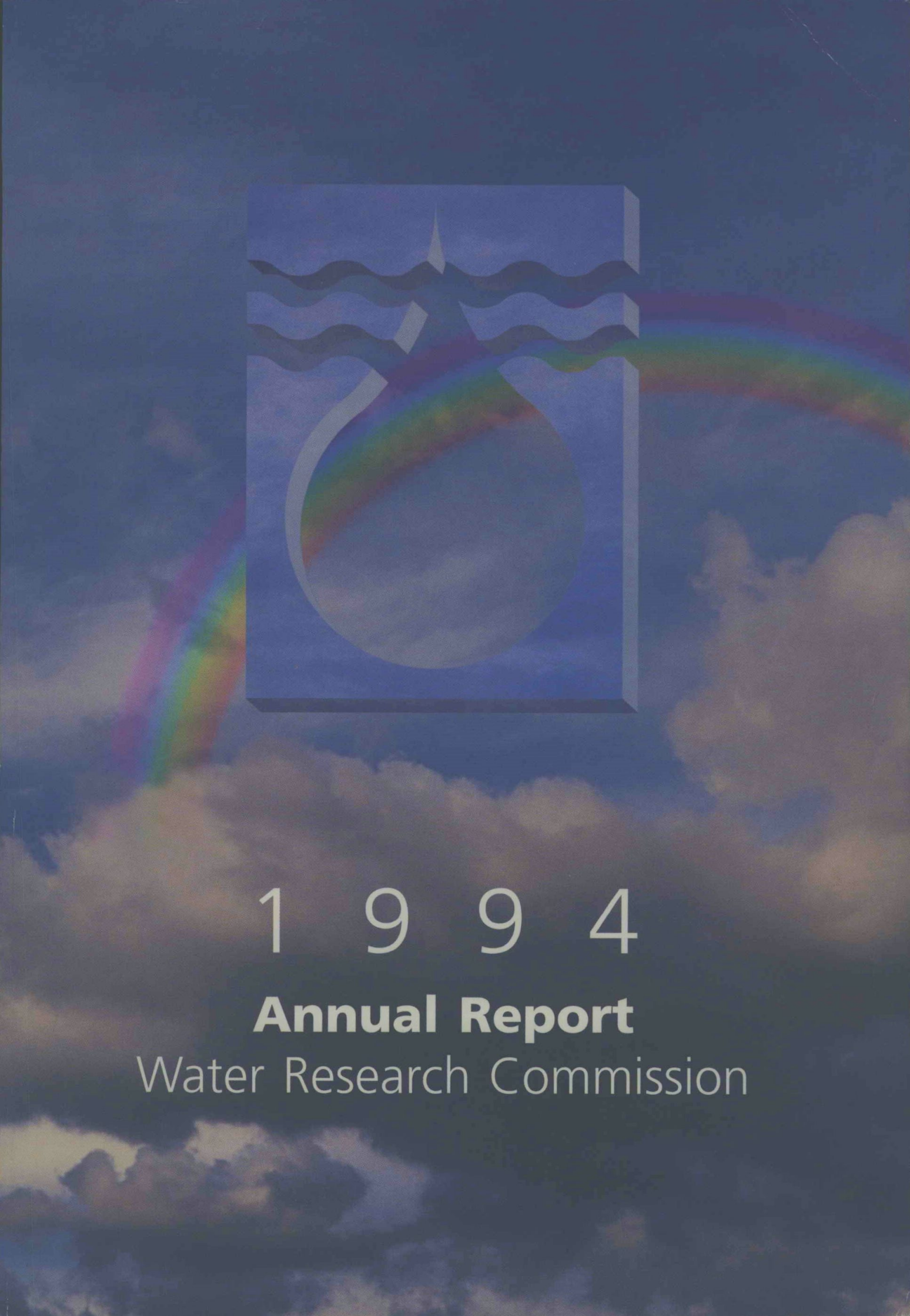

# 1994

# Annual Report

## Water Research Commission

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# Annual Report

# Water Research Commission


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Water Research Commission
PO Box 824
Pretoria
0001
31 March 1995

Dear Prof Asmal

We take pleasure in submitting to you, herewith, the report of the Water Research Commission for the period 1 January to 31 December 1994.

The balance sheet and statement of revenue and expenditure for the financial year to 31 December 1993, as certified by the Auditor General, as well as a receipts and payments account for the year ended 31 December 1994 and a budget for 1995, are furnished under **Financial Statements** of this report.

Yours respectfully

AJ Raubenheimer
CHAIRMAN

PE Odendaal
EXECUTIVE DIRECTOR

Prof Kader Asmal
Minister of Water Affairs and Forestry
Private Bag X313
PRETORIA
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# Contents

# Senior personnel

## Professional

### Deputy Executive Director

Mr DS van der Merwe

(Municipal effluents; industrial water and waste-water; urban water reticulation; water and sanitation for developing communities; water utilisation for agricultural and ecological purposes; membrane technology)

### Deputy Executive Director

Dr GC Green

(Surface- and groundwater resources; water resource management; drinking water; water treatment technology; water pollution; mine water; hydrometeorology)

**Research managers**

Mr HC Chapman
Dr SA Mitchell
Mr ZT Ngcakani
Dr PCM Reid
Dr HM Saayman
Dr OO Hart

**Research managers**

Mr HM du Plessis
Dr TC Erasmus
Mr H Maaren
Mrs APM Oelofse
Mr G Offringa
Mr AG Reynders

## Administrative

**Director: Administration**

Mr PM van der Schyff

# Members of the Water Research Commission

as on 31 December 1994

Sitting:
**Mr DW Steyn** – Former Minister of Economic Affairs and Technology
**Mr AJ Raubenheimer** (DMS) (Chairman) – Former Minister of Water Affairs
**Mr PE Odendaal** – Executive Director: Water Research Commission
**Mr DH Marx** – Chairman: Magalies Water

Standing:
**Mr VJ Bath** – Chief Executive: Rand Water
**Prof T Erasmus** – Vice-Principal: University of Pretoria
**Prof PD Tyson** – Director: Climatological Research Group, University of the Witwatersrand
**Mr AJ Clayton** (Co-opted member) – City Engineer: Cape Town

Absent:
**Mr M Erasmus** – Director-General: Department of Water Affairs and Forestry
**Dr WL van Wyk** – Former Deputy Director-General: Department of Mineral and Energy Affairs

# 1
# The year under review

The diverse number of research fields supported by the Water Research Commission (WRC) bears testimony to its multidisciplinary approach to water research. The research fields and allocation of funds to the various areas for 1994 are indicated in the accompanying bar chart.

