corrosion. The water sent to the plant is not treated. The water is flocculated, settled and

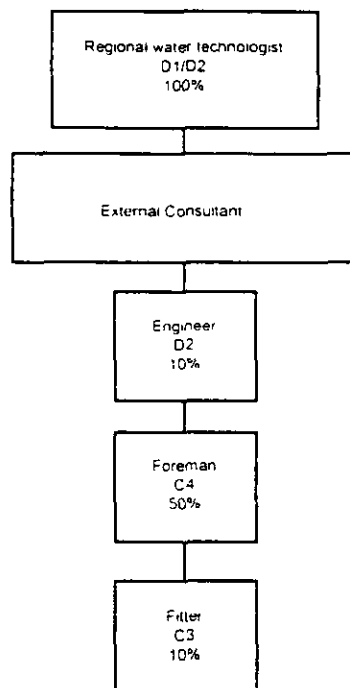
disinfected before being pumped to surface. A blend of lime and soda ash is added to increase buffer capacity. Oxidising biocide is added to the water. The total cost of the biocides for President Steyn mine is R 45000/ month in total.

3. Effluent systems

The effluents arising from the service water circuits are sent to the evaporation dams. No treatment of these effluents takes place.

4. Water management structure

The basic management structure of the water management in the service water circuits is shown below :



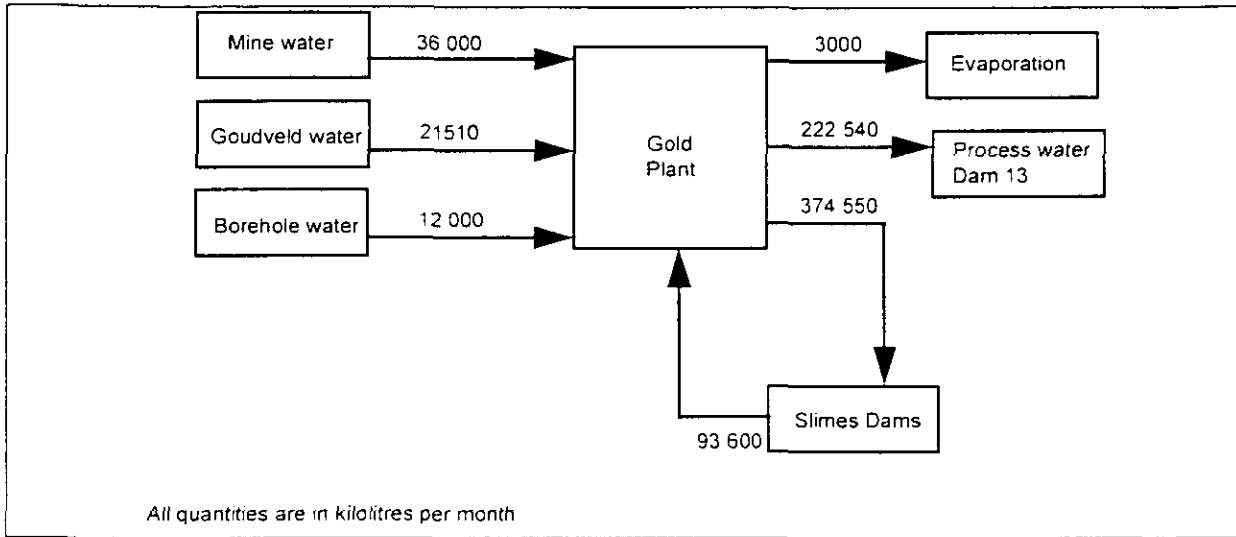
5. Management Options

Option B is currently being used where they are treating the water in order to control the water to a constant salinity and hold the volumes of input water constant. Option A is purchasing increased supplies of fresh water in order to control the water to a constant salinity. The problem with this choice is that water restrictions do not allow for the increased volumes of water in Option A.

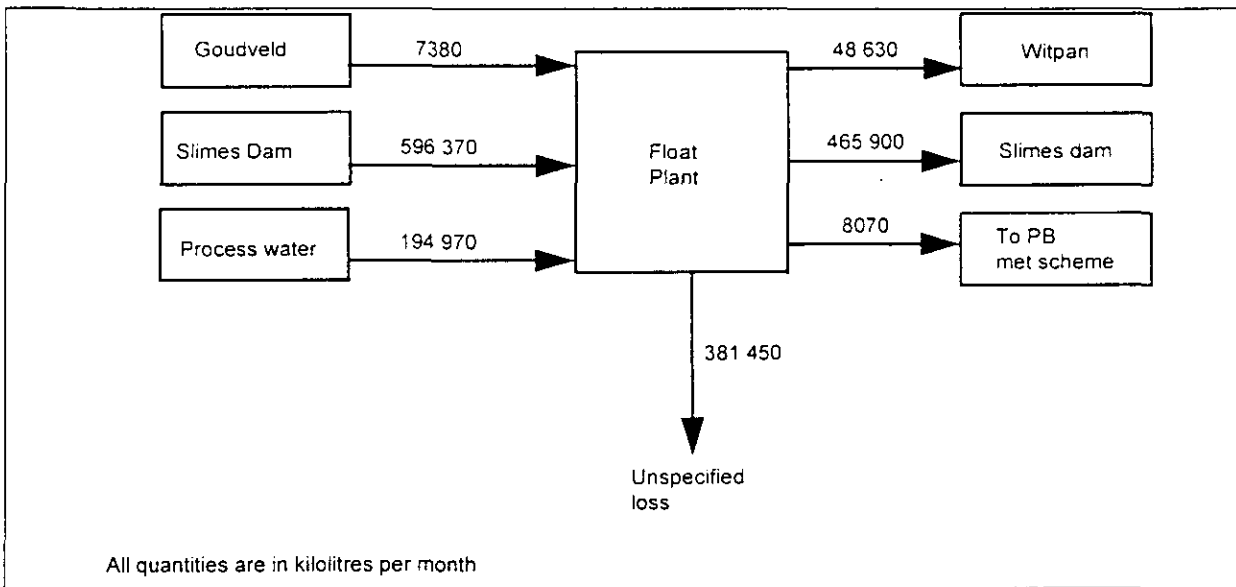
IV METALLURGICAL PLANT WATER CIRCUITS

1. Water Reticulation Diagram

A simplified water reticulation diagram of the input and output of the metallurgical plants is shown below :



A flotation plant is located at President Steyn mine consuming Goudveld water. A simplified reticulation diagram of the flotation plant is shown below :



2. Water Quality Aspects

2.1 Water quality in metallurgical plant water circuits

Residue is pumped to the slimes dams. The water is not treated in the metallurgical plant.

Water Source	Ca	Na	SO ₄	Cl	TDS
Residue filtrate	760	520	1320	1150	4320
SD return water	580	575	1430	1010	3250
Dam 13 water	1560	-	1920	1510	6300
Witpan evap. dam.	-	-	450	550	1580



2.2 Water sources

The current water sources are adequate for present and future water requirements. If draught causes the process dams to become an inadequate supply for make-up, there are arrangements with Joel, Beatrix and Harmony to acquire their excess U/G water.

2.3 Water quality problems

The water is used in the metallurgical plant untreated. No scaling or other water quality problems have been experienced.

2.4 Water management

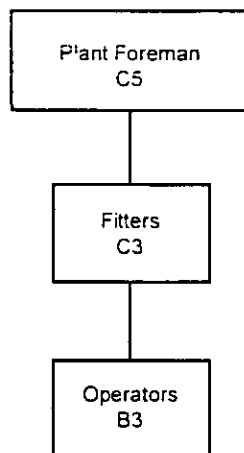
No actions are currently being undertaken to manage the quality of the water circulated in the metallurgical plant.

3. Effluent Systems

Effluent sources arising from the metallurgical plant water circuits are sent to the slimes dams and evaporation dams. Effluent from the flotation plant (269 kl/day) is sent to the President Brand metallurgical scheme.

4. Water Management Structure

The management structure for the water management of the plant can be schematically represented, with the level on the Patterson Grading System, as shown below.



5. Management Options

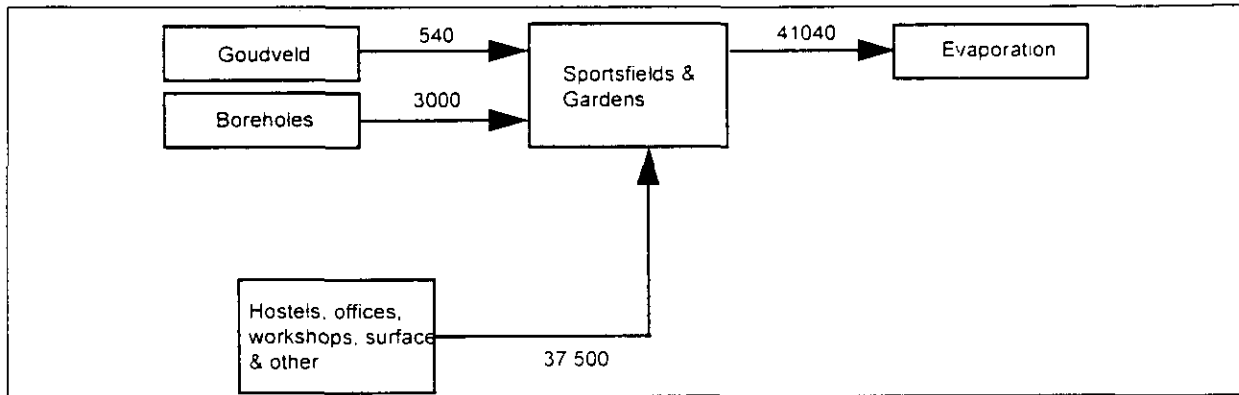
No water treatment is practised in the plant. The increased TDS is considered to have no effect in the plant. No specific sensitive users are in use at the

plant. The make-up water in the metallurgical plant is reticulated water from the mine.

V IRRIGATION WATER CIRCUITS

1. Water Reticulation Diagram

The simplified reticulation diagram of the irrigation circuit at President Steyn is shown below.



All quantities indicated are in kilolitres per month

2. Water Quality Aspects

2.1 Water quality

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Goudveld water	33	-	-	198	111	581

2.2 Water sources

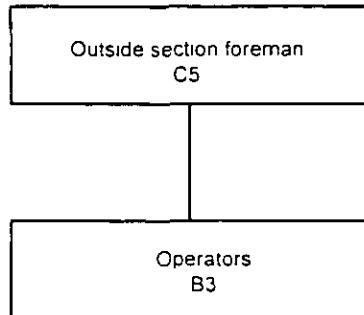
The current water sources are adequate. Sewage water can be planned for in the future if water shortages occur.

2.3 Water quality problems

No problems are being experienced.

3. Water Management and Structure

A schematic diagram of the management structure of the irrigation water circuits is shown below.



QUANTIFYING THE IMPACT OF THE SALINISATION OF SOUTH AFRICA'S WATER RESOURCES WITH SPECIAL REFERENCE TO ECONOMIC EFFECTS

MINE SURVEY REPORT

Name of mine : Western Holdings Gold Mine

Geographical location : Central Northern Free State

Water supplier : Goudveld Water Board

1. INTRODUCTION

The salinity of the Vaal River has been increasing steadily over the last few years. This increase in salinity has certain cost implications on the gold mining industry which relies on the river as a source of water. In order to quantify these cost implications, the water circuits affected by an increase in the TDS of river or Board water can be classified into four circuits; namely, evaporative cooling water circuits, mine service water circuits, metallurgical plant water circuits and irrigation water circuits. The variables determining the total cost of the increased TDS in the water to the mining industry have been identified in terms of formulae developed in Phase 1 of the project and can be quantified by extracting information from the survey questionnaire. See Appendix 1 for detailed information as collected in the questionnaire.

2. EVAPORATIVE COOLING WATER CIRCUITS

Water quality related problems experienced in cooling water circuits at Western Holdings include scaling in the boilers, the fridge plants and the compressors. The make up water used in the cooling circuits is Goudveld Water Board water. Effluents arising from the evaporative cooling circuits are bled off into evaporation dams at no operational cost other than pumping. Shaft 2 fridge plant bleeds off into the service operational cost other than pumping. Shaft 2 fridge plant bleeds off into the service water circuit. These effluents are not treated in any way. The current management of the evaporative cooling water circuits at Western Holdings is following Option B which is to treat the water in order to control the water in the circuit to a constant salinity. If the TDS levels increase to 1000 mg/l and above, increased supplies of fresh water for make-up will be purchased to control the salinity. The chemical treatment cost in the compressors was calculated using an average of 4 cycles of concentration. The evaporative cooling circuits water is treated by BHT Chemicals. BHT provided the make up volumes, blow down volumes and treatment chemical cost for each compressor. The value

indicated in the table above is a total for the cooling circuits at Western Holdings.

	VARIABLE	FUNCTION	QUANTITY
BV	Blow down volume		16 054 kl/month
CE	Control equipment maintenance cost		-
EC	Evaporative cooling circuit cost		Will be calculated
MC	Maintenance chemicals		R1000*
MS	Maintenance staff cost		-
MV	Make-up volume		64 011 kl/month
TC	Treatment chemical cost		R151 130 /month
WC	Water unit cost		R1,15 /kl
WM	Water management cost	MS+CE	R219 740 **
X _{PC}	Site specific discharge cost		

* Estimated maintenance chemical cost per fridge plant per year.

