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ASSESSMENT OF THE FEASIBILITY AND IMPACT OF ALTERNATIVE WATER POLLUTION CONTROL OPTIONS ON TDS CONCENTRATIONS IN THE VAAL BARRAGE AND MIDDLE VAAL (VAALSURV)

Report to the
WATER RESEARCH COMMISSION
by
STEFFEN, ROBERTSON & KIRSTEN Inc

WRC Report No 326/1/93

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EXECUTIVE SUMMARY

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1 BACKGROUND

In the last 15-20 years increasing demands on limited water resources and increasing pollution of these resources (especially in terms of dissolved salts) have been great cause for concern in South Africa. Demands have been particularly great in the Vaal Barrage and Middle Vaal catchment areas, largely as a result of rapidly increasing urbanisation and growing industrial and mining activity.

Estimates from the many studies that have been carried out on various aspects of pollution of the Vaal River indicate that the contribution from non-point source discharges is about 40% of the total dissolved solids (TDS) load entering the system. Mine dewatering produces another 25% of the total load and industries and sewage works contribute about 35% of the total load.

The current project was intended to relate available information to obtain a comprehensive overview of the recent status of the catchment, particularly in describing the proportion of pollution entering the Vaal River from non-point sources.

2 OBJECTIVES

The aims of the projects were stated as:

- Assess the available information on the Vaal Barrage and Middle Vaal regions and merge it together where possible
- Accurately quantify, by measurement in the field, the TDS load from individual sources in the study area such as industry, mines and power stations where this has not already been done
- Indicate the component salts making up the TDS load and identify their sources
- Re-evaluate and identify any new potential pollution control options applicable to conditions in the study area (such as centralised effluent treatment, blending, source pollution control and dry cooling) by studying the technology available both locally and abroad and reporting on successes and problems encountered
- Test these options in terms of salinity reduction in the Vaal Barrage and Middle Vaal and assess the cost benefits potentially available both individually and in combination

- Report on the optimum pollution control options applicable to the study area as part of a water quality management strategy

3 SUMMARY OF MAJOR RESULTS

3.1 Survey of point sources

All premises using more than 50 m^3 of water per day for an industrial or direct production purpose were included in the study. Data were gathered by direct flow measurement and effluent sampling. Most of the analytical work was carried out by the project's own mobile laboratory.

3.2 Industry

A total of 242 separate premises were identified as significant effluent producers and grouped into 31 distinct industrial activities. There were 216 of the premises in the Vaal Barrage catchment area and 21 in the Middle Vaal area.

The industries producing effluent were found to fall into one of the following categories:

- Effluent discharged directly into a water course, following on-site treatment and eventually entering the Vaal Barrage or Middle Vaal catchment areas
- Effluent discharged to a municipal treatment works and eventually entering the Vaal River
- Effluent discharged to evaporation ponds or irrigation, sometimes via municipal treatment works
- Effluent discharged to a municipal treatment works which discharges outside the Vaal Barrage and Middle Vaal catchment areas

Three industrial premises discharge effluent directly to the Vaal River. These three premises are all located in the Vaal Barrage catchment area. They discharge a total of 63 235 m^3/d and increase the salt load by approximately 40,5 t TDS/d.

The remaining industries discharge to municipal treatment works. A total of 76 310 m^3/d of industrial effluent is discharged to municipal sewage works and the salt load is increased by some 103 t TDS/d.

Relatively few industries in the study area not utilising sewage works do not return their effluent ultimately to the Vaal River. The relative quantities of industrial effluent disposed of by these routes is small with the total volume being approximately 1 500 m^3/d.

The Vaal Barrage catchment receives 66% of the effluent volume and 78% of the

TDS load from industry compared to 34% of the volume and 22% of the TDS load discharged to the Middle Vaal. Both the Sasolburg and Vanderbijlpark works fall within the Vaal Barrage catchment area but discharge below the Barrage. Sasolburg discharges the largest volume of industrial effluent of all the municipal sewage works in the catchment area.

The components of the industrial salt load on a mass basis were found to be:

Component	% of load	Load t/d
Sodium and Potassium	18	37
Calcium and Magnesium	14	30
Total Alkalinity (as $CaCO_3$)	15	31
Sulphate	30	62
Chloride	20	42
Others	3	6
Total	**100**	**208**

The total industrial water intake for the study area is 302 Mℓ/d. If we consider the total industrial effluent volume as 140 Mℓ/d, this indicates a return flow of water by industry to the Vaal River of 46%. The majority of water intake not returned to the river is lost through evaporation with a small proportion leaving industry as part of the produce (eg brewing and soft drinks).

3.3 Mines, Power Stations, and Metal Refineries

In the study area, there are two operational power stations and four metal refineries. Only one of the power stations discharges effluent to the Kliprivier at 23 000 m^3/d with a salt load of 11 500 kg TDS/d. For the metal refineries, no effluent is discharged from three of the sites and no data was accessible for the fourth site.

The gold mining industry in the study area is extensive, with 45 mines being active. Total discharge to the Vaal River is approximately 136 Mℓ/d containing about 348 t TDS/d. Water intake to the mines is about 1 000 Mℓ/d of which about 400 Mℓ/d comes from underground workings.

Mines often operate evaporation dams on their property and for the Orange Free State mines, all effluent produced is stored in on-site evaporation dams. These mines, therefore, discharge no effluent to surface water courses.

The mining industry is more extensive in the Middle Vaal catchment than in the Vaal Barrage. The mines in the Vaal Barrage catchment however contribute 41% of the total mining effluent volume in the study area and 48% of the mining salt load.

In terms of return water flows the mining industry returns about 14% of the water which it abstracts although about 40% of the total water intake comes from underground rather than surface water resources. Approximately half of the total water intake is lost to evaporation and ventilation air.

The components of the mining salt load on a mass basis were found to be:

Component	% of load	Load t/d
Sodium and Potassium	17	58
Calcium and Magnesium	16	55
Total Alkalinity (as $CaCO_3$)	19	66
Sulphate	27	95
Chloride	20	69
Others	1	5
Total	**100**	**348**

3.4 Municipal Sewage Works

The total discharge of effluent from sewage works to the Vaal River is 770 Mℓ/d containing some 402 t TDS/d. The split between the Vaal Barrage and the Middle Vaal catchments is 71% to 29% for effluent volume and 62% to 38% for salt load. The average TDS concentration for sewage works in the Vaal Barrage is 460 mg/ℓ compared with 676 mg/ℓ in the Middle Vaal catchment. The reason for this higher concentration is associated with lower dilution from domestic effluent and the higher salinity of the water intake in the Middle Vaal area.

Analysis of the available information indicates that, for the Vaal Barrage, domestic sources account for 75% of the effluent volume and 33% of the salt load. In the Middle Vaal the domestic sector accounts for 58% of the volume and 31% of the salt load. For industry, power generation and mining combined, the percentages are 25% of the volume and 67% of the salt load for the Vaal Barrage and 42% of the volume and 69% of the salt load for the Middle Vaal.

3.5 Current Situation

Based on limited historical data, the ratio of contribution from point sources compared to non-point sources is assumed to be 50% point sources, 50% non-point sources for times of average rainfall; 60% point sources, 40% non-point sources for below average rainfall; 40% point sources, 60% non-point sources for above average rainfall. The percentages of the volume and salt load contributions were considered to be the same for each of the three conditions of rainfall.

3.6 Description of Salt Load Management Options

In discussing pollution control options, the basic categories which can be considered are:

- blending
- centralised treatment
- in-house pollution management
- change catchment

3.7 Blending

In the past, Vaal Barrage water has been mixed with lower TDS water released directly from the Vaal Dam to control the TDS levels in the water available for supply to the PWV area. Blending has been found to be relatively inexpensive, with a benefit:cost ratio of 25:1.

Blending may not represent a long term solution on its own. Effluent return flows will continue to increase with growing water demand, and as urban and industrial development proceeds it can be expected that the catchment will yield increasing tonnages of salts washed off by rainfall. In addition, illegal and undetected saline industrial effluent discharges into stormwater drainage systems adds to the already high contribution of diffuse sources. In consequence, the quality of water supplied from the Vaal River may keep on deteriorating. However, blending has the major advantage that it improves water quality in the river itself, and thus affects an improvement in pollution derived from both point and non-point sources which centralised treatment and/or pollution control at source will not achieve. Additional water will be available in future from the Lesotho Highlands Water Scheme. The first stage of the scheme is due to come on stream by 1996 and will feed an additional 18 m^3/sec into the Vaal Dam. If the demand warrants it, there are a further three stages of development which will increase the scheme's input to the Vaal Dam to 26 m^3/sec, then 63 m^3/sec, and finally 70 m^3/sec.

3.8 Centralised treatment

Centralised effluent treatment has been proposed as a potential means of dealing with industrial effluents in a cost effective manner due to economies of scale and/or by treating complementary effluents. The concept would be to treat selected high salinity effluents, typically of a mining or other industry origin, either as a pretreatment before discharge to a sewage works, or before direct discharge to a water course. These facilities could either be privately owned and operated, or be operated by local authorities. Successful application of this concept in other countries has occurred when the centralised facilities have been planned for or included at inception in new, custom-built industrial areas. To impose centralised effluent treatment on an already established industrial area with a cross-section of industries already there appears to be impractical.

3.9 In-house pollution management

Point source pollution control is the focus of the legislative approach to pollution control in South Africa. DWA monitor all industrial undertakings which use 150 m^3/d of water for an industrial purpose. The idea held widely that many smaller industries collectively amount to a bigger problem than the large industries seems unlikely to be true in practice. Very few industries, with the notable exception of the metal finishing industry, were found to be viable at a water intake of less than 150 m^3/sec. Work done on Low Pressure Reverse Osmosis (LPRO) processes for the removal of sulphates from underground mine water indicates that it could be part of an economical desalination process. Studies showed that a process consisting of pre-treatment (to reduce membrane fouling) LPRO, and HPRO on the LPRO brine, followed by electrolysis of the HPRO brine solution to give an overall water recovery of 95% and a salt rejection of 99%, would cost about 30 c/m^3 (1989 costs) of blended product water (70% treated, 30% bypassed). Researchers have also examined the possibility of chemical removal of sulphate, calcium and heavy metals from mining effluents. Although these and other processes for removal of salinity have been operated on a pilot plant scale, there are few, if any, examples of the full scale utilisation of these technologies. The technology is considered expensive and requires consideration of site specific factors in order to provide cost-effective solutions. In addition, the question of how to dispose of the highly concentrated brine solutions left after many of these treatment processes remains problematic.