The WRC does not itself undertake research, but enters into agreements with other organisations to carry out the research. In the following table the research sectors which are responsible for the research, are listed, as well as the extent of their involvement:

| Research sector | Number of times involved | % |
|---|---|---|
| Universities | 137 | 51 |
| CSIR | 53 | 20 |
| Consultants | 44 | 17 |
| Government departments | 3 | 1 |
| Local authorities | 3 | 1 |
| Water boards | 13 | 5 |
| Other organisations | 14 | 5 |
| Total | 267 | 100 |

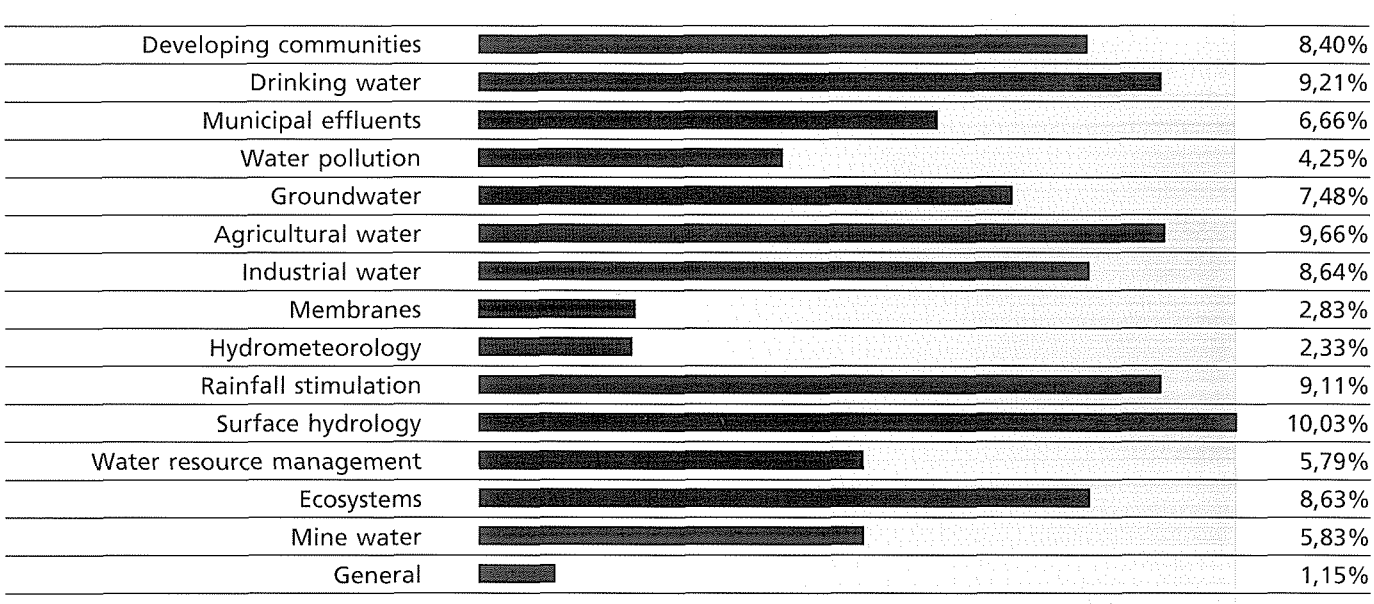
From the figures it is evident that universities are involved in 51% of the total number of contracts. The number of times that organisations are involved, namely 267, exceeds the number of projects supported, for the reason that more than one organisation is, in certain cases, involved in the execution of a project. In 1994 the WRC financially supported 248 projects at a budgeted amount of R39 335 900.

In addition to the direct funding of contractual research projects, the WRC also supports 2 research support services financially:

- The SA Water Information Centre (SAWIC)
- The Computing Centre for Water Research (CCWR).

While the activities pertaining to the past year will be reported on in the various chapters, certain highlights will be singled out in this chapter.

Allocation of funds (%) to the various areas during 1994



## Water research and the Reconstruction and Development Programme (RDP)

In the context of present national priorities, the Reconstruction and Development Programme (RDP), announced by government during the course of 1994, has undoubtedly become the overriding consideration. It is, therefore, incumbent on all government-related institutions to adapt their activities accordingly. The WRC – as a statutory organisation – is no exception, and its initiatives in this regard are briefly set out below.

The provision of adequate water supplies and sanitation services to the total population is a major objective of the RDP. Since 1990 the WRC has been stepping up its research funding in this field when a strategic planning workshop afforded the development of affordable and acceptable sanitation technology for developing communities a highest priority. Similarly, the WRC's strategic research plan for potable water treatment, drafted in 1992, assigned the highest priority to research into *cost-effective provision of water to the unserved communities in South Africa*. These strategic research plans were announced to the water research community at large in order to stimulate relevant research submissions to the WRC.

As research progressed it became clear that technological issues, in many if not most instances, did not constitute the main stumbling blocks in service delivery to underprivileged communities. For example, institutional, sociological, gender, training and financial issues featured prominently (issues that are, in fact, not unique to the water and sanitation fields, but also apply, to a greater or lesser extent, to other fields such as housing, health and education). In its funding of water- and sanitation-related research the WRC has, therefore, progressively become involved in projects on "non-technological" issues. Furthermore, it became clear that with the many "non-technological" issues which were common to both water supply and sanitation, there was a need for a strategic research plan and for a research co-ordinating committee to focus on these issues. Initiative has been taken in this connection, and this is reported on in a subsequent item in this chapter.