** Estimated management cost according to salary package value, positions held on mine and percentage of time spent on management of the cooling circuits. The treatment chemical cost includes the service charges for BHT chemical and water treatment

3. MINE SERVICE WATER CIRCUITS

Water quality related problems experienced with mine service water at Western Holdings are corrosion, erosion and scaling. In order to minimise the erosion problems, the mine flocculates and settles out suspended solids. A blend of lime and soda ash is added to the mine service water to increase the pH buffer capacity. The water quality is kept within reasonable limits by bleeding off saline water and introducing Goudveld Water as make-up. The bleed-off is sent to evaporation dams for storage or disposal. Large quantities of fissure water enter the service water circuits. The following are determinants of the total costs and quantities associated with the TDS of the water :

	VARIABLE	FUNCTION	QUANTITY
Ca	Calcium concentration		766 mg/l**
DC	Discharge cost	f{DV;WQ;WMP;WLA}	-
DV	Discharge volume		3129 kl/day*
FI	Fissure water quality & quantity		
GL	Geographic location		N. Free State
MA	Mine age		
MT	Type of mining practised		Open stoping
PPS	Precipitation potential (CaSO ₄)		83l
RF	Recirculation factor		
SC	Scaling costs	f{WQ;TDS;Ca;SO ₄ }	
SO ₄	Sulphate concentration		2400mg/l***
SW	Service water recirculated	f{SC;DC}	
WLA	Waste load allocation		None yet
WMP	Water management plan		
WQ	Water quality within system	f{WS;RF;GL;MT;MA;FI}	
WS	Water sources		Goudveld Water

*The value obtained for discharge volume is water discharged from underground to Holdings Met Plant and to Welkom Plant. The flow data was obtained from the water balance dated April 1994 to March 1995.

**The concentrations are from a sample of service water at level 37.

***The precipitation potential of CaSO_4 was calculated using AQUACHEM. According to the PPS, the water in circulation in the mine service water circuits is already scaling.

4. METALLURGICAL PLANT WATER CIRCUITS

Further information regarding the metallurgical plants, the water management and circuit costs are required. The process plant water circuits and the relevant water quality management problems depend on the different process stages which are used. The plant at Western Holdings is supplied with Goudveld Water, mine water from the shafts and a surface dam. The plant discharges effluents to the slimes dams and receives return water from the slimes dams. It has been observed that the increased TDS of the water has little or no effect in the metallurgical plant. No actions are currently being taken to manage the quality of the water circulated in the metallurgical plant water circuits. The following determinants have been identified within the metallurgical plant which have cost implications due to TDS in the water.

	VARIABLE	FUNCTION	QUANTITY
FC	Flotation circuits cost	$\frac{\text{TDS}_N \times \text{TC}_o - \text{TC}_o}{\text{TDS}_o}$	Not applicable
MP	Met.plant circuits cost		Will be calculated
MV	Make-up volume		10106 kl/day*
SR	Water treatment plant salt rejection		-
TC	Treatment chemical cost		-
WC	Water unit cost		R1,17 / kl
WR	Water treatment plant water recovery		-
X_{DC}	Site specific discharge cost		0
X_{WT}	Site specific treatment cost, including operating, capital & brine disposal		0

* The value of 8 134 kl/day is made up of the mine water, slimes dam return water, Goudveld water and process water from "D" dam. The value is as indicated on the water balance dated April 1994 to March 1995.

Site specific discharge has no costs associated with it, except pumping costs which cannot be isolated on the mine.

5. IRRIGATION WATER CIRCUITS

The irrigation at Western Holdings is undertaken with Goudveld water. The main areas of irrigation are the slimes dams grassing and on the golf course. However, no flow meters are used so no measurements of volume are available. No sewage is used in these irrigation circuits. The irrigation water circuit costs due to the TDS can be calculated using the following determinants :



	VARIABLE	FUNCTION	QUANTITY
IW	Slimes irrigation water circuit cost		Will be calculated
MV	Make up volume		Unknown*
WC _o	Water unit cost (old)		R 1.15 /kl
TDS	Total dissolved solids		

* The mine is unable to quantify the water used in the irrigation circuits.

8. CONCLUSION

In conclusion, the increased TDS in the Vaal River has cost implications on Western Holdings Gold Mine. The largest cost implications are in the evaporative cooling circuits. The water restrictions do not allow the mines to optimise the processes used in mining and the resultant cost of the treatment of the water is increasing. The water treatment can only be effective to a certain degree, after which good quality make-up water is required in larger quantities.

APPENDIX 1

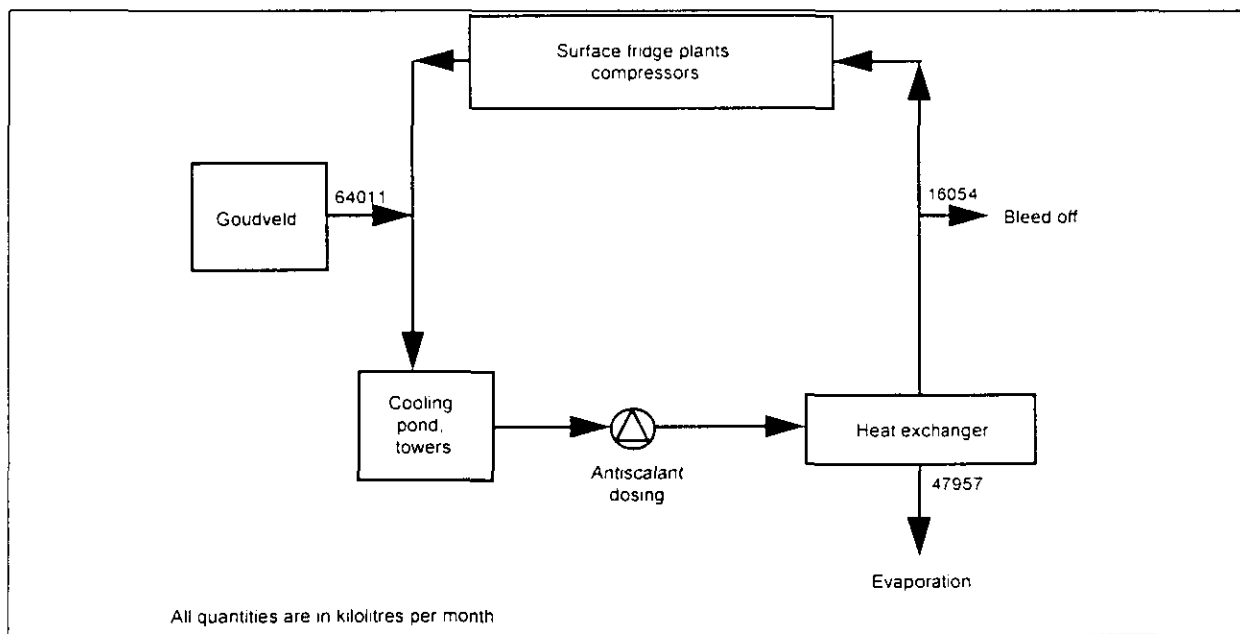
I GENERAL INFORMATION

Theo Pieterse, the Regional Water Technologist at Western Holdings Gold Mine was visited on 26 October 1995. The mine purchases potable water from Goudveld Water Board at R1,15 /kl. The expected life of the mine is to 1995. The mining method used is standard open stoping layout.

II EVAPORATIVE COOLING WATER CIRCUITS

1. Water Reticulation and Flow Diagram

A simplified water reticulation diagram of the cooling systems at Western Holdings Gold Mine is shown below:



The evaporative value in the reticulation diagram is calculated using the water balance.

2. Water Quality Aspects

2.1 Water quality

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Compressor dam 8#	185	-	-	687	526	4858
Fridge plant evaporator (surface)	279	-	-	377	2551	6071
Goudveld Water make-up	67	-	-	158	111	580
Compressor tower	280	-	-	941	555	2328

2.2 Water sources

The current water sources are adequate for present requirements. Future water requirements will result in purchasing more water from Goudveld Water Board or using treated sewage water.

2.3 Water quality problems

Water quality related problems experienced in the evaporative cooling water circuits are calcification (scaling) in the boilers, fridge plants and compressors. Some biological fouling is also experienced.

2.4 Water quality management

A consulting water treatment company, BHT, treats the water in the cooling circuits. The reticulated water in the cooling circuits gets dosed with antiscalant and an oxidising biocide. The chemical treatment cost, for a 28 day month, of the cooling circuit in each shaft is shown in the table below:

The costs cover four cycles in the circuit.

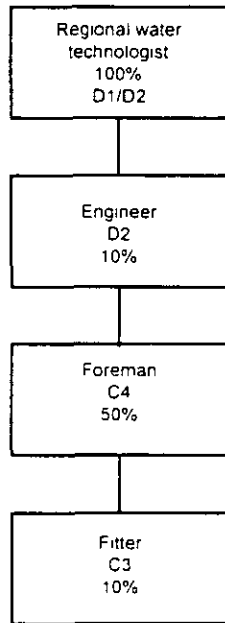
1#	R 51162,77
2#	R 4670,06
4#	R 37667,07
5#	R 11925,35
6#	R 16276,43
7#	R 29428,63
	R151130,31

3. Effluent Systems

Effluents arising from the cooling circuits are sent to evaporation dams. No costs, other than pumping (which cannot be quantified), are associated with the discharge of these effluents or bleed-off from the cooling circuits. The effluents are not treated in any way.

4. Water Management Structure and Personnel

Below is the basic management structure at Western Holdings Gold Mine and the average time spent on the water management in the cooling circuits and the grading on the Patterson scale.



According to the above, the estimated management cost is R219740. The cost is based on 1995/1996 average salary packages on the mine.

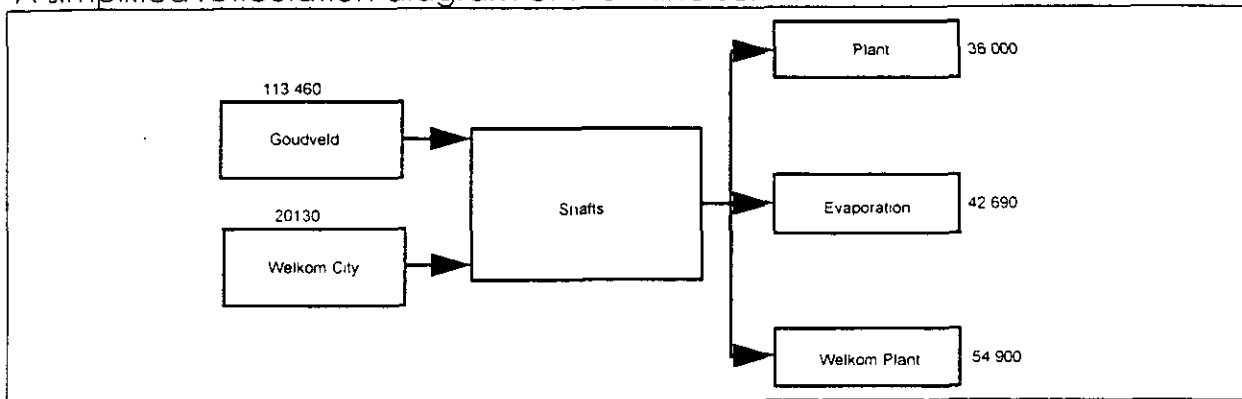
5. Management Options

The Goudveld water has a TDS of between 300 mg/l and 600 mg/l. The current management is (Option B) to treat the water in the circuit in order to control the water to a constant salinity and hold the volumes of input water constant. However, if the TDS is to increase to 1000 mg/l and above, the management would need to change to (Option A), to purchase increased supplies of fresh water in order to control the water to a constant salinity.

III MINE SERVICE WATER CIRCUITS

1. Water Reticulation and Flow Diagram

A simplified reticulation diagram of the mine service water is shown below:



All quantities are in kilolitres per month.

2. Water Quality Aspects

2.1 Water quality in service water circuits.

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Goudveld water	67	-	-	158	111	580
Clear water service water (in Shaft)	380	-	-	1174	1796	5327

2.2 Water sources

The current water sources are adequate for the service water. The evaporation dams store large amounts of water, and these will be tapped to a larger extent if a water shortage occurs.

2.3 Water quality problems

The problems experienced in the mine service water are scaling and corrosion.

2.4 Water quality management

Liming is practised to control the pH of the water and prevent scaling and corrosion. The cost of lime is R10,58 per 25 kilogram bag. The cost to lime 4#, 8# and 7# would currently be R1058/month, R2116/month and R7618/month respectively. The water is still then disinfected and flocculated.

3. Effluent systems

The effluents arising from the service water circuits are sent to the evaporation dams. No treatment of these effluents takes place.

4. Water management structure

The management structure of mine service water circuits is the same as the evaporative cooling circuits.

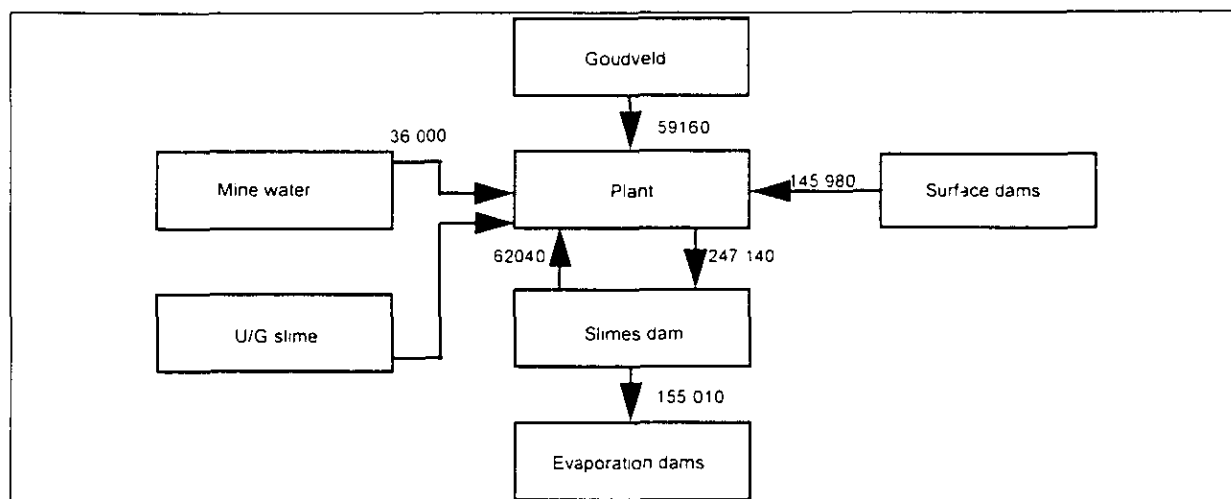
5. Management Options

Option A is currently being used which is purchasing increased supplies of fresh water in order to control the water in the circuit to a constant salinity. This management option will change to Option B if the TDS increases, in other words treating the water in order to control the water to a constant salinity and hold the volumes of input water constant. The main driving force behind this choice is that water restrictions do not allow for the increased volumes of water in Option A. However, the option will be chosen as technology and the economic viability thereof permits.