It is clear that in order to prevent further deterioration of the quality of water in the study areas (even with blending) it is likely that there will come a time when desalination and other forms of treatment will become more widely practised. The managers of the country's water resources must identify, well in advance, the point when the costs to consumers of coping with a deteriorating water quality becomes significant when compared to the cost of reducing the salinity of point source effluents (and diffuse source effluent, where practical). If water resource managers are to take long term decisions to control the increase in salinity, which will inevitably mean committing significant financial resources, they will require an accurate assessment of the costs incurred due to the deterioration of the water resource, on which to base their decision.

3.10 Change Catchment

This option is to change the catchment into which a particular pollution load is discharged. This already happens with the discharges from the Sasolburg and Vanderbijlpark sewage works being discharged downstream of the Vaal Barrage, even though the works are located in the Barrage catchment itself. Logistically, this is a relatively simple transfer but in other cases the costs involved may well make this option unattractive. There is also the viewpoint that transfer of a problem from one catchment to another is not really a solution at all and should only be considered as a last resort.

3.11 Comparison of Salt Load Management Options

Blending is an attractive option as it is an effective means of ameliorating the effects of both point and diffuse source pollution. It is considered to be cost effective and is already in operation. Blending is not a long term solution on its own, but at present and for the foreseeable future, it represents a pragmatic means of countering increasing salinity levels in the Vaal Barrage system.

Centralised treatment is attractive from the point of view of benefits of scale in controlling treatment costs. It is however impractical to implement on existing industrial locations except in very specialised instances. The concept should be reviewed when planning new industrial areas but is likely to make a significant impact only in the longer term. One area which is worth researching is the viability of large scale desalination of outfalls from sewage works which are already centralised treatment works, although largely concentrating on removal of organic pollution.

In-house pollution management covers everything from small-scale process-specific effluent treatment within an individual premises to large scale treatment of the final effluent discharge from individual premises. The main reason this has not been implemented on a large scale is cost, although changes in the cost of pollution which could be brought about by financial disincentives imposed by the authorities could change this situation. The negative implications of most of the treatment routes discussed is that they result in a volume of highly saline effluent, the handling and disposal of which remain problematic.

Transferring effluent to another catchment although already practised to a limited extent is considered only as a last resort or in very specific cases. The operation is likely to be costly and would take some time to implement but is considered the least attractive of the options discussed because it is merely transferring a problem at considerable cost from one catchment to an adjacent one.

Control of diffuse source pollution has received very little attention in the past from researchers but must receive more in the future. Control of stormwater runoff from rock dumps, sand dumps and mining slimes dams can be improved by revegetation, toe paddocks, and in the case of slimes dams with under drains, penstocks, solution trenches, stormwater diversion trenches and return water dams. In the case of runoff from agricultural land and urban stormwater runoff the problems are much more difficult to deal with. Greater use of wetlands, for example, may assist in this respect.

3.12 Impact of Reducing Salt Loads

The following scenarios of treatment were examined:

- major industrial and mining pollution sources
- sewage works discharges
- all industrial and mining pollution sources
- all direct discharge industrial and mining effluents and sewage works discharge (ie all point sources)

Calculations assumed that the effluents would be treated at source and a 90% removal of salinity could be attained. The initial concentration was taken to be the average TDS level; 510 mg/ℓ in the Vaal Barrage area and 465 mg/ℓ for the Middle Vaal.

Treatment of the major industrial and mining pollution sources would reduce Vaal Barrage concentration by 67 mg/ℓ, to 443 mg/ℓ and Middle Vaal concentration by 152 mg/ℓ, to 313 mg/ℓ.

Treatment of sewage works discharges would reduce Vaal Barrage concentration by 114 mg/ℓ, to 396 mg/ℓ and Middle Vaal concentration by 95 mg/ℓ, to 370 mg/ℓ.

Treatment of all industrial and mining pollution sources would reduce Vaal Barrage concentration by 148 mg/ℓ, to 362 mg/ℓ and Middle Vaal concentration by 142 mg/ℓ, to 323 mg/ℓ.

Treatment of all point sources would reduce Vaal Barrage concentration by 281 mg/ℓ, to 229 mg/ℓ and Middle Vaal concentration by 256 mg/ℓ, to 209 mg/ℓ.

Clearly, any of these options would involve treatment of effluent streams for removal of salts on a scale not practised in this country before. Even the first scenario, which is estimated to improve the average TDS level in the Vaal Barrage by a relatively modest 67 mg/ℓ, would involve the treatment of some 83 Mℓ/d of effluent. In addition, some 132 t TDS/d would still have to be disposed of or at least safely contained. It appears that the practical implementation of treatment of point sources of salt load pollution on a scale where significant reduction in average TDS levels in the Vaal River system are likely to be achieved is still some way off in the future. Compared with the benefits realised from the blending option currently in practice, large scale point source treatment appears to be unattractive in the short term. The introduction of Lesotho Highlands Scheme water with very low salinity to the Vaal Dam by 1996 should continue to make blending the most attractive option of control of salinity in the Vaal River system at least for the next 10-15 years.

It is suggested that, apart from continuing with the blending option as at present, DWA policy should aim to make the discharge of salinity to the Vaal River system more economically unattractive. Linked to this would be an updated, rigorous assessment of the economic cost of increasing salinity to all the consumers of Vaal River water. In addition, attention should be given to diffuse sources of pollution and more research should be aimed at identifying practical means for the control of saline discharges from diffuse sources.

In this way, if the quality of water deteriorates to such an extent that large scale treatment to reduce salinity levels becomes necessary, then the economic framework to justify when it should happen and who is to pay for it will be clearly understood and will put DWA in a position to effectively manage what may have to be a major shift in philosophy for many industrialists, mines and municipalities.

4 CONTRIBUTIONS OF THE REPORT

The contract objectives, stated at the beginning of this Executive Summary, have been met. The available information on the Vaal Barrage and Middle Vaal regions has been assessed. The TDS load from individual sources has been quantified and the component salts making up the TDS load have been identified, together with their sources. Pollution control options have been identified and evaluated, with reference to local and international successes and problems. The options have been tested in terms of salinity reduction in the Vaal Barrage and Middle Vaal and costs and benefits have been discussed. Evaluations of the pollution control options have been reported.

This report provides a summary of the relative contributions from major sectors to salinity loads in the Vaal Barrage and Middle Vaal catchment areas. Data from many sources have been assembled, collated, and analysed to provide an integrated view of the issue of salinisation of the Vaal River. Subsequent actions must now include more detailed study of specific aspects of the issue. In particular, goals and objectives of salinity control are required in order to provide a means to evaluate management options. Benefits of various options can be compared only when an objective criterion is available against which to measure the gains.

5 FURTHER RESEARCH

A detailed investigation of salt removal technology for selected point sources should be undertaken. Effluent from the major sources, identified in this assessment, should be investigated to determine more precise costs in relation to the benefits of treatment. Costs and effectiveness of specific treatment processes on the individual effluent streams should be determined.

Diffuse sources of salt load into the Vaal River should be identified and their effects quantified. Methods of reducing those loads should be investigated.

More precise estimates of the effects of increased salinity on water uses should be developed. Those estimates will help define the costs of deteriorating water quality on the water users. Efforts by the DWA to define water quality guidelines for each of the major water uses should be used as a departure point to identify the effects of increased salinity on users of Vaal River water and the costs of using water with less than ideal quality.

Results from those investigations should be used together to determine in advance the point at which further salinity increases would not be acceptable. Plans to avoid reaching that point should be developed.

The Vaal River is the drinking water source for the major population centre of South Africa. It also serves as the transport facility for waste disposal for at least 242 separate premises. Projections are for continued population growth. Waste disposal can also be expected to expand. Lesotho Highlands water appears likely to offer a temporary respite from the dramatic increase in TDS concentration since the mid-1970's, but dependence on water supply from another country poses special dangers and costs can be expected only to increase.

Water quality goals for the protection of the Vaal River and a plan to achieve those goals are essential to ensure continued adequate water supply to the industrial and population centre of the country.

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"Assessment of the feasibility and impact of alternative water pollution control options on tds concentrations in the Vaal Barrage and Middle Vaal (VAALSURV)"

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

Dr T C Erasmus	Water Research Commission (Chairman)
Mr F P Marais	Water Research Commission (Secretary)
Mr H M du Plessis	Water Research Commission
Mr J B Conlin	Eskom
Mr M C Steynberg	Rand Water Board
Mrs M J F Kruger	Western Transvaal Regional Water Company
Mr W Pulles	Chamber of Mines Research Organisation
Mr W van der Merwe	Department of Water Affairs and Forestry
Mr F C van Zyl	Department of Water Affairs and Forestry
Mr J A van Rooyen	Department of Water Affairs and Forestry
Mr J A Easton	Chamber of Mines of South Africa
Mr J A C Cowan	Steffen, Robertson & Kirsten Inc
Mr A J Dippenaar	Orange Free State Goldfields Water Board

The financing of the project by the Water Research Commission and the contribution of the members of the Steering Committee is acknowledged gratefully.

A Technical Committee provided oversight for the technical aspects of the project. The committee consisted of the following persons:

Dr T C Erasmus	Water Research Commission
Mr J A van Rooyen	Department of Water Affairs and Forestry
Mr F C van Zyl	Department of Water Affairs and Forestry
Dr H Wiechers	Eskom
Mr P Skivington	Steffen, Robertson & Kirsten Inc

Their contributions are recognized with gratitude.

Many other people and organisations contributed to the extensive data gathering that was conducted as part of the project. Their cooperation was instrumental in the success of the survey and is acknowledged with grateful appreciation.