It is important to realise that the provision of water supply and sanitation

> The provision of adequate water supplies and sanitation services to the total population is a major objective of the RDP

services on a sustainable basis cannot be pursued in isolation, but should take due cognisance of the broader context of water resource management in the country as a whole. This realisation is, indeed, embedded in the RDP. Although *water and sanitation* is pertinently discussed in various paragraphs of *The Reconstruction and Development Programme – A Policy Framework* (1994), the following aspects which impinge directly on the management of the country's water resources are also addressed:

- Drought management and provision of agrometeorological advice (RDP: 2.6.4; 4.5.2.6)
- Impact of forestry (RDP: 4.5.3.5)
- Sustainable agriculture (RDP: 4.5.2.6)
- Environmental impact of land use (RDP: 2.10.3; 2.10.4; 2.10.10)
- Tariffs for water supply (RDP: 2.6.10)
- Integrated management of water resources (RDP: 2.6.11.1)
- Environmental impact of mining activities (RDP: 4.5.1.12)
- Waste-water management and water pollution control (RDP: 2.6.11.2; 2.10.1; 2.10.5; 2.10.6.1; 2.10.6.4).

Measured against these RDP objectives, most WRC research projects are and have been RDP-relevant over many years.

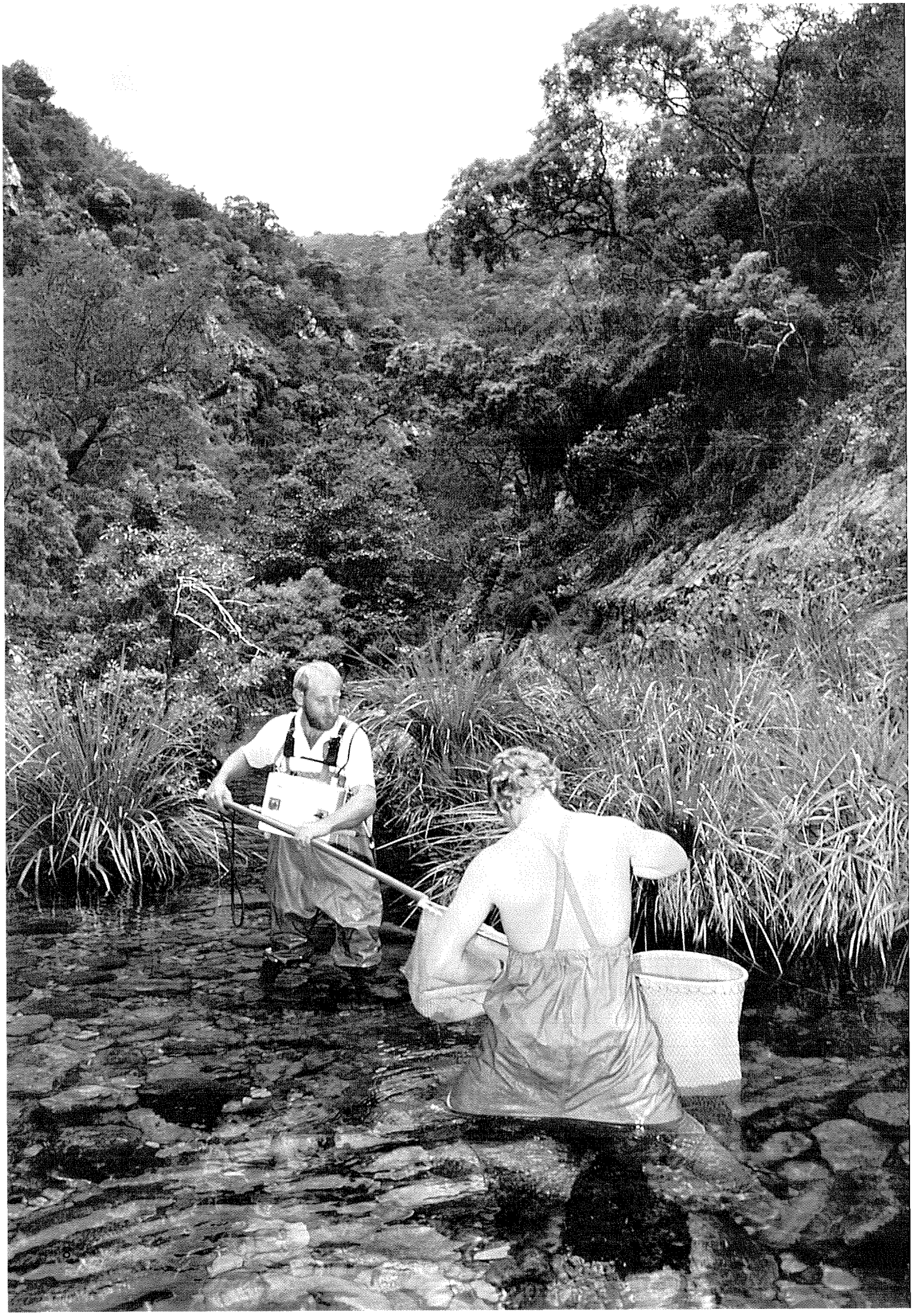
Capacity building is also an important RDP objective. Although the WRC has always been aware of the fact that capacity building was an associated benefit resulting from its research support, this has never been pursued as an end in itself. The focus was on research objectives and the quality of research output. It is now clear that in the process, capacity building did not take place equitably, in the sense that previously disadvantaged academic institutions shared only in a small way, if at all, in the research opportunities offered by the WRC. To redress the situation, the WRC has launched a strategy for promoting water research and capacity building at these institutions. A special RDP capacity-building fund has been created for this purpose. Research funding under the programme, which will commence early in 1995, will create opportunities for the development of centres of expertise which can become important national assets.

## Geohydrological research to support community water supply

The WRC Strategic Research Plan for Geohydrological Research, first prepared in 1975 and revised in 1989, underwent a further revision at a meeting of the Co-ordinating Committee for Geohydrological Research in October 1994.