IV METALLURGICAL PLANT WATER CIRCUITS

1. Water Reticulation Diagram

More detailed information concerning the water in the met plant will be incorporated when available. A simplified water reticulation diagram of the input and output of the metallurgical plants is shown :



All quantities are in kilolitres per month.

1.1 Water sources

Current water sources are adequate. If drought causes the process dams to become an inadequate supply for make-up, there are arrangements with Joel, Beatrix and Harmony to acquire their excess u/g water. The total metallurgical consumption of Goudveld Water is only in the region of 5 - 6% of Freegold consumption.

1.2 Water quality problems.

The water is used in the metallurgical plant untreated. No water quality related problems are experienced in the met. plants.

Source	TDS	Ca	Na	SO ₄	Cl
FSG dam	3610	460	390	1230	900
Goudveld water	84	-	-	210	100
Residue filtrate	5930	870	880	1530	1480
Slimes dam return	2810	350	540	1290	740

2. Water management

No actions are currently being undertaken to manage the quality of the water circulated in the metallurgical plant.

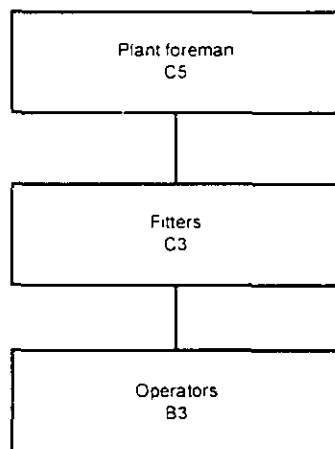
3. Effluent Systems

Effluent sources arising from the metallurgical plant water circuits are sent to the slimes dams and evaporation dams. Occasional excess water in the plants generally flows back to process water dams.

4. Water Management Structure

There are no specific "plant water circuit" management structures within Freegold. Responsibility lies with the operational control management structure. The management ensures primarily that there is sufficient process water available for the plant.

The management structure for the water management at the plant can be schematically represented, with the level on the Patterson Grading System, as follows :



5. Management Options

No water treatment is practised in the plant. The increased TDS is considered to have no effect in the plant.

V IRRIGATION WATER CIRCUITS

No irrigation circuits at Western Holdings have a measured flow. The golf course is watered regularly with Goudveld water. The option of treated sewage water is a long term project at the mine. The irrigation circuits do not use treated water and the circuits do not have a management structure.



2. Water Quality Aspects

2.1 Water quality

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Goudveld water	67	-	-	158	111	580
Sewage water	128	-	-	417	270	870

2.2 Water sources

The current water sources are adequate. Sewage water can be planned for in the future if water shortages occur.

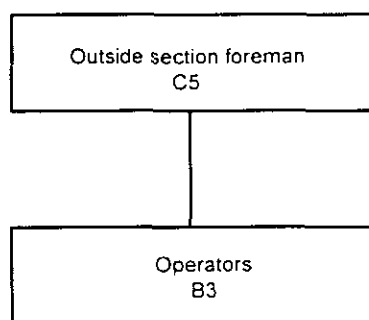
2.3 Water quality problems

No problems are being experienced.

2.4 Water management

The water is treated in the sewage plant. The slimes dams are being irrigated with Goudveld water.

3. Water Management and Structure



The average monthly management cost is R3000/month.

4. Management Options

The current management of the irrigation water circuits is simply to treat the effluents or run-off to meet discharge limits. The Goudveld water is used on the slimes dam, however, if the water restrictions persist, sewage water will most likely be used.

QUANTIFYING THE IMPACT OF THE SALINISATION OF SOUTH AFRICA'S WATER RESOURCES WITH SPECIAL REFERENCE TO ECONOMIC EFFECTS

MINE SURVEY REPORT

Name of Mine : Vaal Reefs Mining & Exploration Limited

Geographical location : South Eastern part of North West Province

Water supplier : Western Transvaal Regional Water Board

1. INTRODUCTION

The salinity of the Vaal River has been increasing steadily over the last few years. This increase in salinity has certain cost implications on the gold mining industry which relies on the river as a source of water. In order to quantify these cost implications, the water circuits affected by an increase in the TDS of river or Board water can be classified into four circuits; namely, evaporative cooling water circuits, mine service water circuits, metallurgical plant water circuits and irrigation water circuits. The variables determining the total cost of the increased TDS in the water to the mining industry have been identified in terms of formulae developed in Phase 1 of the project and can be quantified by extracting information from the survey questionnaire. See Appendix 1 for detailed information as collected in the questionnaire.

2. EVAPORATIVE COOLING WATER CIRCUITS

Water quality related problems experienced in cooling water circuits at Vaal Reefs are severe corrosion and scaling. Scaling inhibition programmes are under way in all the cooling circuits. The make up water used in the cooling circuits is Western Transvaal Regional water. Effluents arising from the evaporative cooling circuits are sent to the plants to be used as process water. No costs can be ascribed to the discharge other than pumping. These effluents are not treated in any way.

The current management of the evaporative cooling water circuits at Vaal Reefs is following Option B, which is to treat the water in order to control the water in the circuit to a constant salinity and hold the volumes of input water constant. However, if the TDS is to increase to 1 200 mg/l and above, the option would change to Option A which is to purchase increased supplies of fresh water in order to control the water in the circuit to a constant salinity. Option A will only be used if the water restrictions permit it. The water restrictions imposed on the mines have a significant effect on the management practice. If the water restrictions persist, the treatment of the water will be impossible and too expensive. Vaal Reefs uses oxidising biocides

and antiscalants in the evaporative cooling circuits in order to prevent scale formation, biological fouling and to minimise corrosion. The following determinants and associated costs, where applicable, have been identified :

	VARIABLE	FUNCTION	QUANTITY
BV	Blow down volume		1 291 kl/day*
CD	Control equipment maintenance cost		
EC	Evaporative cooling circuit cost		Will be calculated
MC	Maintenance chemicals		R625 000/year**
MS	Maintenance staff cost		
MV	Make-up volume		9 320 kl/day*
TC	Treatment chemical cost		R956 878/year***
WC	Water unit cost		R0,8766/kl
WM	Water management cost	MC + MS +CE	
X _{DC}	Site specific discharge cost		

* Blow down volume and the make up volume of the shafts in total.

** The maintenance chemicals may include some treatment chemical costs, the above figure is for the scale inhibition programme chemicals only.

*** The treatment chemical cost is the cost of the biocides (R111 576/year), the boiler water softening treatment (R220 302/year) and the scale inhibitor (R625 000/year).

The chemical treatment cost in the compressors are provided by the mine.

The site specific discharge is considered to be nil except for pumping costs. The pumping costs cannot be isolated from other costs on the mine.

Vaal Reefs has two type of boilers that are sensitive to an increase in TDS. Firstly, nine fire tube boilers are used and 38 electro-boilers. See Appendix 1 (Section II, Point 6) for cost detail associated with the required water treatment for these boilers. A combined total cost of R1 571,42/day additional cost plus a maintenance cost of R3 585/year.

3. MINE SERVICE WATER CIRCUITS

Water quality related problems experienced with mine service water at Vaal Reefs are severe corrosion, erosion and scaling. In order to minimise the erosion problem, the mine flocculates and settles out suspended solids. The water quality is kept within reasonable limits by bleeding off saline water and introducing Western Transvaal water as make-up. The bleed off is sent to evaporation dams for storage or disposal. Vaal Reef is termed a "dry mine" as no fissure water enters the mine service water circuits. The mine is investigating the possibility of receiving Stilfontein Mine's water for use in the Vaal Reefs mine service water circuits.

The management of the water in the mine service water circuit is currently following Option B, namely to treat the water in order to control the water to a constant salinity and hold the input water volumes constant. If the TDS is to increase to 1 200 mg/l, the current treatment would be ineffective. The result would be it increase the supplies of fresh water in order to control the water

to a constant salinity. However, this option will only be viable if the water restrictions are dropped.

The following are determinants of the total costs and quantities associated with the TDS of the water :

	VARIABLE	FUNCTION	QUANTITY
Ca	Calcium concentration		568 mg/l**
DC	Discharge cost	f(DV;WQ;WMP;WLA)	0
DV	Discharge volume		1 120kl/day
FI	Fissure water quality & quantity		No fissure water
GL	Geographic location		N W Province
MA	Mine age		50 years
MT	Type of mining practised		Deep level conventional
PPS	Precipitation potential (CaSO ₄)		-284 mg/l***
RF	Recirculation factor		
SC	Scalin costs	f(WQ;TDS;Ca;SO ₄)	
SO ₄	Sulphate concentration		1 029 mg/l**
SW	Service water recirculation	f(SC;DC)	
WLA	Waste load allocation		None yet
WMP	Water management plan		R0.8766/kl
WQ	Water quality within system	f(WS;RF;GL;MT;MA;FI)	
WS	Water sources		W.tvl Regional

* The value obtained for discharge volume is a total of the water in the fridge plants for all the shafts in total.

** The concentrations are averages between machine water for 5#, 1#, 2# and 9#.

*** /the precipitation potential of CaSO₄ was calculated using AQUACHEM. According to the PPS, the water in circulation in the mine service water circuits is non scaling.

The water treatment in the service water circuits costs a total of R1,09 million/year for the disinfection, R200,000/year for the flocculation and R575 000/year for the liming.

The discharge of effluents does not have, other than pumping, any costs ascribed to it. The effluents arising from the service water circuits are sent to the plant for reuse as process water. The effluent is not treated.

4. METALLURGICAL PLANT WATER CIRCUITS

Further information regarding the metallurgical plants, the water management and circuit costs are required. The process plant water circuits and the relevant water quality management problems depend on the different process stages which are used. It has been observed that the increased TDS of the water has little or not effect in the metallurgical plant. No actions are currently being taken to manage the quality of the water circulated in the metallurgical plant water circuits. The following determinants have been identified within the metallurgical plant which have cost implications due to TDS in the water.



	VARIABLE	FUNCTION	QUANTITY
FC	Flotation circuits cost	$\frac{TDS_N TCo - TCo}{TDS_o}$	
MP	Met.plant circuits cost		Will be calculated
MV	Make-up volume		
SR	Water treatment plant salt rejection		
TC	Treatment chemical cost		
WC	Water unit cost		R 0.8766 / kl
WR	Water treatment plant water recovery		
X _{DC}	Site specific discharge cost		
X _{WT}	Site specific treatment cost, including operating, capital & brine disposal		

Site specific discharge has no costs associated with it, except pumping costs which cannot be isolated on the mine.

5. IRRIGATION WATER CIRCUITS

The irrigation at Vaal Reefs is undertaken with Western Transvaal. Regional water. The main areas of irrigation are West slimes dam grassing and the Orkney Golf Course. The Orkney Golf Course is irrigated with river water, 182 000 kl/year. The Oppenheimer stadium and other sports fields are irrigated with Western Transvaal Regional water. A total of 146 140 kl/year was consumed. The irrigation water circuits costs due to the TDS can be calculated using the following determinants :

	VARIABLE	FUNCTION	QUANTITY
IW	Slimes irrigation water circuit cost		Will be calculated
MV	Make-up volume		
WC _o	Water unit cost (old)		R0.8766/kl
TDS	Total dissolved solids		800 mg/l

*The TDS is a value for winter. The TDS drops to 400-500 mg/l in summer.

6. CONCLUSION

In conclusion, the increased TDS in the Vaal River has cost implications on Vaal Reefs. The largest cost implications are in the evaporative cooling circuits. The water restrictions do not allow the mines to optimise the processes used in mining and the resultant cost of the treatment of the water is increasing. The water treatment can only be effective to a certain degree, after which good quality make-up water is required in larger quantities.