CONTENTS

ASSESSMENT OF THE FEASIBILITY AND IMPACT OF ALTERNATIVE WATER POLLUTION CONTROL OPTIONS ON TDS IN THE VAAL BARRAGE AND MIDDLE VAAL (VAALSURV)

1 INTRODUCTION

1.1 Background

1.1.1 In the last 15 - 20 years increasing demands on limited water resources and increasing pollution of these resources (especially in terms of dissolved salts) have been great cause for concern in South Africa. Demands have been particularly great in the Vaal Barrage and Middle Vaal catchment areas, largely as a result of rapidly increasing urbanisation and growing industrial and mining activity.

1.1.2 Pollution in these catchments can be divided into point and non-point sources. Point sources include sewage works, industries, power stations and mines. These sources are reasonably easily identifiable. Non-point sources include stormwater runoff from urban areas, runoff and seepage from mine residues, acid mine drainage, air pollution and agricultural sources including fertilizers, fungicides, pesticides, herbicides and irrigation return flows. As these pollutants, by definition, arise from many points their contribution is difficult to quantify.

1.1.3 Many studies have been carried out on various aspects of pollution of the Vaal River. From these, estimates have been made that for the Vaal Barrage Catchment area the contribution from non-point source discharges is about 40% of the total dissolved solids (TDS) load entering the system. [1] Mine dewatering produces another 25% of the total load and industries and sewage works contribute about 35% of the total load. [1]

Notwithstanding this information, it has been identified by researchers and legislators alike that the need exists to inter-relate the information available in order to obtain a comprehensive overview of the recent status of the catchment (see Figure 1 and Figure 2) from a pollution point of view. This has been particularly stressed by the Department of Water Affairs (DWA) who have identified it as a priority, particularly in terms of coming to grips with the proportion of the pollution entering the Vaal River derived from non-point sources.

1.2 Aims and objectives

1.2.1 Taking the above as a motivation for the project, the Water Research Commission (WRC) entered into a contract with Steffen, Robertson and Kirsten Inc Consulting Engineers (SRK) to carry out such a study on their behalf during 1990 and 1991. A steering committee to guide the progress of the project was formed which was made up of representatives of the WRC, DWA, SRK, the Chamber of Mines of South Africa (COM) and Eskom. In addition, it was decided after the first meeting of the project steering committee that the Rand Water Board (RWB) as well as the water boards of the Western Transvaal and Orange Free State Goldfields be invited to nominate representatives for appointment to the steering committee. It was further decided by the steering committee that a technical sub-committee be formed, on which the WRC, DWA, Eskom and SRK would be represented, to examine more detailed technical issues.

1.2.2 The aims of the project were stated as:

- Assess the available information on the Vaal Barrage and Middle Vaal regions and merge it together where possible.
- Accurately quantify, by measurement in the field, the TDS load from individual sources in the study area such as industry, mines and power stations where this has not already been done.
- Indicate the component salts making up the TDS load and identify their sources.
- Re-evaluate and identify any new potential pollution control options applicable to conditions in the study area (such as centralised effluent treatment, blending, source pollution control and dry cooling) by studying the technology available both locally and abroad and reporting on successes and problems encountered.
- Test these options in terms of salinity reduction in the Vaal Barrage and Middle Vaal and assess the cost benefits potentially available both individually and in combination.
- Report on the optimum pollution control options applicable to the study area as part of a water quality management strategy.

1.3 Mode of operation

1.3.1 The VAALSURV study took place from January 1990 to December 1991. The main categories of premises included in the VAALSURV study were industries, mines, power stations and metal refineries. All premises using more than 50 m^3 of water per day for an industrial or direct production purpose were included in the study. This naturally excludes large office complexes, warehouse operations, distribution points and other similar premises which use water for domestic purposes, although they may be located in a designated industrial area.

1.3.2 Data was gathered for these premises by direct flow measurement and effluent sampling. Where records were presented for use by the project, these were verified wherever possible. A large amount of information was obtained from a very wide range of different sources for incorporation by the project team.

1.3.3 The majority of the analytical work required for the project was carried out by the project's own mobile laboratory. All flow measuring equipment used by the project team was also regularly calibrated to ensure a high level of reliability in the data.

2 INDUSTRY (EXCLUDING MINES, POWER STATIONS AND METAL REFINERIES)

2.1 Industrial classification

2.1.1 Industrial activities encountered in the study area were classified into groups as defined by the project (see Table 1). In total 33 distinct industrial activities were encountered being undertaken by a total of 248 separate premises. The split between the Vaal Barrage catchment area and the Middle Vaal catchment area was 221 premises in the Vaal Barrage and 27 in the Middle Vaal, indicating the overwhelmingly higher concentration of industry in the Vaal Barrage catchment.

2.1.2 Not all of these industries produced significant volumes of effluent due to the nature of their activities. However, 31 distinct industrial activities were found to be significant in terms of effluent, carried out by 242 separate premises. The split between the Vaal Barrage and Middle Vaal areas was 216 and 26 premises respectively. It should be noted that some significant volumes of effluent are discharged into the Middle Vaal catchment by industry situated in the Vaal Barrage catchment. The total industrial water intake in the study area is estimated as 302 $M\ell/d$.

2.1.3 The industries producing effluent were found to fall into one of the following categories:

- Effluent discharged directly into a water course, following on-site treatment and eventually entering the Vaal Barrage or Middle Vaal sections of the Vaal River.
- Effluent discharged to a municipal treatment works and eventually entering the Vaal River.
- Effluent discharged to evaporation ponds or irrigation, sometimes via municipal treatment works.
- Effluent discharged to a municipal treatment works which discharges outside the Vaal Barrage and Middle Vaal catchment areas.

Table 1 : Industrial Water Intake (January 1990 - December 1991)

No. of Industries	Industry	Water Intake (m^3/d)	Water Intake (million m^3/a)
33	Chemicals	38 862	14,18
51	Plating	7 260	2,65
5	Printing and publishing	191	0,07
7	Baking	511	0,19
1	Photographic	150	0,05
9	Soft drinks	4 494	1,64
10	Sorghum brewing	2 606	0,95
18	Motor trade	1 037	0,38
3	Malt brewing	12 265	4,48
5	Tanning and leather	1 000	0,37
11	Food miscellaneous	4 121	1,50
6	Rubber and plastic	1 027	0,37
7	Dairy	930	0,34
9	Laundries	2 675	0,98
4	Vegetable oils	4 180	1,53
7	Paper products	5 510	2,01
4	Glass and glass products	1 027	0,37
4	Fruit and vegetable	3 595	1,31
1	Synthetic diamonds	148	0,05
2	Pulp and paper	678	0,25
7	Concrete	403	0,15
9	Iron and steel	3 687	1,35
1	Motor vehicles	138	0,05
3	Grain	760	0,28
3	Pottery	318	0,12
1	Non-ferrous metals	118	0,04
1	Gas	229	0,08
2	Vehicle depots	181	0,07
12	Meat	6 786	2,48
2	Tobacco products	717	0,26
4	Bricks, tiles, clay pipes	743	0,27
2	Textiles	545	0,20
2	Wood and cork products	392	0,14
245		107 427	39,21
	Superfactory 1	32 000	11,68
	Superfactory 2	68 000	24,82
3	Superfactory 3	95 000	3,47
248		302 472	110,39

Note: The figures given in Table 1 are average values based on records of measurements, verified wherever possible by actual flow measurement.

2.2 Industrial effluent discharge

2.2.1 If we consider first those industrial premises which discharge effluent directly to the Vaal River (after pretreatment) we find that there are three in the study area (Table 2). These three premises are all located in the Vaal Barrage catchment area and discharge a total of 63 235 m^3/d containing a TDS load of some 75 t/d. The increase in salt load generated by these industries is approximately 40,5 t TDS/d. (The increase in salt load is the difference between the salt load in the water taken into the industrial premises and that discharged as effluent).

Table 2 : Industrial Effluent Discharged Directly to the Vaal Barrage (January 1990 - December 1991

Factory Type	Effluent Volume (m^3/d)	Effluent TDS Load (kg TDS/d)	TDS Load in Intake Water (kg TDS/d)	Salt Load Increase (kg TDS/d)	% TDS Load Increase
Iron and steel	33 235	35 042	14 960	20 082	134
Pulp and paper	25 000	34 050	16 225	17 825	110
Chemicals	5 000	5 870	3 288	2 582	79
Total	**63 235**	**74 960**	**34 473**	**40 489**	

2.2.2 A more common situation is that of industrial premises discharging effluent to a municipal treatment works before discharge in combination with treated domestic sewage to the Vaal River. The contributions of industry to the municipal sewage works in the study area are indicated in Table 3. A total of 76 310 m^3/d of industrial effluent is discharged to municipal sewage works in the study area containing some 133 t/d of TDS. The increase in salt load was a total of approximately 103 t/d.

Table 3 : Industrial Effluent Discharged From Sewage Works (January 1990 - December 1991)

Municipality	Industrial Effluent Volume (m^3/d)	TDS Load (kg/d)	Salt Load Increase (kg TDS/d)	% TDS Increase	Discharges Into
Johannesburg	7 825	34 560	32 560	1 670	Kliprivier
Germiston	12 762	18 907	14 828	415	Natalspruit
Boksburg	4 467	19 534	18 196	1 360	Natalspruit
Brakpan	21	237	177	300	Blesbokspruit
Benoni	1 037	2 381	1 998	520	Blesbokspruit
Springs	1 571	2 797	2 310	585	Blesbokspruit
Nigel	630	4 613	4 474	3 220	Blesbokspruit
Heidelburg	342	287	189	195	Blesbokspruit
Vereeniging	240	480	420	700	Vaal Barrage
Sub-total for Vaal Barrage	28 895	83 800	75 150	-	
Krugersdorp	3 351	3 317	2 640	390	Rietspruit
Vanderbijlpark	598	1 322	1 081	449	Vaal Barrage
Sasolburg	40 000	34 400	15 400	80	Vaal River
Potchefstroom	983	3 455	3 075	810	Mooi River
Randfontein	1 984	5 773	5 132	800	Rietspruit
Kroonstad	500	516	382	285	Vals River
Sub-total for Middle Vaal	47 416	48 783	27 912	-	
Total	**76 310**	**132 583**	**103 060**	-	

2.2.3 It is interesting to compare relative magnitudes of salt load increase from Table 3. It can be seen that the Johannesburg, Boksburg and Nigel works experience the largest percentage increase in salt load. Although small in terms of total salt load increase, Nigel experiences the largest percentage salt load increase. This is due to the presence of a large tannery in the Nigel industrial area which has a very large impact on a relatively small treatment works. [2]. For Boksburg and Johannesburg the food and chemical industries have the largest impact on salt load. In Johannesburg a particularly large contribution is from the yeast industry.