Although there was general agreement that the overall goals and structure remain relevant, the Co-ordinating Committee recommended that the weights allocated to the primary goals should be reviewed. This was a result of changing priorities in the groundwater research field and the fact that many of the issues identified 5 years ago had been addressed.

Following a prioritisation exercise, the primary goal *Identification and characterisation of groundwater resources in terms of their occurrence, quality and development potential* emerged as the top priority. Attainment of the objectives embodied within this primary goal, will contribute significantly towards the provision of community water supplies and will support the Department of Water Affairs and Forestry's (DWAF) regional groundwater characterisation programme.



## Groundwater highly valued in rural disadvantaged areas

Economists have shown that the level of management accorded to a resource is related to the value that society attaches to it. It is postulated that a more realistic valuation of groundwater will establish a justifiable basis for its appropriate utilisation and management.

The WRC appointed Economic Project Evaluation (Pty) Ltd to develop methodologies for the valuation of groundwater systems based on the importance of the use to which the water is put. Although these values are likely to vary from one groundwater use to another, and from one location to the another, they are considered as being potentially important criteria for the allocation of resources to groundwater management.

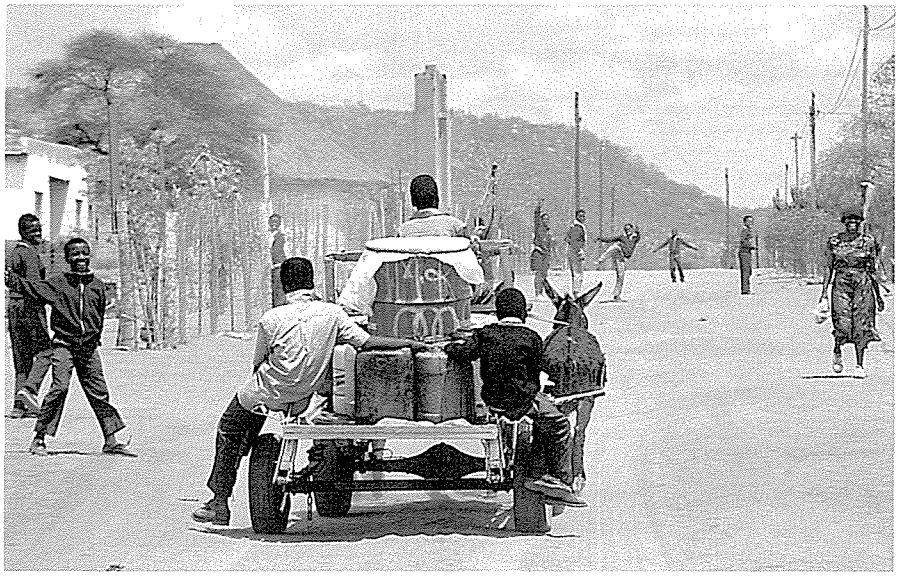
A workshop to provide feedback on the initial findings of 4 case studies, and to stimulate debate on the methods used and issues raised during the project, was held in September 1994. One of the issues which clearly emerged is the acute sense of the value of water in disadvantaged rural areas, together with a willingness to pay for the provision of potable water. The outcome of the workshop will be incorporated in the final report of the project **The Economics of Groundwater Usage: The Importance of Intrinsic Value as a Basis for Sustainable Management**.

In order to accommodate community water supply needs the existing strategic plan for geohydrological research is being revised.

## Tariff-investment model for water supply

As part of a project for the WRC, dealing with financial and institutional aspects of water supply and sanitation in urban areas, the Palmer Development Group developed a tariff-investment model for water supply in urban areas. Taking into account factors such as demographic projections, available funding, and level of services, the model guides decision-making by local and other authorities in developing water supply services.

The model was adopted and applied by Durban Corporation, who subsequently adapted the model, at own cost, to also cater for the provision of sanitation services. Other local authorities have also commenced using the model and, in fact, the Department of Finance has recommended its use as a



The value that a community attaches to groundwater is related to its availability.

guideline for all local authorities nationwide. The WRC is now funding the adaptation of the model for application in rural water supply and sanitation.

## Education and training of plant operations staff

The education and training of water and waste-water treatment plant operations personnel has not been satisfactorily addressed in the past. The result of this has been that the organisations which have seen the need to train their staff have developed their own training courses, but other organisations offer no training. This means that not only is there no national standard of competence, but that people trained in one organisation may not be able to transfer to another without retraining.

The DWAF requested the WRC to conduct research on this to determine the best course to follow. The investigation was undertaken by MTI Consultants. It took the form of a series of workshops and wide individual consultation both within the industry and the educational institutions traditionally providing the education to ensure that the product to be developed will be acceptable to the water industry as a whole.

It was decided that the Competency Based Individualised Modular Training would suit the needs of the industry best. The competencies required to operate each process, as well as the tasks required for each competency have been identified, and the first curricula have been drawn up.

## SWAP (School Water Project)

The SWAP project, being developed and promoted by the Department of Didactics, University of Stellenbosch, is aimed at generating an awareness of environmental quality amongst schoolchildren. The WRC is providing some financial support in order to develop and promote the viability of the programme. Schoolchildren are actively involved in monitoring water quality in streams. They are provided with simple but effective test kits for measuring basic water quality parameters, such as the presence or absence of oxygen. The test kit also contains a sliding scale from which the tests may be interpreted to give the state of the water body. The kits are sold at cost price, and refilled at the cost of the consumables.

The project is proving to be very popular with schools, particularly in the Western Cape. The training to use the test kits effectively has been kept simple, and the children are encouraged to participate for curriculum enrichment. The success of the project may be attributed to both the enthusiasm of the project team and the affordability of the test kits. This project is linked internationally with GREEN (Global Rivers Environmental Education Network) in Michigan, USA, as well as a programme in Australia, and locally with centres in the Umgeni Valley and the Witwatersrand.

