A Manual on Mine Water Treatment and Management Practices in South Africa

APPENDIX
Volume 5
Catalogue of Relevant WRC Research Projects

W Pulles • D Howie • D Otto • J Easton

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A MANUAL ON MINE WATER TREATMENT AND MANAGEMENT PRACTICES IN SOUTH AFRICA

W Pulles
D Howie
D Otto
J Easton

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INTRODUCTION

In order to plan and develop an effective research strategy it is essential to have an accurate record of relevant research being undertaken both in South Africa and elsewhere in the world. Unfortunately, information is not readily available on the research programmes of the various international research organisations and even the different mining Groups in south Africa. The Water Research Commission on the other hand, provides a detailed annual listing of research which it is funding. This report catalogues those research projects funded by the WRC, which are directly or indirectly relevant to the disciplines of mine water management and treatment, environmental management and aquatic ecology. The relevant research has been classified into the following sections:

1. Prevention of mine water pollution
2. Active mine water treatment
3. Passive mine water treatment
4. Environmental aspects of mining
5. Active industrial water treatment with relevance to the mining industry
6. Active potable water treatment with relevance to the mining industry
7. Fouling, corrosion and piping systems
8. Passive and biological industrial water treatment with relevance to the mining industry
9. Vegetation, land use and agricultural aspects
10. Surface hydrology
11. Geohydrology
12. Regulatory, infrastructural and economic issues
13. Conservation of aquatic ecosystems
14. Monitoring, sampling and analytical techniques
15. Developing areas and socio-economic aspects
16. General

This report is based on published information extracted from the WRC Annual Reports for the period 1985 to 1993.

1. PREVENTION OF MINE WATER POLLUTION

1.1 INHIBITION OF BACTERIAL OXIDATION OF PYRITE AND CONCOMITANT ACID DRAINAGE

The natural oxidation of pyrite to form iron sulphates and sulphuric acid is a slow process, but it is largely accelerated by the action of certain bacteria. This is a widespread problem in the coal and gold mining industry and causes serious salinisation of water sources. The research, undertaken over a 6 year period was aimed at drenching certain materials with bactericidal chemicals. These materials can be placed in residue dumps where the inhibiting chemicals can be released slowly in the course of time.

The first phase of the research comprised the successful production of pellets or membrane sachets made of natural or synthetic rubber in which the inhibiting substances were impregnated in order that controlled release thereof could be obtained. The elastomeric membrane sachet has been found to be the most economic release mechanism. In further studies various chemicals were tested as inhibitors of the bacteria *Thiobacillus ferrooxidans* in gold mine dumps. Sodium lauryl sulphate was the best inhibitor, but the use of the inhibitors deep inside gold mine dumps, where pyrite oxidation also occurs, is a big problem. The last phase of the research focused on coal residue dumps and several inhibitors and combinations thereof were tested. The advantages of using sodium benzoate and sorbic acid were apparent, but a major problem regarding the adsorption of the chemicals on the coal and the variance in the coal particle size was experienced. Apart from the practical problems the use of the inhibitors, as tested, is also not an economical proposition.

1.2 INVESTIGATION OF THE OCCURRENCE OF BACTERIA CAUSING ACID MINE DRAINAGE IN THE OUTER LAYERS OF COAL WASTE DUMPS

Acid mine drainage is a serious water pollution problem in the coal mining areas of South Africa and is caused by a combination of chemical and bacterial reactions when pyrite in mined coal or coal waste is exposed to air and moisture. The natural oxidation of pyrite is a slow process but is greatly facilitated by the action of specific bacteria.

One method to control the oxidation of pyrite by bacteria is to create anaerobic conditions by means of appropriate coal dump construction and reclamation techniques. Recent developments in dump construction and reclamation techniques have the aim of counteracting both acid drainage and spontaneous combustion of the coal waste, by reducing access of air to the dumps and the flow of water through and from the dumps. Dump compaction is one such technique while covering dumps with soil which is vegetated or with a clay cap and vegetated soil, are other techniques. In order to assess the success of dump construction and concomitantly the ability to establish anaerobic conditions, the occurrence of iron oxidation in the dumps could be used. This may most rapidly give an evaluation of the

success of the different dump construction techniques in limiting acid drainage and also indicate where problems still exist.

The purpose of the research, to be undertaken over a 3 year period will, therefore, be to do comparative, quantitative and qualitative studies of iron-oxidising bacterial populations which could catalyse acid drainage production in the outer layers of coal waste dumps of different construction or reclaimed dumps. For this purpose, non-compacted and compacted dumps, dumps without and with clay and/or soil caps and vegetated and non-vegetated dumps will be investigated. From these results, identification of dump construction or reclamation techniques which most successfully limit populations of acid producing bacteria will be possible. Identification of problem sites in the various dumps will also be indicated. In the end, an assessment of the success of the present construction and reclamation techniques for coal waste dumps in inhibiting or limiting the development of iron bacteria could be achieved.

1.3 CALIBRATION OF MODELS FOR THE DESIGN OF COVERS FOR OPEN-CAST MINE AND WASTE DUMP REHABILITATION

Acid drainage, a major cause of water quality degradation in many coal mining areas, can fortunately be restricted by means of suitable covers to limit water percolation through the underlying acid generating strata. The 3-year project aims at establishing reliable design procedures for such finishing covers to enable acceptable rehabilitation of open-cast mines and waste dumps. A field-scale experimental site, established by DWA and F in Northern Natal, will be used to measure the water balance components and the collected data will be used to test and calibrate existing cover design computer models.

2. ACTIVE MINE WATER TREATMENT

2.1 DESALINATION OF MINE WATER

A 2-year desk and laboratory study was undertaken in order to assess the technical and economical feasibility of a wide range of desalination technologies for the treatment of underground mine waters. The study revealed that electrodialysis reversal (EDR) and tubular reverse osmosis (TRO) were the most promising for treating non-scaling mine water, while seeded reverse osmosis (SRO) was identified as the most promising option for treating scaling mine waters. As a result of this study, further pilot plant investigations were undertaken of the three identified technologies.

2.2 PILOT PLANT STUDIES ON THE DESALINATION OF UNDERGROUND MINE WATER WITH EDR

A 1,6 ℓ/s EDR pilot plant was erected at the Beatrix Gold Mining Company and evaluated over a 2-year period to establish the following:

- whether EDR is a technically viable desalination process for brackish type mine water;
- the levels of product water recovery and salt rejection attainable;
- the pretreatment requirements to ensure adequate plant performance;
- the extent of membrane fouling and scaling that may occur; and
- the techno-economic implications.

After 5 900 hours of continuous testing it was possible to decide on consecutive feed water pretreatment steps. Under these specified pretreatment conditions the plant achieved a product water recovery and an average salt rejection of 84 and 80 per cent respectively. The level of total dissolved solids of the product water averaged 637 mg/ℓ, rendering it suitable for use in hydropower systems, for discharge to the environment and for human consumption if appropriate disinfection is applied.

No excessive membrane deterioration was evident and membrane life was estimated at four and seven years for anion and cation membranes respectively. The data obtained during the study were sufficient to enable realistic cost estimates to be made for full-scale plants.

2.3 CHEMICAL REMOVAL OF SULPHATES

This 2-year investigation showed that the addition of barium carbonate and lime to sulphate-containing mine effluents effectively removes all dissolved solids except for Group I and VIII ions. The sulphates in the effluents are captured in the form of a concentrated hydrogen sulphide stream which is amenable to further processing into valuable sulphur products, while the barium salts may be effectively recycled, requiring minimal make-up. The barium salts are reduced to water-soluble barium salts with coal in a kiln and the liberated carbon dioxide is used to carbonate the barium sulphide

solution to barium carbonate, which is recycled. The raw materials required, namely barites and coal, exist in abundance in South Africa while the products, sulphur and water, are in demand. This process does not have a solids or brine disposal problem.

2.4 DEVELOPMENT OF SEEDED REVERSE OSMOSIS TECHNOLOGY

This research caps a 7-year research programme. Conventional desalination technologies such as electrodialysis reversal and reverse osmosis cannot be directly used to economically treat those waters encountered in the South African gold mining industry which are scaling with regard to calcium sulphate. It was therefore decided, in the early 1980's, to undertake research into the development of seeded reverse osmosis technology for treating scaling mine waters. This research culminated in the development of the Slurry Precipitation and Recycle Reverse Osmosis (SPARRO) technology. Extensive pilot plant investigations were undertaken and it was shown that the SPARRO process is technically capable of producing a high quality product water at water recoveries of around 95 per cent. Problems were encountered, however, with fouling of the tubular cellulose acetate membranes, resulting in declines in the flux rate. It is postulated that the fouling is mainly due to the presence of quartzitic suspended material, although the mechanism of fouling cannot be explained. Further research is being undertaken to clarify the potential fouling mechanisms and to optimize the membrane cleaning regimes. The capital cost for a 46.3 ℓ/s (4 Mℓ/d) SPARRO plant has been estimated at R16.2 million, with an estimated operating cost of R 1.48 / m^3 of product water.

2.5 A STUDY ON A MINE WATER RECLAMATION TEST PLANT

This project was undertaken over a 3-year period. One of the options for reducing water pollution from gold mining operations is to reclaim effluents to replace purchased fresh water. Although the gold mining industry already practices a high degree of water reuse, between 150 and 200 Mℓ/d of effluents are still discharged to the surface water environment. Reclamation of these effluents requires careful consideration of the associated costs, as reuse without adequate treatment could lead to severe problems with corrosion, fouling and scaling. On the other hand, water treatment is expensive and care must be taken not to treat the water more than is required. A need was therefore identified to obtain reliable data which establishes the cost benefits and operating costs associated with each water treatment unit process.

The Mine Water Reclamation Test Plant was constructed at the Water Treatment Test Site at ERPM Gold Mine. The plant treats waste water pumped from underground by applying neutralisation, settling, filtration, disinfection and desalination. Two different blends are made of desalinated and undesalinated water. Eight water streams of different qualities are fed to eight parallel corrosion monitoring units to measure general corrosion, biofouling and biocorrosion potential. A water quality monitoring rig measures and

records the flow rate, temperature, pH, conductivity, turbidity and dissolved oxygen for each of the eight different streams. The data produced in this study is collected by a PLC and automatically stored on computer and will then be assessed in order to correlate corrosion, fouling and water treatment costs with water quality.

The study will look at three different raw water types:

- ERPM water;
- a simulated West Wits gold mine water by blending ERPM water with desalinated water; and
- a simulated Klerksdorp gold mine water by blending ERPM water with SPARRO plant brine and sodium chloride solutions.

2.6 REACTION KINETICS IN A SLURRY PRECIPITATION AND RECYCLE REVERSE OSMOSIS (SPARRO) SEED REACTOR

Earlier work on the slurry precipitation and recycle reverse osmosis (SPARRO) plant has led to the belief that if the short contact time between the raw water and the seeded slurry before entering the RO modules were increased, it would enable raw water "contaminants" to be captured in the gypsum crystal matrix and prevent them from degrading membrane performance.

This study concluded that membrane degradation does not appear to be due to the foregoing postulate, but rather to a combination of phenomena associated with the increasing concentration of dissolved and suspended solids in the feed to successive rows of membrane modules. Radioactivity may be one such phenomenon; radionuclides appear to be almost totally rejected by the membranes, even when their overall salt rejection is poor.

2.7 THE NEUTRALISATION OF WATER CONTAINING HIGH CONCENTRATIONS OF SULPHURIC ACID WITH CALCIUM CARBONATE

This project was undertaken over a 2-year period. In this project the focus is on an alternative process whereby effluents containing sulphuric acid could possibly be neutralised more cost-effectively than with the currently used lime process. The project investigates the use of a fluidised bed to enable the neutralisation with calcium carbonate pellets to take place at a constant rate.

2.8 OPTIMISATION OF MINE SERVICE WATER DISINFECTION

Although nitrite build-up in natural water is not a common phenomenon, recent research into the inhibitive effect of various chemical species found in gold mine service water on ammonia- and nitrite-utilising bacteria, suggests that certain disinfection practices may lead to nitrite build-up in water. Although the phenomenon of nitrate build-up is not unknown, many of the factors proposed in the literature as contributing to this situation (such as substrate and temperature inhibition and specific toxins such as free

ammonia, chlorite, nickel (II), silver (II), etc.) have not been found to describe the problem fully.

In view of the cost and health implications of this problem to the mines, and the environmental implications when excess water id discharged into local water courses, a 1-year research project was undertaken to investigate possible solutions to the problem.

2.9 SURVEY OF CURRENT WATER MANAGEMENT AND TREATMENT PRACTICES IN THE SOUTH AFRICAN GOLD AND COAL MINING INDUSTRIES

The South African mining industry covers a vast geographical area and consequently individual mines experience different water management problems. The mines have, therefore, developed and applied different strategies to reduce fresh-water intake and to treat the water for reuse or discharge.

In an endeavour to effect technology transfer the 2-year research project aims to:

- Prepare a comprehensive document setting out the current "state of the art" with regard to water management and treatment in the mining industry, which can be used as a practical tool by water management practitioners in the mining industry and which can serve to identify the best available technology not entailing excessive cost (BATNEEC)

- Identify knowledge gaps with regard to mine-water treatment and management as a guide to future research projects.

3. PASSIVE MINE WATER TREATMENT

3.1 USE OF VEGETATION IN THE AMELIORATION OF THE WATER QUALITY IMPACTS OF MINING - AN ASSESSMENT OF SPECIES AND WATER USE

This is a three-year project. The use of vegetation, and particularly fast-growing tree species, such as *Eucalyptus*, is seen as an effective way of reducing leaching to the groundwater table and providing a useful form of land management for stabilisation and rehabilitation. The main objectives of this project are:

- To assess the degree to which vegetation can be effective in utilising rain and surface water, thus preventing its movement through, and leaching of, mining waste piles and replaced soil profiles with resultant potential deterioration of groundwater quality. Research will determine how much water is utilised by different species and vegetation types and will further assess which species should be established to achieve the management objectives of minimising through-flow to the groundwater.

- The development of modelling and predictive methods to extrapolate water use estimates over scales of time and climate variation.

- Rehabilitation sites could be managed through the production of commercial timber and/or establishment of ecological preserves. Longer-term objectives may include the rehabilitation of sites to former agricultural potential, or potential for urban development or recreation. Agroforestry practices may prove ideal as an interim land management measure.

3.2 PRELIMINARY ASSESSMENT AND REVIEW OF THE NEED FOR INTEGRATED PASSIVE WATER TREATMENT SYSTEMS FOR MINE EFFLUENT STREAMS

Effluent streams from mining operation have long been recognised as major contributors to the pollution load entering watercourses and eventually the water resources of the country. The principles and procedures of integrated environmental management have been accepted as a requirement by the mining industry.

The biggest problems occur when a mine closes and the effluent streams continue to flow, uncontrolled and untreated.

The 2-year project is looking at the magnitude of the problem in terms of the number of mines affected and the extent to which treatment of the high concentration effluents will benefit the country.

4. ENVIRONMENTAL ASPECTS OF MINING

4.1 THE CONTRIBUTION OF MINE DUMPS TO MINERAL POLLUTION IN THE VAAL BARRAGE

The research was carried out in three phases, over a 5-year period. Three mine dumps were selected for a monitoring study over a period of three years.

Phase one comprised the installation of a monitoring network for surface and groundwater on a sand dump and two slimes dams. During phase two, data were collected and analysed. During phase three, an inventory of the 273 mine dumps in the study area was compiled, as well as the extrapolation of the results of phase two to all mine dumps, in order to estimate the total contribution from all the mine dumps to the salt load of the Vaal Barrage.

The sand dump delivered significant quantities of dissolved salts (e.g. 2 300 t in 1985) to the water environment, while the contribution of the slimes dams to the salt loads was negligible. The major contribution of the sand dump to the salt load can be attributed mainly to seepage water.

Extrapolation of the results has shown that the mine dumps in the Vaal Barrage area contributed a pollution load of approximately 50 000 t in 1985, of which an unknown quantity reached the Vaal Barrage. If the Department of Water Affairs' estimate of the total pollution load in the PWV area is accepted, viz. approximately 400 000 t/a, the contribution of the mine dumps would amount to about 12,5 per cent.

4.2 DEVELOPMENT OF TECHNIQUES FOR THE EVALUATION AND EFFECTIVE MANAGEMENT OF SURFACE AND GROUNDWATER CONTAMINATION IN THE ORANGE FREE STATE GOLDFIELDS

The geographically isolated nature of the Orange Free State gold fields provided a unique opportunity to study the impact of certain waste disposal activities on both surface and groundwater and the behaviour of pollutants as they travel through soils and aquifers.

During the first year of this 3-year project a regional investigation was carried out, while for the remaining 2 years the research concentrated on more detailed investigations.