2.2.4 Although a significant volume of treated or semi-treated sewage works' effluent is irrigated rather than discharged to the Vaal River, relatively few industries in the study area not utilising sewage works do not return their effluent ultimately to the Vaal River. Of those which do not, disposal of effluent is typically by irrigation or evaporation of effluent from holding ponds. The relative quantities of industrial effluent disposed of by these routes is small with the total volume being approximately 1 500 m^3/d for the whole study area.

2.3 Vaal Barrage compared to Middle Vaal catchment

2.3.1 From Table 4 it can be seen that the Vaal Barrage catchment is much more significant in terms of both effluent volumes and TDS load than the Middle Vaal catchment although in terms of area the Middle Vaal (107 911 km^2) is a much larger catchment area than the Vaal Barrage (8 614 km^2). The relative percentages are that 66% of the effluent volume and 78% of the TDS load from industry is discharged to the Vaal Barrage catchment with only 34% of the volume and 22% of the TDS load being discharged to the Middle Vaal. These figures can be explained by considering the much higher concentration of industry and population in the Vaal Barrage catchment. The figures are somewhat distorted due to the discharges from both the Sasolburg (Sasol 1) and Vanderbijlpark works being below the Barrage although these areas fall within the Vaal Barrage catchment area. If this is taken into account then industry located inside the Vaal Barrage discharges 95% of the total industrial effluent volume and 93% of the industrial TDS load for the whole study area.

2.3.2 In total industry discharges about 140 Mℓ/d of effluent to the Vaal with a TDS load of about 208 t TDS/d. Direct discharges account for 45% of this volume and 36% of the load, with the remainder being discharged via sewage works. It is interesting to note that three superfactories discharge between them 81 Mℓ/d of the total industrial effluent volume (57%) and 89 t TDS/d of the total industrial salt load (43%).

Table 4 : Vaal Barrage Compared to Middle Vaal - Industry

Discharge of Industrial Effluent	Effluent Volume (m^3/d)	% of Total	TDS load kg/d	% of Total	TDS Concentration mg/ℓ
Direct to Vaal Barrage	63 235	45	74 960	36	1 185
Via sewage works to Vaal Barrage	28 895	21	83 800	40	2 900
Sub-Total	92 130	66	158 760	76	1 723
Via sewage works to Middle Vaal	47 416	34	48 783	24	1 029
Sub-Total	47 416	34	48 783	24	1 029
Total	**139 546**	**100**	**207 543**	**100**	**1 487**

2.3.3 From 2.1.2 the total industrial water intake for the study area is 302 Mℓ/d. If we consider the total industrial effluent volume as 140 Mℓ/d this indicates a return flow of water by industry to the Vaal River of 46%. This is of interest because a large proportion of the water available for abstraction by the water supply authorities is comprised of return flows. The majority of the water intake not returned to the river is lost through evaporation with a small proportion leaving industry as part of the produce (eg brewing and soft drinks).

2.4 Components of the salt load

2.4.1 So far the salt load discharged by industry has been expressed as a global TDS figure. From the extensive chemical analyses carried out during the study, it is possible to indicate the main components of this salt load and their relative percentages. Looked at on an individual industry basis, these differ quite considerably depending on the activities carried out by each industry. However, taken as a whole the breakdown of TDS was found to be:

Table 5 : Main Components of Industrial Salt Load

Parameters	% Breakdown	Load (t/d)
Sodium and Potassium	18	37
Calcium and Magnesium	14	30
Total Alkalinity (as $CaCO_3$)	15	31
Sulphate	30	62
Chloride	20	42
Others	3	6
Total	**100**	**208**

This indicates that sulphate is the most common species with typically 62 t/d of sulphate being discharged to the Vaal River.

3 MINES, POWER STATIONS AND METAL REFINERIES

3.1 Power stations and metal refineries

3.1.1 In the study area there are two operational power stations and four metal refineries. Of the power stations, only one discharges effluent to the Kliprivier at a rate of 23 000 m^3/d. This effluent contains a salt load of 11 500 kg TDS/d. For the metal refineries, no discharge of effluent to a watercourse takes place from three of the sites. No data was accessible for the fourth site.

3.2 Mines

3.2.1 The gold mining industry in the study area is extensive, with 45 mines being active. For the purposes of this study the mines will be reported on according to areas, namely Welkom and Virginia, Klerksdorp and Orkney, Carltonville and the West Rand and the East Rand. Results available for the mining industry are given in Table 6.

Table 6 : Effluent Discharge by the Mining Industry

Area (No.)	Water Intake (m^3/d)	Effluent Discharge (m^3/d)	Effluent Salt Load (kg TDS/d)	TDS Load Intake Water (kg TDS/d)	Salt Load Increase (kg TDS/d)	% TDS Load Increase
East Rand (9)	111 500	43 425	128 000	167 250	- 39 250	0
West Rand and Carltonville (18)	243 000	55 940	162 575	243 000	- 80 425	0
Klerksdorp and Orkney (7)	210 045	36 270	57 400	315 070	- 257 670	0
Welkom and Virginia (11)	440 150	0	0	660 225	- 660 225	0
Total	**1 004 695**	**135 635**	**347 975**	**1 385 545**	**- 1 037 570**	

NB 1 Water pumped from underground workings is included in water intake.

2 Salt load increase is calculated as the difference between the salt load in the water taken onto the mine (including underground water) and that discharged as effluent. In the case of mines the negative figure indicates that the salt load in the effluent discharged is less than that of the intake water. The reason for this is on-site storage of mine effluent in evaporation dams.

3.2.2 Examination of these results indicates that the gold mining industry in the study area discharges about 136 Mℓ/d of effluent to the Vaal River, containing about 348 t TDS/d. Water intake to the mines is about 1 000 Mℓ/d of which about 400 Mℓ/d comes from underground workings.

This water is usually highly alkaline (TDS in excess of 2 500 mg/ℓ). In addition to the 136 Mℓ/d of effluent discharged by gold mines to the surface water environment, it is estimated that a further 320 Mℓ/d of effluent is lost to the groundwater environment in the form of seepage, based on published figures for the total discharge of effluent to both the surface and groundwater environments for the gold mining industry [15]. Mines often operate evaporation dams on their property and for the Orange Free State mines all effluent produced is stored in on-site evaporation dams. These mines, therefore, discharge no effluent to surface water courses.

3.2.3 The mining industry is more extensive in the Middle Vaal catchment than in the Vaal Barrage. The mines in the Vaal Barrage catchment however contribute 41% of the total mining effluent volume and 48% of the mining salt load. Five mines between them contribute 86% of the salt load discharged by the mining industry to the Vaal River (ie 299 t TDS/d).

3.2.4 In terms of return water flows the mining industry returns about 14% of the water which it abstracts although about 40% of the total water intake comes from underground rather than surface water resources. Approximately half of the total water intake is lost to evaporation and ventilation air [15].

3.2.5 A small number of collieries operate in the study area. To date, no information has been received which indicates that any of them discharge effluents to the Vaal River.

3.3 Components of the salt load

3.3.1 Again, from the analytical data available a breakdown of the components of the salt load from the mining industry is possible. Taking individual mines into account the variation is large, dictated mainly by the underground water quality from each particular mine. Taken as a whole, the mining industry salt load breakdown is:

Table 7 : Salt Load Breakdown for the Mining Industry

Parameters	% Breakdown	Load (t/d)
Sodium and Potassium	17	58
Calcium and Magnesium	16	55
Total Alkalinity (as $CaCO_3$)	19	66
Sulphate	27	95
Chloride	20	69
Others	1	5
Total	**100**	**348**

3.3.2 This data indicates that the main constituents of mine effluent waters are sulphate (95 t/d) chloride (69 t/d) and total alkalinity (66 t/d). The mine water chemistries for the various regions differ quite considerably.[3] Waters in the Orkney/Klerksdorp region are predominantly calcium sulphate/sodium chloride type waters. In the Orange Free State there are mainly sodium chloride/calcium sulphate type waters and in the West Rand area there are mainly calcium sulphate/bicarbonate waters.

4 MUNICIPAL SEWAGE WORKS

4.1 Sewage works data

4.1.1 All the main sewage works in the study area have supplied data on their effluent discharge volumes and the TDS (or conductivity) of the discharge. These results are given in Table 8. This table indicates that the total discharge of effluent from sewage works to the Vaal River is 770 Mℓ/d containing some 402 t TDS/d. The split between the Vaal Barrage and the Middle Vaal catchments is 71% to 29% for effluent volume and 62% to 38% for salt load. The average TDS concentration for sewage works in the Vaal Barrage is 460 mg/ℓ compared with 676 mg/ℓ in the Middle Vaal catchment. The reason for this higher concentration is associated with lower dilution from domestic effluent and the higher salinity of the water intake in the Middle Vaal area.

4.2 The split between industrial and domestic effluent

4.2.1 Combining the results from Tables 3 and 8 gives the split between industrial and domestic (households and non-manufacturing-related water use, eg offices, etc) effluents. This data is expressed in Table 9. This indicates that the total domestic effluent discharged from sewage works (693 Mℓ/d) is split in the ratio 75% to the Vaal Barrage and 25% to the Middle Vaal. For domestic salt load the total figure is 270 t TDS/d split 62% to the Vaal Barrage and 38% to the Middle Vaal. These figures indicate that the industrial effluent discharged to sewage works in the Vaal Barrage is significantly more saline than that discharged to sewage works in the Middle Vaal (2 900 mg/ℓ TDS compared with 1 030 mg/ℓ TDS). Consideration of the industry types found in the two areas supports this, with a higher proportion of industries such as the chemical, iron and steel and food industries found in the Vaal Barrage.