The WRC is in the process of establishing a Research Co-ordinating Committee for Water Supply and Sanitation for Developing Rural and Urban Communities (CCRUC)

## Establishing research needs and priorities for water supply and sanitation

The WRC is in the process of establishing a Research Co-ordinating Committee for Water Supply and Sanitation for Developing Rural and Urban Communities (CCRUC). A broad spectrum of stakeholders has been invited to nominate representatives on the committee. The founding meeting of CCRUC will take place on 1 February 1995. One of the functions of CCRUC will be to establish a strategic research plan, based on research needs and priorities.

In order to lay some groundwork for the establishment of CCRUC, a workshop was held in April 1994 to establish the main issues to be addressed by future research. The workshop was attended by 34 delegates, likewise representing a cross-section of the main stakeholders. The proceedings of the workshop will serve as input to the initial deliberations of CCRUC in developing a strategic research plan. An interesting feature of the workshop's outcome is that technology development hardly featured in the range of themes that had been identified for research. Emphasis fell on aspects such as institutional matters, the role of women, communication strategies with user communities, and training.

## A novel solar distillation unit for potable water production

The Institute for Polymer Science of the University of Stellenbosch has developed a novel system for potable water production from saline water by enhanced solar distillation. Sunlight is allowed to enter the unit through a clear polymer film and is absorbed in a black bag, which contains water and allows water vapour to permeate through it. The vapour is then condensed and used.

A feasibility study was conducted on a small-scale solar still for emergency use, and a larger-scale still for rural household use as well as stock watering. An experimental single-effect unit was constructed first and results obtained with it were found to compare favourably with computer simulation results. A double-effect unit was constructed next and was found to be 60% more effective. Computer software models were developed for the units.

## Further light on novel low-cost sewage treatment process

The *1992 WRC Annual Report* (**Chapter 1**) mentioned PETRO (pond-enhanced trickling filter operation), a patented process whereby oxidation pond systems may be upgraded by the addition of trickling filters. Thereby the capacity of the system is substantially increased at reasonable cost. The system produces a consistently good quality effluent and can be operated with a minimum of supervision. The system has been developed and is being researched by the consulting engineering firm Wates, Meiring and Barnard Inc.

The PETRO project, now in its final year, has yielded exciting and novel results. The research team has shown that by passing a percentage of the effluent directly to the trickling filter, the biofilm within the filter changes and is able to capture micro-algae. The captured micro-algae apparently contribute to the effluent treatment process while in the biofilter, and the humus from a PETRO biofilter is more consolidated than from a conventional biofilter, settling more easily. Thus, not only can the process remove algae from oxidation pond effluent, but the final effluent has a lower suspended solids content than that from traditional trickling filters.

Full-scale plants are now operational in the following provinces at:

| | |
|---|---|
| KaNyamazane: | Eastern Transvaal |
| Letlhabile: | Northwest |
| Phola: | Eastern Transvaal |
| Elliot: | Eastern Cape |

## American experts advise on low-cost technology for effluent purification

During January / February Prof William Oswald and Dr Bailey Green of the Richmond Research Station, University of California, USA visited South Africa and participated in the 7th International Symposium on Anaerobic Digestion, held in Cape Town.

During the symposium, Prof Oswald elucidated his Integrated Algal High Rate Oxidation Pond (HROP) process. Before and after the symposium both he and Dr Green also acted as consultants for 2 WRC projects in which the HROP process is being evaluated by

> The PETRO system produces a consistently good quality effluent and can be operated with a minimum of supervision

Rhodes University for various applications. One of the projects involves the purification of tannery effluent by Western Tanning in Wellington, while the other involves the purification of sewage in Grahamstown.

The advantages of the HROP process are the low capital, and operational costs and the low technology involved. Designed properly (this being critical) the HROP process can be operated with only a small staff. An added advantage is that sewage can be purified to such a degree that it is suitable for irrigation. Applying the process to an industrial effluent with a high salt concentration, the possibility exists of culturing the micro-alga *Spirulina* which has a high protein content and is, among others, ideal nutrition for aquaculture.

## A new tool to facilitate decision-making in water allocation

A new decision-making tool to assist water resource managers to evaluate different (and often conflicting) policy options has been developed by the Department of Statistical Sciences, University of Cape Town. It is relatively simple to determine monetary advantages of, for instance, a new irrigation scheme or a forestry development; it is, however, far more difficult to place a concrete value on recreational or environmental considerations. It then becomes very difficult, in decision-making, to achieve an equitable balance between the conflicting requirements of society when non-material issues are at stake.

The new procedure is termed scenario-based policy planning and makes it possible for decision-makers to express value judgements by means of direct comparisons between alternative policy options. It can be applied when developing new water schemes or allocating water between competing uses, such as irrigation, public recreation and wildlife conservation and is based on the principles of widespread negotiation and consensus.

The full software support for the procedure is now being developed. Two further objectives of the ongoing research being funded by the WRC are to integrate the procedure with GIS or similar technologies for the most effective display of scenarios, and to test the procedures in real-life policy planning.

## Evaluation of waste sites to avoid groundwater pollution

It is generally accepted that most wastes can be landfilled without unacceptable detriment to the environment if the sites are carefully selected. Further, if expensive and technically difficult clean-up of groundwater contamination is to be avoided, landfills and aquifers must be kept apart. This separation concept is central to the method developed during the study **Development of a Systematic Method for Evaluating Site Suitability for Waste Disposal Based on Geohydrological Criteria**, undertaken by the CSIR's Division for Water Technology. This led to the waste-aquifer separation principle, abbreviated as WASP.

User-friendly software has been developed to calculate the WASP index. The WASP procedure is used for initial site screening and ranking, for defining further data needs, and for the final determination of site suitability.

## "Emerging technologies" in drinking-water treatment

From 5 to 9 March 1994 a group of scientists, engineers and managers from 12 different countries assembled in Cape Town to share information on innovative technologies relating to potable water.

This was the sixth in the series of "Emerging Technologies" summits, arranged by the American Water Works Association Research Foundation (AWWARF) since 1984. These meetings are held biennially, each time in a different country. The WRC acted as host for the Cape Town event.