APPENDIX 1

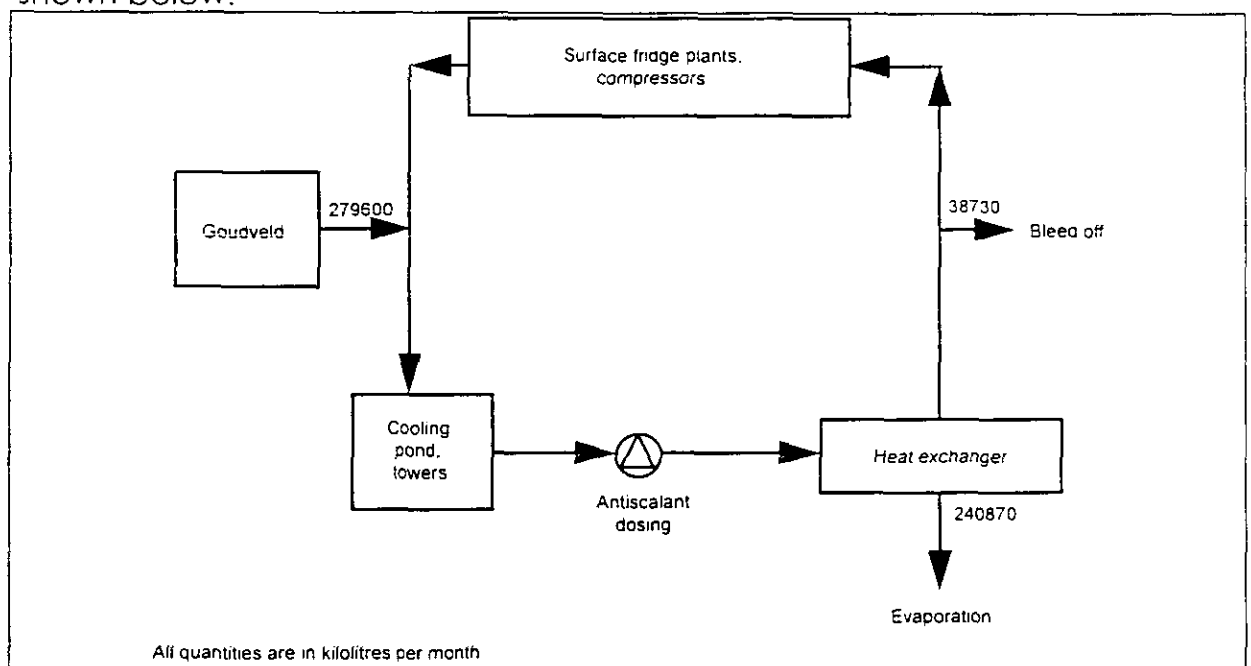
I. GENERAL INFORMATION

Chris Brits, the Regional Water Technologist, provided the data required in the questionnaire. Vaal Reef currently has 10 producing shafts and 5 gold and uranium plants. The monthly tonnages mined are 562 000 tons/month. The monthly tonnages milled are 1 063 000 tons/month. Vaal Reefs treat all the rock brought to the surface, not only for the extraction of gold. This includes the waste dumps and the reclaimed slimes dams. The type of reef being mined is the Ventersdorp Contact Reef, the Vaal Reef and a small portion of the "C" Reef. The mine is 50 years old and has an expected remaining life of 25 years. The mining method used is deep level convention blast stoping. The mine produces gold and uranium in the plants using the acid treatment and the carbon in pulp process. The mine purchases potable water from Western Transvaal Regional Water Company at R0,8766/kl.

II. EVAPORATION COOLING WATER CIRCUITS

1. WATER RETICULATION AND FLOW DIAGRAM

A simplified water reticulation diagram of the cooling systems at Vaal Reefs is shown below.



The evaporation in the reticulation diagram was calculated using the water balance.



2. WATER QUALITY ASPECTS

2.1 Water quality

Description	Ca	Mg	Na	SO4	CO	TDS
W. Tvl water make-up	53	16	43	107	58	800*
Compressor cooling water	271	-	-	460	350	2838
Cooling pond 10#	223	-	-	355	283	2323
Surface fridge plant 9#	164	-	-	510	310	2500

*The TDS is representative of winter, the summer values are - mg/l.

2.2 Water sources

The current water sources are adequate for present requirements. Future water requirements will result in possibly using treated sewage water.

2.3 Water quality problems

Water quality related problems experienced in the evaporative cooling water circuits are calcification (scaling) in the boilers, fridge plants and compressors.

2.4 Water quality management

The water in the cooling circuits is treated. The reticulated water in the cooling circuits is dosed with antiscalant and oxidising biocide. The chemical treatment costs of the cooling circuits are totalled as follows :

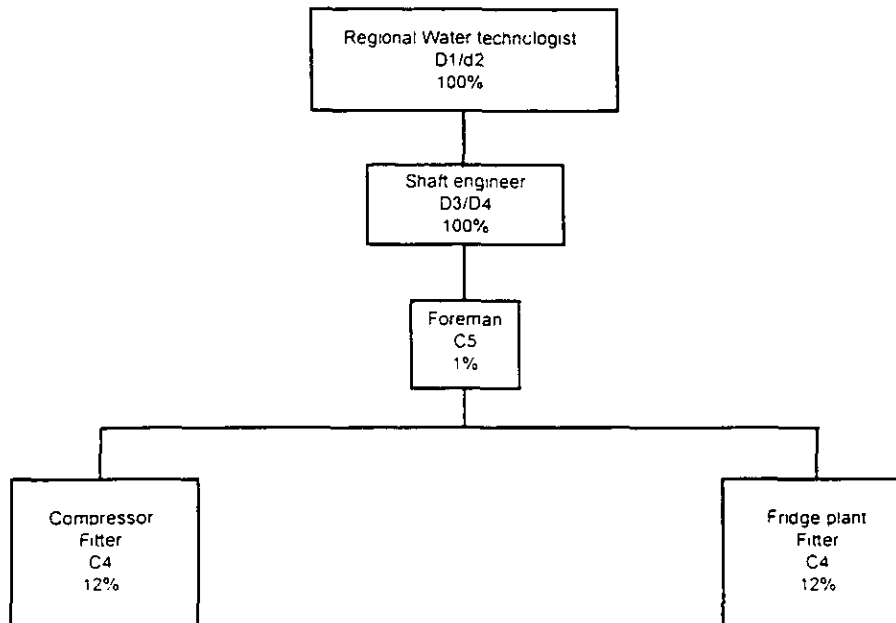
Scale inhibitions	:	R625 000 /year
Biocide	:	R 111576 /year
Boiler water Softening	:	R220 302 /year
TOTAL	:	R956 878 /year

3. Effluent Systems

Effluent arising from the cooling circuits are bled off into drains, collected to run into the Eye and then used in the plants as process water. No costs are associated with the discharge of these effluents or bleed-off from the cooling circuits. The effluents are not treated in any way.

4. Water Management Structure and Personnel

Below is the basic management structure at Vaal Reefs and the average time spent on the water management in the cooling circuits and the grading on the Patterson scale.



5. Management Options

The Western Transvaal water has a TDS of between 400 mg/l and 800 mg/l. The current management is Option B, to treat the water in the circuit in order to control the water to a constant salinity and hold the volumes of input water constant. However, if the TDS is to increase to 1 200 mg/l and above, the management would need to change to Option A, to purchase increased supplies of fresh water in order to control the water to a constant salinity. The water restrictions will however have a large influence the management option chosen.

6. Sensitive Boilers

Nine fire tube boilers with a steaming capacity of 16 000 kg in use at Vaal Reefs. The make-up water is neutralised. The blow down volume of the boiler is 264 kl/day. The water is regenerated twice a day. One regeneration requires 397 kg of salt. The total cost for the salt is R230/day.

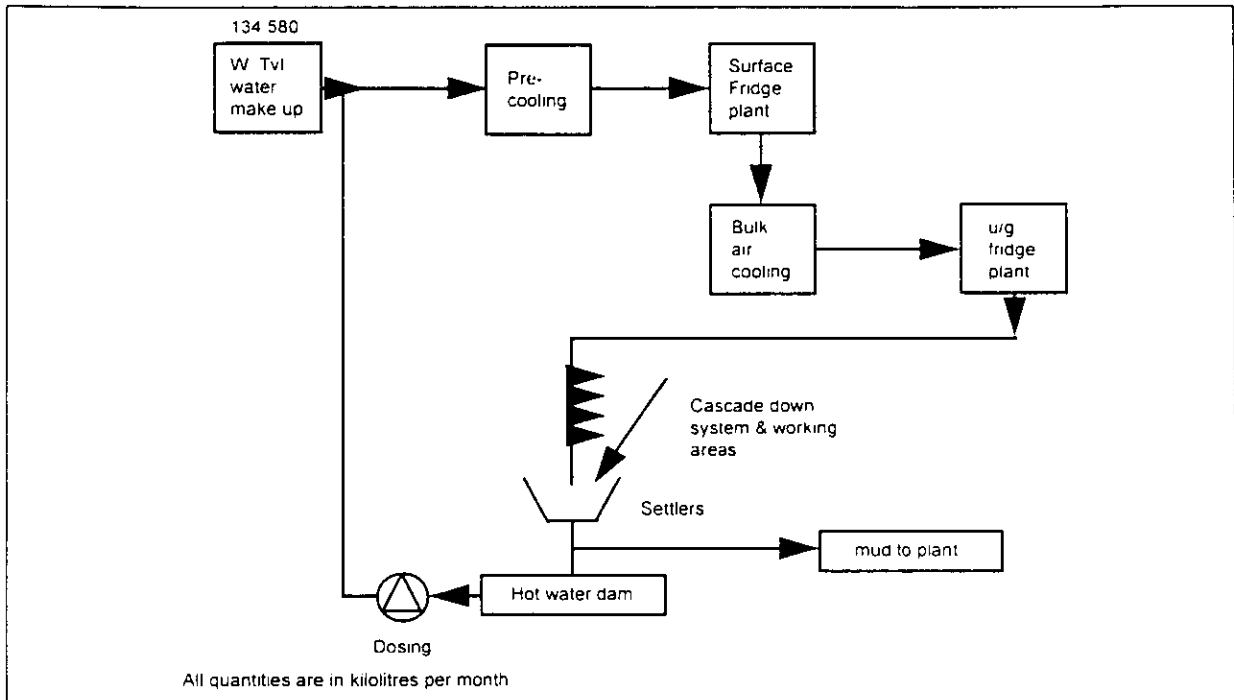
The boilers are treated with phosphonate carbonate costing R 475/day.

Thirty eight electro-boilers are present at Vaal Reefs. The water is softened at a cost of R80,71 /day. An additional maintenance cost for replacing the resin in the boilers three times a year is R3 585 / year.

III. MINE SERVICE WATER CIRCUITS

1. WATER RETICULATION AND FLOW DIAGRAM

A simplified reticulation diagram of the mine service water is shown below :



2. WATER QUALITY ASPECTS

2.1 Water quality in service water circuits

Description	Ca	Mg	Na	SO4	CO	TDS
W. Tvl make-up water	53	16	43	107	58	800*
Machine water 5#	476	-	-	1570	360	4790
Machine water 1#	224	-	-	45	230	1680
Fridge plant	124	-	-	450	80	1270
Machine water 9#	164	-	-	470	150	1900

2.2 Water sources

The current water sources are adequate for the service water. A potential water source that is available is Stilfontein mine water. Sewage effluent may not be used as service water due to the Health Regulations.

2.3 Water quality problems

The problems experienced in the mine service water are scaling and severe corrosion.

2.4 Water quality management

The water is disinfected, flocculated and limed. The costs of these chemicals are :

Disinfection	:	R1,09 million/year
Flocculation	:	R 200 000 /year
Liming	:	R 575 000 /year

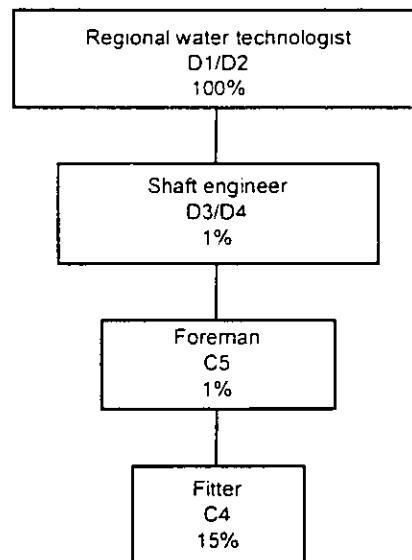
The disinfection cost is sometimes lower due to biocide left in the water from the cooling circuits.

3. EFFLUENT SYSTEMS

The effluents are discharge to the plant to be used as process water. No treatment of these effluents takes place.

4. WATER MANAGEMENT STRUCTURE

The management structure of mine service water circuits is as shown below :



5. MANAGEMENT OPTIONS

The Western Transvaal water has a TDS of between 400 mg/l and 800 mg/l. The current management is Option B, to treat the water in the circuit in order to control the water to a certain salinity and hold the volumes of input water constant. However, if the TDS is to increase to 1 200 mg /l and above, the



management would change to Option A, to purchase increased supplies of fresh water in order to control the water to a constant salinity. The water restrictions will influence the choice of management options.

IV. METALLURGICAL PLANT WATER CIRCUITS

1. WATER RETICULATION

More detailed information concerning the water management and treatment in the metallurgical plant will be incorporated when available. The plant water is reticulated water from the service water circuits and the cooling water circuits on the mine. Slimes dam return water is also used in the plants. Effluents from the cooling water circuits are stored in the Eye and drawn off as process water for the plant.

1.1 Water sources

The current water sources are adequate for present and future water requirements.

1.2 Water quality problems

The water used in the metallurgical plant is untreated

2. WATER QUALITY ASPECTS

Description	Ca	Mg	Na	SO ₄	CO	TDS
W. Tvl make-up water	53	16	43	107	58	800*
West gold plant effluent water	480	30	-	2200	220	3440
Mispah return water	660	80	-	2250	380	4270
North met & U plant effluent	960	100	-	4450	360	26500
Eye water	400	-	320	1620	250	2940

3. WATER MANAGEMENT

No actions are currently being undertaken to manage the quality of the water circulated in the metallurgical plant.

4. EFFLUENT SYSTEMS

Effluent sources arising from the metallurgical plant water circuits are sent to the slimes dams and evaporation dams.

5. MANAGEMENT OPTIONS



No water treatment is practised in the plant. The increased TDS is considered to have little or no effect in the plant.