Table 8 : Municipal Sewage Works - Total Salt Loads (January 1990 - December 1991)

Municipality	Total Effluent Volume (m^3/d)	Total Salt Load (kg TDS/d)	TDS Concentration (mg/ℓ)
Johannesburg	285 100	106 170	372
Germiston	115 000	61 320 *	533
Boksburg	51 540	26 595	516
Brakpan	7 000	3 150	450
Benoni	29 080	15 640	538
Springs	10 400	7 100	683
Nigel	6 390	7 630 *	1 194
Sebokeng	30 000	14 220	474
Heidelburg	4 620	1 810	392
Meyerton	2 500	1 200	480
Vereeniging	5 660	6 870	1 214
Sub-total for Vaal Barrage	547 290	251 705	460
Krugersdorp	44 000	27 375	622
Vanderbijlpark	20 900	11 290 *	540
Sasolburg	56 000	48 160	860
Potchefstroom	20 000	10 320	516
Randfontein	26 600	14 800 *	556
Kroonstad	16 000	6 240	390
Welkom	46 000	35 000	761
Klerksdorp	17 000	11 900	700
Orkney	6 100	6 770 *	1 110
Parys	2 500	900	360
Virginia	13 280	12 670	954
Sub-total for Middle Vaal	222 380	150 425	676
Total	**769 670**	**402 130**	**522**

* Note : Calculated from conductivity values using the relationship 6 x EC = TDS
All townships falling within the municipal areas are included in the figures given.

Table 9 : The Split Between Domestic and Industrial Effluent Discharged from Sewage Works (January 1990 - December 1991)

Municipality	Industrial Effluent (m^3/d)	Domestic Effluent (m^3/d)	Industrial Salt Load kg TDS/d	Domestic Salt Load kg TDS/d	Industrial TDS Concentration (mg/ℓ)	Domestic TDS Concentration (mg/ℓ)
Johannesburg **	7 825	277 275	34 560	71 610	4 417	258
Germiston	12 762	102 238	18 907	42 413	1 482	415
Boksburg	4 467	47 073	19 534	7 061	4 373	150
Benoni	21	6 979	237	2 913	11 286	417
Benoni	1 037	28 043	2 381	13 259	2 296	473
Springs *	1 571	8 829	2 797	4 303	1 780	487
Nigel	630	5 760	4 613	3 017	7 322	524
Sebokeng **	-	30 000	-	14 220	-	474
Heidelburg	342	4 278	287	1 532	839	358
Meyerton **	-	2 500	-	1 200	-	480
Vereeniging * *	240	5 420	480	6 390	2 000	1 179
Sub-total Vaal Barrage	28 895	518 395	83 800	167 910	2 900	324
Krugersdorp	3 351	40 649	3 317	24 058	990	592
Vanderbijlpark	598	20 302	1 322	9 968	2 211	491
Sasolburg	40 000	16 000	34 400	13 760	860	860
Potchefstroom	983	19 017	3 455	6 865	3 515	361
Randfontein	1 984	4 616	5 773	9 027	2 910	367
Kroonstad	500	15 500	516	5 724	1 032	369
Klerksdorp	-	17 000	-	11 900	-	700
Orkney	-	6 100	-	6 770	-	1 110
Parys	-	2 500	-	900	-	360
Virginia	-	13 280	-	12 670	-	954
Sub-total Middle Vaal	47 416	174 963	48 783	101 642	1 029	581
Total	**76 311**	**693 358**	**132 583**	**269 552**	**1 737**	**389**

* Corrected for effluent discharged to Sappi Enstra for reuse

** Corrected for irrigated effluent not discharged to river

4.2.2 If data from Table 2 and Table 9 are combined we get a total effluent volume discharged by industry from all sources of 139 Mℓ/d (66% to the Vaal Barrage, 34% to the Middle Vaal) and a total salt load of 208 t TDS/d (76% to the Vaal Barrage, 24% to the Middle Vaal). Taking data from Tables 2, 6 and 9 gives the total point source discharges for the two catchments. (Table 10)

Table 10 : Total Point Source Discharges for the Study Area

	Vaal Barrage		Middle Vaal		Total	
	Volume (Mℓ/d)	Salt Load (t TDS/d)	Volume (Mℓ/d)	Salt Load (t TDS/d)	Volume (Mℓ)	Salt Load (t TDS/d)
Industry	92	159	47	49	139	208
Domestic	518	168	175	102	693	270
Mining	56	167	80	181	136	348
Power generation	23	12	-	-	23	12
Total	**689**	**506**	**302**	**332**	**991**	**838**

Hence the total discharge of effluent from mining, power generation and other industry is 298 Mℓ/d containing a salt load of 568 t TDS/d (average concentration = 1 900 mg/ℓ TDS). Domestic effluent accounts for 693 Mℓ/d containing a salt load of 270 t TDS/d (average concentration = 390 mg/ℓ TDS). Percentage wise, mining, power generation and other industry accounts for 30% of the total point source effluent volume and 68% of the total point source salt load.

4.2.3 The information in Table 10 is reproduced in percentage form in Table 11.

Table 11 : Total Point Source Discharges for the Study Area (%)

	Vaal Barrage		Middle Vaal		Total	
	Volume (% of total)	Salt Load (% of total)	Volume (% of total)	Salt Load (% of total)	Volume (% of total)	Salt Load (% of total)
Industry	13	31	16	14	14	24
Domestic	75	33	58	31	70	32
Mining	8	33	26	55	14	42
Power generation	4	3	-	-	2	2
Total	**698 Mℓ/d**	**506 t TDS/d**	**302 Mℓ/d**	**332 t TDS/d**	**991 Mℓ/d**	**838 t TDS/d**

This indicates that for the Vaal Barrage domestic sources account for 75% of the effluent volume and 33% of the salt load. In the Middle Vaal the domestic sector accounts for 58% of the volume and 31% of the salt load. For industry, power generation and mining combined the percentages are 25% and 67% respectively for the Vaal Barrage and 42% and 69% respectively for the Middle Vaal.

5 CURRENT SITUATION

5.1 Introduction

5.1.1 The figures discussed in the previous section indicate the impact of point sources of pollution on the water resources of the Vaal Barrage and Middle Vaal. However another significant class of pollution source, namely diffuse or non-point source pollution, has not been taken into account in the figures at all. Diffuse source pollution arises from sources such as stormwater runoff from urban areas, runoff and seepage from mine residues, acid mine drainage, air pollution, agricultural sources and irrigation return flows. To carry out a detailed mass balance for the Vaal River, which would enable the contribution from diffuse sources to be accurately assessed, is beyond the scope of this project. However, it is estimated that the contribution is likely to be split 50:50 between point and diffuse sources. In practice this is dependant on rainfall and it has been shown [4] that the salt load entering the Vaal Barrage varied in origin from 65%:35% in favour of point sources for the relatively dry 1983/84 to 53%:47% in favour of diffuse sources in the wetter (but still below average) 1986/87 period . These are the latest years for which such a detailed mass balance is available. For the year 1989/90 726 mm of rain fell in the Vaal Barrage catchment [18] which was equivalent to 93% of the long term average of 780 mm. A split of 50:50 between point and non-point sources of pollution for the study period is therefore considered reasonable given that these years were close to average in terms of rainfall. For the Middle Vaal catchment the split between point and non-point sources is assumed to be the same (50:50). Although there is more potential for agricultural runoff in this area, there is less urbanisation so the relative magnitude of diffuse source pollution is considered to be similar to that in the Vaal Barrage catchment. As extremes a split of 60%:40% in favour of point sources is postulated for a below average rainfall season and 60%:40% in favour of diffuse sources for an above average rainfall season.

5.2 Relative impacts of pollution sources

5.2.1 Given that there is an assumed 50:50 split between point and non-point sources for the study area, the relative impacts of the various point source sectors can be discussed.

Table 12 : Total pollution Discharge for the study area (%)
(50:50 split between point and diffuse sources)

	Vaal Barrage	Middle Vaal	Total
	Salt Load (% of total)	Salt Load (% of total)	Salt Load (% of total)
Industry	16	7	12
Domestic	16,5	15	16
Mining	16,5	28	21
Power generation	1	-	1
Diffuse sources	50	50	50
Total	**1 012 t TDS/d**	**664 t TDS/d**	**1 676 t TDS/d**

Table 13 : Total pollution discharge for the study area (%)
(60:40 split in favour of point sources)

	Vaal Barrage	Middle Vaal	Total
	Salt Load (% of total)	Salt Load (% of total)	Salt Load (% of total)
Industry	19	9	15
Domestic	20	18	19
Mining	20	33	25
Power generation	1	-	1
Diffuse sources	40	40	40
Total	**843 t TDS/d**	**553 t TDS/d**	**1 397 t TDS/d**

Table 14 : Pollution discharge for the study area (%)
(60:40 split in favour of diffuse sources)

	Vaal Barrage	Middle Vaal	Total
	Salt Load (% of total)	Salt Load (% of total)	Salt Load (% of total)
Industry	13	6	10
Domestic	13	12	13
Mining	13	22	16,5
Power generation	1	-	0,5
Diffuse sources	60	60	60
Total	**1 265 t TDS/d**	**830 t TDS/d**	**2 095 t TDS/d**

5.2.2 It is interesting to note that at the extremes of the scenarios postulated the variance in contributions from the main categories of point sources varies from 10% - 15% for industry, 13% - 19% for domestic sources and 16,5% - 25% for mining. Given that the assumptions about variability in contribution by point and diffuse sources are reasonable, the contributions by categories of point sources vary in relatively small ranges. For the years of the study period (1990-91) the rainfall was close to average for the period so the contributions by industry, domestic sources and mining to the total salt load entering the system are taken (from Table 12) as 12%, 16% and 21% respectively of the total salt load. These figures will be used as the basis for further discussion.

5.3 Water quality variability

5.3.1 At the RWB monitoring station of Engelbrecht's Drift Weir the average TDS of the water upstream of the Vaal Barrage was 140 mg/ℓ for 1989/90 [17]. At the Vaal River No 1 Intake near Vereeniging, the average TDS for the same period was 510 mg/ℓ [17]. This point is downstream of the inflows from the Klip and Suikerbosrand Rivers (average TDS 630 mg/ℓ and 500 mg/ℓ respectively).