Although it was found that contamination of surface and subsurface water resources does occur, this is on a significantly reduced scale due to preventive actions taken by responsible organisations. In general, contamination of groundwater resources is contained within close proximity of the source. However, spillages of effluent into river and vlei systems have spread the contaminants over relatively large distances.

4.3 REGIONAL INVESTIGATION INTO GROUNDWATER QUALITY DETERIORATION IN THE OLIFANTS RIVER CATCHMENT ABOVE THE LOSKOP DAM, WITH SPECIALISED INVESTIGATIONS IN THE WITBANK DAM SUB-CATCHMENT

This is a four-year project. Elevated sulphate and low pH levels in the surface waters of the Olifants River and specifically in the Witbank Dam sub-catchment, clearly indicate that the quality is deteriorating. At this stage the origin of the pollutants is still uncertain. It is known, however, that mining activity and power generation in this area expanded significantly during the past number of years. The impact that this expansion will have on the environment, especially on slow-reacting systems like groundwater, is expected to become visible only over an extended period of time. This investigation aims to quantify the contribution of various activities to the water quality deterioration in the area, predict future salt loads in groundwater, improve management and precautionary measures to minimise groundwater quality deterioration and assist with integrating this information with that from other investigations, in order to derive a catchment management programme, aimed at reducing or reversing the trend towards water quality deterioration.

4.4 OCCURRENCE AND ACCUMULATION OF SELECTED HEAVY METALS IN FRESH WATER ECOSYSTEMS AFFECTED BY MINE AND INDUSTRIAL POLLUTED EFFLUENT

This is a three year project. Mining and industrial activities and residential pollution on the Witwatersrand are causing serious disturbances of freshwater ecosystems in the Elsburg, Natal and Blesbokspruit catchments. Heavy metals also occur in these tributaries in relatively high concentrations but their effect on ecosystems has as yet not been investigated. Rehabilitation of these tributary systems can contribute to the development of green belts on their banks where open-air recreational areas could be established to the advantage of the entire East Rand community. The purpose of the research is to trace the sources of the heavy metal pollution and to determine the accumulation of heavy metal ions in both the abiotic and the biotic components of the water environment.

4.5 CONCENTRATION RATIOS OF SELECTED RADIONUCLIDES IN AQUATIC ECOSYSTEMS AFFECTED BY MINE DRAINAGE EFFLUENTS

This project was carried out over a period of two years. South Africa produces gold and uranium on a large scale. As a result of mining activities, uneconomic concentrations of uranium and radium end up on mine dumps and in water courses. These effluents are radioactive and can therefore harm the environment and eventually also man. Relatively little is known of the effects that uranium and other radioactive substances may have on the flora and fauna of an area surrounding such activities. The purpose of the project is to determine the short and long-term effects of the radionuclides on the agricultural activities and the links with plants and animals. The results will lay

the foundation for the quantification of the impact of radiological water quality on the ecosystem and on man.

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

The 2-year study reviewed the relative contributions from major sectors to the salinity loads in the Vaal Barrage and Middle Vaal catchment areas. Data from industrial premises, mines, power stations and municipal sewage works were assembled, collated and analysed to provide an integral view of point-source salinisation of the Vaal River. The combined point sources discharge 298 Mℓ/d of effluent, containing 568t of TDS, to the Vaal River.

Of the various pollution control options, blending still seems the most attractive interim means of controlling TDS levels; this is because it is relatively inexpensive and is also applicable to non-point sources. Centralised effluent treatment can be considered when adequate areal grouping of similar industry types is realised in future.

4.7 GUIDELINES AND PROCEDURES TO ASSESS AND AMELIORATE THE IMPACT OF GOLD MINING OPERATIONS ON THE WATER ENVIRONMENT

Although it is estimated that the gold-mine industry consumes only 1% of South Africa's water resources, it is being implicated increasingly as a significant contributor to the pollution of the water environment. Expectations are that the application of the new approach to water quality management, coupled with general environmental management principles will lead to renewed pressure on the mining industry to reduce their contribution to the pollution of the water environment. The aim of this 4-year project is to draw up guidelines and procedures to reduce and ameliorate the effect of gold-mining activities on the water environment.

4.8 CATCHMENT WATER QUALITY DETERIORATION AS RESULT OF WATER-LEVEL IN ABANDONED GOLD MINES ON THE EASTERN AND CENTRAL WITWATERSRAND

There is a growing concern with regard to the recovery of water levels in abandoned gold mines following the cessation of water pumping. Upon full recovery, the groundwater within a mine can mostly be expected to seep into surface water courses. Since the quality of water within gold mines generally deteriorates with time, a possibility exists that seepage of mine water will cause a deterioration of surface water quality to manifest itself some time after the closure of a mine. At present this scenario is still largely circumvented by the draw down of the water table as a result of the pumping of water by the remaining active mines within the Witwatersrand gold fields.

This 3-year project aims to investigate the rate of water-level recovery in the abandoned gold mines of the eastern and central Witwatersrand, investigate

processes affecting the quality of water in these mines and quantify possible seepages upon full recovery of the groundwater level. In this way the overall impact on catchment water quality will be estimated and possible ameliorative measures recommended.

4.9 THE EFFECT OF POLLUTION ON THE PHYSIOLOGY OF FISHES IN THE OLIFANTS RIVER

This project is being undertaken over a 3-year period. Up to the present most similar studies were aimed at determining the results of acute exposures of fish to pollutants. Under these conditions the death of the organism was the only measurable variable. It is, however, accepted that an organism ceases to function physiologically normally and effectively long before dying. For this reason the project aims at determining the effect of pollutants on the physiology of, in this case, fish, from exposure to such substances to serious physiological disturbance.

4.10 LOWER VET RIVER WATER QUALITY SITUATION ANALYSIS WITH PARTICULAR REFERENCE TO THE OFS GOLDFIELDS

As part of a previous WRC-funded investigation in the OFS Goldfields a good deal of water quality related information was gathered which should form the background for the drawing-up of tap water quality management plan for the area. The gap between the information gathered during this investigation and the needs of a management plan can be best bridged by an analysis of the water quality situation in the greater catchment area. As such a situation analysis will assist in the practical application of research results, the WRC supports this 1-year project.

4.11 DEVELOPMENT OF AN INTEGRATED AND GENERIC WATER QUALITY SIMULATION MODEL FOR OPEN-CAST COAL MINING WATER CIRCUITS

Due to its inherent economic advantages, the technology of open-cast coal mining has found significant application in South Africa. However, these mining operations cause substantial disturbance of the natural hydrological cycle in the mining area. To control such disturbances the DWA & F allocates allowable pollutant waste loads to specific catchments and it will be the task of colliery management to develop and implement a water system in compliance with the allocated waste load.

To assist colliery management in this regard, the 18-month project aims to develop a generic model which can be applied to any open-cast mining environment, and which can simulate and predict the effluent flow and pollution waste load emanating from a colliery complex under different hydrological conditions.

4.12 PREDICTION OF POLLUTION LOADS FROM COARSE SULPHIDE CONTAINING ROCK MATERIALS

Acidic saline leachate from coarse materials in mine dumps is termed acid rock drainage (ARD) and is perhaps the most significant contributor to pollution of South Africa's water resources.

A predictive mathematical model is needed not only to provide a quantitative estimation of waste quality issuing from a proposed or existing waste rock dump, but also to enable mine management to evaluate options (blending, stacking) for waste rock disposal and dump composition.

In addition to the development of the required model the 3-year project also aims to evaluate:

- Kinetic laboratory test methods which determine the propensity of coarse discards to develop ARD

- The practicability of inundation of acid-generating materials as a control technology under local conditions

5. ACTIVE INDUSTRIAL WATER TREATMENT WITH RELEVANCE TO THE MINING INDUSTRY

5.1 DEVELOPMENT OF SUPPORT SYSTEMS FOR CROSSFLOW MICROFILTRATION AND TECHNICAL PERFORMANCE EVALUATION ON INDUSTRIAL WATERS AND WASTE WATERS

This project was undertaken over a 3-year period and followed on from the development phase of crossflow microfiltration which was undertaken during 1984. A process which is based on the use of a woven hose has been developed for the treatment of a wide range of industrial effluents. The crossflow microfiltration technique has been developed into a simple and economic process for the thickening and dewatering of mainly waterworks sludge. The tubular filter press has been patented both locally and overseas.

5.2 DEVELOPMENT OF POLYMERS FOR THE FORMATION OF DYNAMIC MEMBRANES AND THE EVALUATION THEREOF FOR THE TREATMENT OF INDUSTRIAL EFFLUENTS

The objectives of this project were to improve the performance and extend the range of application of dynamic membranes and to consider the use of inexpensive support systems. The following investigations were carried out during the course of the project :

- Standardisation of methods for the preparation of hydrous zirconium (iv) oxide membranes
- Preparation of composite membranes from special polymers supplied by the Institute for Polymer Science, University of Stellenbosch
- Development of a technique for the formation of dynamic membranes at low pressure on rigid and non-rigid tubes for use with high pressures
- Modification of pore size of porous stainless steel tubes using fumed silica
- Study of substituted acrylic acid homo-, co- and terpolymer membranes, and maleic anhydride copolymer membranes
- Use of dynamic membrane chemistry to take low-rejection, low-pressure membranes.

5.3 TREATMENT OF INORGANIC BRINES AND CONCENTRATES

This research was undertaken over a 4-year period. The objectives of this project were to develop the methodology and strategies to enable alternative on-site disposal options of inorganic brines and concentrates to be assessed, with special reference to their isolation from the aquatic environment by undertaking the following:

- Chemically characterise previously identified sources of inorganic brines and concentrates.

- Undertake and develop theoretical chemical equilibrium calculation procedures on the above streams in order to predict the effects of physical, chemical, physico-chemical and electrical treatment processes.

- Undertake laboratory scale experiments to verify, and if necessary, modify the chemical calculation procedures.

- Undertake on-site pilot plant test work on identified priority streams.

5.4 DEVELOPMENT OF FIXED AND DYNAMIC MEMBRANE SYSTEMS FOR THE TREATMENT OF BRACKISH WATER AND EFFLUENTS

The main aim of this study was to effect improvements in cellulose acetate membranes and newly developed ultrafiltration and reverse osmosis membranes.

The main results emanating from this work were:

- Substandard cellulose acetate membranes could be regenerated by novel cross-linking of polymers and deteriorated spiral-wrap membranes could be upgraded.

- Polyether-sulphone ultrafiltration and non-filtration membranes were produced with low molecular mass cut-offs and also used as support media for dynamic membranes.

- Stable, thin-film composite membranes were developed with improved reverse osmosis performance.

5.5 TECHNICAL SUPPORT FOR THE APPLICATION OF DYNAMIC MEMBRANE PLANTS FOR THE TREATMENT OF INDUSTRIAL EFFLUENTS

This project is being undertaken by the Pollution Research Group of the University of Natal. Some textile effluents such as those from wool-scouring mills are extremely difficult to treat to an acceptable standard for discharge to the environment. Others, such as dyeing effluents, cause colour problems in water streams used as a drinking-water source, even if the effluent has been treated beforehand by a sewage treatment plant.

The relatively newly developed dynamic membrane process is very suitable where high temperatures as well as high pressures are required to accomplish separation between the liquid and solid phases of industrial effluents. Currently there are three plants in South Africa where this process is being applied, viz. for the purification of wool-scouring effluents, dyeing effluent from a textile factory and the purification of the effluent from a factory manufacturing synthetic paints. Because this is the first application of such a

process, teething problems are to be expected. This two-year project is therefore being undertaken to provide technical support for the application of membrane plants for the treatment of industrial effluents.

5.6 CONCENTRATION OF INDUSTRIAL EFFLUENTS WITH SEALED-CELL ELECTRODIALYSIS

The sealed-cell electrodialysis (SCED) process makes use of a new concept - a sealed-cell membrane configuration which makes it possible to concentrate effluents to very high levels to recover salts, acids, bases or water and to reduce effluent volumes significantly.

The characteristics of sealed cells were determined and computer models were developed to study the performance of both home-made and commercially available membranes. It was found that SCED could be used to concentrate/desalinate relatively dilute, non-scaling waters to recover chemicals or water. A simple membrane potential measurement could be used to predict membrane performance for salt, acid and base concentration/desalination.

5.7 DESIGN CRITERIA FOR CROSSFLOW MICROFILTRATION

This three-year project is being undertaken by the Pollution Research Group of the University of Natal. Because of the need for a more scientific understanding of crossflow microfiltration, two particular studies have been undertaken. The first examines the fundamental transport mechanisms occurring inside a crossflow microfiltration tube and the second examines the design and optimisation of crossflow microfiltration systems as a whole.

5.8 RECOVERY OF WATER AND CHEMICALS FROM ION EXCHANGE RESIN REGENERATION EFFLUENTS

This three-year research project is being carried out by the Pollution Research Group of the University of Natal, in close collaboration with Eskom. Ion exchange is commonly used for the partial softening and desalination of water. The resins are regenerated by means of chemicals, resulting in large salt quantities eventually landing in the water environment. Various chemical and membrane separation techniques will be evaluated for reclaiming these chemicals from the regeneration effluents. Two of these were previously developed on other effluents and patented in the name of the Water Research Commission.

5.9 MODELLING OF TUBULAR REVERSE OSMOSIS SYSTEMS

It is expected that in future, the use of reverse osmosis to desalinate brackish and sea water and to purify industrial effluents will find increasing applications. From the experience gained at Eskom's Lethabo power station it became evident that there were serious gaps in the knowledge of the design and operation of such a large plant where use is made of a large number of

parallel series of reverse osmosis modules. The complex interactions between certain factors such as pipe shape, module configuration, flow rates and pressure distribution cause complications, which lead to operational problems resulting in under-utilisation of the plant. This three-year project which is being carried out by the Department of Chemical Engineering of the University of Natal, aims at developing techniques which may contribute towards a better understanding of the problems associated with large tubular reverse osmosis plants. Attempts will also be made to improve the operation of existing plants and to optimise the design of new plants.

5.10 THE DEVELOPMENT OF TOLERANT MEMBRANES

This project is being undertaken by the Institute for Polymer Science of the University of Stellenbosch. Thin-film membranes play an important role in reverse osmosis, where they generally provide a high flux at reasonably low operating pressures. However, most commercial membranes of this type show a limited tolerance of chlorine. The objective of this project is to develop a new family of low-pressure thin-film membranes, which are tolerant of chlorine and which should offer a distinct advantage over currently available membranes. Two types will be considered: a medium-to-high sodium chloride (salt) retaining reverse osmosis membrane and a low-to-medium salt retention nanofiltration membrane.

5.11 INDUSTRIAL APPLICATION OF MEMBRANES

This project is being undertaken by the Institute for Polymer Science of the University of Stellenbosch. This project involves the small-scale laboratory evaluation of various membranes on real or simulated effluents, as well as at industrial sites. The work will be conducted in close co-operation with Membratek (Pty) Ltd in order to create specially selected membranes for specific markets, as well as to ensure that the required production technology falls within the scope of their production capability. The work will involve pre-treatment studies with experimental ultrafiltration or nanofiltration membranes and will make use of pilot-plant studies to gain hands-on experience in effluent treatment situations.

5.12 THE DEVELOPMENT AND PRODUCTION OF MEMBRANE SYSTEMS

This project is being undertaken by the Institute for Polymer Science of the University of Stellenbosch. Ultrafiltration (UF) membranes, commonly produced from polyether-sulphone (PES) or polysulphone (PS), have found widespread use in the form of spiral-wrap, tubular and capillary forms in the medical, food-processing and water purification fields. Microfiltration (MF) membranes are produced from polyethylene or polypropylene, usually in the form of self-supporting capillaries, and are generally used in the fields of water and sewage purification. The proposed work will endeavour to develop novel, supported tubular UF membranes with extended molecular cut-off ranges in the case of PES and PS membranes. New materials will also be used.

5.13 DEVELOPMENT OF A SOUTH AFRICAN ELECTRODIALYSIS MEMBRANE SYSTEM

The main aims of this limited investigation were to:

- Design and construct a laboratory-size prototype electrodialysis (ED) Unit from materials available in South Africa
- Evaluate the performance of the ED unit for brackish water desalination
- Evaluate the batch ED system for the treatment of nickel and zinc electroplating rinse waters
- Develop heterogeneous ion-exchange membranes and to determine their characteristics.

The main results obtained were:

- A prototype ED unit could be wholly manufactured from local materials
- The performance of the prototype ED unit compared favourably with that of a commercially available ED unit, for brackish water desalination
- It was possible to treat nickel and zinc electroplating rinse waters effectively with ED for metal and water recovery
- Heterogeneous ion-exchange membranes could be prepared from local resins.

5.14 INVESTIGATION INTO THE ORGANIC FOULING OF ION-EXCHANGE MEMBRANES

Electrodialysis (ED) is used extensively for the treatment of industrial effluents. The ion-exchange membranes used are particularly susceptible to fouling by a wide variety of organic materials, such as humic acid, detergents, dyes, phenolic compounds and organic electroplating bath additives.