Discussions ranged over a wide range of topics, with 3 special themes receiving special attention: Advances in water quality monitoring; water utility software; and membrane applications in potable water treatment. Summary reports on 123 leading-edge technolo-

gies were made available to the meeting by the AWWARF in the form of a bound resource book. Each country representative(s) had to make one or two presentations at the meeting for in-depth discussion. The South African presentation demonstrated an expert software package for water treatment process selection and plant design, currently being further developed under the auspices of the WRC.

## The use of waterworks sludges to produce bricks or tiles

Vast amounts of sludges and silts produced by waterworks often create serious disposal problems and can cause the degradation of land or fouling of waterways. The Division of Materials, Science and Technology of the CSIR studied the technical and economic feasibility of using waterworks sludges for the manufacture of bricks, blocks, tiles or other ceramic products.

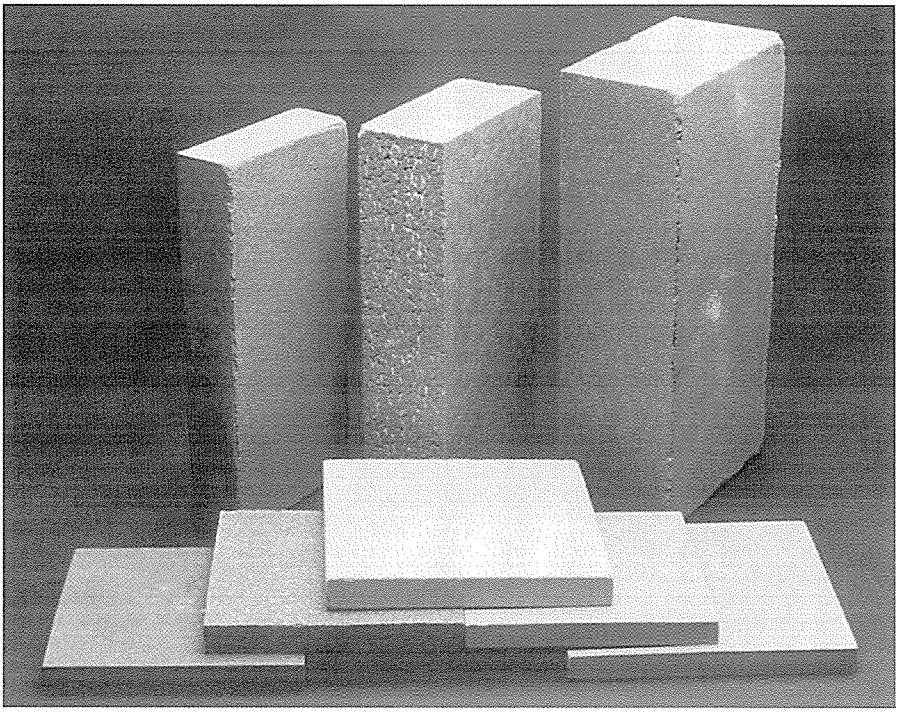
It was found that the sludge obtained from Umgeni Water's Wiggins plant was quite suitable for the production of rustic tiles and stock and face bricks, particularly for use in low-cost housing.

Seen at Emerging Technologies VI at the Cape Sun Hotel in March 1994 are, from left to right: Ir. Jan Janssens, Belgium (World Bank), Prof Dan Bursill, Australia, Dr Ken Roberts, Canada, Mr Bill Richards, SA, Mr James Manwaring, USA, Prof Jan Schippers, the Netherlands. With backs to camera: Prof Géza Öllös, Hungary, Dr Wim van Craenenbroeck, Belgium.

## Salinisation a growing problem in water supply

Pollution of South Africa's water sources creates a growing problem for sustainable water supply, inasmuch as it significantly diminishes the suitability of water for the majority of uses. Certain experts are of the opinion that the problem of sustained provision of water of acceptable quality presents a bigger long-term challenge than meeting quantitative needs. In this regard salinisation probably is South Africa's most serious pollution problem. Various sources contribute to this problem: Industrial and municipal effluents, drainage waters from irrigation areas, seepage from mining waters, stormwater drainage from urban and agricultural areas, etc.

Uncertainties regarding methodology and suppositions during a previous attempt to determine the financial losses posed by salinisation for various user sectors were recently identified. These uncertainties create risks in analysing the cost benefit of alternative options to lower the salt content of water. This gave rise to a feasibility study in 1994, funded jointly by the WRC and the DWAF, for the establishment of a generic methodology to calculate the financial, economic and social impact of increasing salinisation. A similar methodology has not yet been developed elsewhere in the world.



Rustic tiles and bricks made of waterworks sludges.

## Occurrence of radionuclides in aquatic environment

The occurrence of radium and uranium in 3 aquatic environments affected by gold and uranium mining activities, was investigated by the Department of Zoology, Rand Afrikaans University.

In order to evaluate the potential effects of these radionuclides on man, studies were conducted on the concentration ratios of radium and uranium in selected aquatic plants, fish and water birds, and the abiotic environment in which they occur, including vegetable crops irrigated with mine-polluted river water. A dose assessment model was used to study various potential pathways of both radionuclides to man including via the soil, drinking water, vegetables, a cereal and fish.

Field results showed that in virtually all cases the presence and concentrations recorded for both radionuclides were at least an order of magnitude lower than concentrations found in countries such as Japan, Germany and the USA. In all cases concentrations also fell below the maximum recommended guideline values laid down by the Council for Nuclear Safety in South Africa. The dose assessments for the scenarios chosen indicated that the annual effective dose for uranium and radium is a fraction of the allowable limit for humans.

## Passive systems to curb mining pollution

Pollution of water by mining activities is increasingly coming to the fore and in recent times the attention of the DWAF's Division of Pollution Control has become more sharply focused on its impact.

According to the strategic research plan for research into mining-related water pollution, developed in 1993, the most urgent need was the identification and evaluation of strategies and technology to manage this type of pollution. In this regard research on passive systems (e.g. artificial marshlands) for sustainable treatment of mining effluents and drainage, has been identified as a high priority. In pursuance hereof the WRC entered into an agreement with the CSIR to undertake a feasibility study to test the potential extent and advantage of such technology in South Africa. The indications of the investigation were positive to such a degree that a full-scale investigation will be launched in 1995.