5.3.2 At the Rietspruit Weir just upstream of the Vaal Barrage wall the TDS of the inflow to the Vaal is 730 mg/ℓ on average while at the Vaal Barrage outlet the average TDS is 520 mg/ℓ [17], also for 1989/90. Downstream of the Barrage the average TDS for Lindesquesdrift Weir, Pilgrims Estate (Orkney) and Kliplaatdrift are 550 mg/ℓ [17]. 465 mg/ℓ and 429 mg/ℓ respectively. The last two figures are from data supplied by the Department of Water Affairs monitoring stations.

5.3.3 Clearly the impact of the PWV area on water quality in the Vaal Barrage is very considerable. As the trends will be towards increasing urbanisation in this area, the quality of water available to consumers in the study area may continue to deteriorate. Fitness for use of the water available will become increasingly important and a study currently under way by the CSIR and various other contributors aims to define very clearly what the water quality requirements of various end users are and to what extent any further deterioration in the quality of water available will impact on them.

5.3.4 The water quality data indicates that the Middle Vaal appears to recover partially in terms of TDS with the average improving by about 120 mg/ℓ along the course of the river between just downstream of the Barrage and upstream of the Bloemhoff Dam. A major influence on water quality in the Middle Vaal is clearly the load discharged downstream from the Vaal Barrage catchment, in addition to the impacts of point and diffuse sources from the Middle Vaal catchment itself.

6 SALT LOAD MANAGEMENT OPTIONS

6.1 Introduction

6.1.1 In discussing pollution control options, the basic categories which can be considered are:

- blending
- in-house pollution management
- centralised treatment
- change catchment

Consideration must be given to whether it is point source or diffuse source pollution or both which are to be treated. By definition diffuse source pollution is difficult in most instances to control or treat at source. Point source pollution is more amenable to pollution control at source.

6.2 Blending [4], [5], [6], [16]

6.2.1 The TDS concentration of the Vaal Barrage has risen alarmingly since the mid-1970's. During the very severe drought of the early 1980's TDS concentrations at the RWB Zuikerbosch intakes, which are upstream of the infalls of the Klip and Zuikerbosrand Rivers were found to be frequently above the TDS concentrations of the water released from the Vaal Dam. This was indicative of reverse flow conditions in the Vaal Barrage during which saline water was advected upstream. In an attempt to control the TDS levels in the water available for supply to the PWV area, Vaal Barrage water has been mixed with lower TDS water released directly from the Vaal Dam.

6.2.2 A more precise blending of Vaal Dam water with Vaal Barrage water has since been implemented as required. A maximum acceptable TDS level in the supply water is identified (normally 250 mg/ℓ - 300 mg/ℓ TDS) and the water from the Vaal Barrage and the Vaal Dam is blended to meet this level. At the same time provision must be made for enhancing the supply of water to Vaal Dam. To keep the TDS of the water supply within the required limits, the blending ratio between the two water sources must be varied continuously, depending on the changing quality of the untreated waters. Blending has been found to be relatively inexpensive with a benefit/cost ratio of 25:1 [16].

6.2.3 Blending may not represent a long term solution on its own. Effluent return flows will continue to increase with growing water demand, and as urban and industrial development proceeds it can be expected that the catchment will yield increasing tonnages of salts washed off by rainfall. In addition, illegal and undetected saline industrial effluent discharges into stormwater drainage systems adds to the already high contribution of diffuse sources. In consequence, the quality of water supplied from the Vaal River may keep on deteriorating.

6.2.4 Having said all this, however, blending offers a relatively inexpensive [16] and highly effective means of slowing down the rate of deterioration of Vaal River quality. It has the major advantage that it improves quality of the water in the river itself, and thus effects an improvement in pollution derived from both point and non-point sources which centralised treatment and/or pollution control at source will not achieve.

6.2.5 An additional factor which must be taken into account will be the Lesotho Highlands Water Scheme. The first stage of the scheme is due to come on stream by 1996 and will feed an additional 18 m^3/s at full capacity into the Vaal Dam. By 1996 the Rand Water Board project [18] that the demand for water will have reached an average of 40,5 m^3/s in its supply area at a projected 8% growth rate. For 1989/90 the average rate of raw water abstraction by the Rand Water Board was 26,5 m^3/s so the additional input from the Lesotho Highlands Water Scheme will enable the additional demand from consumers by 1996 to be met without utilising further existing raw water sources. In addition, the Lesotho water is of a very high quality and contains very low levels of salts (less that 50 mg/ℓ TDS). It will therefore provide an opportunity to blend with Vaal Dam water of a significantly lower TDS level than at present. On the negative side, concern has been expressed that the water will be corrosive and may also encourage higher rates of algal growth due to its lack of turbidity. If the demand warrants it, there are a further three stages of development planned for the Lesotho Highlands Scheme which will increase the scheme's input to the Vaal Dam from the 18 m^3/s already mentioned to 26 m^3/s, then 63 m^3/s and finally 70 m^3/s.

6.3 Centralised treatment

6.3.1 Centralised effluent treatment has been proposed as a potential means of dealing with industrial effluents in a cost effective manner due to economies of scale and/or by treating complimentary effluents. Further, centralised water treatment facilities are operated by professional waste handlers who can often treat and manage the water more efficiently than the industries which generate it. Centralised waste treatment facilities also have the potential for chemical recovery as well as dealing with sludge handling and disposal more efficiently.

6.3.2 Municipal sewage works, of course, offer a form of centralised effluent treatment for mixed industrial and domestic wastes which has been operational for a significant period of time and has been generally very successful in complying with the requirements of the General Standard for discharge to the Vaal River system. However, the levels of salinity are not significantly influenced by municipal treatment processes and concentrations are reduced by dilution with less saline domestic effluents. The concept of centralised industrial effluent treatment would be to treat selected high salinity effluents, typically of a mining or other industry origin, either as a pretreatment before discharge to a sewage works, or as a direct discharge to a water course. These facilities could either be privately owned and operated, or be operated by local authorities.

6.3.3 Examining experience from Europe (particularly the Ruhr area of Germany) and from Japan, indicates that centralised effluent treatment for specific industrial wastes has been practised to some extent for the last 30 years. However, in almost all cases the centralised facilities have been planned for or included at inception in new, custom-built industrial areas. To impose centralised effluent treatment on an already established industrial area with a cross-section of industries already there appears to be impractical.

6.3.4 In Japan for example, the concept of industry specific areas has been used successfully. An industrial area is developed for, say, metal finishing and only electroplaters, anodisers and other metal surface treatment operations set up there. In this way, the very specific requirements of the industry's effluent [7] in terms of pH variations, high salinity, heavy metals and cyanide, for example can be dealt with in the most efficient way. High and low pH streams can be combined and neutralised and heavy metal sludges can be disposed of safely. Where sensible, metals can be recovered to generate income to offset the operating costs of the facility.

6.3.5 At the moment, Johannesburg Municipality is examining the viability of tackling the problem of discharges of heavy metals in a centralised manner. The scheme under consideration is to collect the wastes from individual dischargers of heavy metals by tanker and transport them to a centralised treatment facility. Although costly in terms of transport of the wastes the scheme, if successful, will have a very significant benefit of reducing heavy metal levels in the Municipal sewage works sludges. The initial viability of this scheme is dependant on the relatively low volumes of heavy metal-containing effluents produced by individual premises, allowing their collection by tanker to be considered. Similar schemes have been successfully implemented in Europe, Japan and the United States.

6.3.6 Another option for centralised treatment would be to use the already existing sewerage infrastructure which routes effluents to Municipal sewage works and then remove salts from the sewage works discharge. Taking advantage of the existing infrastructure would be attractive from a cost point of view and would pick up saline discharges from domestic sources, many industries and some mines.

6.4 In-house pollution management

6.4.1 Point source pollution control is the focus of the legislative approach to pollution control in South Africa. This is quite understandable as the only effective means of legislating against pollution is when it comes from an identifiable source who can be held responsible for it. DWA monitor all industrial undertakings which use 150 m^3/d of water for an industrial purpose and it is encouraging to note that the data available here suggests that this is an effective cut-off point for monitoring purposes. The idea held widely that many smaller industries collectively amount to a bigger problem than the large industries seems unlikely to be true in practice. Very few industries, with the notable exception of the metal finishing industry, were found to be viable at a water intake of less than 150 m^3/d. Indeed, the information that three "superfactories" and five mines between them discharge a very significant proportion of the point source (24%) effluent volume and salt load (45%) in the study area might support the increase of the cut-off point for monitoring industry to, say, 500 m^3/d. This would certainly be of benefit to the DWA in terms of more efficient utilisation of resources. Care needs to be taken however, as a number of industry groups such as electroplaters, dairies and abattoirs typically fall into the range of water intake between 150 and 500 m^3/d and would therefore be missed if there was any change to the present system. It is concluded therefore that based on observations made during the study, the present cut-off point of 150 m^3/d water intake is a reasonable figure to work with and it should continue to be the basis of the DWA permitting system.

6.4.2 In terms of what can be done to improve point source pollution control, there must be an ongoing management input from the authorities to encourage industry to upgrade their practices. DWA have recognised this in principle with their latest review of their approach to water quality management in South Africa [(20)]. The DWA views its mission as that of "being the custodian of a limited national resource that has to be judiciously managed to ensure that a continuous supply of adequate water of an acceptable quality for recognised water uses, such as urban, industrial, agricultural, recreational and environmental conservation uses, be available" [(21)]. In essence, the DWA is adopting the principle of precautionary or anticipatory environmental protection, such as applied by the United States Environmental Protection Agency. An important implication of the principle is "avoiding or reducing risks threatening the environment by gradually and drastically reducing emission levels of all substances introduced by man into the environment, even when there is no scientific proof that existing levels of emissions are causing harm to the environment [(21)]. In the majority of cases, however, the primary factor from industries point of view in considering improvements in point source pollution control is economic. Particularly for reduction in TDS levels this is the case. Extensive studies have been done by researchers and by industry and the mining houses themselves, some examples of which are given in the next section.