Membrane fouling by humic acid could be controlled by reversal of the polarity of the ion-exchange membranes, together with regular rinses with dilute caustic soda solutions.

Fouling of membranes by detergents was more difficult to control because the detergents penetrate the pores of anion-exchange membranes and foul them irreversibly. Removal of detergents by pretreatment with activated carbon is the preferred method to prevent fouling.

Conventional ion-exchange membranes are oxidised by chromium, hence specially designed membranes should be used.

5.15 RESEARCH ON PERFORMANCE CRITERIA FOR PACKAGE WATER TREATMENT PLANTS

This project is being undertaken by the Umgeni Water Board. The supply of potable water to rural and peri-urban areas is a national development priority. Package or preconstructed plants have a major role to play in the rapid provision of water. A major component of the selling price of water is the capital redemption. The installation of package plants which operate at full capacity within days of purchase will lead to a substantial decrease in the cost of supplying potable water. There is an obvious need for such plants in the provision of water to communities that do not have immediate access to potable water. However, there is a reluctance of consultants to recommend such equipment because of the lack of long term testing or authoritative evaluation of this type of equipment.

Package water treatment plants form part of Umgeni Water's strategy in providing purified water cost-effectively to satisfy the needs of the community, especially in extending the provision of purified water to regions where the population does not have a reliable supply. Over the years Umgeni Water have been approached by a number of vendors of package plants with the request that the package plant be allowed to operate at a waterworks. No formal testing programme or evaluation criteria have been developed and the quality of the information obtained from such tests is generally poor. In order to assist smaller organisations and to provide positive feedback to the designers and vendors of such equipment, formal testing procedures should be developed in conjunction with all the classes of users and taking into account the range of capacities and degree of sophistication required.

5.16 FLUORO-CARBON COATING OF ION-EXCHANGE MEMBRANE SURFACES TO OVERCOME FOULING AND GENERAL SCALING

Electrodialysis and reverse osmosis are widely used for the desalination of various waters at industrial installations in Southern Africa. A major expense in the operation of such desalination plants is the replacement cost of a anionic, cationic and cellulose acetate membranes, which are fouled irreversibly by an array of organic substances.

The main aims of this 1-year project are to coat the surface of ion-exchange membranes with a selection of fluorinated carbon compounds and to evaluate the effect of this on the flux of membranes which are prone to fouling, to reduce the quantity of water required for membrane cleaning purposes and to optimise membrane performance.

5.17 CHARACTERISATION OF SOUTH AFRICAN MEDIA FOR SAND FILTRATION

No uniform, generally accepted method of media specification exists for rapid gravity filtration in South Africa. This 2-year study characterises local, commercial filter sand and anthracite with regard to durability, particle size distribution, sphericity, solubility under acid and alkaline conditions and

density. The media are rated according to international specifications in order to make recommendations for a possible local specification for filter media.

5.18 EXTRACTIVE PURIFICATION OF INDUSTRIAL EFFLUENTS

The plating industry generates large quantities of heavily contaminated effluents containing a variety of metal cations, organic acids and other organic derivatives. Such effluents are difficult to treat, even with existing precipitative techniques. Consequently the effluents either have to be disposed of in costly evaporation ponds, thereby merely transferring the ecological problem, or have to be treated destructively, resulting in further and worse ecopollution.

There is therefore a need for real purification of plating effluents. The techniques to be investigated in the course of this 1-year project, will be restricted to the so-called liquid-membrane extraction systems. Selective chemical precipitation is a strong support technique planned for complementary application.

5.19 APPLICATION OF CAPILLARY MEMBRANES IN THE BIOTECHNOLOGICAL TREATMENT OF INDUSTRIAL EFFLUENTS

Pressure-driven membrane separation is a relatively new unit process initially developed for the purpose of water desalination. As the various unit processes have become established in the course of time, membrane separators have also been used more often in applications other than the traditional removal of salt or colour from drinking water.

The pressure-driven membrane processes in particular, can profitably be used in conjunction with other unit processes for the treatment of industrial effluents. The effective separation and reclamation of biomass or its products in the biotechnological treatment of effluents represent a problem and delay the establishment of this technology.

The aim of this 2-year project is specifically to investigate the use of capillary membranes in the biotechnological treatment of industrial effluents. The research will centre on two biological treatment processes.

5.20 MAGNETITE AS FLOCCULANT IN WATER PURIFICATION PROCESSES

Large quantities of magnetite are produced annually as a by-product by various mines in South Africa and only a small quantity is commercially utilised.

Various aspects of the water purification ability of magnetite, as reported in the literature, were verified for the South African conditions. It was demonstrated that the magnetite removes organic colour in particular, as well as turbidity, phosphates, geosmin and COD. The efficiency of removal increases when the pH of the water drops.

It was recommended that the following possible applications exist in the South African water purification industry, for which the magnetite process presents an economically competitive alternative to other purification processes:

- Drinking-water sources high in colour, and low in turbidity, alkalinity and pH.
- Industrial effluents having high colour, especially of organic origin, and low pH.
- Acid mine water.

Pilot-scale studies will, however, be necessary to establish these possibilities in practice.

5.21 GUIDELINES TO COAGULATION AND FLOCCULATION FOR SOUTH AFRICAN WATERS

In a previous report (Report No 217/1/89)) submitted to the WRC it was found that effective coagulation and flocculation were still two of the main problem areas in drinking-water treatment in South Africa. Surveys showed that many water treatment plant coagulation and flocculation systems were incorrectly and inadequately designed for the type of water that was treated.

Upgrading the systems for chemical dosing and floc formation, and eliminating outdated designs and arrangements, would lead to improved product water quality, greater permissible hydraulic loadings and cost savings because of smaller-sized plants and reduced consumption of chemicals.

The aim of this 2-year project is thus to provide a manual for the design of more efficient chemical dosing plants and coagulation-flocculation systems for purifying most of the typical South African waters.

5.22 EVALUATION OF PROTOTYPE CAPILLARY MICRO- AND ULTRAFILTRATION MEMBRANES FOR INDUSTRIAL APPLICATION

This project comprised 2 phases, namely the investigation and modelling of the hydrodynamic characteristics of the capillary system and evaluation of its performance in the laboratory by using real feed waters.

The prototype capillary modules had characteristics similar to regular 9mm tubular ultrafiltration units, with the major advantage of lower pressure drop at increased flow velocities.

The major advantages of the capillary modules were found to be the following:

- Capillary modules could operate at higher linear flow velocity for increased turbulence, with resultant higher flux

- The high packing density, together with the low cost of construction, renders this capillary configuration eminently suitable for the clarification of a variety of feed waters

- Fouling could be controlled by adopting higher than normal flow velocities and standard chemical cleaning methods.

5.23 ELECTRICALLY DRIVEN MEMBRANE SEPARATION PROCESSES FOR THE TREATMENT OF INDUSTRIAL EFFLUENTS

Electrically driven membrane separation processes, such as electrodialysis (ED) and its variants - electrodialysis reversal (EDR); electro-osmotic pumping ED (EOP-ED); electro-electrodialysis (EED); and bipolar electrodialysis (BED), are proven technologies which are eminently suited to the reclamation of water and chemicals from industrial effluents.

A prototype ED system has been manufactured from locally available materials. Several ED and EDR systems are available for large-scale investigations such as the reclamation of chromium, nickel and water from plating effluents and rinse waters, the recovery of waste ion-exchange regenerants and the reclamation of acids from pickling baths.

This 1-year investigation will evaluate these electrically driven membrane separation processes for the reclamation of water and chemicals from industrial effluents in full-scale plants.

5.24 REASSESSMENT OF THE STRATEGY WITH RESPECT TO INDUSTRIAL EFFLUENT DISCHARGE WITH SPECIAL REFERENCE TO ADVANCED TECHNOLOGY TREATMENT METHODS : PHASE 1

This study was undertaken with the purpose of reassessing the WRC's strategy with respect to problematic industrial effluent discharges and the possible utilisation of treatment technologies to address these problems. The following areas country-wide were identified:-

- Mine waters from coal-mining areas in the Witbank and Northern Natal areas (i.e. Transvaal and Natal Regions) and from gold mining operations in the Highveld and Orange Free State Regions.

- Agricultural activities - Effluents arising from agricultural activities and from industries related to these activities.

- Freshwater aqua cultures (Western and Eastern Cape regions)

- Storm-water runoff from e.g. feedlots and in urban areas from e.g. fertiliser plants etc.

- Coloured effluents - Colour in discharge waters from e.g. textile dye house operations (Natal Region)

- Tanning industry, including possible problems with new chemicals replacing salt in some areas.

With respect to technologies for the treatment of difficult and toxic wastes it is considered (not necessarily by the regional water pollution control authorities) that emerging/advanced technologies that may have application in the treatment of effluents where the priority requirement is high should be critically examined either by direct experimentation or by careful monitoring of research/application world-wide.

6. ACTIVE POTABLE WATER TREATMENT WITH RELEVANCE TO THE MINING INDUSTRY

6.1 COMPARATIVE STUDY ON CHLORINE DIOXIDE AND OTHER OXIDANTS IN POTABLE WATER TREATMENT

This project set out to assess whether alternative combinations of oxidants such as chlorine, chlorine dioxide and ozone could result in a significant improvement of the treatment process of eutrophied source water such as found in the lower Vaal River.

It was found that ozone pre-oxidation followed by chlorine dioxide post-disinfection was the most successful combination to achieve low levels of trihalomethane formation. Chlorine dioxide is not recommended for use as a pre-oxidant in the treatment of lower Vaal River water because of the high dose required and the resultant high level of chlorite and chlorate, as well as the very high costs. However, in terms of chlorophyll removal, biofouling control, lowest cost and (with the aid of potassium permanganate) iron and manganese removal, chlorine was still one of the most effective oxidants for the treatment of lower Vaal River water.

6.2 EFFECT OF WATER QUALITY ON THE EFFECTIVENESS OF CHLORINE DIOXIDE IN DRINKING WATER TREATMENT

In this study, to be conducted by the Rand Water Board over a period of 18 months, the efficacy of chlorine dioxide and chlorine as pre-oxidants and algaecides will be compared for the production of high quality drinking water from eutrophic water sources. As it has been found, during preliminary studies, that unknown factors influence the efficacy of the oxidants, an attempt will be made to determine the nature and range of these factors. The investigation will furthermore attempt to establish whether there is a difference in the resistance of different Vaal Barrage algal species in respect of the efficacy of chlorine dioxide and chlorine.

6.3 EVALUATION OF NON-CONVENTIONAL DISINFECTION TECHNOLOGIES FOR SMALL WATER SYSTEMS

The aim of this 2-year project is to identify potential non-conventional disinfection technologies and their comparative disinfection abilities, power consumption (where applicable), reliability, cost and operational needs, in order to be able to select the appropriate system for small water treatment plants.

The traditional way of disinfecting waters by using chlorine has proved to be very effective in may developed countries. Nevertheless, UN agencies usually refer to chlorine disinfection in rural areas as a failure, because procuring the chemicals poses a difficult obstacle in small rural and informal settlements. Therefore, support has gone into non-traditional ways of disinfection and in the last years new technologies have come into use. If these technologies

prove to be adequate, new possibilities in the ways of disinfecting water may come into operation, with the concomitant health benefits to the communities involved.

7. FOULING, CORROSION AND PIPING SYSTEMS

7.1 ASSESSMENT OF WATER QUALITY PROBLEMS DUE TO MICROBIAL GROWTH IN DRINKING WATER DISTRIBUTION SYSTEMS

This project was undertaken by the CSIR over a period of two years on the nature and extent of problems pertaining to water quality related to biofilms. Despite adequate disinfection at the point of distribution it can happen that certain micro-organisms collect in the distribution system by forming biofilms. Several factors in the distribution systems contribute to this after-growth and biofilm formation. This microbial growth can include several different types of micro-organisms. There are, *inter alia*, those which constitute health implications, those which cause bad odours and tastes and those which cause biocorrosion. It also appears that these organisms develop a resistance to biocides.

In this project biofilm formation (due to microbial after-growth) and the microbiological quality of the potable water in the distribution system of a major metropolitan area were studied. Water samples were collected from private houses, apartment buildings and other public institutions. Total coliform bacteria were isolated from 33 percent of the samples of which 10 percent exceeded the South African recommended guidelines. Bacterial numbers counted in the distribution system of apartment buildings were found to be higher than in private houses. Substantially higher bacterial counts were found in water samples collected from older buildings.

7.2 EFFECT OF BIOCORROSION IN WATER SYSTEMS

Many industries recirculate water which can result in microbially influenced corrosion, or biocorrosion, in water distribution systems.

One of the aims of the project was the development of an instrument to measure biocorrosion quantitatively and to evaluate a number of biocides *in situ*. Certain problems were, however, experienced with regard to the short retention time in the missing drums and controlling the flow rate through the test pipes.

It was shown that the flow rate of water, the surface properties of the substrate and the concentration of sulphates and dissolved organic carbon have a direct influence on the development of biofilms which are a prerequisite for biocorrosion.

Results indicated that as much as 38 % of the total corrosion in industrial water systems may be due to biocorrosion.

7.3 EFFECTS OF VARYING WATER QUALITY ON THE CORROSION OF DIFFERENT PIPE MATERIALS IN THE PWV/KLERKSDORP AREAS

The South African industry as well as the steel pipelines used by local authorities in the water supply network are severely affected by corrosion. The corrosive attack from the outside of the pipes is of much greater magnitude than the corrosive attack from the water inside the pipes. For this reason external corrosion has received most attention thus far. In terms of a three-year agreement, the CSIR will research internal corrosion. The aims of the project are to evaluate the corrosion characteristics of water introduced from areas beyond the Vaal River catchment and the effects of various blends of these waters on the performance of pipes in the PWV/Klerksdorp regions. Water chemistry and the related corrosion prediction indices and diagrams will be compared with actual corrosion studies using these blended waters.

The results obtained from these investigations will be used to provide the necessary technology for predicting the likely performance of pipe materials. As the water authority supplying the bulk of the water to the regions, the Rand Water Board is closely involved in a consultative capacity and has made sample collection and laboratory facilities available to the project team.

7.4 OPTIMISATION OF BIOFOULING CONTROL PROGRAMMES

This project is being carried out by the University of Pretoria, in collaboration with Anglo American Research Laboratories, the results being intended for release to all industries. Microbial growth in water cooling systems leads to the fouling of pipelines, causes and accelerates the biocorrosion of metals, and reduces heat transfer. Industries annually spend millions of rands, especially on the use of biocides, to overcome these problems. The principal aim of this three year project is to develop techniques to control biofouling and to promote the reuse of water for cooling purposes. Techniques will be developed to identify sulphate-reducing bacteria *in situ* and to determine their role in microbially-induced corrosion. An attempt will also be made to determine whether bacteria can build up resistance to biocides.

7.5 EFFECT OF WATER QUALITY AND CHEMICAL COMPOSITION ON CORROSIVITY IN MILD STEEL PIPELINES

Corrosion of pipelines is a major cost component of municipal and industrial assets. In terms of an agreement with the Rand Water Board, methods to measure corrosion rates in municipal water distribution systems are to be researched. Existing corrosion indices which are normally used to indicate the chemical stability of water will be correlated against measured data, while the characteristics required to limit corrosion to a minimum will be identified. The project aims to develop treatment practices which will inhibit corrosion tendencies without causing scaling or other harmful effects, especially at the furthest extremities of a distribution system. The project will run for two years.

7.6 DEGRADATION OF MORTAR LININGS AND CONCRETE BY MICRO-ORGANISMS IN INDUSTRIAL WATER SYSTEMS

This study evaluated the effects of micro-organisms and the concentration of aggressive chemical species on the mortar linings and concrete used to protect mild steel pipework.

Active microbially induced corrosion occurred in the test rigs as demonstrated by the metal loss determined on the mild steel samples. The evaluation showed no deleterious effects on the concrete and mortar samples under the test conditions, while uniform microbial attachment was identified on all the material evaluated.

The addition of a biodispersant to the non-sterile rig resulted in a significant reduction in the numbers of attached bacteria.

Mortar linings and concrete were therefore considered to be suitable alternative materials for the corrosion protection of industrial water systems with similar water chemistry to that used in this investigation.

7.7 THE CORROSION PERFORMANCE OF VARIOUS NON-METALLIC PIPING MATERIALS AND COATINGS IN POTABLE WATER

This project is being undertaken by the CSIR. In an earlier project the Mine Hoisting, Metallurgical and Corrosion Services Programme of the CSIR's Division of Materials Science and Technology investigated the corrosion of metallic pipelines. This follow-up project aims to evaluate the performance of non-metallic piping materials, linings and coatings by determining which water parameters are important when selecting piping materials and recommending candidate coatings and piping materials to reduce internal corrosion of pipes. It is anticipated that through the correct selection of piping materials, less water will be lost unnecessarily due to leaks and that water quality will not deteriorate due to products of corrosion entering the water column. The effect of raw dam waters on generic coatings will also be investigated to provide information required by the Department of Water Affairs and Forestry.