V. IRRIGATION WATER CIRCUITS

1. FLOW DATA

The Orkney Golf course is irrigated with river water (15 583 kl/month). The Oppenheimer sports stadium is irrigated with Western Transvaal water (3 643 kl/month). West slimes dam is being grassed and is irrigated with sewage water (8 270 kl/month). The irrigating circuits do not use treated water, other than treated sewage, and the circuits do not have a management structure.

2. WATER QUALITY ASPECTS

2.1 Water quality

Description	Ca	Mg	Na	SO4	CO	TDS
W. Tvl make-up water	53	16	43	107	58	800*

2.2 Water sources

The current water sources are adequate.

2.3 Water quality problems

No water quality problems are being experienced.

QUANTIFYING THE IMPACT OF THE SALINISATION OF SOUTH AFRICA'S WATER RESOURCES WITH SPECIAL REFERENCE TO ECONOMIC EFFECTS

MINE SURVEY REPORT

Name of Mine : Hartebeesfontein Gold Mine

Geographical location : South Eastern part of North West Province

Water supplier : Western Transvaal Regional Water Board

1. INTRODUCTION

The salinity of the Vaal River has been increasing steadily over the last few years. This increase in salinity has certain cost implications on the gold mining industry which relies on the river as a source of water. In order to quantify these cost implications, the water circuits affected by an increase in the TDS of river or Board water can be classified into four circuits; namely, evaporative cooling water circuits, mine service water circuits, metallurgical plant water circuits and irrigation water circuits. The variables determining the total cost of the increased TDS in the water to the mining industry have been identified in terms of formulae developed in Phase 1 of the project and can be quantified by extracting information from the survey questionnaire. See Appendix 1 for detailed information as collected in the questionnaire.

2. EVAPORATIVE COOLING WATER CIRCUITS

Water quality related problems experienced in cooling water circuits at Hartebeesfontein are severe corrosion and scaling. Some pitting corrosion has been encountered. The make-up water sources used in the cooling circuits are Western Transvaal Regional water, Stilfontein Mine's Margaret shaft water and a blend of regional water and domestic water. Effluents arising from the evaporative cooling circuits are pumped to the slimes dams. The effluents are not treated in any way.

The current management of the evaporative cooling water circuits at Hartebeesfontein is following Option B, which is to treat the water in order to control the water in the circuit to a constant salinity and hold the volumes of input water constant. However, if the TDS is to increase to 1 200 mg/l and above, the option would change to Option A which is to purchase increased supplies of fresh water in order to control the water in the circuit to a constant salinity. Option A will only be used if the water restrictions permit it. The water restrictions imposed on the mines have a drastic effect on the management practice, water treatment of the water will be difficult and expensive. Hartebeesfontein treats the water in the evaporation cooling circuits with scale inhibitor, biocide, and various other chemicals in order to prevent scale.

formation, biological fouling and to minimise corrosion. The following determinants and associated costs, where applicable, have been identified.

	VARIABLE	FUNCTION	QUANTITY
BV	Blow down volume		1 081 kl/day
CD	Control equipment maintenance cost		R1 000,00**
EC	Evaporation cooling circuit cost		Will be calculated
MC	Maintenance chemicals		-
MS	Maintenance staff cost		-
MV	Make-up volume		7 703 kl/day
TC	Treatment chemicals cost		R163 548*
WC	water unit cost		R0,75 /kl
WM	Water management cost	MS +MC	R160 032
XDC	Site specific discharge cost		-

* This value is the sum of the treatment chemical costs of the shafts. Maintenance chemicals are included.

** The control equipment maintenance cost is estimated R1 000 per fridge plant per year.

*** The management cost was calculated using percentage time spent on management in the circuit and the average salary package value for 1995/1996.

The values in the reticulation diagram were obtained from a water balance dated 1994. A water and salt balance was calculated resulting in the make-up volume of regional water of 7 703 kl/day, a blow volume of 1 081 kl/day and an evaporative loss was assumed to be zero and the TDS in the circuit and bleed off as 3 600 mg/l per water sample from 6# cooling circuit.

The site specific discharge is considered to be nil except for pumping costs. These pumping costs cannot be quantified.

3. MINE SERVICE WATER CIRCUITS

Water quality related problems experienced with mine service water at Hartebestfontein are severe corrosion, erosion and scaling. In order to minimise the erosion problems, the mine flocculates and settles out suspended solid. The water quality is kept within reasonable limits by bleeding off saline water and introducing Western Transvaal water as make-up. The service water circuits receive large amounts of Stilfontein, Margaret shaft water.

The management of the water in the mine service water circuit is currently following Option B, namely to treat the water in order to control the water to a constant salinity and hold the input water volumes constant. If the TDS is to increase to 1200 mg/l, the current treatment would be ineffective. The result would be to increase the supplies of fresh water in order to control the water to a constant salinity. However, this option will only be viable if the water restrictions are dropped.

The following are determinants of the total costs and quantities associated with the TDS of the water :

	VARIABLE	FUNCTION	QUANTITY
Ca	Calcium concentration		272 MG/L*
DC	Discharge cost	$f(DV;WQ;WMP;WLA)$	0
DV	Discharge volume		
FI	Fissure water quality & quantity		No fissure water
GL	Geographic location		SE part of NW Province
MA	Mine age		50
MT	Type of mining practised		Conventional blasting
PPC	Precipitation potential ($CaCO_3$)		43 mg/l**
RF	Recirculation factor		
SC	Scaling costs	$f(WQ;TDS;Ca;SO_4)$	
SO ₄	Sulphate concentration		Not measured or monitored
SW	Service water recirculated	$f(SC;DC)$	
WLA	Waste load allocation		None yet
WMP	Water management plan		
WQ	Water quality within system	$f(WS;RF;GL;MT;MA;FI)$	
WS	Water sources		W. Tvl Regional

* The calcium concentration was taken from a sample taken at level 71 in 6#.

** The precipitation potential of $CaCO_3$,due to no value for SO_4 , was calculated using AQUACHEM. According to the PPC, the water in circulation in the mine service water circuits has scaling potential..

The discharge of effluents does not have, other than pumping, any costs ascribed to it. The effluents arising from the service water circuits are sent to the slimes dams, then to the plant for reuse as process water. The effluent is not treated.

4. METALLURGICAL PLANT WATER CIRCUIT

The process plant water circuits and the relevant water quality management problems depend on the different process stages which are used. It has been observed that the increased TDS of the water has little or no effect in the metallurgical plant. No specific sensitive water users were identified in the metallurgical plant. The water in the plants is made up of sewage water, domestic water and some gland water. The only area in the plant identified with sensitive water users are the filtration plants. The water is chlorinated in these circuits. No actions are currently being taken to manage the quality of the water circulated in the metallurgical plant circuits.

Site specific discharge has no costs associated with it, except pumping costs which cannot be isolated on the mine. Residue from the plants is sent to slimes dams and to the evaporation dams for storage or disposal.

The following determinants have been identified within the metallurgical plants which have cost implications due to TDS in the water :

	VARIABLE	FUNCTION	QUANTITY
FC	Flotation circuits cost	$\frac{TDS_N TCo}{TDS_o} - TCo$	
MP	Met.plant circuits cost		Will be calculated
MV	Make-up volume		* 41 194 kl/day
SR	Water treatment plant salt rejection		-
TC	Treatment Chemical cost		None
WC	Water unit cost		R0,75 / kl
WR	Water treatment plant water recovery		N/A
X _{DC}	Site specific discharge cost		-
X _{WT}	Site specific treatment cost, including operating, capital & brine disposal		-

*Calculated from the water balance dated March 1994

Option A is the only management option that the met plants would like to use. However, the plants do not necessarily require water with a low TDS level.

5. IRRIGATION WATER CIRCUITS

The 7# Hostel soccer field is irrigated with sewage water. The irrigation water circuits costs due to the TDS can be calculated using the following determinants :

	VARIABLE	FUNCTION	QUANTITY
IW	Slimes irrigation water circuit cost		Will be calculated
MV	Make-up water		4 964 kl/day*
WC _o	Water unit cost (old)		R0,75/kl
TDS	Total dissolved solids		505 mg/l**

* The make-up value as obtained from the water balance dated March 1994.

** The average tds for winter and summer.

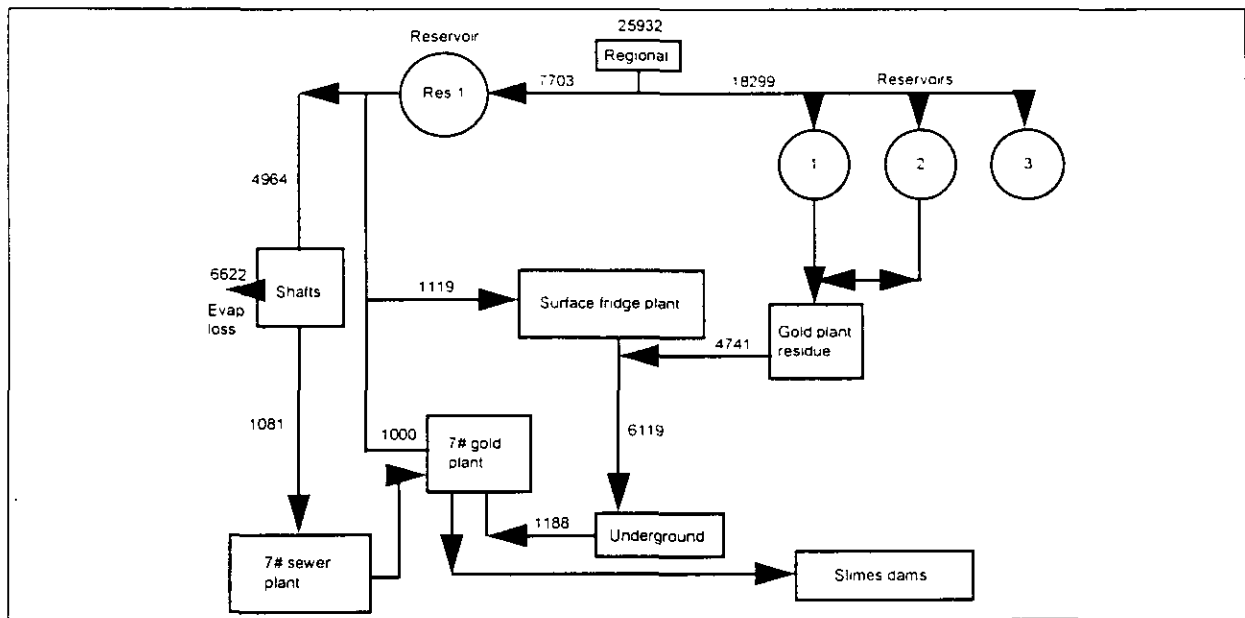
6. CONCLUSION

In conclusion, the increased TDS in the Vaal River has cost implications on Hartebeesfontein. The largest cost implications are in the evaporative cooling circuits. The water restriction do not allow the mines to optimise the processes used in mining and the resultant cost of the treatment can only be effective to a certain degree, after which good quality make-up water is required in larger quantities.

APPENDIX 1

I GENERAL INFORMATION

Hartebeestfontein is situated in the south eastern part of the North West Province. Henk Taute, the Surface Services Engineer, provided the information required in the questionnaire. Chemical and water treatment consultants gave valuable input to the questionnaire. The current monthly tonnages milled are 190 000 tons. The type of reef being mined is the Vaak Reef using conventional blasting and drilling techniques. The current age of the mine is 50 years, with an expected remaining life of 10 years. The mine purchases potable water from Western Transvaal Regional Water Company. Gold and uranium are produced in the metallurgical plants. Hartebeestfontein currently has six producing shafts and four metallurgical plants. A schematic diagram of the reticulation systems on Hartebeestfontein Gold Mine.



All quantities are in kilolitres per month.

II. EVAPORATIVE COOLING WATER CIRCUITS

1. WATER QUALITY ASPECTS

1.1 Water quality

Description	Ca	Mg	Na	SO ₄	Cl	TDS
W.Tvl water make-up (summer)	32	-	-	190	36	230
W.Tvl water make-up (winter)	70	-	-	240	104	780
6# 71 level (in evaporation circuit)	272	-	-	-	-	3600

1.2 Water sources

The current water sources are adequate for present water requirements. The mine foresees no potable or regional water being purchased. Stilfontein mine water and fissure water will provide enough water for these circuits.

1.3 Water quality problems

Water quality related problems experienced in the evaporative cooling water circuits are scaling in the boilers, fridge plants and compressors.

1.4 Water quality management

The water in the cooling circuits is treated. The reticulated water in the cooling circuits is dosed with anticalan and oxidising biocide. The total chemical treatment costs of the cooling circuits is R980 000 per year.

2. Effluent Systems

No costs, other than pumping (which cannot be quantified), are associated with the discharge of these effluents or bleed off from the cooling circuits. The effluents are not treated in any way.

3. Water Management Structure and Personnel

The basic management structure and percentage of time spent on water management has been likened to those of other mines using the same methods. The total cost is approximately R1 60 032 per annum.

4. Management Options

The Western Transvaal water has a TDS of between 400 mg/l and 800 mg/l. The current management is Option B, to treat the water in the circuit in order to control the water to a constant salinity and hold the volumes of input water constant. However, if the TDS is to increase to 1 200 mg/l and above, the management would need to change to Option A, to purchase increased supplies of fresh water in order to control the water to a constant salinity. The water restrictions will however have a large influence on the management option chosen.

III. MINE SERVICE WATER CIRCUITS

1. WATER QUALITY ASPECTS

1.1 Water quality in service water circuits



Description	Ca	Mg	Na	SO ₄	Cl	TDS
W.Tvi water make-up (summer)	32	-	-	190	36	230
W.Tvi water make-up (winter)	70	-	-	240	104	780
Margeret Shaft	339	-	-	870	92	1500

1.2 Water sources

The current water sources are adequate for the service water. Stilfontein mine water and fissure water are alternative sources of water.