6.4.3 Work done on the use of a Low Pressure Reverse Osmosis (LPRO) processes for the removal of sulphates from underground mine water could be part of an economical desalination process [(19)]. Researchers have shown [(19)] that a LPRO membrane will produce flux rates at 500 kPa similar to a high pressure membrane at 4 000 kPa. The salt rejection of the LPRO membrane was greater than 99% for bivalent modules such as sulphate and high recoveries were also realised for monovalent molecules such as chlorides. It was concluded that a process consisting of pre-treatment (to reduce membrane fouling), LPRO and HPRO on the LPRO brine, followed by electrolysis of the HPRO brine solution, to give an overall water recovery of 95% and a salt rejection of 99% would cost about 30 c/m^3 of blended product water (70% treated, + 30% bypassed). (1989 costs).

6.4.4 Researchers have also examined the possibility of chemical removal of sulphate, calcium and heavy metals from mining effluents [10]. With a two stage barium carbonate process, sulphate, calcium and heavy metals can be removed in a fluidised bed reactor, packed with barium carbonate, and soluble barium in a second reactor by introducing sulphate from the raw water to it. In addition a barium sulphide process was studied, consisting of $BaSO_4$ crystallisation, H_2S stripping, CO_2 stripping and softening stages. It was found that sulphate, calcium magnesium, heavy metals and ammonia can be removed efficiently. It was found that both the barium processes could be used successfully to treat industrial and mining effluents such as neutralised process water from a slimes dam recovery plant, acid mine drainage, gold plant filter wash water and power station cooling water.

6.4.5 Although these and other processes for removal of salinity, such as the Chamber of Mines SPARRO process and JCI's GYP-CIX process have been operated on a pilot plant scale there are few, if any, examples of the full scale utilisation of these technologies. The technology is considered expensive and requires consideration of site specific factors in order to provide cost-effective solutions [15]. In addition, the question of how to dispose of the highly concentrated brine solutions left after many of these treatment processes remains problematic.

6.4.6 In a sense, the use of holding ponds and other impoundments to store saline effluents for eventual evaporation, is another form of point source pollution control widely practised. It is not however a particularly desirable route because such dams require high levels of maintenance to operate them effectively. They are also expensive in terms of capital costs. In addition, the possibility of seepage from ponds cannot be discounted and as such, they are of concern to the authorities.

6.4.7 However it is clear that in order to prevent further deterioration of the quality of water in the study area (even with blending) it is likely that there will come a time when desalination and other forms of treatment will become more widely practised. The trigger for this would presumably be tighter legislation aimed at maintaining the TDS level in the Vaal River system at a level where it still meets the needs of the various sectors of consumers of water resource. The point when the costs to consumers of coping with a deteriorating quality water becomes significant in comparison with the cost of reducing the salinity of point source effluents (and diffuse source effluents, where practical) must be identified well in advance by the managers of the country's water resources. Fundamental to this is a rigorous economic assessment of the impact of increasing salinity levels on consumers. Previous work [8] on this critically important area is at least 4 years old now and in many cases up to 10 years old. If water resource managers are to take long term decisions to control the increase in salinity, which will inevitably mean committing significant financial resources, they will require an accurate assessment of the costs incurred due to the deterioration of the water resource, on which to base their decision.

6.5 Change of catchment

6.5.1 The last pollution control option to be considered is to change the catchment into which a particular pollution load is discharged. This already happens with the discharges from the Sasolburg and Vanderbijlpark sewage works being discharged downstream of the Vaal Barrage even though the works are located in the Barrage catchment itself. Logistically, this is a relatively simple transfer but in other cases the costs involved may well make this option unattractive. There is also the viewpoint that transfer of a problem from one catchment to another is not really a solution at all and should only be considered as a last resort. The Rand Water Board states that "It is also unacceptable that highly polluted water be released to consumers downstream of the Barrage" [18]. Although this statement was made in the context of controlling levels of pollution in the Vaal Barrage itself which inevitably reach consumers downstream of the Barrage, it reflects a high level of concern about the impact which activities in one catchment can have in terms of polluting an adjacent catchment.

6.6 Comparison of salt load management options

6.6.1 In comparing various salt load management options the following criteria should be used:

- effectiveness
- location
- cost
- time frame for implementation
- implications

6.6.2 Taking each of the options examined in turn indicates that blending is an attractive option as it is an effective means of ameliorating the effects of both point and diffuse source pollution. It is considered to be cost effective [16] and is already in operation. The main implication of blending is the necessity to ensure that sufficient water of an acceptable quality is available for blending which the contribution from the Lesotho Highlands Water Scheme appears to assist with from 1996. Blending is not a long term solution on its own, but at present and for the foreseeable future represents a pragmatic means of countering increasing salinity levels in the Vaal Barrage system.

6.6.3 Centralised treatment is attractive from the point of view of benefits of scale in controlling treatment costs. It is however impractical to implement on existing industrial locations except in very specialised instances. The concept should be reviewed when planning new industrial areas but is likely to make a significant impact only in the longer term. One area which is worth researching is the viability of large scale desalination of outfalls from sewage works which are already centralised treatment works, although largely concentrating on removal of organic pollution.

6.6.4 In-house pollution management covers everything from small-scale process-specific effluent treatment within an individual premises to large scale treatment of the final effluent discharge from an individual premises. It is already practised to varying degrees in some premises but has not been implemented on the large scale to any significant extent. The main reason for this is cost though changes in the cost of pollution which could be brought about by financial disincentives imposed by the authorities could change this situation. The effectiveness of many treatment options has been proved on the pilot plant scale and implementation could be relatively swift on full-scale, though location-specific considerations would have to be taken into account. The negative implications of most of the treatment routes discussed is that they result in a volume of highly saline effluent, the handling and disposal of which remains problematic.

6.6.5 Transferring effluents to another catchment although already practised to a limited extent is considered only as a last resort or in very specific cases. The operation is likely to be costly and would take some time to implement but is considered the least attractive of the options discussed because it is merely transferring a problem at considerable cost from one catchment to an adjacent one.

6.6.6 Control of diffuse source pollution has received very little attention in the past from researchers and must receive more in the future. In some instances, the control of diffuse source pollution is well understood and has been implemented to some extent. Control of stormwater runoff from rock dumps, sand dumps and mining slimes dams can be improved by revegetation, toe paddocks, and in the case of slimes dams with under drains, penstocks, solution trenches, stormwater diversion trenches and return water dams [15]. In the case of runoff from agricultural land and urban stormwater runoff the problems are much more difficult to deal with. Greater use of wetlands, for example, may assist in this respect.

7 IMPACT OF REDUCING SALT LOADS FROM POINT SOURCES ON WATER QUALITY IN THE VAAL RIVER

7.1 Introduction

7.1.1 From the various scenarios postulated in Section 5, the impact of reducing the salt load from point sources of pollution on the water quality in the Vaal River can be estimated. For the purposes of this discussion the figures for point source contributions from Table 12 (based on a 50:50 split between point and non-point sources for the years 1990-91 which were close to average in terms of rainfall) will be used.

7.1.2 These figures indicate that of a total salt load discharged in the study area of 1 670 t TDS/d the Vaal Barrage contributed 1 010 t TDS/d (61%) and the Middle Vaal 660 t TDS/d (39%). If we take the average TDS levels in the Vaal River as 510 mg/ℓ for the Vaal Barrage and 465 mg/ℓ for the Middle Vaal then the following scenarios can be examined:

- treatment of major industrial and mining pollution sources (1)
- treatment of sewage works discharges (2)

- treatment of all industrial and mining pollution sources (3)
- treatment of all direct discharge industrial and mining effluents and sewage works discharges (ie all point sources) (4)

7.1.3 As discussed in Section 2.3.2, three "superfactories" discharge between them 89 t TDS/d which is 43% of the total industrial salt load. The load is split 69 t TDS/d to the Vaal Barrage and 20 t TDS/d to the Middle Vaal Catchment. In addition, five mines discharge 299 t TDS/d or 86% of the total salt load from mining to the Vaal River. In this case the split is 78 t TDS/d to the Vaal Barrage and 221 t TDS/d to the Middle Vaal Catchment. If we assume that these effluents could be treated at a 90% removal of salinity the reduction in salt load to the Vaal Barrage would be 132 t TDS/d and 217 t TDS/d to the Middle Vaal. This would result in a reduction in TDS concentration in the Vaal Barrage on average of 67 mg/ℓ to 443 mg/ℓ and a reduction of 152 mg/ℓ to 313 mg/ℓ in the Middle Vaal Catchment.

7.1.4 Examining the treatment of sewage works discharges indicates that the total contribution from sewage works to the salt load entering the Vaal Barrage is 252 t TDS/d and 150 t TDS/d from sewage works discharging to the Middle Vaal. If we again assume a 90% removal of salinity from these discharges the reduction in salt load from sewage works would be 227 t TDS/d to the Vaal Barrage and 135 t TDS/d to the Middle Vaal. This would result in a reduction in TDS concentration in the Vaal Barrage on average of 114 mg/ℓ to 396 mg/ℓ and a reduction of 95 mg/ℓ to 370 mg/ℓ in the Middle Vaal Catchment.

7.1.5 Salt load from all industrial and mining sources is estimated as 326 t TDS/d to the Vaal Barrage and 226 t TDS/d to the Middle Vaal. Although it is more realistic in practice to consider treatment of most industrial effluent discharges at a sewage works, the figures are given for all industrial effluents as if treated at source. A 90% reduction in salt load from these sources to the Vaal Barrage would result in a reduction of 293 t TDS/d and to the Middle Vaal a reduction of 203 t TDS/d. This would result in a reduction in TDS levels on average in the Vaal Barrage of 148 mg/ℓ to 362 mg/ℓ and for the Middle Vaal of 142 mg/ℓ to 323 mg/ℓ

7.1.6 Taking the salt load from all direct discharges from mining and industrial (including power generation) sources, as well as all sewage works, gives a total salt load of 506 t TDS/d to the Vaal Barrage and 332 t TDS/d to the Middle Vaal. A 90% reduction in salt load from these sources to the Vaal Barrage would result in a reduction of 455 t TDS/d and to the Middle Vaal a reduction of 299 t TDS/d. This would result in a reduction in TDS levels on average in the Vaal Barrage of 281 mg/ℓ to 229 mg/ℓ and for the Middle Vaal of 256 mg/ℓ to 209 mg/ℓ.