7.8 MICROBIAL CORROSION OF COMMON PIPING MATERIALS IN THE PWV AREA

Stimulated by earlier investigations on failures of water pipelines which revealed that up to 60% of pipe failures may be attributable to microbially induced corrosion, this project aims to address this frightening scenario by determining to what extent micro-organisms are involved in the corrosion of common piping materials carrying potable waters and how widespread the problem is.

The aim of this 2-year project would be to gain a better understanding of the failure mechanisms of potable water pipes using a multidisciplinary approach

involving microbiological, metallurgical and chemical studies. This will provide guidelines for materials selection and recommending remedial and/or preventative measures if micobially induced corrosion proves to be a widespread problem. Information gained from the project would ultimately be of benefit to all users and suppliers of water.

8. PASSIVE AND BIOLOGICAL INDUSTRIAL WATER TREATMENT WITH RELEVANCE TO THE MINING INDUSTRY

8.1 PREPARATION OF ENGINEERING GUIDELINES FOR ARTIFICIAL WETLANDS FOR WASTE WATER TREATMENT

This project is being undertaken jointly by the CSIR and Sviridov, de Waal & Associates and is aimed at the preparation of guidelines for the engineering aspects in the design of wetlands, to be used in rural sanitation. The aims of the project, which is scheduled to run for one year, are:

- to evaluate the use of artificial wetlands as an alternative waste water treatment technology under South African conditions and thus to identify appropriate applications for the system;
- to conduct comparative economic appraisals to assess/ensure the viability of artificial wetlands for various applications;
- to prepare engineering design guidelines for the construction and use of wetland systems in this country;
- to initiate a framework for the continued collection and evaluation of data with a view to periodically updating the design guidelines.

The need for sewage treatment processes for small communities which require only minimal input by unskilled operators and supervisory staff has long been known. Some degree of success has been achieved with the design and construction of more fundamental, yet adequate, sewage treatment facilities. One such process is that of artificial wetlands, a potentially reliable and fundamental process for treatment of secondary effluents and for the removal of nutrients from these effluents. However, whilst wetlands may have considerable merit for future application, little is known of the economics of the system in comparison with present alternatives, or of the engineering design criteria to be used under South African conditions. A computer model will be developed for the rapid economic assessment of wetland systems for various applications.

8.2 THE MICROBIOLOGICAL TRANSFORMATION OF METAL CONTAMINATED EFFLUENTS

This project is being undertaken by the Department of Microbiology of the University of Durban-Westville. This project aims to treat effluents high in heavy metals using waste sludge to capture the metal ions biologically. The project will initially characterise available sludges in terms of the microbial population and the metal contents. The adsorption and desorption capacities of the various sludges will then be ascertained for a range of effluents, and appropriate methods for the recovery of metals from the sludges will be investigated. Once the best performing sludges have been identified, management parameters will be optimised in batch-fed reactors. This technology could be applied in e.g. metal-plating industries for the on-site treatment of heavy-metal containing effluents.

8.3 USE OF YEAST BIOMASS AND YEAST PRODUCTS TO ACCUMULATE TOXIC AND VALUABLE HEAVY METALS FROM WASTE WATER

In this study the bioaccumulation of heavy metals by micro-organisms and its application for the removal of toxic metals from industrial waste waters, using yeasts, was investigated.

The accumulation was adversely affected by high hydrogen ion concentrations, but not by moderate levels of alkaline-earth metal ions. Metal-laden biomass could be harvested from solution by ultrafiltration.
During further investigations yeast biomass was chemically modified to yield a dry, stable material that was found to be capable of accumulating a wide range of heavy metal ions, such as Cd^{2+}, Co^{2+}, Cu^{2+}, Hg^{2+}, Ag^{2+}, Fe^{3+}, Cr^{3+} and Pb^{+}. This granular biomass could be stored indefinitely in a dehydrated form and could be rehydrated again, when required.

8.4 BIOTECHNOLOGICAL APPROACH TO THE REMOVAL OF ORGANICS FROM SALINE EFFLUENTS

This 3-year project entails the development of a saline high-rate algal oxidation ponding process (HRAOP) based on halophilic algae:

- For the treatment of saline effluents to remove organics and dissolved nutrients (NPK)

- For the co-disposal of organic solids such as secondary treatment sludges and other refractory organics

- To evaluate the production of algal products of economic value by the selective culture of halophilic micro-algae such as *Dunaliella salina* in high-salinity brines and *Spirulina* sp. in alkaline brine wastes

- To establish a utility for brine wastes based on saline algal biotechnology.

8.5 THE APPLICATION AND PERFORMANCE OF FULL-SCALE ARTIFICIAL WETLANDS FOR WASTE-WATER TREATMENT IN SOUTH AFRICA

This project is being undertaken by Steffen Robertson and Kirsten and has the following objectives:

- Compile a directory of constructed wetland systems in South Africa and collating available design, economic and performance data.

- Investigate and monitor the application of the full scale constructed wetland technology as applied in South Africa in order to:

- evaluate the relative performance of each wetland system in meeting the desired criteria of wastewater treatment for the application;

- to develop reliable, appropriate "practical" design, operational and management strategies for each wetland type and application in relation to the preliminary guidelines developed in the WRC project of 1988 - 1989;

- to evaluate and optimise the developed strategies under operational conditions;

- to determine the "practical" economics of the constructed wetland systems in comparison with conventional alternatives for the desired uses of the systems in South Africa; and

- to transfer "practical", appropriate and reliable engineering criteria to end users and regulators in South Africa.

8.6 BIO-AUGMENTATION TECHNOLOGY FOR WASTE-WATER TREATMENT IN SOUTH AFRICA

Bio-augmentation is a major industry in developed countries, and has been successfully employed in incidents such as the Exxon Valdez oil spill. However, the indication is that not all products perform as claimed. The primary aims of this 3-year project are to:

- Establish criteria for the evaluation of biosupplements to make sure that they meet specifications and are safe to use

- Establish micro-organism screening, isolation, culture and storage protocol for the successful implementation of bio-augmentation technology in South Africa

- Develop and/or improve biosupplements for local conditions.

8.7 USE OF YEAST BIOMASS AND YEAST PRODUCTS TO ACCUMULATE TOXIC AND VALUABLE HEAVY METALS FROM WASTEWATER

Many industrial processes and mining operations produce heavy metal-containing wastewaters representing toxic effluents or a loss of valuable metals. The increasing demand for high quality potable water makes the removal of toxic metals from wastewater a major priority.

A number of microorganisms, such as yeasts, have been shown to accumulate and remove metal ions from solutions and effluents.

The aims of this 2-year project which is a follow-up on Project No 392, are to:

- Identify cellular components responsible for metal accumulation by yeasts

- Determine the efficiency and kinetics of heavy metal accumulation by yeast cells at varying metal ion concentrations

- Use yeast biomass systems for the removal of metals from selected industrial wastewaters.

8.8 POND ENHANCED TRICKLING FILTER OPERATION (PETRO)

This 3-year project is investigating the potential for enhancing the performance of existing low technology sewage treatment works such as oxidation ponds by the addition of trickling filters. This combination produces a good effluent at low cost and straightforward operational requirements. During the project, the process will be studied at pilot-scale and full-scale with a view to optimising the advantages of systems which have stood the test of time, and at the same time avoiding the disadvantages. Experience has shown that the PETRO process can easily meet the general water quality standards as laid down by the Water Act of 1956 (Act 54 of 1956) as amended.

8.9 CONTINUING RESEARCH INTO THE WETLANDS OF NATAL/KWAZULU

In a publication entitled *World Conservation Strategy* published in 1980 by the International Union for Conservation of Nature and Natural Resources (IUCN), with its headquarters in Gland, Switzerland, it is stated that wetlands are one of the most globally endangered habitat types. Throughout the world vast areas of wetland have been modified to alternative land uses. A similar trend in wetland losses has occurred in South Africa and urgent steps should be taken to improve the conservation and management of wetlands. In order to do this it is necessary to develop a better knowledge base of the wetland situation in South Africa. In particular, users of wetland areas need to be made more aware of wetlands and their potential value.

Because wetland areas, representing important habitats, need to be managed to maintain their natural values, this 2-year project aims to build a decision support system and produce a manual to serve as tools for identifying wetland landscape units, assist decision-makers in making land-use choices for each of the given landscape units and recommend how the given units should be managed for the chosen land uses and, secondly, to provide integrated management plans for priority wetlands in Natal to maximise the benefit derived by individual owners and society at large.

9. VEGETATION, LAND USE AND AGRICULTURAL ASPECTS

9.1 DEVELOPMENT OF RIGOROUS ENGINEERING METHODOLOGY FOR DESIGNING VEGETATIVE EROSION PROTECTION SYSTEM

Well-established suitable plant growth remains the most cost-effective, pro-active, erosion control measure. Some instances where these measures can be applied could however, benefit from a design approach where for example, the selection of a suitable plant type could be made on sound scientific principles. The 2-year project will develop engineering methodologies for the design of vegetative erosion controls, with special reference to:

- Mathematical formulation of the reinforcement of soils by means of root systems.
- Laboratory determination of the strength properties of root-reinforced soils.
- Determination of the erodibility of root-reinforced soils.
- Investigation of existing root morphologies suitable for specific areas.
- Developing a design guideline for erosion control by means of root-reinforced soils.

9.2 DEVELOPMENT OF METHODS TO ASSESS THE IMPACT OF AGRICULTURAL PRACTICES ON WATER RESOURCES IN SOUTHERN AFRICA

This project has developed the agrohydrological component of the ACRU modelling system. The impact on water resources of alternative land management options can now realistically be simulated. Crops include maize, wheat, sugar cane and timber. The results are given in a comprehensive report with a complete review of the theory behind the ACRU modelling system and many examples of model verification and scenario testing. The modelling system provides comprehensive default values for most of the important input variables and it is based on the South African 1:250 000 land type maps and the associated binomial soil classification.

9.3 QUANTIFICATION OF THE EFFECTS OF LAND USE ON RUNOFF QUALITY IN SELECTED CATCHMENTS IN NATAL

Development trends and expected land use changes in the catchment areas of the Mgeni River system are believed to constitute a serious threat to the long-term water quality in general and specifically as far as eutrophication of the river system is concerned. To a large degree, the knowledge required to predict the consequences these land use changes may have on water quality, is lacking. As part of this three-year project, the CSIR will attempt to quantify the effects of land use on runoff water quality. The research will be carried out in close collaboration with the Universities of Natal and Zululand that will be conducting complimentary research projects. The aims of this project are to characterise and compare runoff water quality and loads from different types of land use, to synthesize the collected data into a suitable form for inclusion into a proposed Mgeni catchment water

quantity/quality model to be developed by the University of Natal, and to investigate the need to establish a longer term monitoring programme on one or more selected catchments with specific land uses, in order to assess the spatial, temporal and development aspects on water quality.

9.4 AN INVESTIGATION INTO THE QUALITY OF WATER FOR ANIMAL PRODUCTION

This project will be carried out over a period of four years by the Department of Animal Science of the University of Pretoria. The problem of minimum water quality for animal production was identified by the Directorate of Soil Conservation and Drilling Services of the Department of Agricultural Development and brought to the attention of the WRC.

The situation is that boreholes are being sunk at great cost and that the quality of the water found is often suspect. The standards to which water intended for the watering of cattle have to conform are, however, based on outdated and haphazard information, to such an extent that the question may well be asked if the standards are realistic. Information available in South Africa in this regard is extremely inadequate, therefore use is being made of either overseas information (which is not really valid locally) or of standards which have not been thoroughly investigated experimentally. As the situation stands, extensive research on the maximum acceptable salt content of water for the watering of cattle has as yet not been undertaken in the RSA. This is a complex problem which involves not only the local climatic and grazing conditions, but also the kind of stock, gestation and whether it is meat, milk or wool production that is at stake.

9.5 THE USE OF SALINE WATER FOR IRRIGATION PURPOSES AND AN ASSESSMENT OF SALT TOLERANCE CRITERIA OF CROPS

This project is to be carried out over a period of five years by the Department of Soil and Agricultural Water Science of the University of Stellenbosch. The research strategy in respect of salinisation is based on a dual approach, viz. on the one hand to conduct research aimed at combating salinisation, and on the other hand to conduct research which will improve the possibility of living with salinisation. This research project focuses on increasing the efficacy of the use of saline water for irrigation. During the past few years criteria were formulated for the salt content of irrigation water at a number of irrigation schemes, based on overseas findings which had not been checked under local conditions. Criteria which are either too strict or too lenient are unacceptable, depending on the point of view from which this is approached. The aim of this project is to check the validity of one of the sets of criteria (for the irrigation of vines in the Bree River valley), as well as the methodology used to establish the criteria.

9.6 ASSESSING THE IMPACTS OF VARYING RAINFALL CONDITIONS ON VEGETATION DYNAMICS, PRODUCTION AND CERTAIN HYDROLOGICAL PROPERTIES OF NATURAL GRASSLAND, USING A SYSTEM MODELLING APPROACH

This project is being undertaken by the Department of Plant Sciences of the Potchefstroom University for CHE. While hydrological and agricultural responses of natural grassland (veld) to rainfall are conditioned by the current state of the veld, this veld condition in turn responds, in terms of its vegetation dynamics, either beneficially or deleteriously to each rainfall event. Vegetation dynamics are manifested by species compositional changes within postulated limits of ecological resilience, largely determined for a given habitat by recent management practices. The interactions between rainfall, habitat, veld condition, runoff, phytomass production and veld management are therefore extremely complex, but must be addressed if important questions concerning water use, water-use-efficiency and runoff production of natural veld are to be answered. In view of this complexity, a system modelling approach to this investigation has been adopted.

9.7 THE COMPLETION OF RESEARCH RELATING TO THE DISA MODEL - A DAILY IRRIGATION AND SALINITY ANALYSIS SYSTEM MODEL

This project is being undertaken by Ninham Shand (Cape) Incorporated. Irrigation return flow has been identified as one of the major non-point sources of the salinisation of rivers. This project aims to further refine and test the DISA model, developed by the Department of Water Affairs and Forestry in collaboration with Ninham Shand for the prediction of salinisation due to irrigation in the Bree River, by using flow and salinity data collected during the preceding year. The findings of complementary projects will also be used. Steps will, furthermore, be taken to convey the application of the DISA model and supporting research findings to interested parties.

9.8 SOIL BUFFERING OF RAIN-WATER SALINITY IN THE VAAL DAM CATCHMENT

Indications are that the sulphur dioxide levels, due to combustion, in the Eastern Transvaal highveld air are equivalent to ten times the annual salt load entering the Vaal Dam. If only 10 % of the sulphur dioxide dissolved as sulphates in rain should fall in the catchment area, it will in the long term cause the salt content of the Vaal Dam to double. One of the uncertainties in this regard is the degree to which these salts can be retained by the soil. This investigation indicated that although certain soils in the catchment area have the ability to absorb large quantities of salts, these in total cannot retain significant amounts. On the other hand the present sulphate content of the soil is already at such levels as to make it virtually impossible to distinguish it from additionally added sulphate in rain.

9.9 MODELLING THE EFFECT OF THE AGRICULTURAL ENVIRONMENT ON WATER RESOURCES.

As we approach the turn of the century the impact of human modification of the natural environment are becoming a cause for increasing concern. Successful research funded during the past 5 years has provided certain useful modelling tools and information bases but has simultaneously left some existing and newly emerging questions unanswered. This 4-year project through fieldwork, collaborative research, synthesis and model development aims at enhancing the ACRU agrohydrological modelling system, to help make it an objective planning tool to those questions and challenges of the water-related agricultural environment for which decision-makers currently, or in the near future, seek answers. These include questions on impacts related to afforestation practices, irrigation, agricultural management systems and global climate change on water resources as well as on agricultural water utilisation and production.

9.10 ROOT DEVELOPMENT AND WATER USAGE OF COMMERCIAL TIMBER SPECIES

This project is being undertaken by the Department of Agronomy of the University of Natal. With the forestry industry due to expand considerably within the next 20 years, there can be no doubt about the potential impact on water resources. In the course of this expansion, afforestation of marginal sites will take place despite a lack of knowledge concerning the long-term sustainability of production and the effect on water yield of such sites. The manner in which roots develop in soil profiles with varying physical and hydraulic properties is likely to be a key factor in sustaining water extraction and production as soil drying progresses. Consequently the Department is undertaking a four-year research project to investigate root development and soil water usage of commercial timber species on a range of soils. Investigations, which will take place under partly controlled conditions, will initially focus on *Eucalyptus* species.