Pollution of water by mining activities is increasingly coming to the fore and in recent times the attention of the DWAF's Division of Pollution Control has become more sharply focused on its impact

## Collaboration with Australian aquatic scientists

A group of Australian aquatic scientists and resource managers visited South Africa in March 1994 to join their South African colleagues in a workshop on river classification and river health assessment. The Australian delegation was led by Prof Barry Hart, Director of the Water Studies Centre at Monash University, Melbourne. Some 50 South African water researchers and managers attended the workshop which was organised jointly by the WRC and the Foundation for Research Development (FRD).

Considerable diversity in approaches along with new insights and ideas generated by the workshop, contributed to the overriding impression that there is much to be gained from collaborative research with regard to both river ecology and management practices.

## Managing pollution in urban impoundments

Urban impoundments are created for the dual purpose of providing recreation and to control storm water. The increasing pressures of urban living on the man-in-the-street enhance the value of such facilities. It provides some escape from the "concrete jungle" and often congested living conditions.

Unfortunately, these impoundments are fed predominantly by the often polluted storm-water runoff from urban catchments. The result can be highly polluted impoundments which lose aesthetic appeal, and could become a public liability by posing safety and health risks. A firm of consulting engineers Stewart Scott Inc. has, therefore, been contracted to investigate problems experienced by existing impoundments, to identify and evaluate appropriate ameliorating processes, to apply these on a few selected impoundments, and to compile a manual providing guidelines for their management.

## Dilution studies for marine discharge of effluents

The environmental impact of effluent discharge through offshore pipelines, is governed by both initial and secondary dilution. Initial dilution takes place when the effluent which is discharged at the seabed rises to the surface. Secondary dilution is effected by currents which move the surfaced effluent away from the discharge area.

The extent of initial dilution in a stagnant and uniform environment, i.e. where no currents or temperature variations exist, is relatively easy to calculate. Such calculations have been used in the past for the design of marine outfalls in South Africa. However, as stagnant uniform conditions are rarely encountered, these calculations underestimate the initial dilution and result in the over-design of outfalls. Although this results in a better-than-aimed-for environmental impact, it also results in unduly expensive outfalls.

The performance of 3 variations of South Africa's currently operating offshore pipelines was monitored by the Division of Earth, Marine and Atmospheric Technology (EMATEK) of the CSIR. The localities were Richards Bay, Hout Bay and Mossgas and the purpose was to rate the accuracy of available numerical design models, in terms of initial dilution, under actual field conditions. The study constituted the first step towards optimising the design of future outfalls.

It was shown that stagnant uniform theories are inappropriate if ambient current speeds exceed 30 cm/s, underestimating initial dilution by a factor of more than 6. On the other hand, the dilutions predicted by the more sophisticated models developed by the US Environmental Protection Agency, the UK

Water Research Centre and by EMATEK, compared well with the measured dilutions, despite the diversity of ambient conditions.

## Protein reclamation from abattoir effluents

The University of Pretoria has developed a process whereby single-cell protein is cultured in abattoir effluent and reclaimed for the enrichment of feed.

A feasibility study was conducted at Abakor's abattoir in Kimberley by consulting engineers Burger, Pretorius and Partners. Positive results have led to the commissioning of a full-scale plant at Abakor's abattoir in Johannesburg. The process removes in excess of 90% of the abattoir's organic load in the effluent and saves the abattoir approximately R4m. in disposal costs annually, while producing protein to the value of about R1m. per year.

Certain of the advantages of the process are that it is environmentally friendly, provides an additional protein source, and relieves the pollution at existing municipal sewage purification works, leading to the prolonged design lifetime of works.

According to estimates, the investment capital and interest of the plant will be paid off within one year through the reclamation of protein.

## "EMILY" – the electronic membrane information library

EMILY was developed by the Pollution Research Group of the University of Natal. It was first conceived as a means to disseminate information on and to stimulate evaluation of a model for tubular reverse osmosis systems, developed in terms of a WRC project. The idea was to make the model data globally available through Internet, the international computer network. From these modest beginnings, EMILY has grown to become an international clearing-house for membrane information, covering – in addition to computer models – information on aspects such as membrane-related conferences, publication lists, manufacturer's data and newsletters.

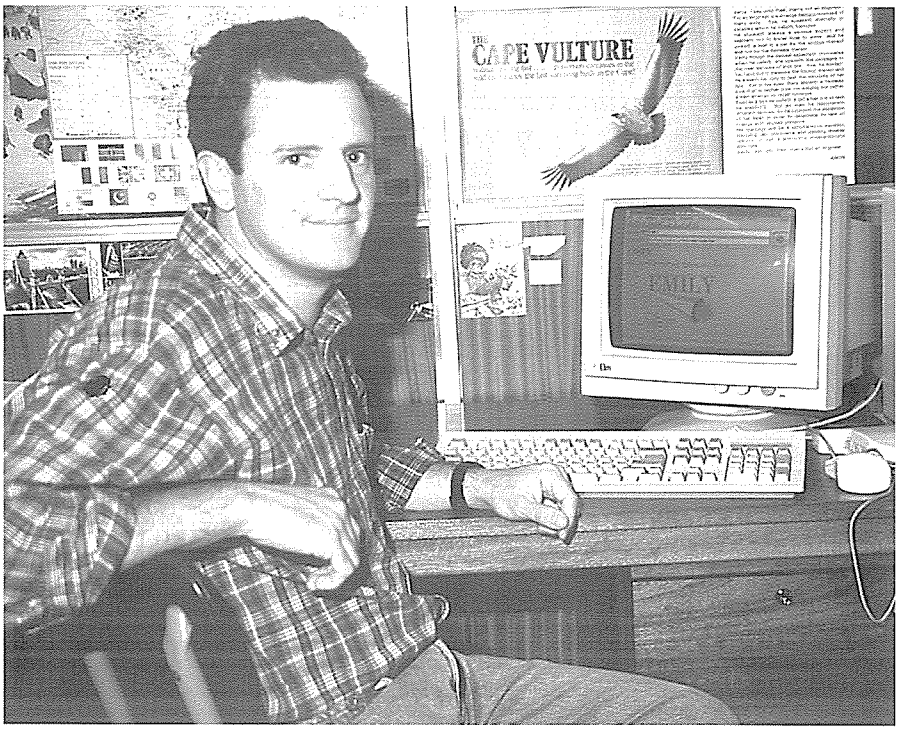
EMILY forms a sound basis for establishing a global network of membrane specialists. During the first 3 months of its existence, EMILY recorded more than 4 000 log-ins from all over the world, representing more than 2 000 different users. The administration of EMILY will continue during 1995 and it is planned to use it as a basis to train water researchers in the use of Internet.