1.3 Water quality problems

The problems experienced in the mine service water are scaling and severe corrosion. The TDS levels in the circuits are high, 1 000 mg/l to 1 200 mg/l. The circuit is still operating efficiently. The pH is well controlled.

1.4 Water quality management

The water in the service water circuit should be treated with lime, flocculants and disinfectants. No detailed information on the management and the treatment cost is available yet.

2. EFFLUENT SYSTEMS

The effluents are discharged to the slimes dams. No treatment of these effluents takes place.

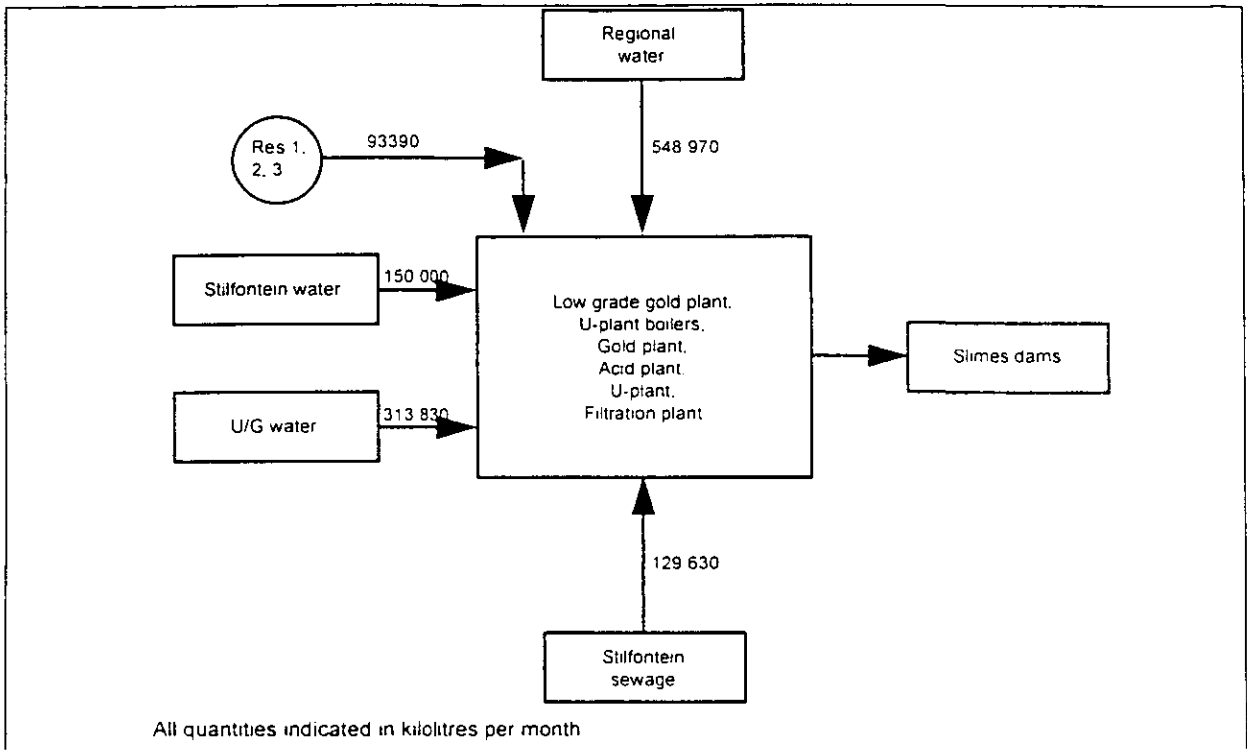
3. MANAGEMENT OPTIONS

The Western Transvaal water has a TDS of between 400 mg/l and 800 mg/l. The current management is Option B, to treat the water in the circuit in order to control the water to a constant salinity and hold the volumes of input water constant. However, if the TDS is to increase to 1 200 mg/l and above, the management would change to Option A, to purchase increased supplies of fresh water in order to control the water to a constant salinity. The water restrictions will influence the choice of management options.

IV. METALLURGICAL PLANT WATER CIRCUITS

1. WATER RETICULATION

A simplified water reticulation diagram of the metallurgical plant water circuits at Hartebeestfontein is shown below :



NOTE: No discharge figures are indicated in the diagram because the met. plant water circuits are not closed. They are complex networks of water flow. The above diagram is a simplified model to illustrate the water entering the plant and the sources of water available.

1.1 Water sources

The current water sources are adequate for present and future water requirements. The Stilfontein mine water is available to the plants as well as some fissure water.

1.2 Water quality problems

The water used in the metallurgical plants is untreated. No water quality problems are experienced. The staff cost to manage the filtration plant at 2# is a total of R 8 733 /month.

2. WATER QUALITY ASPECTS

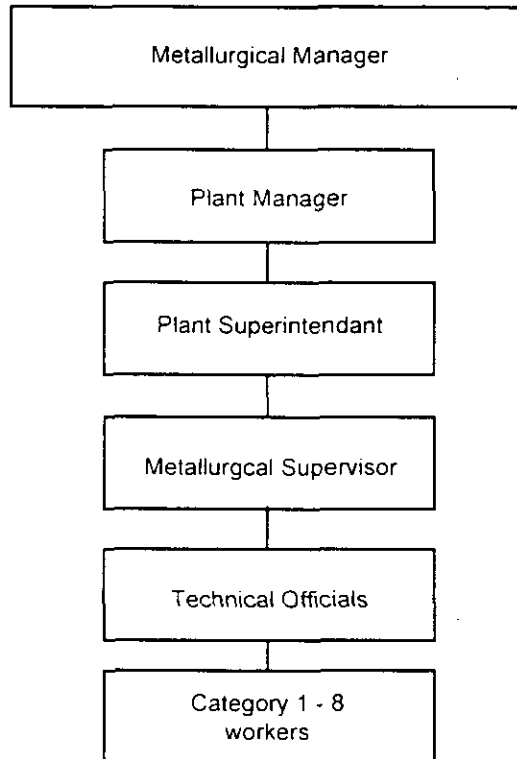
Description	Ca	Mg	Na	SO ₄	Cl	TDS
W.Tvl water make-up (summer)	32	-	-	190	36	230
W.Tvl water make-up (winter)	70	-	-	240	104	780
Margaret Shaft	339	-	-	870	92	1500
*Filtered U/G water	167	104	296	945	151	2000
*Domestic water (Res water)	100	39	107	322	90	892

* Figure from the Hartebeestfontein EMPR for March 1994.



3. WATER MANAGEMENT

No actions are currently being undertaken to manage the quality of the water circulated in the metallurgical plant. A schematic diagram of the management structure is shown below:



Note: The metallurgical plant management do not treat the water in any way, the management ensures that the correct quantity of water is available in the plant, and water quantity is not considered important.

4. EFFLUENT SYSTEMS

Effluent sources arising from the metallurgical plant water circuits are sent to the slimes dams and evaporation dams.

5. MANAGEMENT OPTIONS

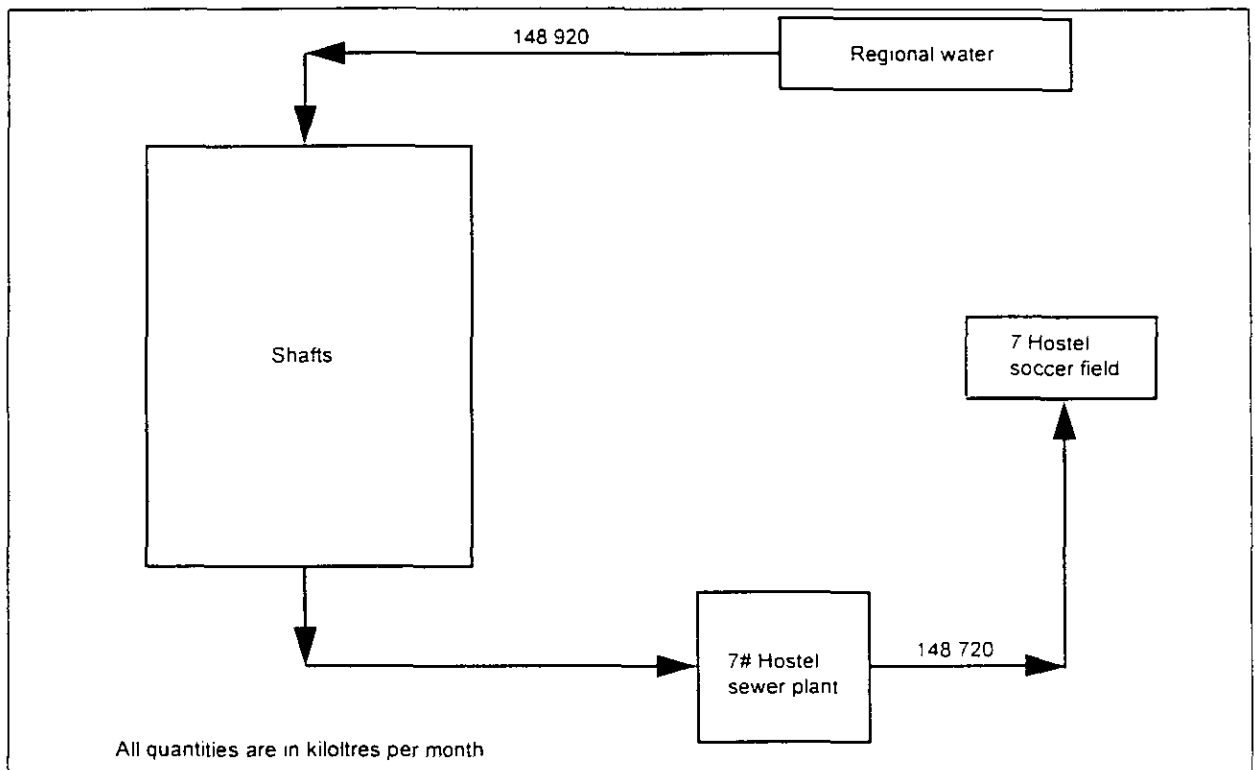
No water treatment is practised in the plant. The increased TDS is considered to have little or no effect in the plant.



V. IRRIGATION WATER CIRCUITS

1. SCHEMATIC RETICULATION

The 7# Hostel soccer field is irrigated by sewage water. A simplified water reticulation diagram of the irrigation water circuit at Hartebeestfontein is shown below.



2. WATER QUALITY ASPECTS

2.1 Water quality

Description	Ca	Mg	Na	SO ₄	Cl	TDS
Treated sewage (7#)	10	2000	-	-	-	1013

2.2 Water sources

The current water sources are adequate.

2.3 Water quality problems

No water quality problem are being experienced.

Appendix D: Results Of Cost Formula Applications For Evaporative Cooling
Circuits and Demineralisation Plants

Appendix D

BEATRIX

MVo - Make up Volumes	572400	572400	572400	572400	572400	572400
WCo - Water Unit Cost (old)	1.3	1.3	1.3	1.3	1.3	1.3
TDS _o - TDS old	400	400	400	400	400	400
TCo - Treatment Chemical Cost	129780	129780	129780	129780	129780	129780
BVo - Blow Volumes (old)	116070	116070	116070	116070	116070	116070
TDS _{sys} - TDS of system	2000	2000	2000	2000	2000	2000
TDS _n - TDS new	200	400	600	800	1000	1200
WMo - Water Management Cost	55344	55344	55344	55344	55344	55344
Tonnage mined per annum	2364000	2364000	2364000	2364000	2364000	2364000
Water Unit Cost (new)	1.495	1.495	1.495	1.495	1.495	1.495
	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1000 mg/l	1200 mg/l
WATER SUPPLY COST	-82680	0	106303	248040	446472	744120
TREATMENT CHEMICAL COST	-14420	0	18540	43260	77868	129780
MANAGEMENT/LABOUR COST	55344	55344	55344	55344	55344	55344
WATER SUPPLY COST/TM/ANNUM	-0.03	0.00	0.04	0.10	0.19	0.31
CHEMICAL COST/TM/ANNUM	-0.01	0.00	0.01	0.02	0.03	0.05
LABOUR COST/TM/ANNUM	0.02	0.02	0.02	0.02	0.02	0.02

TDS Actual

Appendix D

HARMONY						
MVo - Make up Volumes	393228	393228	393228	393228	393228	393228
WCo - Water Unit Cost (old)	1.3	1.3	1.3	1.3	1.3	1.3
TDS _o - TDS old	550	550	550	550	550	550
TCo - Treatment Chemical Cost	505296	505296	505296	505296	505296	505296
BVo - Blow Volumes (old)	108137	108137	108137	108137	108137	108137
TDS _{sys} - TDS of system	2000	2000	2000	2000	2000	2000
TDS _n - TDS new	200	400	600	800	1000	1200
WMo - Water Management Cost	193920	193920	193920	193920	193920	193920
Tonnage mined per annum	6572000	6572000	6572000	6572000	6572000	6572000
Water Unit Cost (new)	1.495	1.495	1.495	1.495	1.495	1.495
	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1000 mg/l	1200 mg/l
WATER SUPPLY COST	-99399	-47925	18257	106499	230038	415347
TREATMENT CHEMICAL COST	-98252	-47372	18046	105270	227383	410553
MANAGEMENT/LABOUR COST	193920	193920	193920	193920	193920	193920
WATER SUPPLY COST/TM/ANNUM	-0.02	-0.01	0.00	0.02	0.04	0.06
CHEMICAL COST/TM/ANNUM	-0.01	-0.01	0.00	0.02	0.03	0.06
LABOUR COST/TM/ANNUM	0.03	0.03	0.03	0.03	0.03	0.03