9.11 DETERMINATION OF THE RELATIONSHIP BETWEEN TRANSPIRATION RATE AND DECLINING AVAILABLE WATER FOR EUCALYPTUS GRANDIS

The extent of eucalyptus plantations and their potentially large impact on water resources along the escarpment regions are well appreciated. However, the ability to accurately model water use by such plantations is still severely limited by a lack of understanding of soil water uptake patterns and transpiration in relation to soil water status in the topsoil and subsoil. As plantations extend into areas of marginal soils, the transpirational behaviour of trees under conditions of restricted soil water availability is becoming even more relevant and the need for research on the topic even more acute.

In this 3-year project attention will be given to quantifying the total amount of soil water potentially available to trees; the soil water threshold below which transpiration begins to decline; relationships between transpiration and

declining soil water content below this threshold; and the relative importance to transpiration of water in the soil profile and the subsoil. This information will then be applied in developing prediction models of transpiration of *Eucalyptus grandis* under conditions of limited soil water.

9.12 IMPROVED ESTIMATION OF PLANT AND SOIL EVAPORATION FROM CROPPED LANDS

The partitioning of total crop evaporation into the transpiration (effective use) component and the soil evaporation (wastage) component is one of the weakest links in current crop growth and hydrological models. Such models are in increasing demand for planning and managing irrigation and for contributing information on the hydrology of agricultural lands. Recent evidence suggests that soil evaporation is a larger and more variable contributor to inefficient crop water use than previously realised. In order to use available models for optimising water use efficiency in various crop production systems, their ability to correctly partition total crop evaporation into plant and soil components will have to be improved. The main aim of this 2-year research project is to bring about such an improvement.

9.13 MODELLING THE WATER BALANCE OF BENCH-MARK ECOTYPES

In recent years much effort by researchers in the field of irrigation, dry land crop water use and surface hydrology has gone into the development and adaptation of simulation models to be used for water management within these fields. However, these models, which are in increasing demand for decision support purposes, still have weaknesses.

In South Africa model validation, especially with regard to the all-important water budgeting components, has been largely opportunistic. The main reason for this deficiency is that the acquisition of representative data sets is extremely costly and laborious. It has therefore become necessary to undertake a well-planned data acquisition and model evaluation programme which will reduce this deficiency.

This 3-year research project aims to identify 8 benchmark situations, in each of which a comprehensive data set of lasting value will be obtained, expressly for the purpose of evaluating the refining water budgeting model routines typical of those used in the models to which reference has been made.

9.14 ABILITIES OF SEVERAL SOLUTE AND WATER TRANSPORT MODELS TO PREDICT THE QUANTITY AND QUALITY OF WATER LEAVING THE ROOT ZONE

Although sophisticated mathematical models are available to describe the physical and hydrochemical processes occurring in the root zone of soils the difference between reality and the ideal situation which they simulate often prevents the full potential of the models from being realised. The abilities of such models which have varying degrees of process description sophistication, were evaluated against field data, as part of the project.

Based on these evaluations guidance is provided to researchers and other potential users with regard to the selection of mathematical models which can be used to predict the quantity and composition of water draining through the root zone of irrigated solid. In this way a contribution is made to the responsible application of the type of model used.

9.15 PILOT STUDY TO INVESTIGATE ALTERNATIVE MANAGEMENT OPTIONS TO ENHANCE THE USE OF SALINE WATER FOR IRRIGATION PURPOSES

Salt concentration is one of the major variables which determines the quality of water for irrigation purposes. The Department of Water Affairs and Forestry attempts to manage water quality in such a way that it complies with the demands of among others, irrigators. In order to verify these requirements for wine-grapes under local conditions, the WRC already funds research to determine how yields are affected when irrigating with water of varying salt concentrations. For this purpose irrigation practices generally found in the area, are employed. It is, however, known that the effect of high salt concentrations in irrigation water can be reduced by management measures at form level, e.g. high-frequency and subsurface drip irrigation. During this pilot study over 30 months the effectiveness of such alternative management measures will be investigated.

9.16 TECHNOLOGY TRANSFER OF AQUATIC CHEMICAL SPECIATION MODELLING

An in-depth knowledge of the chemical composition of a water system and its interaction with its surroundings is essential for the understanding of phenomena as diverse as bioavailability and nutrient cycling, biotoxicity, scaling and corrosion, groundwater quality, leachate attenuation, water and effluent treatment, chemical dosing and desalination.

The United States Environmental Protection Agency (USEPA) has funded the development of a PC-based general geochemical speciation program, called MINTEQA2, which can be used to calculate the equilibrium composition of solutions or natural aquatic systems. The aim of the 2-year project is to promote the local use of the chemical speciation program MINTEQA2 - acting as a link between the USEPA and South African users.

9.17 SCREENING OF CROP, PASTURE AND WETLAND SPECIES FOR TOLERANCE OF POLLUTED WATER ORIGINATING IN COAL MINES

Despite remedial actions, water which is toxic to most plant species will always emanate from mining sites. If a species, capable of surviving exposure to such waters, could be found it would enable both the utilisation of such waters and the upgrading of its quality in wetlands. Not only is there a world-wide dearth of information on suitable plant species, but information pertaining to local problem waters, climatic and soil conditions is practically non-existent. The 4-year project therefore, aims to establish a facility for

identifying plant species suitable for irrigation with problem waters or for use in wetlands to improve the quality of the water.

9.18 DEVELOPMENT OF AN URBAN COMPONENT FOR THE ACRU MODEL

The ACRU modelling system in its present state is essentially a catchment model for rural land uses and its effective application is restricted to catchments where urban settlements represent less than 20 % of the total area. In many areas rapid urbanisation is taking place and for sound management, this effect must be incorporated into the present modelling system. Benefits of developing the proposed urban components would be the wider use of the ACRU modelling system and the improved simulation of areas of urban development. In addition it would provide water resource managers with information on factors affecting urban and catchment water quality and quantity, and a better understanding of how they interact. Since this development is of major importance to Umgeni Water, the 2-year project will be executed in close collaboration with this organisation.

10. SURFACE HYDROLOGY

10.1 EVALUATION OF HYDROLOGICAL FLOOD ESTIMATION TECHNIQUES FOR SMALL UNGAUGED CATCHMENTS

This project was undertaken by Steffen, Robertson & Kirsten. The project's objectives were to compare recognised techniques, which are often used in practice, for estimating floods from small ungauged catchments. Given the present stage of development of the techniques and the data limitations, the research concluded that urban catchments could be modeled adequately by most of the seven methods tested. However, flood estimation for rural areas was far less reliable.

In general, the ability of the methods to estimate the volume of runoff was found to be better than their ability to determine peak flow rates. The synthetic rainfall distributions which must be used by the methods, have a major effect on peak flow estimation. While these conclusions are considered valid for use in 'real' event modelling, the authors caution the reader on their interpretation for 'design' events because of the research constraints. However, the results represent the most general overall evaluation of methods under objective 'design mode' testing available in South Africa.

10.2 DESIGN STORM FLOW AND PEAK DISCHARGE RATES FOR SMALL CATCHMENTS IN SOUTHERN AFRICA

This project was carried out by the Department of Agricultural Engineering of the University of Natal. It involved, firstly, updating and revising the SCS (Soil Conservation Service of America) manual for the estimation of flood events from small catchments in Southern Africa and secondly, research into the use of joint associations of rainfall and catchment antecedent conditions for improving flood estimation. A new and much improved manual can now be made available to South African hydrological practitioners. This work represents the culmination of some ten years effort by the University of Natal and the WRC into small catchment flood estimation techniques, in particular the SCS method. Because of its great practical application possibilities the results are released as one of the reports in the WRC's technology transfer series.

10.3 DEVELOPMENT OF A SYSTEMS MODEL FOR THE MGENI CATCHMENT

This three-year research project was undertaken by the Department of Agricultural Engineering of the University of Natal. The major water supply systems to the large metropolitan areas are becoming more and more complex as they are being developed and as demands for water increase. As with the Vaal River system, for which a major simulation study is being undertaken by the Department of Water Affairs with the aid of a consulting engineering group, there was a need to be able to simulate the Mgeni River system. To undertake such a simulation, from both a quality and quantity point of view, an appropriate model needed to be developed.

In the first phase of this project attention was focused mainly on the development and testing of a physical conceptual systems model to represent the water quantity components of the hydrologic system. The systems model developed makes use of existing, generally available data on land type (soils), rainfall and 1:50 000 topographical maps. Special surveys were carried out to provide data on land use and land cover, storage reservoirs and irrigation abstractions. Simulations of the systems model are verified against observed flow data and the results are generally highly acceptable. The models can address the effect of afforestation in certain parts of the catchment or the effect of farm dams, etc.

10.4 HYDROLOGICAL SYSTEMS MODEL DEVELOPMENT

In terms of water and catchment management, a hydrological modelling system can be seen as the first step in processing the large variety and volume of data involved in a situation. In most management and planning situations one has to work with existing, readily available data, but these data rarely meet the requirements. In a new project to be carried out by the Department of Agricultural Engineering of the University of Natal, the work will concentrate on finding ways and means of improving the ACRU modelling system, mainly with regard to interlinking with contemporary and future data networks and systems. The main objective is to provide input to sophisticated decision support systems. Emphasis will be placed on the development of relatively fast and user-friendly scenario evaluation techniques taking account of spatial and temporal variability in water management parameters. The project will be executed over a period of five years.

10.5 A DISTRIBUTED HYDROLOGICAL MODELLING SYSTEM TO ASSIST WITH WATER QUANTITY AND QUALITY MANAGEMENT IN THE MGENI CATCHMENT : PHASE II

This project is being undertaken by the Department of Agricultural Engineering of the University of Natal. Development of the distributed modelling system will continue, to enable simulation of, and to provide initial information on selected critical water quality parameters required by those responsible for planning and managing the Mgeni River catchment water resources. Research will focus on the incorporation of selected dominant water quality components and subroutines into the modelling system developed in Phase I (see section 5.7). Initially conservative determinants such as conductivity and possibly chloride or sodium ion concentrations will be modeled. Ultimately the modelling system will be expanded to cater for the simulation of non-conservative determinants such as phosphates, nitrates, *E. coli*, chlorophyll *a*, turbidity and dissolved oxygen to enable representation of water quality in terms of, *inter alia*, the national water quality index.

The modelling system will be developed in collaboration with researchers and institutions working in water quality, specifically the Department of Water Affairs and Forestry; Umgeni Water; the CSIR's Division of Water Technology; and the University of Zululand. Collaborators' research findings will be

incorporated into the hydrological modelling system, where beneficial to the project.

10.6 DEVELOPMENT AND TESTING OF A WATER BALANCE MODEL FOR A GRASSLAND CATCHMENT IN THE SUMMER RAINFALL AREA OF SOUTH AFRICA

A large proportion of our surface water resources is derived from our mountain catchment areas. Grasslands in these areas form an important baseline for natural evaporative losses with which the line for natural evaporative losses with which the evaporative losses of other land uses and vegetation covers can be compared. This 4-year project aims to provide an in-depth understanding of grassland water use at the catchment scale. New technologies with respect to the measurement of soil water and soil-water movement will be employed, and a modelling framework for the extrapolation of catchment water balance estimates will be established. Three main objectives are therefore aimed at:

- To quantify the spatial and temporal patterns of evaporation and soil water within a grassland catchment near Cathedral Peak.
- To describe these processes in terms of the controlling environmental variables.
- To develop and adapt existing modelling frameworks for catchment water balance for use in water resource management planning.

10.7 DEVELOPMENT OF MODELS TO STOCHASTICALLY GENERATE SPATIALLY DISTRIBUTED DAILY RAINFIELDS

All currently available rainfall information is based on rain gauge (point) measurements which have been shown to be a poor representation of areal or spatially distributed rainfall. However, catchment runoff and agricultural production respond to areal rainfall and ideally, therefore, areal rainfall data are required as inputs to distributed models. A promising start to the problem of modelling spatially distributed rainfields has already been made but these efforts need to be extended to address questions concerning both seasonal variation in parameters and validation of models. The aims of this one-year project are to develop a daily model of spatially distributed rainfall which accurately reflects seasonal rainfall patterns and to investigate methods of stochastically generating rainfields that fit a random set of point measurements.

10.8 EFFECTS OF URBANISATION ON CATCHMENT WATER BALANCE

Previous research into urban hydrology has shown that urban development affects runoff and thus the water balance in catchments. Consequently, more intense flood runoff was anticipated, resulting in less residual water to maintain the ecological balance within the catchment.

Results of this 7-year research project indicate that stormwater runoff for the developed portion of catchments was increased by a factor of up to four over that from an undeveloped catchment. This is mainly attributed to impervious surfaces such as roads and roofs, and the consequent decrease in infiltration, garden watering, using imported municipal water, and the unquantifiable outflow of groundwater were complicating factors. The results highlight the need to amend the Town Planning Regulations to incorporate flood retention on private gardens and the use of dual draining systems to enable floods to be stored on roads or preferably on parks and purpose-made infiltration strips.

10.9 CLASSIFICATION AND HYDROLOGICAL MODELLING OF LOW FLOWS IN SOUTHERN AFRICA

From an ecological, hydrological and water resource management point of view, it is becoming increasingly important to understand the impacts of land-use change on streamflow and specifically to be able to predict changes in flow regimes.

Rivers are not only used to supply water but are often used for the disposal of sewage and waste water. The assimilative capacity of rivers becomes most critical during periods of low flow which may be extended by afforestation, construction of dams, abstractions, etc. The aims of this 3-year study are to use existing hydrological data to characterise low-flow regimes within Southern Africa and to assess and possibly improve existing rainfall-runoff models to specifically simulate low-flow regimes.

10.10 CASE STUDY OF STORMWATER POLLUTION CONTROL IN A REPRESENTATIVE VALLEY

Formal, semi-formal and informal urban developments which are springing up around nearly all of our major towns and cities are creating problems of unprecedented pollution, through inadequate, or a total lack of, facilities for sanitation and refuse collection and sometimes unacceptable social habitats.

During the course of this 1-year project, qualitative information will be collected from a specific valley and the effectiveness of pollution control measures will be evaluated.

The site selected to carry out the research programme is the Hennops Valley, upstream of and including the Verwoerdburg downtown lake. The reason for selecting this valley is that a wide assortment of pollution sources is found there, such as the Olifantsfontein sewage works, a quarry, Tembisa and Ivory Park townships, semi-formal and squatter areas in the Rietspruit and Natalspruit catchments as well as various agricultural and industrial activities. Extended reedbeds also occur in the catchment and the effect of these on the pollution load will also be observed. It is therefore a representative drainage system.

Similar situations have been identified elsewhere and it is the purpose of this study to evaluate cost-effective measures to rectify these situations. There are two approaches to this problem:

- Firstly, the quantitative approach, requiring detailed studies over long periods for the solution to the problem.
- Secondly, the qualitative approach, which identifies the worst cases and solves these, thereby eliminating 80 % of the pollution for 20 % of the cost.

The research will lead to guidelines for local authorities for the control of stormwater pollution which may include most of the points raised above.

11. GEOHYDROLOGY

11.1 APPLICABILITY OF GROUNDWATER MODELS AS AN AID TO THE STUDY AND EVALUATION OF SOUTH AFRICAN AQUIFERS

This project was undertaken by the Institute for Groundwater Studies of the University of the Orange Free State. During the project, the initial model development phase was successfully carried out for:

- the Sishen area which has a secondary fractured hard rock aquifer;
- the Atlantis area which has a primary sandy coastal aquifer; and
- the Crocodile River system which has an unconsolidated alluvial aquifer interacting with the river system.

The level of expertise available to South Africa for simulation modelling of groundwater systems has been substantially advanced as a result of this project and the resulting simulation models are already being used by various organisations as aids to solving groundwater problems in many areas. A follow-up project entitled "Modelling of the groundwater quality in the Atlantis aquifer" has been undertaken in order to extend the modelling expertise to groundwater quality problems.

11.2 DEVELOPMENT OF A NATIONAL DATA BANK FOR GROUNDWATER DATA

One of the basic requirements for groundwater research programmes as well as routine short-term groundwater investigations is access to all of the available information that is relevant to the study. Knowledge of what information is already available and where to find it, considerably improves our ability to find a viable groundwater supply, to evaluate the extent of the aquifer and to assess the potential yield of the resource.

With this in mind, the Institute for Groundwater Studies (IGS) developed a National Data Bank facility for groundwater data. The data base is housed at the Directorate of Geohydrology of the Department of Water Affairs. For the use of the data base, the IGS has developed software which facilitates the processing of geohydrological and geohydrochemical data. The Groundwater Data Bank has been completed and is available for use by geohydrologists, as well as by various other professionals working in the field of groundwater development, supply and research. Certain shortcomings were, however, perceived and this has led to research on the enhancement of the National Groundwater Data Base facilities.

11.3 ENHANCEMENT OF THE NATIONAL GROUNDWATER DATA BASE FACILITIES

Following the completion of the National Groundwater Data Base (NGDB) project in 1987, the Institute for Groundwater Studies (IGS) perceived a need to provide additional computer software to enable geohydrologists to enter and process the data on a personal computer and to display the results in the form of graphs, maps and tables.