7.1.7 The results from this simplified analysis of various pollution control scenarios is summarised below:

Table 15 : ***Summary of the Impact of Various Pollution Control Scenarios on TDS Concentrations in the Vaal Barrage***

Option (See 7.1.2)	Reduction in Salt Load (t TDS/d)	New Average TDS Concentration (mg/ℓ)
1	132	443
2	227	396
3	293	362
4	455	229

Table 16 : Summary of the Impact of Various pollution Control Scenarios on TDS Concentrations in the Middle Vaal

Option (See 7.1.2)	Reduction in Salt Load (t TDS/d)	New Average TDS Concentration (mg/ℓ)
1	217	313
2	135	370
3	203	323
4	299	209

7.1.8 Clearly any of these options would involve treatment of effluent streams for removal of salts on a scale not practised in this country before. Even the first scenario, which it is estimated would improve the average TDS level in the Vaal Barrage by a relatively modest 67 mg/ℓ, would involve the treatment of some 83 Mℓ/d of effluent. In addition some 132 t TDS/d would still have to be disposed of or at least safely contained. Almost certainly the volume of effluent to be treated could be reduced by the more selective application of treatment to specific high salinity streams. However the smaller the treatment plants provided the higher the cost per unit volume treated. Similarly, for the second scenario described (7.1.4) the reduction in average TDS levels in the Vaal Barrage by 114 mg/ℓ would involve the treatment of 547 Mℓ/d of effluent, an even more daunting proposition.

7.1.9 In summary, therefore, it appears that the practical implementation of treatment of point sources of salt load pollution on a scale where significant reduction in average

TDS levels in the Vaal River system are likely to be achieved is still some way off in the future. Compared with the benefits realised from the blending option currently in practice, large scale point source treatment appears to be unattractive in the short term. The introduction of Lesotho Highlands Scheme water with very low salinity to the Vaal Dam by 1996 should continue to make blending the most attractive option for control of salinity in the Vaal River system at least for the next 10-15 years.

7.1.10 It is suggested that apart from continuing with the blending option as at present, DWA policy should aim to make the discharge of salinity to the Vaal River system more economically unattractive. Linked to this would be an updated, rigorous assessment of the economic cost of increasing salinity to all the consumers of Vaal River water. In addition, attention should be given to diffuse sources of pollution and more research should be aimed at identifying practical means for the control of saline discharges from diffuse sources.

7.1.11 In this way, if the quality of water deteriorates to such an extent that large scale treatment to reduce salinity levels becomes necessary, then the economic framework to justify when it should happen and who is to pay for it will be clearly understood and will put DWA in a position to effectively manage what may have to be a major shift in philosophy for many industrialists, mines and Municipalities.

8 SUMMARY

8.1 Some 242 industrial premises excluding mines were found to discharge effluent in the study area. The majority of these (89%) are found in the Vaal Barrage catchment area, indicating the much higher concentration of industrial activity in this catchment as compared with the Middle Vaal.

8.2 Three industrial premises discharge effluent directly to the Vaal Barrage after on-site pretreatment. The effluent volume is 63 Mℓ/d and it contains 75 t TDS/d. Industrial effluent discharged to the Vaal River via sewage works was found to be 76 Mℓ/d containing 133 t TDS/d. Thus the total effluent generated by industry in the study area was found to be 139 Mℓ/d in volume and contained 208 t TDS/d. Return flow by industry was found to be 46% of the water intake.

8.3 Three "superfactories" discharge between them 81 Mℓ/d of the total industrial effluent volume (57%) and 89 t TDS/d of the total industrial salt load (43%).

8.4 The split of industrial activity between the Vaal Barrage and the Middle Vaal catchments means that 66% of the industrial effluent volume and 78% of the industrial salt load is discharged to the Vaal Barrage. The main component of the industrial salt load was found to be sulphate (62 t/d).

8.5 Mines were found to discharge 136 Mℓ/d of effluent to the Vaal River containing 348 t TDS/d. The West Rand and Carltonville area discharged the largest portion of the salt load at 47% of the total. Mines in the Vaal Barrage catchment contribute 41% of the total mining effluent volume and 48% of the mining salt load. Five mines between them contribute 86% of the mining salt load discharged to the Vaal River system. Return flow by the mines was found to be 14% of water intake with a large tonnage of salts being stored on mine property in holding dams.

The main components of the mining industry salt load were sulphate 95 t/d, chloride 69 t/d and total alkalinity 66 t/d. This is largely dictated by the quality of underground water in the mining areas which differs widely depending on the region.

8.6 By examining data for Municipal sewage works discharge, the contribution to effluent volume and salt load from domestic sources can be quantified. The total domestic effluent discharge was found to be 693 Mℓ/d with 75% being from the Vaal Barrage catchment. The total domestic salt load was 270 t TDS/d with 62% discharged to the Vaal Barrage catchment. Domestic effluent in the Middle Vaal catchment was significantly more saline than that from the Vaal Barrage, due to the higher salinity of the water intake from the Middle Vaal.

8.7 Combining all the point source discharges indicates that mining, power generation and other industry discharges 298 Mℓ/d of effluent to the Vaal River containing 568 t TDS/d. This represents 30% of the total point source effluent volume and 68% of the total point source salt load.

8.8 Examining the various pollution control options, blending still seems to be the most attractive option for controlling TDS levels. Although it is not a long term solution on its own, blending has the advantages that it is relatively inexpensive and that it has an influence on controlling pollution from both point and non-point sources. Centralised effluent treatment has been successfully implemented in other countries but only where it has been planned from the beginning of an industrial area. The concept should therefore be considered when new industrial areas are planned for South Africa, particularly for grouping of similar industry types in the same area. In-house pollution management has been practised in South Africa for many years in the form of disposing of saline effluent to evaporation ponds. However, the authorities do not view this route particularly favourably. At present the economics of large scale treatment make it an unattractive option for treatment of point source discharge. As urbanisation and industrialisation continue to increase, however, particularly in the PWV area, it is probable that desalination of point source effluents will become more common practice.

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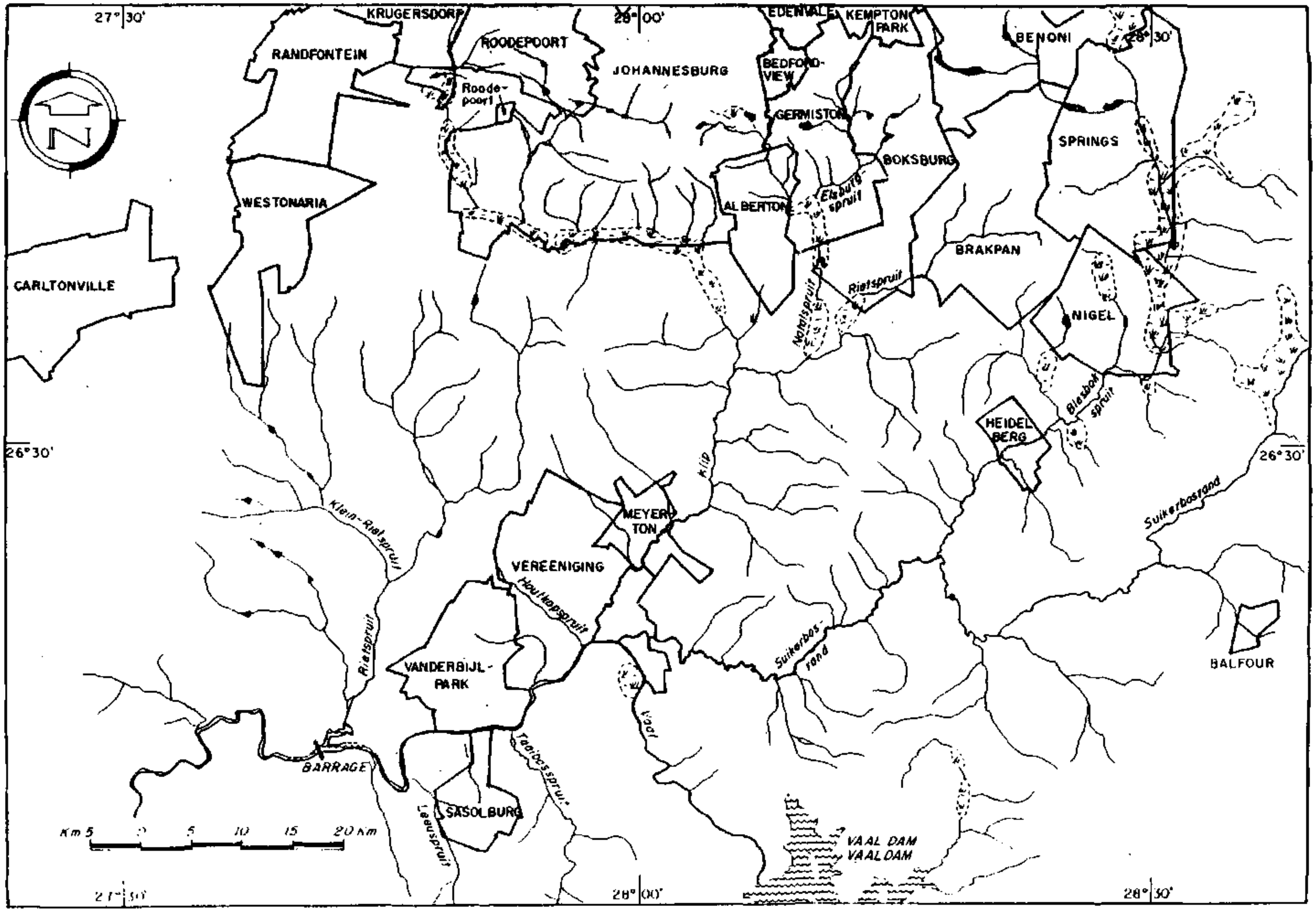

FIG No 1