TDS Actual

Appendix D

PRESIDENT STEYN

MVo - Make up Volumes	2945496	2945496	2945496	2945496	2945496	2945496
WCo - Water Unit Cost (old)	1.15	1.15	1.15	1.15	1.15	1.15
TDS _o - TDS old	580	580	580	580	580	580
TCo - Treatment Chemical Cost	1132872	1132872	1132872	1132872	1132872	1132872
BVo - Blow Volumes (old)	516432	516432	516432	516432	516432	516432
TDS _{sys} - TDS of system	2100	2100	2100	2100	2100	2100
TDS _n - TDS new	200	400	600	800	1000	1200
WMo - Water Management Cost	433960	433960	433960	433960	433960	433960
Tonnage mined per annum	3600000	3600000	3600000	3600000	3600000	3600000
Water Unit Cost (new)	1.32	1.32	1.32	1.32	1.32	1.32
TDS LEVEL	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1000 mg/l	1200 mg/l
WATER SUPPLY COST	-677464	-358657	45164	573239	1293341	2333487
TREATMENT CHEMICAL COST	-226574	-119951	15105	191717	432551	780423
MANAGEMENT/LABOUR COST	433960	433960	433960	433960	433960	433960
WATER SUPPLY COST/TM/ANNUM	-0.19	-0.10	0.01	0.16	0.36	0.65
CHEMICAL COST/TM/ANNUM	-0.06	-0.03	0.00	0.05	0.12	0.22
LABOUR COST/TM/ANNUM	0.12	0.12	0.12	0.12	0.12	0.12

TDS Actual

Appendix D

WESTERN HOLDINGS

MVo - Make up Volumes	815160	815160	815160	815160	815160	815160
WCo - Water Unit Cost (old)	1.15	1.15	1.15	1.15	1.15	1.15
TDS _o - TDS old	580	580	580	580	580	580
TCo - Treatment Chemical Cost	151130	151130	151130	151130	151130	151130
BVo - Blow Volumes (old)	236396	236396	236396	236396	236396	236396
TDS _{sys} - TDS of system	2000	2000	2000	2000	2000	2000
TDS _n - TDS new	200	400	600	800	1000	1200
WMo - Water Management Cost	231740	231740	231740	231740	231740	231740
Tonnage mined per annum	3360000	3360000	3360000	3360000	3360000	3360000
Water Unit Cost (new)	1.32	1.32	1.32	1.32	1.32	1.32
	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1000 mg/l	1200mg/l
WATER SUPPLY COST	-197903	-105461	13392	171863	393722	726511
TREATMENT CHEMICAL COST	-31905	-17002	2159	27707	63475	117126
MANAGEMENT/LABOUR COST	231740	231740	231740	231740	231740	231740
WATER SUPPLY COST/TM/ANNUM	-0.06	-0.03	0.00	0.05	0.12	0.22
CHEMICAL COST/TM/ANNUM	-0.01	-0.01	0.00	0.01	0.02	0.03
LABOUR COST/TM/ANNUM	0.07	0.07	0.07	0.07	0.07	0.07

Appendix D

VAAL REEFS

MVo - Make up Volumes	3355200	3355200	3355200	3355200	3355200	3355200
WCo - Water Unit Cost (old)	0.87	0.87	0.87	0.87	0.87	0.87
TDS _o - TDS old	620	620	620	620	620	620
TCo - Treatment Chemical Cost	956878	956878	956878	956878	956878	956878
BVo - Blow Volumes (old)	464760	464760	464760	464760	464760	464760
TDS _{sys} - TDS of system	1600	1600	1600	1600	1600	1600
TDS _n - TDS new	200	400	600	800	1000	1200
WMo - Water Management Cost	382740	382740	382740	382740	382740	382740
Tonnage mined per annum	12704000	12704000	12704000	12704000	12704000	12704000
Water Unit Cost (new)	1	1	1	1	1	1
	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1000 mg/l	1200 mg/l
WATER SUPPLY COST	-875707	-535154	-58380	656780	1848715	4232585
TREATMENT CHEMICAL COST	-287063	-175428	-19138	215298	606023	1387473
MANAGEMENT/LABOUR COST	382740	382740	382740	382740	382740	382740
WATER SUPPLY COST/TM/ANNUM	-0.07	-0.04	0.00	0.05	0.15	0.33
CHEMICAL COST/TM/ANNUM	-0.02	-0.01	0.00	0.02	0.05	0.11
LABOUR COST/TM/ANNUM	0.03	0.03	0.03	0.03	0.03	0.03

TDS Actual

Appendix D

HARTEBEESTFONTEIN

MVo - Make up Volumes	1533744	1533744	1533744	1533744	1533744	1533744
WCo - Water Unit Cost (old)	0.75	0.75	0.75	0.75	0.75	0.75
TDS _o - TDS old	500	500	500	500	500	500
TCo - Treatment Chemical Cost	1512000	1512000	1512000	1512000	1512000	1512000
BVo - Blow Volumes (old)	715740	715740	715740	715740	715740	715740
TDS _{sys} - TDS of system	3000	3000	3000	3000	3000	3000
TDS _n - TDS new	200	400	600	800	1000	1200
WMo - Water Management Cost	166032	166032	166032	166032	166032	166032
Tonnage mined per annum	4933000	4933000	4933000	4933000	4933000	4933000
Water Unit Cost (new)	0.86	0.86	0.86	0.86	0.86	0.86
	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1000 mg/l	1200 mg/l
WATER SUPPLY COST	-123247	-44243	47930	156860	287577	447342
TREATMENT CHEMICAL COST	-162000	-58154	63000	206182	378000	588000
MANAGEMENT/ILABOUR COST	166032	166032	166032	166032	166032	166032
WATER SUPPLY COST/TM/ANNUM	-0.02	-0.01	0.01	0.03	0.06	0.09
CHEMICAL COST/TM/ANNUM	-0.03	-0.01	0.01	0.04	0.08	0.12
LABOUR COST/TM/ANNUM	0.03	0.03	0.03	0.03	0.03	0.03

TDS Actual

Appendix D

MINES IN MIDDLE VAAL AREA AND TONNAGE MINED PER ANNUM	
*Vaal Reefs	12704000
*Hartebeestfontein	4933000
Stilfontein	988000
Buffelsfontein	3360000
HJ Joel	691000
*Beatrix	2364000
Oryx	1440000
St Helena	810000
Unisel	683000
Saaiplaas	-
President Brand	-
*President Steyn	22550000 All Freegold mines combined
Freddies	-
Free State Geduld	-
*Western Holdings	-
Welkom Gold Mine	-
Loraine	1579000
*Harmony	6572000
TOTAL	58674000
* Mines surveyed	33533000 tons mined
Percentage surveyed	57.15

TDS Actual

Appendix D

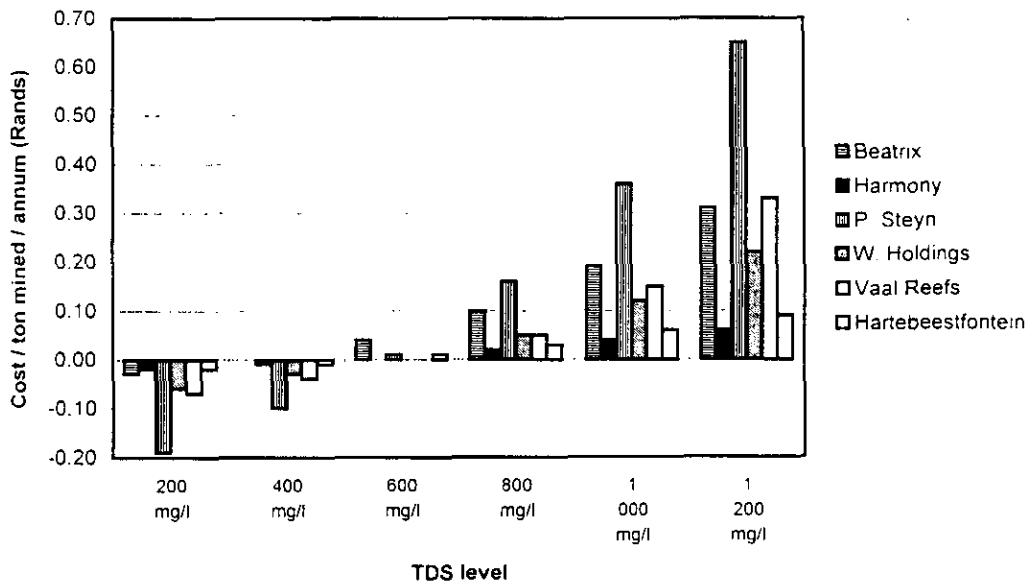
SUMMARY INCREMENTAL COST OF WATER SUPPLY

	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1 000 mg/l	1 200 mg/l
Beatrix	-0.03	0.00	0.04	0.10	0.19	0.31
Harmony	-0.02	-0.01	0	0.02	0.04	0.06
P. Steyn	-0.19	-0.1	0.01	0.16	0.36	0.65
W. Holdings	-0.06	-0.03	0	0.05	0.12	0.22
Vaal Reefs	-0.07	-0.04	0	0.05	0.15	0.33
Hartebeestfontein	-0.02	-0.01	0.01	0.03	0.06	0.09
Average	-0.07	-0.03	0.01	0.07	0.15	0.28
Maximum	-0.02	0	0.04	0.16	0.36	0.65
Minimum	-0.19	-0.1	0	0.02	0.04	0.06

TOTAL INCREMENTAL COST FOR GOLD MINING INDUSTRY IN MIDDLE VAAL AREA

Average	-3813810	-1858010	586740	4009390	8996680	16233140
Maximum	-1173480	0	2346960	9387840	21122640	38138100
Minimum	-11148060	-5867400	0	1173480	2346960	3520440

Water Supply Cost per Ton Mined



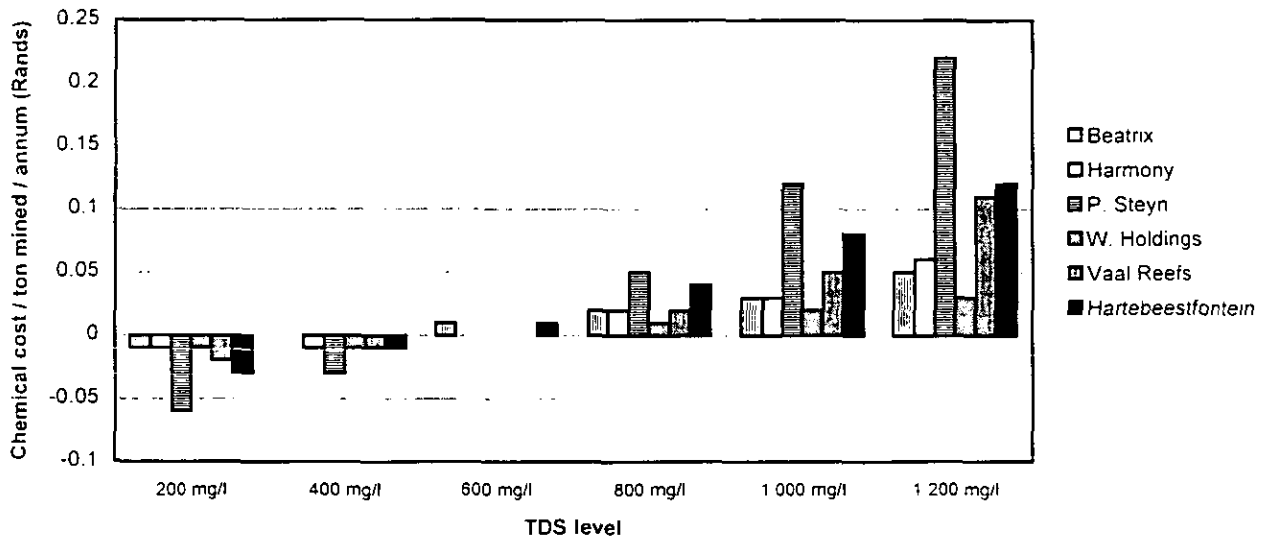
SUMMARY INCREMENTAL COST OF CHEMICALS

	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1 000 mg/l	1 200 mg/l
Beatrix	-0.01	0	0.01	0.02	0.03	0.05
Harmony	-0.01	-0.01	0	0.02	0.03	0.06
P. Steyn	-0.06	-0.03	0	0.05	0.12	0.22
W. Holdings	-0.01	-0.01	0	0.01	0.02	0.03
Vaal Reefs	-0.02	-0.01	0	0.02	0.05	0.11
Hartebeestfontein	-0.03	-0.01	0.01	0.04	0.08	0.12
Average	-0.02	-0.01	0.00	0.03	0.06	0.10
Maximum	-0.01	0	0.01	0.05	0.12	0.22
Minimum	-0.06	-0.03	0	0.01	0.02	0.03

TOTAL INCREMENTAL COST FOR GOLD MINING INDUSTRY IN MIDDLE VAAL AREA

Average	-1369060	-684530	195580	1564640	3227070	5769610
Maximum	-586740	0	586740	2933700	7040880	12908280
Minimum	-3520440	-1760220	0	586740	1173480	1760220

Chemical Cost per Ton Mined



TDS Actual

Appendix D

WATER SUPPLY COST USING A FACTOR TO TOTAL FOR INDUSTRY

	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1000 mg/l	1200 mg/l
Beatrix	-82680	0	106303	248040	446472	744120
Harmony	-99399	-47925	18257	106499	230038	415347
P. Steyn	-677464	-358657	45164	573239	1293341	2333487
W. Holdings	-197903	-105461	13392	171863	393722	726511
Vaal Reefs	-875707	-535154	-58380	656780	1848715	4232585
Hartebeestfontein	-123247	-44243	47930	156860	287577	447342
TOTAL SURVEYED	-2056400	-1091440	172666	1913281	4499865	8899392
FACTOR	1.7497	1.7497	1.7497	1.7497	1.7497	1.7497
INDUSTRY TOTAL	-3598083	-1909693	302114	3347668	7873414	15571266