The G-base software, developed in-house by the IGS, provided the basis for enhancing the capabilities of the NGDB and from this the software package HydroCom was born.

The HydroCom software consists of 2 basic units, namely HydroCad and HydroBase. While HydroBase is the equivalent of the NGDB, HydroCad is used to display the data in the form of graphs and maps.

Apart from the obvious benefits of providing the geohydrologist with a powerful tool to store, process and display groundwater data, HydroCom has become an important data capturing facility. Valuable sources of data outside of the Department of Water Affairs and Forestry can be stored on HydroCom and at a convenient opportunity loaded onto the NGDB in Pretoria. This capability has provided, and will in the future provide the foundation for hydrogeological mapping efforts in South Africa.

11.4 EVALUATION AND DEVELOPMENT OF GEOPHYSICAL TECHNIQUES FOR CHARACTERISING THE EXTENT AND DEGREE OF GROUNDWATER POLLUTION

Geophysical techniques are used world-wide as an aid in the detection and monitoring of groundwater and soil contamination. Most of these techniques have been refined and are applied in areas of primary aquifers comprising unconsolidated sediments. This project consequently investigated the usefulness of these techniques in the hard rock aquifers common to South Africa for the delineation of pollution plumes at waste sites.

During the course of the project the importance of understanding the structural geological setting of aquifers, in particular around waste disposal sites, was realised. A set of guidelines for the use of geophysical techniques for mapping and monitoring contamination has been prepared. The researchers strongly recommend that detailed geophysical surveys should be carried out as part of the geohydrological investigation prior to the establishment of a new waste site, and continued after site closure to monitor the movement of the pollution plume.

11.5 DEVELOPMENT AND EVALUATION OF GEOHYDROLOGICAL AND ISOTOPE HYDROLOGICAL METHODOLOGIES FOR THE IDENTIFICATION OF AREAS POTENTIALLY SUITABLE FOR WASTE DISPOSAL

In the rapidly expanding urban areas, waste disposal is becoming a significant problem with attendant pressure on available sites. Unless clear guidelines and useful approaches to impact assessment are in place, major damage could be inflicted on groundwater resources which are being, or may have to be, harnessed for domestic supply. This project has as its main aim the development of methodologies by which the disposal of waste can be planned so as to minimise the impact on groundwater. To this end, geohydrological and isotope hydrological studies are being conducted jointly by the Earth and Environmental Technology Division of the Atomic

Energy Corporation of South Africa and the Schonland Research Centre at the University of the Witwatersrand.

11.6 ASSESSMENT OF HEALTH ASPECTS OF THE IMPACT OF DOMESTIC AND INDUSTRIAL WASTE DISPOSAL ACTIVITIES ON GROUNDWATER RESOURCES

The transmission of hazardous chemical substances and infectious diseases through contaminated drinking water is a frequent and well documented occurrence. Any disease caused by drinking contaminated water can be transmitted through groundwater if the disease-causing agent reaches the water source in ineffective doses to cause the specific illness. Some contaminants are more likely than others to be present in groundwater with the result that some water-borne diseases occur more frequently. This literature review was aimed at gaining knowledge about the impact of domestic and industrial waste disposal practices on groundwater supplies and the associated health implications.

Based on international experience, the researchers believe that the few documented cases of groundwater contamination in South Africa should not be seen as an indicator that similar problems do not exist in this country.

11.7 TECHNIQUES FOR RISK ANALYSIS AND GROUNDWATER MANAGEMENT OF SOUTHERN AFRICAN AQUIFERS

This project is being undertaken by the Institute for Groundwater Studies of the University of the Orange Free State and the Division of Earth, Marine and Atmospheric Science and Technology of the CSIR. South Africa's water resources, limited both by unfavourable climatic conditions and poor geographic distribution, are being further stressed by the impact of industrial, mining and agricultural activities. It is becoming increasingly important to manage, distribute and control water resources in a more efficient manner. Although considerable time and money have been expended on mathematical models to describe the physical nature and behaviour of groundwater in South Africa, linking these to management models will make effective groundwater management a reality. This project aims not only to investigate the availability and usefulness of groundwater management models under South African conditions, but also to use risk analysis techniques for determining the potential of an aquifer during periods of below normal rainfall.

11.8 DEVELOPMENT OF A STRATEGY TO MONITOR GROUNDWATER QUALITY ON A NATIONAL SCALE

The evaluation of groundwater quality in terms of spatial differences and quality associated with the various geological units published in the mid-1940's is still used today as a major reference by those requiring groundwater quality information on a national scale. The advent of the National Groundwater Data Base and associated water quality data base has,

however, made it possible to update and refine this work to facilitate the preparation of a strategy to monitor groundwater quality on a national scale.

The above 18-months project aims to identify suitable and practical strategies to be employed during the establishment of a national groundwater quality monitoring network. The researchers plan to draw heavily on similar exercises carried out overseas and on the experience gained during the establishment of surface water monitoring networks in South Africa.

11.9 THE COMPILATION OF A HYDROGEOLOGICAL MAP OF SOUTH AFRICA

This project is being undertaken by a private consultant - Mr J R Veger. The project involves the compilation of a hydrogeological map of South Africa (including TBVC states) on a scale of 1 : 1,5 million depicting aquifer types and the potential for groundwater development with an accompanying explanation.

11.10 DEVELOPMENT OF A SYSTEMATIC METHOD FOR EVALUATING SITE SUITABILITY FOR WASTE DISPOSAL BASED ON GEOHYDROLOGICAL CRITERIA

This research is being undertaken by the CSIR. The proposed research aims to develop and field-validate a South African based methodology which will address the geohydrological components of waste site selection and suitability evaluation. The final methodology is to have the following characteristics:

- it is to be valid, appropriate and accurate under South African conditions;
- the method is to be systematic, physically based, objective and the results repeatable;
- it is to be suitable for site-specific investigations; and
- the model is to be suitable for use by the central government permitting authority, local authorities and private companies entrusted with waste disposal as well as consultants undertaking waste disposal site selection and suitability determination studies.

It is envisaged that the method is to be nationally applied such that standardisation of site evaluation is attained. The method will have the following applications:

- initial site screening;
- setting of data requirements to be obtained from fieldwork;
- final site suitability determination; and
- defining of site engineering requirements.

An integral part of setting the data requirements will be to define levels of work required. This will enable pollution control officers to advise permit applicants with respect to the degree of work and detail of information required. The level of work required is to be directly related to the risk of

contamination and the long term consequences thereof. This aspect is primarily aimed at standardising the cost of investigations and the nature of work required. It must be stressed that the final product of this study cannot be expected to replace expert geohydrological input nor the need for appropriate fieldwork when selecting and evaluating waste disposal sites.

11.11 IDENTIFICATION AND VERIFICATION OF POLLUTED AREAS IN THE DOLOMITIC AQUIFER OF THE PWV AREA

This research is being undertaken by the Atomic Energy Corporation. The objectives of this research are:

- To locate boreholes in the field that have positively been proved polluted by previous studies of the Department of Water Affairs and have been entered on the National Groundwater Data Base.
- Re-sample those boreholes to verify that pollution does exist.
- Establish the type and extent of pollution.
- Establish the source of the pollution and temporal variation thereof.
- Suggest remedial measures to reduce or stop further pollution.

11.12 INTEGRATION OF REMOTE SENSING, DIGITAL IMAGE PROCESSING AND GEOGRAPHICAL INFORMATION SYSTEMS TECHNOLOGIES FOR REGIONAL-SCALE GROUNDWATER RESOURCES ASSESSMENT IN SOUTH AFRICA

The high costs and time required to collect hydrogeological data over a large area during an assessment of the groundwater resources potential of a region has often resulted in an uneven distribution of data and an insufficient data base with which to make assessments with any degree of confidence.

The type of data most commonly used in regional groundwater investigations, such as geology, soils, relief, vegetation type and density, and drainage, although very expensive to collect in the field, can be obtained rapidly and at a fraction of the cost of ground surveys through the use of satellite imagery.

Digital image processing allows one to extract valuable data from satellite imagery and other digital data sets. This project has demonstrated the value of combining these technologies in a geographic information system environment for the preparation of a groundwater resources potential map of the Magalakwena River Basin. This approach will make an important contribution to the regional hydrogeological mapping programme.

11.13 APPLICATION OF SEISMIC TOMOGRAPHY AND GROUND-PENETRATING RADAR FOR THE DETECTION OF FRACTURES AND THE DETERMINATION OF HYDRAULIC PROPERTIES OF FRACTURED ROCK AQUIFERS

It has been estimated that more than 90% of South Africa' s groundwater occurs in fractured rock aquifers. In order to locate these water-bearing zones, and to exploit them in a manner that will assure their long-term integrity, a thorough understanding of the location, physical nature and orientation of these fractures is required. Fractures, when present in an aquifer system, also influence the flow of groundwater. Geophysical fracture characterisation techniques based on seismic anisotropy and related shear-wave splitting as well as radar have been under investigation for a number of and hardware developments, significant progress has been made in fracture characterisation.

The main aim of this 3-year project is to investigate the physical nature of hardrock aquifers using seismic borehole tomography and ground-penetrating radar techniques.

11.14 REVIEW OF APPROACHES AND METHODOLOGIES FOR DETERMINING RECHARGE AND LEACHATE GENERATION RATES AT WASTE DISPOSAL SITES

The CSIR is currently undertaking a literature review of methods used to determine groundwater recharge and to predict leachate generation rates at waste disposal sites. When dealing with drier or water-deficient areas, the two approaches apparently yield contradicting results. The 1-year project will evaluate local and internationally used approaches in order to assess the apparent problem in greater detail. From this, the state of current knowledge and practice can be appraised and further research needs defined.

11.15 HYDROGEOLOGICAL, ISOTOPIC AND HYDROCHEMICAL ASSESSMENT OF THE RESPONSE OF A FRACTURED MULTI-LAYERED AQUIFER TO LONG-TERM ABSTRACTION

A fractured sandstone aquifer in the Northern Kalahari has been used for groundwater abstraction since 1967. Excellent records of draw downs and volumes pumped have been maintained. This vast wealth of data is being used to evaluate the response of a fractured rock aquifer to long-term abstraction. The same aquifer can be found in NW South Africa and Zimbabwe. Through an understanding of the behaviour of one part of the aquifer, the management of future groundwater schemes may be enhanced.

The objectives of this 1-year project are:

- To establish a GIS compatible data base and interpret 22 years of monitoring data

- To establish the extent and characteristics of the aquifers in the study area with reference to the Karoo sequence

- To develop a preliminary mathematical model for assessing the response of a fractured and multi-layered aquifer to long-term abstraction with specific attention being paid to the analysis of test pumping results

- To assess recharge to the fractured aquifer using historical and new isotopic analyses, hydrochemistry and water level monitoring data.

11.16 INVESTIGATION OF THE CONTAMINANT ATTENUATION CAPACITY OF THE SOIL/AQUIFER SYSTEM WITH SPECIAL EMPHASIS ON THE VADOSE ZONE

During infiltration through soils and transport in aquifers many contaminants are naturally attenuated, but not all subsurface environments are equally effective in this respect. The unsaturated zone provides the first line of natural defence against groundwater pollution. This is not only because of its strategic position between the land surface and the groundwater table, but also because it provides a favourable environment for pollution attenuation or elimination. Attenuation may occur as a result of processes such as adsorption, retardation, physical filtration, precipitation, biological and radioactive decay.

During the course of this 4-year study, the contaminant attenuation capacity characteristics of various soils, aquifers and the subsurface environment as a whole for specific contaminants will be determined. The results are expected to provide planners, policy makers and pollution control authorities with a useful tool with which to assess groundwater pollution risks.

11.17 COMPARATIVE STUDY OF TWO- AND THREE- DIMENSIONAL GROUNDWATER MODELS

Insufficient observational data prevented a detailed comparison of two- and three- dimensional models for actual aquifers. Numerical experiments with hypothetical and theoretical aquifers have shown that a two-dimensional model can be used in the study of a homogeneous aquifer, or a single-layer, heterogeneous aquifer, provided that the pumping and observation boreholes penetrate the full extent of the aquifer. A two-dimensional model, however, should never be used to interpret data from a multi-layer aquifer.

Although being able to handle quite complex situations, even the three-dimensional models developed during this investigation were not sufficient to interpret the behaviour of water levels in a heterogeneous aquifer. Improved observation methods that can be used to delineate the exact nature of the heterogeneous aquifer are required.

Considerable progress was made both in the development of improved methods for estimating groundwater levels and in the contouring of arbitrarily spaced data and the computation of groundwater velocities.

12. REGULATORY, INFRASTRUCTURAL AND ECONOMIC ISSUES

12.1 QUANTITATIVE STRUCTURING OF NATIONAL WATER PLANNING OBJECTIVES FOR USE IN DECISION SUPPORT SYSTEMS IN SOUTH AFRICA

This project was carried out over a three year period. The objective of the project was to develop management procedures and support systems to assist planners and managers in interpreting and evaluating the consequences of proposed plans or policies in order to identify courses of action which best satisfy the goals of society. A decision support system handles, in a structured way, the information overload with which managers are burdened. Conflicting goals have to be satisfied and therefore the operative word is not optimisation but equitable compromise. To demonstrate the practical utility of the methodology being developed, certain demonstration projects are selected to test management procedures. The Sabie catchment in the Eastern Transvaal was found to be suitable for this purpose.

This project summarises the results of research aimed at providing a justifiable basis for systematically incorporating multiple goals and perspectives into water management in South Africa, particularly where the goals include less tangible issues (such as the environment). A procedure has been developed which incorporates concepts of scenario planning and multiple criteria decision making (MCDM), and which emphasizes the participation of many interest groups in the planning process, consistently with the principles of integrated environmental management. Although more research is needed in order to refine the procedure, it has been successfully tested in experimental workshops with different groups concerned with the Sabie-Sand river catchment area, and decision support software is already available for supporting implementation of the procedures.

12.2 THE SURFACE WATER RESOURCES OF SOUTH AFRICA 1990

This five-year project is carried out by a consortium of consulting engineers. The evaluation of Southern Africa's available surface water resources needs continuous attention. The severe drought since 1981, when the previous inventory was completed, can now be evaluated. The study will use an updated version of the Pitman model. The survey will cover Southern Africa south of the Limpopo and will include the RSA, Swaziland, Lesotho, the TBVC countries and the National States. The project will not only review new data but will also develop an advanced GIS-based methodology for streamlining such an update at regular time intervals. The survey will be based on the "official" tertiary and quaternary catchment boundaries of the Department of Water Affairs and Forestry.

12.3 UTILISATION OF GEOGRAPHIC INFORMATION SYSTEMS (GIS) AND INTEGRATED ENVIRONMENTAL MANAGEMENT (IEM) IN THE PLANNING AND MANAGEMENT OF WATER RESOURCES WITHIN RIVER CATCHMENTS

This three-year project is being carried out by the University of Pretoria's Department of Landscape Architecture. In future, water resources and the catchments from which the water originates will be utilised to their full potential. Changing environmental conditions, such as land use and storage reservoirs, will affect the ecology of down-stream aquatic systems. The use of GIS will allow evaluation of alternative development scenarios in a holistic manner, allowing the consequences of certain development actions to be taken into account in the selection of the most acceptable solution. To ensure the practicality of the methodology to be developed, the Sabie River catchment has been selected as a test region. Practical problems with the use, computer storage and integration of different data sources and products will also be addressed in this project. One of the by-products will most probably be a guideline for land-use and land-cover classification for South African water management.

12.4 THE APPLICATION OF RESOURCE ECONOMICS TO WATER MANAGEMENT DECISION-MAKING IN SOUTH AFRICA

This project is being undertaken by the Institute of Natural Resources of the University of Natal. As a natural resource, water has been the subject of study within the specialised field known as resource (or environmental) economics. This discipline is relatively new in South Africa, and has as yet not been widely applied to facilitate decision-making in situations characterised by scarcity of resources. It will, for example, be particularly useful in decision-making affecting the allocation of water to users such as conservation, rural communities, irrigation and recreation. Not everyone will always agree with the role that resource economics could play, but the advantages are that decisions can be reached in a logical, transparent and objective manner. The theoretical aspects of this research and the usefulness of the approach will be tested with the aid of a limited number of presently popular case studies.

12.5 A MANUAL FOR WASTE LOAD ALLOCATIONS IN SOUTH AFRICA

This project is being undertaken by the Environmental Services of the CSIR. The concept of waste load allocation is central to the new approach to water quality management followed by the Department of Water Affairs and Forestry. A shortage of manpower skilled in the application of these concepts is, however, delaying the implementation of this approach. The intention with this project is to alleviate this shortage by summarising the available expertise in one authoritative document. The focus of the manual will be on the finding of techniques for the solution of local problems and will provide guidance on the specific tasks expected of regulators, the industry and consultants.

12.6 A STRUCTURAL ANALYSIS OF THE WATER APPORTIONMENT MECHANISMS IN THE WATER ACT 54/1956, IN VIEW OF THE REQUIREMENTS OF COMPETING USER SECTORS

This project is being undertaken by a legal consultant, Adv. M Uys. The rapidly increasing competition for the RSA's limited water resources could lead to conflict of interest between the various user sectors. The project will research the historical development of the SA Water Act with the aim of re-evaluating the efficiency of the Water Act's express acknowledged and unacknowledged mechanisms of water apportionment between competing user claims. Out of this, guidelines will be drawn up for possible incorporation in future relevant amendments to the Water Act.

12.7 DEVELOPMENT OF AN INTEGRATED CATCHMENT MANAGEMENT SYSTEM FOR THE CROCODILE RIVER CATCHMENT.

The marked competition for land and water in the more humid areas of South Africa and the anticipated shortfall in water supply relative to growth in demand has brought the issue of the equitable allocation of these resources within catchments into sharp focus. The forest industry, in particular, is concerned that it is the only industry subject to a land-use allocation system.

The broad objective of this study is the development of a generic catchment-centred resource allocation and management system, using the Crocodile catchment in the Eastern Transvaal as a study area. The 2-year project will consist of several modules, some of which will be funded by other organisations such as the Departments of Environment Affairs and of Water Affairs and Forestry.

12.8 SOCIO-ECONOMIC EFFECTS OF WATER RESTRICTIONS ON IRRIGATION, FARMING, MINING, ELECTRICITY SUPPLY AND CENTRAL GOVERNMENT

Water restrictions are and will remain one of the most important measures for conserving water during times of restricted water supplies. Little is known, however, of the nature and magnitude of the consequences of such restrictions - neither locally nor overseas. This project was therefore undertaken by the Institute for Social and Economic Research of the University of the Orange Free State. The study concentrated on the Vaal River system and investigated the water restriction period of 1 March 1984 to 31 March 1985, although these restrictions were only lifted in October 1987. In the Vaal River system, the economic impact was found to be the largest for households, viz. R255,5 million. The net tangible effect on the mining industry in the Vaal River system was found to be R44,8 million.

12.9 WATER RIGHTS OF NATURE CONSERVATION

In order to address the protection of nature's water requirements satisfactorily in the existing legislation, an in-depth study on the development of the South African Water Act over the years is required. The aim of this one-year project,

carried out by a lawyer, is to investigate the existing legislation with a view to establishing guidelines for future research, which could possibly lead to practical amendments of the law.

12.10 POTENTIAL FOR THE USE OF ECONOMIC INSTRUMENTS TO PROTECT THE QUALITY OF WATER RESOURCES IN SOUTH AFRICA

It is generally accepted that the traditional legislative, or command-and-control , approach to controlling water quality faces many difficulties. This approach can experience daunting administrative problems and is often difficult and costly to apply. It can, furthermore, be inequitable, and may also have dubious incentive effects. It is anticipated that an economic approach to water quality control may offer significant benefits by way of enhanced effectiveness and reduced cost. This, however, needs to be confirmed in practice. This 2-year project will use the upper Olifants River basin to compare the two approaches and assess the practicality of employing economic measures to protect water quality in South Africa. It will also assess the benefits that could ensue from adopting an economic approach to water quality management.

12.11 DEMONSTRATING THE POTENTIAL OF GEOGRAPHIC INFORMATION SYSTEMS TECHNOLOGY IN HYDROSALINITY MODELLING BY USING THE DISA MODEL

Most hydrological models require geographically based input data. Before the advent of geographical information systems (GIS) most of the required data were labour-intensively measured and calculated from existing maps. Due to the time-consuming nature of the process the potential of the hydrological models could often not be fully realised. Currently the potential of GIS technology is still not properly realised in hydrological modelling, one of the reasons being that it is necessary to bring together the skills of divergent disciplines for this. The aim of this 18-month project is to demonstrate the potential of GIS technology by integrating a GIS model with the DISA model (a daily irrigation and salinisation analysis systems model).

13. CONSERVATION OF AQUATIC ECOSYSTEMS

13.1 RELATIONSHIP BETWEEN LOW FLOWS AND RIVER FAUNA IN THE LETABA RIVER

The project, which had as overall objective the quantification of the effects of low flows on river fauna, was conducted over a period of two and a half years.

The results indicate that the invertebrates and fish fauna of the Letaba River have recovered rapidly from the severe drought of the mid-1980s. It would appear that the permanently flowing section of river, immediately downstream of the Fanie Botha Dam, is an important epicentre for the re-colonisation of the dried-up sections of the river, when flow resumes.

There are several aquatic insects, particularly among the mayflies, which only occur in the lower part of the river which is subject to occasional flow cessation. These insects are apparently able to survive such conditions. Various invertebrate species, especially those with short life cycles, can however, be severely affected by very low flows and can thus be considered to be flow-sensitive species.

13.2 ASSESSMENT OF THE INSTREAM FLOW REQUIREMENTS OF RIVERS

The aim of this research was to establish acceptable methods for assessing the instream flow requirements of South African rivers. Efforts would be focused on the understanding of a sophisticated North American methodology, namely instream flow incremental methodology (IFIM).

The baseline result of the research was that the use of IFIM is very suitable for the determination of the instream flow requirements of South African rivers. The methodology is, however, very data-intensive, specifically as regards biological interactions. Such data are scarce in South Africa.

The research team was nevertheless able to formulate guidelines, in conjunction with Australian scientists, for the implementation of simplified methodologies that are less data-intensive and therefore more suited than IFIM to South African data sets.

Due to the nature of IFIM, the project team was able, to a large extent, to promote communication and collaboration between engineers and ecologists.

13.3 PHYTOPLANKTON BLOOMS IN THE VAAL RIVER AND THE ENVIRONMENTAL VARIABLES RESPONSIBLE FOR THEIR DEVELOPMENT AND DECLINE

This project is being undertaken by the Botany Department of the University of the Orange Free State. Phytoplanktonic algal growth is stimulated by the presence of nutrients in the water, and dense populations (blooms) make

water purification difficult. This project aims to identify the factors responsible for the onset and decline of algal blooms by the various species assemblages in the river. This will be done by relating the phytoplankton present to current and recent physical and chemical environmental variables. Results will be incorporated in a predictive mathematical model for use by water resource managers. This project will also indicate which algae are responsible for nuisance conditions in the waterworks, and therefore which nutrients should be controlled in order to limit algal growth.

13.4 THE EFFECT OF WATER QUALITY VARIABLES ON RIVERINE BIOTA

This project is being undertaken by the Department of Zoology of the University of Cape Town. Water quality determines the number and types of aquatic species and communities in aquatic ecosystems and the functioning thereof. One method of assessing water quality impact on a water body is to construct a rating curve of the concentration of each quality variable against some measure of "harmfulness". This project will determine the effects of the concentration of a number of water quality variables on riverine biota in order that the necessary rating curves may be constructed.

13.5 GEOMORPHOLOGICAL RESPONSE TO CHANGING FLOW REGIMES OF THE SABIE AND LETABA RIVER SYSTEMS

This project is being undertaken by the Department of Botany of the University of the Witwatersrand. The form of a river channel, which defines the physical environment for aquatic biota, is determined by water and sediment supply from upstream. Changes in these supply rates result in significant modification of the river form and habitat. Specifications of water allocations for the conservation of aquatic environments therefore require understanding of the river response to these changes in a quantitative and predictive sense. The objectives of this study have been formulated to develop such understanding and predictive capability.

13.6 AN OVERVIEW OF THE PESTICIDE AND HEAVY METAL LEVELS PRESENT IN POPULATIONS OF THE LARGER INDIGENOUS FISH SPECIES OF SELECTED SOUTH AFRICAN RIVERS

This research is being undertaken by the CSIR. The main objectives of this study are as follows:

- To integrate information from, and collaborate with, researchers studying the ecological features of five rivers in the Eastern Transvaal and Kruger National Park and one Western Cape River. Existing data and study sites with habitats specific to selected species of fish will be used in order to maximise fishing efforts.

- To utilise information from completed and presently undertaken catchment studies of the selected rivers, in collaboration with researchers currently working in the field, to determine the point and possibly diffuse

sources of pesticides and metal pollution. Existing land usage, estimates of the pesticides most commonly used and the specific metal variables associated with the industries in each river catchment will be used to select the specific variables for analysis.

- To catch selected species of the larger indigenous fish in these rivers, at sites where pesticide and/or metal pollution is expected. Techniques developed by the researcher in charge of this proposal will be used to select specific species of fish as well as the particular fish tissues in which pesticide and metal levels will be determined.

- To establish baseline loads of pesticides and metals present in the larger species of indigenous fish in the selected rivers.

- In collaboration with other researchers and the Department of Water Affairs and Forestry, the baseline loads and monitoring techniques developed in this proposal will be used to implement a river surveillance system for pesticides and metals in South African rivers.

13.7 DEVELOPING AN INTEGRATED APPROACH TO PREDICTING THE WATER USE OF RIPARIAN VEGETATION

This research is being undertaken by the Botany Department at the University of the Witwatersrand. The natural riverine biota, have in recent years, come to be recognised as a legitimate demand sector in water resources management. One of the largest requirements for water within this sector is undoubtedly for the maintenance of the riparian vegetation. There are three main issues which need attention in order to effectively manage riparian water requirements:

- the need for non-consumptive flows, such as seasonal flooding, to provide seed germination opportunities and a disturbance regime which maintains diversity;

- the minimum supply which will permit persistence of the vegetation during times of drought; and

- the need to model consumptive water use by vegetation (transpiration) under different flow and meteorological conditions.

The first two issues require detailed physiological and ecological studies of riparian plant species. This proposal focuses on the third issue and thus aims to provide the means to predict the water use by the riparian zone under different riverine and atmospheric conditions. It is, however, contended that information from this research will be essential in streamlining the potentially limitless need for research on the first two issues noted above.

13.8 PHOSPHATE EXPORT MODELS FOR CATCHMENTS

This project was aimed at providing the tools to predict phosphate export from catchments experiencing changing phosphate loads from point and non-point sources. Water quality management requires predictions of the effects catchment changes will have on reservoir eutrophication under conditions of both good and poor data availability. To cater for both situations two distinct types of models were developed to predict P-export from non-point sources, viz. a deterministic model coupled to hydrology, and a stochastic model based on measurements of P-concentrations. The products of this project facilitate improved predictions of P-export, both for catchments with sufficient data on land use characteristics, as well as for catchments with few land use data, but with phosphate concentration measurements.

13.9 APPLICABILITY OF HYDRODYNAMIC RESERVOIR MODELS FOR WATER QUALITY MANAGEMENT IN STRATIFIED WATER BODIES IN SOUTH AFRICA

This project aimed to evaluate existing mathematical models for their ability to predict stratification and related processes for South African impoundments, adapt them as required and demonstrate their application value. Modelling data bases were assembled for Hartebeespoort Dam and Vaal Barrage. Four hydrodynamic reservoir models (DYRESM, MINLAKE, CE-QUAL-W2 and WASP4) were selected for the investigations. It was found necessary to develop supporting software to enhance both the input and output side of models, with a strong accent on computer screen graphics. The technical feasibility of destratification by air bubble plume action was demonstrated for Roodeplaat Dam and the two-dimensional nature of the translation of the low-salinity release through the Vaal Barrage was successfully simulated. Additional applications will be demonstrated as part of an extension of the project to the end of 1994.

13.10 DEVELOPMENT OF A DYNAMIC MODEL FOR THE GROWTH AND BLOOM OF ALGAE IN THE VAAL RIVER

The runoff to the Vaal River of domestic and industrial waste products rich in plant nutrients leads to a eutrophic condition and therefore favourable conditions for algal bloom. These algae cause aesthetic problems for all river users, increase the purification costs of drinking water and create considerable problems for the organisations having to provide drinking water from the river, *inter alia* due to the unpleasant odours and tastes of this water. From a managerial point of view it is therefore desirable to have an efficient mathematical model with which reliable predictions can be made of the occurrence, nature and extent of algal blooms, in order that suitable countermeasures may be taken timeously. The purpose of this 3-year project is to develop such a management model, based on a promising model already developed by the University.

13.11 EFFECTS OF DIFFERENT MAGNITUDE FLOWS ON SOUTH AFRICAN RIVERINE ECOSYSTEMS

The continued population increase is leading to rapid development of the country's remaining unexploited water resources. At the same time, there is a growing awareness of, and concern for, the welfare of our natural environment as a sustainable resource. Planners and water managers are increasingly seeking guidance on how to develop water resources with minimum impact on aquatic ecosystems. In the planning of new water resource developments - almost all of which involve rivers in some form - a new important question now routinely asked by the planners and developers concerns the quantity of water needed by the river itself for ecosystem maintenance.

The overall aim of this 3-year project is thus to increase our ability to advise water resource managers/developers as regards instream requirements of rivers by:

- Increasing the understanding of the effects of different magnitudes of flow on riverine biotas, through focused research on South African rivers

- Continuing the development of scientifically acceptable methodologies for assessing the water quantity requirements of rivers.

13.12 EFFECTS OF CATCHMENT PARAMETERS AND LAND USE ON RUNOFF QUALITY AND ESTUARY ECOLOGY

Land-use patterns in South Africa are continually changing through an increasing trend towards urbanisation and population growth. As the current socio-economic trends continue, increasing areas of farmland will become settled by people practising a more subsistence level of farming, with an associated development of townships having a relatively unsophisticated infrastructure, with a consequent increase in pollution load in stormwater runoff. It is, therefore, crucial to establish what effects catchment trends are likely to have on water quality and runoff.

This 4-year study will address this by looking at small catchments in the Eastern Cape area, and comparing the effects of different land cover and land use on the quality of the water running off these catchments. In particular, the study will concentrate on the meiofauna, the interstitial fauna of the water course sediments. This fauna may be a very useful indicator of water quality, especially in seasonally flowing streams where moisture may only persist far below the surface during dry periods.

Given South Africa's relatively arid climate, such an indicator would be of great value.

13.13 GEOMORPHOLOGICAL CLASSIFICATION SYSTEM FOR SOUTH AFRICAN RIVER SYSTEMS

Many South African river systems have been strongly impacted by man-made disturbances, resulting in adjustments in channel morphology and habitat. The mode and extent of these adjustments and the sensitivity of the channel to disturbance are a function of channel geomorphology described in terms of gradient, bed and bank materials and vegetation cover. The aim of this 4-year project is to establish a classification system which will assist in the identification and management of river reaches sensitive to change or those most resilient, thereby reducing costly reclamation programmes.

14. MONITORING, SAMPLING AND ANALYTICAL TECHNIQUES

14.1 INVESTIGATION OF TECHNIQUES FOR THE DETERMINATION OF MICROBIAL ASPECTS OF WATER QUALITY OF SOUTH AFRICAN RIVERS

This project is being undertaken by the CSIR and the Rand Water Board. In order to improve on water quality management the Department of Water Affairs and Forestry adopted a new approach, namely that of receiving water quality objectives, which they combine with the prevention of pollution. In terms of this approach it is accepted that receiving water bodies have a quantifiable and manageable capacity to absorb waste products without deteriorating to such a degree that its quality is unfit for recognised uses. In order to apply this approach, the relationship between pollution loads and the resulting quality of the receiving water needs to be understood. The ability to determine microbiological waste load allocations has not yet been achieved locally. This project aims at acquiring the expertise still lacking with regard to the microbiological aspects of water quality and to establish such guidelines and tools.

14.2 RAPID BIOLOGICAL ASSESSMENT OF WATER QUALITY IMPACTS ON STREAMS AND RIVERS

Due to the fact that river life is exposed to all variations in water quality, and so reflects a time-integrated water quality measure, a biological monitoring procedure, which is more cost-effective than chemical procedures, can determine the impact of pollutants on river fauna and flora. This 3-year project proposes to refine and develop a South African version of a British-developed biological monitoring system.

14.3 DEVELOPMENT OF WATER QUALITY MONITORING STRATEGIES AND PROCEDURES FOR WATER QUALITY DATA INTERPRETATION

The existence of reliable water quality data, together with careful collection, interpretation and utilisation thereof is important. A number of related components, of which some are better developed than others, play a part in the assessment of water quality. All these components received attention in this project, but the development of monitoring strategies and procedures for water quality data interpretation and analysis received priority. This was done so that reliable information could be made available for use in decision making systems in respect of, for instance, water resource development, water quality control, etc. These results will be used mainly by the Department of Water Affairs, one of the partners in this five-year tripartite agreement between the WRC, the CSIR and the Department.

The project produced a strategy to satisfy the information requirements for trend detection in river water quality. Principal features of the strategy were the use of a small number of variables to be measured at carefully selected sites and a focus on ensuring a consistent record over time. A statistical

protocol to provide reliable data analysis procedures was developed to complement the data collection activities.