TREATMENT CHEMICAL COST USING A FACTOR TO TOTAL FOR INDUSTRY

	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1000 mg/l	1200 mg/l
Beatrix	-82680	0	106303	248040	446472	744120
Harmony	-98252	-47372	18046	105270	227383	410553
P. Steyn	-226574	-119951	15105	191717	432551	780423
W. Holdings	-31905	-17002	2159	27707	63475	117126
Vaal Reefs	-287063	-175428	-19138	215298	606023	1387473
Hartebeestfontein	-162000	-58154	63000	206182	378000	588000
TOTAL SURVEYED	-888474	-417907	185475	994214	2153904	4027695
FACTOR	1.7497	1.7497	1.7497	1.7497	1.7497	1.7497
INDUSTRY TOTAL	-1554563	-731212	324526	1739576	3768686	7047258

TOTAL COST	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1000 mg/l	1200 mg/l
Beatrix	-165360	0	212606	496080	892944	1488240
Harmony	-197651	-95297	36303	211769	457421	825900
P. Steyn	-904038	-478608	60269	764956	1725892	3113910
W. Holdings	-229808	-122463	15551	199570	457197	843637
Vaal Reefs	-1162770	-710582	-77518	872078	2454738	5620058
Hartebeestfontein	-285247	-102397	110930	363042	665577	1035342
TOTAL SURVEYED	-2944874	-1509347	358141	2907495	6653769	12927087
FACTOR	1.7497	1.7497	1.7497	1.7497	1.7497	1.7497
INDUSTRY TOTAL	-5152646	-2640904	626639	5087244	11642100	22618524

TDS Actual

APPENDIX D: BOILER AND DEMINERALISATION PLANT DATA

FREEGOLD						
MVo - Make up Volumes	30840	30840	30840	30840	30840	30840
WCo - Water Unit Cost (old)	1.15	1.15	1.15	1.15	1.15	1.15
TDS _o - TDS old	436	436	436	436	436	436
TCo - Treatment Chemical Cost	272000	272000	272000	272000	272000	272000
TDS _{sys} - TDS of system	3000	3000	3000	3000	3000	3000
TDS _n - TDS new	200	400	600	800	1000	1200
Tons mined	6960000	6960000	6960000	6960000	6960000	6960000
WATER SUPPLY COST	-2989	-491	2424	5868	10001	15053
CHEMICAL COST	-22926	-3766	18587	45004	76704	115449
TOTAL BOILER COST	-25915	-4257	21010	50872	86705	130502
WATER SUPPLY COST/TM/ANNUM	-0.00043	-0.00007	0.00035	0.00084	0.00144	0.00216
CHEMICAL COST/TM/ANNUM	-0.00329	-0.00054	0.00267	0.006466	0.011021	0.016587
HARTEBEESTFONTEIN						
MVo - Make up Volumes	290400	290400	290400	290400	290400	290400
WCo - Water Unit Cost (old)	0.75	0.75	0.75	0.75	0.75	0.75
TDS _o - TDS old	500	500	500	500	500	500
TCo - Treatment Chemical Cost	600000	600000	600000	600000	600000	600000
TDS _{sys} - TDS of system	3000	3000	3000	3000	3000	3000
TDS _n - TDS new	200	400	600	800	1000	1200
Tons mined	4933000	4933000	4933000	4933000	4933000	4933000
WATER SUPPLY COST	-23336	-8377	9075	29700	54450	84700
CHEMICAL COST	-64286	-23077	25000	81818	150000	233333
TOTAL BOILER COST	-87621	-31454	34075	111518	204450	318033
WATER SUPPLY COST/TM/ANNUM	-0.005	-0.002	0.002	0.006	0.011	0.017
CHEMICAL COST/TM/ANNUM	-0.01303	-0.00468	0.005068	0.016586	0.030407	0.0473
BEATRIX						
MVo - Make up Volumes	66252	66252	66252	66252	66252	66252
WCo - Water Unit Cost (old)	1.3	1.3	1.3	1.3	1.3	1.3
TDS _o - TDS old	450	450	450	450	450	450
TCo - Treatment Chemical Cost	216000	216000	216000	216000	216000	216000
TDS _{sys} - TDS of system	3000	3000	3000	3000	3000	3000
TDS _n - TDS new	200	400	600	800	1000	1200
Tons mined	2364000	2364000	2364000	2364000	2364000	2364000
WATER SUPPLY COST	-7690	-1656	5383	13702	23685	35887
CHEMICAL COST	-19286	-4154	13500	34364	59400	90000
TOTAL BOILER COST	-26976	-5810	18883	48066	83085	125887
WATER SUPPLY COST/TM/ANNUM	-0.003	-0.001	0.002	0.006	0.010	0.015
CHEMICAL COST/TM/ANNUM	-0.008	-0.002	0.006	0.015	0.025	0.038
These figures disregard the capital component of a new demin/softener plant						

Appendix D: Boiler Water Data

MINES IN MIDDLE VAAL AREA AND TONNAGE MINED PER ANNUM	
Vaal Reefs	12704000
*Hartebeestfontein	4933000
Stilfontein	988000
Buffelsfontein	3360000
HJ Joel	691000
*Beatrix	2364000
Oryx	1440000
St Helena	810000
Unisel	683000
Saaiplaas	-
President Brand	-
*President Steyn	22550000 All Freegold mines combined
Freddies	-
Free State Geduld	-
*Western Holdings	-
Welkom Gold Mine	-
Loraine	1579000
Harmony	6572000
TOTAL	58674000
* Mines surveyed for boiler water data	29847000 tons mined
Percentage surveyed	50.87

Appendix D: Boiler Water Data

SUMMARY INCREMENTAL COST OF BOILER WATER SUPPLY COST

	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1 000 mg/l	1 200 mg/l
Beatrix	-0.003	-0.001	0.002	0.006	0.010	0.015
Freegold	-0.00043	-0.00007	0.00035	0.00084	0.00144	0.00216
Hartebeestfontein	-0.005	-0.002	0.002	0.006	0.011	0.017
Average	-0.003	-0.001	0.001	0.004	0.007	0.011
Maximum	0.000	0.000	0.002	0.006	0.011	0.017
Minimum	-0.005	-0.002	0.000	0.001	0.001	0.002

TOTAL INCREMENTAL COST FOR GOLD MINING INDUSTRY IN MIDDLE VAAL AREA

Average	-164874	-60043	85077	251125	438882	668101
Maximum	-25230	-4107	117348	352044	645414	997458
Minimum	-293370	-117348	20536	49286	84491	126736

SUMMARY INCREMENTAL WATER SUPPLY COST OF BOILER CHEMICAL COST

	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1 000 mg/l	1 200 mg/l
Beatrix	-0.008	-0.002	0.006	0.015	0.025	0.038
Freegold	-0.003	-0.001	0.003	0.006	0.011	0.017
Hartebeestfontein	-0.013	-0.005	0.005	0.017	0.030	0.047
Average	-0.008	-0.002	0.005	0.013	0.022	0.034
Maximum	-0.003	-0.001	0.006	0.017	0.030	0.047
Minimum	-0.013	-0.005	0.003	0.006	0.011	0.017

TOTAL INCREMENTAL CHEMICAL COST FOR GOLD MINING INDUSTRY IN MIDDLE VAAL ARE

Average	-475064	-141209	268688	742422	1298651	1991004
Maximum	-193037	-31684	352044	968121	1783690	2775280
Minimum	-762762	-274594	156659.6	379034	645414	968121

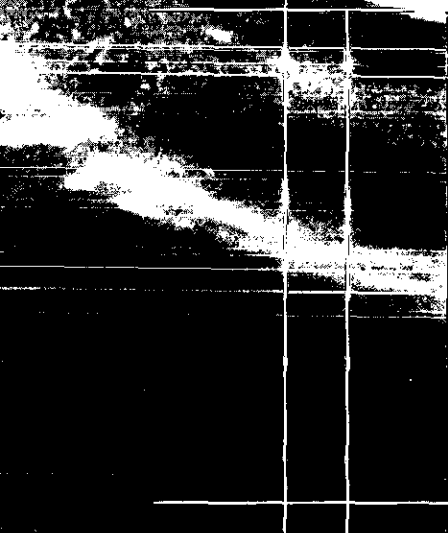
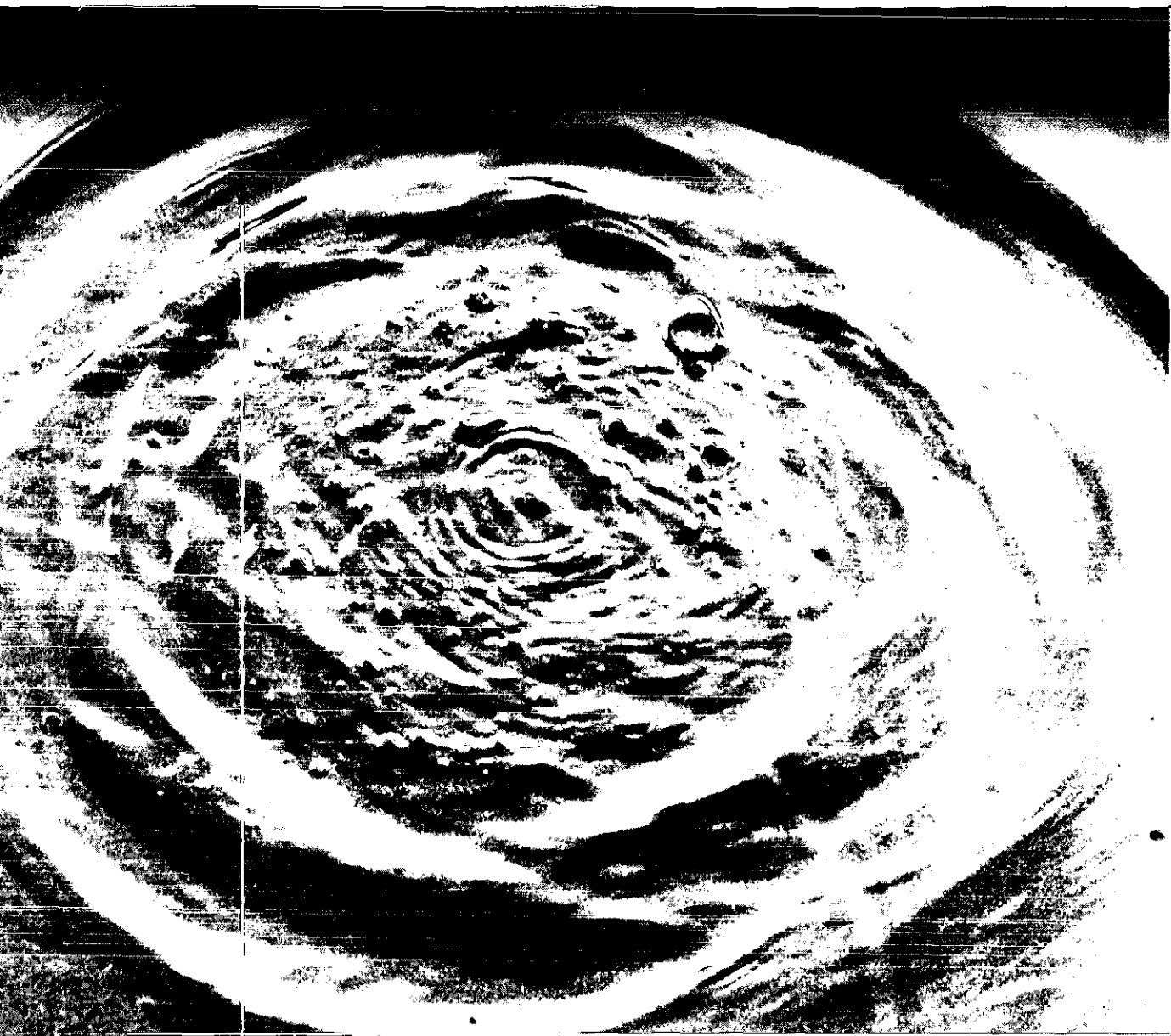
APPENDIX D: BOILER WATER- FACTORED BASIS

BOILER WATER SUPPLY COST USING A FACTOR TO TOTAL FOR INDUSTRY

	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1000 mg/l	1200 mg/l
Beatrix	-7690	-1656	5383	13702	23685	35887
Freegold	-2989	-491	2424	5868	10001	15053
Hartebeestfontein	-23336	-8377	9075	29700	54450	84700
TOTAL SURVEYED	-34015	-10524	16882	49270	88136	135640
FACTOR	1.9658	1.9658	1.9658	1.9658	1.9658	1.9658
INDUSTRY TOTAL	-66867	-20688	33187	96855	173258	266641

BOILER CHEMICAL COST USING A FACTOR TO TOTAL FOR INDUSTRY

	200 mg/l	400 mg/l	600 mg/l	800 mg/l	1000 mg/l	1200 mg/l
Beatrix	-19286	-4154	13500	34364	59400	90000
Freegold	-22926	-3766	18587	45004	76704	115449
Hartebeestfontein	-64286	-23077	25000	81818	150000	233333
TOTAL SURVEYED	-106498	-30997	57087	161186	286104	438782
FACTOR	1.9658	1.9658	1.9658	1.9658	1.9658	1.9658
INDUSTRY TOTAL	-209354	-60934	112222	316859	562423	862558



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