14.4 COMPILATION OF A COMPREHENSIVE GUIDE FOR GROUNDWATER SAMPLING IN SOUTH AFRICA

The lack of a comprehensive cross-referenced manual on sampling methodology has resulted in little or no standard protocol being followed for groundwater sampling in South Africa. Each research institute, consulting group, groundwater and waste-disposal agency has developed in-house standards for sampling. Consequently, samples collected at various times and by various institutions or persons cannot really be compared in a meaningful way, frequently leading to doubts in terms of data reliability.

The fact that groundwater pollution incidents are increasingly resulting in litigation, together with the high standards required when collecting groundwater samples for trace element and organic element analysis, has necessitated the formulation of a standard sampling protocol. Although such protocols are available overseas, until now no such comprehensive manual was available for South African conditions. The purpose of this manual, then, is to provide consistent groundwater sampling techniques that will ensure that all groundwater quality data collected are representative of *in situ* groundwater conditions. Using these techniques will reduce sampling error to a minimum and will result in groundwater quality data that can be used with confidence to evaluate hydrogeochemical conditions.

14.5 THE USE OF ALGAE TO BIOASSAY FOR TOXIC SUBSTANCES IN WATER

This project is being undertaken by the Department of Botany and Genetics of the University of the Orange Free State. This project will use the rate of certain physiological reactions in algae as a measure of toxins in the environment. The aim is to develop a bioassay which is both cost-effective and reliable. If possible, tests will be automated, or proposals for the automation of tests will be made. An advantage of using measurements of the physiological rates, as proposed in this project, is that reactions such as photosynthesis respond quickly to variations in the environment. This short response time makes tests based on these organisms potentially useful. The envisaged application of this technology is the monitoring of effluent quality before it is allowed to return to the receiving water body.

14.6 GUIDELINES FOR TOXICITY BIOASSAYING OF DRINKING AND ENVIRONMENTAL WATERS IN SOUTH AFRICA

This project is being undertaken by the CSIR. A number of bioassay tests exist world-wide. Some are more sensitive than others to particular pollutants or toxins, and some are easier to use than others. This project will assess bioassays currently used in South Africa for their ability to detect toxicity in water, and their potential applications will be evaluated in the light of literature findings. The research findings will be presented as guidelines for the use of various

tests with the objective of allowing users to identify the best test for their specific application and to present standardised methods so that results from different laboratories will be comparable. This technology can be applied in the monitoring of water quality at the intakes of installations such as water purification works.

14.7 DEVELOPMENT OF IMPROVED FLOW GAUGING STRUCTURES FOR SOUTH AFRICAN RIVERS

Gauging weirs are commonly used in South Africa for flow gauging as a result of a lack of stable river reaches where calibration can be done by velocity gauging and also as a result of the limited periods during which flow gauging can be done, especially at high flow rates. Where siltation upstream of these gauging weirs exceeds certain limits, it can cause the structure to operate outside the application field of the theory with serious consequences for flow gauging accuracy. Against this background the 30-month project aims at:

- Upgrading existing gauging stations and the standardisation thereof, as far as possible, to ensure more reliable flow gauging results.
- Developing a gauging structure which requires minimum maintenance but ensures flow gauging of adequate accuracy.

14.8 DEVELOPMENT OF PROCEDURES TO ASSESS WHOLE EFFLUENT TOXICITY

This research is being undertaken by the CSIR. The objectives of this research are to:

- establish a set of toxicity testing procedures with which to quantify whole effluent toxicity;

- develop procedures to evaluate and interpret the results of toxicity tests; and

- establish techniques to determine the dilution of an effluent that would not be toxic after discharge to receiving water.

14.9 STUDIES ON MICROBIOLOGICAL DRINKING WATER QUALITY GUIDELINES

This research is being undertaken by the CSIR. The objectives of this research are to:

- conduct an in-depth investigation of available data on guidelines and standards which are utilised in different parts of the world, including both first and third world situations;

- study the applicability of various guideline scenarios to the present situation in South Africa; and

- provide a task group with the working document to be used for the assessment and re-evaluation and possible reformulation of drinking water guidelines for South Africa.

14.10 STANDARD LABORATORY ORGANISMS FOR WATER QUALITY STUDIES

The receiving water quality objectives approach now adopted by the Department of Water Affairs and Forestry requires that there be a method for assessing the ability of the receiving rivers to absorb the effluent. Existing organisms for bioassaying are all from standing water, while the requirement for South Africa is riverine organisms. During the course of this 3 year project the researchers aim to identify suitable riverine organisms for use in laboratory studies, to develop techniques for maintaining populations of these organisms in the laboratory and to establish protocols for the use of these organisms for bioassaying.

15. DEVELOPING AREAS & SOCIO-ECONOMIC ASPECTS

15.1 HYDROLOGICAL INVESTIGATION OF STORMWATER RUNOFF FROM THE KHAYELITSHA URBAN CATCHMENT IN THE FALSE BAY AREA, SOUTH-WESTERN CAPE

Recognising the need for in-depth geohydrological investigation of stormwater runoff from Third-world type catchments, the objective of the study was to assess the magnitude of the stormwater contamination, identify pollution sources and assess the resultant effect on the receiving water body.

The stormwater runoff originating in the Khayelitsha catchment was found to be polluted throughout the year and mainly of a microbiological nature with high concentrations of nutrients and organic loads.

The major source of pollution was the litter and faecal contaminations which abound throughout the catchment, ascribed to the high population density, poor living conditions and a general lack of environmental awareness. In addition on-going violence and periodic strikes adversely affect basic services and result in the accumulation of garbage, blocking of drains and services and the local dumping of bucket latrines. All forms of urbanisation involving shacks resulted in contamination of the water leaving the catchment. The magnitude of the contamination appears to depend more on the population density than on the degree of infrastructure provided.

15.2 TECHNICAL, SOCIO-ECONOMIC AND ENVIRONMENTAL EVALUATION OF SANITATION SYSTEMS FOR DEVELOPING URBAN AREAS IN SOUTH AFRICA

Diseases related to inadequate water supply and waste disposal are major contributory causes of infantile mortality and also account for a large proportion of adult morbidity.

Given this situation, it is clear that much needs to be done to effect improvements from a social, health and economic point of view.

This study provided an overview of the provision of sanitation facilities to developing urban communities through a review of the current situation regarding the provision of sanitation and an evaluation of the various types of sanitation systems currently in use.

A series of 6 workshops was held across the country and from the input obtained on these occasions, strategies for the improvement of sanitation were developed.

The work carried out in the study is reported in detail in 24 working papers.

15.3 DEVELOPMENT OF DROUGHT RESPONSE POLICY OPTIONS FOR THE COST-EFFECTIVE PROVISION OF WATER SUPPLY TO RURAL COMMUNITIES SUBJECT TO RECURRING DROUGHT

From the history of the development of drought schemes in South Africa, and the scheme to evaluate drought intensity, it is apparent that the drought policy has mainly focused on assisting the commercially orientated livestock and crop (dry land or irrigated) farming communities. Thus, a substantial part of the population consisting of the poorer rural subsistence communities which are vulnerable to drought, have been largely neglected. It is estimated that 10 million people live in these rural communities. Of these, 48 % do not have access to adequate, safe drinking water and 70 %, 41 % and 2 % have a problem with distance, quality and availability of drinking water respectively.

The aims of this 1-year research project are :

- To identify susceptible subsistence farming areas in South Africa
- Investigate alternative water supplies
- Investigate back-up and emergency systems
- Establish a rationing and pricing policy
- Compile policy options relevant to South African conditions

15.4 GROUNDWATER CONTAMINATION AS A RESULT OF THIRD-WORLD TYPE URBANISATION

Aquifers underlying informal and semi-formal settlements act both as a source of cheap, readily available drinking water and as a repository for wastes emanating from the sanitation systems and waste disposal activities associated with these settlements. Although the contamination problem is considered to be significant, few data are available to support this hypothesis as present studies in South Africa have concentrated on surface water. Contamination of groundwater not only results in the transmission of water-borne diseases within the local community, but discharge of shallow groundwater into surface-water courses allows the spread of pollution to unsuspecting communities down-stream.

This 30-month project aims to ascertain the magnitude of any possible groundwater contamination originating from Third-World type urban catchments in South Africa, thereby providing the scientific input necessary for such guidelines.

15.5 DEVELOPMENT OF PROGRAMMES TO COMBAT DIFFUSE SOURCES OF WATER POLLUTION IN RESIDENTIAL AREAS OF DEVELOPING COMMUNITIES

The more concentrated the source of pollution becomes, the greater the impact it has on the immediate environment. News media are very quick to focus on pollution disasters such as oil tankers and chemical spills, but lower-level pollution events are not so startling and are therefore, largely, ignored. However, the longer term effects of pollution originating from increasing urban developments can be as catastrophic as their more dramatic cousins. Community management members usually lack the basic knowledge and are, therefore, ill-equipped to manage community projects effectively. It would be beneficial for elected committee members to undergo management training, even before a project is initiated, to enable them to participate in the decision-making process from the outset. This inevitably leads to greater acceptance of the scheme in all its stages. Projects of this nature are a response to the world-wide recognition for the need for courses which are directed specifically towards the level of the village management committees.

The project will be executed over an 18-month period.

15.6 GUIDELINES ON APPROPRIATE TECHNOLOGIES FOR WATER SUPPLY AND SANITATION IN DEVELOPING COMMUNITIES

During the next decade the provision of housing and services to disadvantaged communities will be the primary focus. Conventional technologies will give rise to capital expenditure and on-going operation and maintenance costs beyond the capacity of the economy. Such an approach will also not lead to any significant progress in the development of human resources.

The WRC is totally committed to supporting and being actively involved in social development projects. This will promote the use of more appropriate technologies which will significantly reduce costs and result in improved human resources development and more sustainable systems in the longer term.

A number of guidelines will be prepared during the project as well as a simplified "training package" on each topic, for use in the training of community level operators and managers.

The project will be executed over a 3-year period.

15.7 WATER SCHEME COST RECOVERY

The primary aim of this study is to determine the acceptability and applicability of different cost recovery techniques for water supplies to informal urban communities. The need for this work was prompted by poor cost recovery for water supplies in developing areas, which is one of the major stumbling blocks to the longer term sustainability of these systems. It also

limits the capacity of organisations to increase service coverage as all of their income goes towards subsidising the non-payment of water.

It is also realised that the use of technology without the correct community approach, has little chance of success. Hence an important consideration of this project will be to establish which approaches for community participation with respect to cost recovery are likely to ensure optimum success with each particular system.

The project will be executed over a 2-year period.

15.8 DYNAMIC CROSS-FLOW SAND FILTER FOR RURAL WATER TREATMENT

Water clarification is an important step in the production of potable water. Although the technologies of flocculation and sedimentation are well understood, the control thereof could prove beyond the capabilities of unskilled operators if these were to be implemented in rural areas.

The dynamic cross-flow sand filter is a more appropriate technology for rural application. It functions like a slow sand filter but being self-cleaning requires little attention. Auto-cleaning is effected by causing a major portion of the raw water to flow across the sand bed to remove excess deposits.

The 2-year project aims to produce a technical guide for the design and operation of the dynamic cross-flow sand filter under South African conditions.

15.9 WATER AND SANITATION IN URBAN AREAS: SURVEY OF ON-SITE CONDITIONS

The social conditions under which poorer people live in urban areas has a major impact on access to water and sanitation services and hence on stormwater runoff quality.

This is particularly the case in areas where densities are high and the infrastructure is over-extended, resulting in a high proportion of people in these areas living in "backyard shacks". While inadequate provision of serviced land for poor people is a feature of our economy, the number of backyard shack dwellers is likely to increase. Indications are that there are many people living under these conditions whose access to sanitation, and to a lesser extent water supply, is denied. This forces them into a situation where their options are limited resulting in health risks and high organic and pathogen loads in stormwater runoff. The 1-year study will evaluate conditions affecting water and sanitation on individual sites in developing urban areas, particularly where there are multiple dwellings on the site. Such multiple dwellings would typically comprise a formal house and one or more informal "backyard shacks".

15.10 EFFECT OF WATER SUPPLY, HANDLING AND USAGE ON WATER QUALITY IN RELATION TO HUMAN HEALTH INDICES IN DEVELOPING COMMUNITIES

The rapid urbanisation occurring in South Africa at the moment has resulted in some peri-urban communities with limited provision of water and sanitation. Under these conditions, an increase in disease, particularly water-borne, may be expected. World-wide, water-borne diseases cause very high mortality amongst people living under these conditions. The aims of this project are to examine patterns of water usage, to monitor changes in water quality from the time of collection to the time of usage for various usage patterns and to correlate water quality with health indices of the population. The project will be executed over a 4-year period.

15.11 SANPLAT - A SIMPLIFIED LATRINE SYSTEM FOR RURAL AND SQUATTER AREAS

"Some for All, Rather than More for Some". This was the message which came out of the New Delhi Global Consultation on Safe Water and Sanitation for the 1992, organised by UNDP. The rationale behind this statement was the need for substantial reduction of costs of services through increased efficiency in the designs and use of low-cost appropriate technologies.

This concept is also very relevant to the South African situation where as many as 18 million people do not have access to adequate sanitation. Of these, some 7 million are located in rural or low density communities where SANPLAT is particularly suitable and at a cost of 10 to 20% of a VIP latrine. Squatter camps are another ideal application where these latrines can serve as an interim service pending more permanent tenure and upgraded services. This 1-year project will identify the features which such a system should have in order to be acceptable to local communities.

15.12 WATER AND SANITATION IN URBAN AREAS: FINANCIAL AND INSTITUTIONAL REVIEW

International experience teaches that sound financial policy and well-structured institutions play a crucial role in the provision of water and sanitation services. In South Africa, where there is a serious under-provision of these services, improvements in financial efficiency and institutional effectiveness are therefore particularly important. Proper organisational arrangements are also important in minimising the environmental effects associated with human settlements.

With the current transition, where political and social restructuring is taking place at national, regional and local level, the provision of water and sanitation services will be substantially affected by these changes and it is vital that policy development takes this into consideration.

This 18-month project is oriented towards research to provide background information for the development of new policy and organisational arrangements.

15.13 DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR THE SELECTION OF THE MOST APPROPRIATE SANITATION OPTION FOR DEVELOPING COMMUNITIES

The provision of safe and adequate water and sanitation to developing areas has become an urgent priority in South Africa. The selection of inadequate or inappropriate sanitation systems may endanger the health of the community and fail to uplift their quality of life. Current decision-making procedures for the selection of sanitation systems are largely cost-driven with little consideration being given, for instance, to existing and future surface and groundwater quality scenarios.

Extensive evidence already gathered, indicates that the sewerage reticulation systems in many of the densely populated townships of coastal Natal result in the discharge of massive volumes of untreated sewage into the local watercourses. At the other end of the sanitation spectrum, the installation of pit latrines into hydrogeologically unsuitable areas and the misuse of pit latrines, has resulted in the deterioration of surface and groundwater quality.

The diversity of factors affecting the selection of a sanitation system underlines the need for the development of a formalised multidisciplinary decision support system which will enable the most appropriate sanitation option to be selected on a practical environmental, sociological and cost-effective basis, removing much of the subjectivity from the current selection process.

The project will run for 3 years.

15.14 PER CAPITA WATER DEMAND IN DEVELOPING COMMUNITIES

Developing communities, in general, have an urgent need for improved water supply as a large percentage of the several million people comprising these communities only have rudimentary water supply systems.

Pressure is constantly being exerted on authorities to extend, improve and upgrade water supply systems. Past experience has shown that water demand per family unit may increase by anything from 3 to 10 times depending on the nature of the existing water supply and the degree of upgrading (community stand-taps, on-site stand-taps or full reticulation and drainage) and may involve capital expenditure upwards of R300/dwelling unit.

The above pressures arise because available resources, particularly water and funds, are scarce. Estimates of water demand are usually arrived at by

extrapolation and are complicated by deviations in the trend line while historical water use information is often not available.

This 2-year project aims to analyse and assess the importance and sensitivity of all the above factors and their interrelationship. It is important that guidelines be established to facilitate estimation of the domestic water demand of developing communities. Appropriate parameters specific to each of the economic, social and cultural groupings, need to be determined.

16. GENERAL

16.1 RELATIONSHIP BETWEEN ATMOSPHERIC DEPOSITION AND WATER QUALITY IN A SMALL UPLAND CATCHMENT

The saline load from the Vaal Dam catchment area can in time double due to the relatively high levels of air pollution in the Eastern Transvaal Highveld and the concomitant wet and dry deposition of salts. This will have far-reaching consequences for users of Vaal Dam water. Owing to difficulties encountered with measuring wet and dry deposition the establishment of a yardstick of the absolute and relative amounts thereof remains one of the uncertainties in predicting the extent to which the Vaal Dam will salinise. The aim of this 2-year project is to use a small catchment area (supplemented with small runoff plots and other instrumentation) as a large-scale sampler of wet and dry deposition.