## Removal/recovery of heavy metals from waste waters

Heavy metal ions are toxic when released into the environment, due to a process of bio-accumulation, for example by fish consumed by humans. Similarly, the use of metal-contaminated effluent and sludges in agriculture poses a real threat to consumers, since the metal ions are concentrated by crops or animals intended for human consumption.

A study by the Department of Biochemistry and Microbiology of Rhodes University, indicated that yeast cells are capable of accumulating various heavy metals, preferentially metals that are valuable and those having potential toxicity. The yeast cells were found to retain their ability to accumulate heavy metals under a wide range of ambient conditions. For bio-accumulation it is necessary to retain the biomass, and this was done through cell immobilisation. The metals can be freed from the biomass by chelating agents, and the biomass then recycled for further use. This process not only enables the remediation of metal-contaminated waste waters, but also allows the recovery of valuable metals.

In a separate study, the Department of Microbiology of the University of Durban-Westville conducted an investigation into the biosorptive capacities of industrial sludges for heavy metals. It was shown that waste-activated sludges served as efficient biosorbents for heavy metals from various effluents. The metals could be readily desorbed at a later stage and safely disposed of, or recovered for reuse.



Mr Quentin Hurt at the electronic membrane information library (EMILY) repository.

## Computer models maximise irrigation efficiency

Researchers at the Department of Agrometeorology at the University of the OFS successfully demonstrated – under normal farming conditions – the validity of a computerised irrigation scheduling method employing weather data and based on 20 years of irrigation research. This was done during a project where irrigation farmers at Winterton, Taung, Karkloof and Reitz participated on a voluntary basis. Thereby the scheduling method was tested under different climatic and soil conditions, using a range of irrigation equipment and water supplies.

During the project, the farmers did not modify their normal farming methods. They decided what, where and when to plant and, as in the past, used the same irrigation equipment. They did, however, apply the researchers' advice on irrigation scheduling. Participating farmers not only increased their crop yields, but also experienced significant savings in pumping costs. Indicative of the success of the experiment is that some of the larger irrigation farmers have invested in automatic weather stations and computer equipment and that some smaller farmers are now prepared to pay for routine irrigation advice.

The experiment is now being extended over a much wider area, so as to test the success of providing irrigation scheduling services to even more remote farms. Farms as far afield as Northern Transvaal and Western Cape are being included in the project. The level of interest generated is such that costs of the research are largely being recovered through payment for services provided by researchers. In fact, the project has sponsored full-time irrigation scheduling consultants who provide a commercial service based on methods developed in this project.

## Co-operation with the UN Food and Agricultural Organisation (FAO) on crop irrigation requirements

A local consulting engineering firm Murray, Biesenbach & Badenhorst Inc. (MBB) completed a project on the development of a PC-based program for crop irrigation requirement determination.

A Southern African collaborative hydrological project known as FRIEND, has been launched

This program, called SAPWAT (Southern African Procedure for estimating irrigation WATer requirements) is currently being further developed, and in order to bring it in line with procedures used elsewhere in the world, a workshop was organised in June 1994 to attend to this need. Mr Martin Smith, at present heading the FAO's activities as far as standardisation is concerned, participated in and guided the workshop on the refinement of SAPWAT and its further development.

The following fields for future co-operation with the FAO were identified at the workshop:

- Involving local researchers in the FAO Working Group on Crop Water Requirements and introducing FAO methodologies in local irrigation planning and management
- Involving local scientists in the International Commission on Irrigation and Drainage (ICID) Irrigation Scheduling Seminar in 1995
- Co-operation of the FAO in local development priorities, in particular as far as assistance programmes for developing farmers are concerned.

## Weather modification research about to enter a new phase

Since 1990 research aimed at rainfall enhancement from summer cumulus clouds has focused on the use of aircraft-mounted pyrotechnic flares to deliver hygroscopic seeding material into the updraught regions near the bases of clouds. The research is being carried out by the Weather Bureau and CloudQuest.

A randomised cloud seeding experiment based on this hygroscopic seeding technique has now been conducted in two areas (Eastern Transvaal and North-Eastern Free State) over a period of 3 seasons. The research provided convincing statistical evidence that individual thunderclouds, some 25-30 minutes after seeding, begin to produce substantially more rain than their non-seeded counterparts. The average increase over the lifetime of the clouds appears to be approximately 30%. The repeatability of the responses to seeding has been such that continuation of the experiment is regarded as unnecessary.

Microphysical observations of the nature and behaviour of hygroscopic particles before and after ingestion by the clouds, support the hypothesis that these particles initiate accelerated growth of cloud droplets to precipitation particle sizes through coalescence.

The initial phases will be devoted to pilot investigations designed to provide information for a formal, statistically planned experiment in this regard.

## International hydrological co-operation

A Southern African collaborative hydrological project has been launched, known as FRIEND (Flow Regimes from International Experimental and Network Data). The project is organised within the framework of UNESCO's International Hydrological Programme. Financial support is provided by UNESCO, Ireland, the British Overseas Development Aid and the WRC.

The project is supported by the Environmental and Land Management Sector of the Southern African Development Community (SADC) and all the SADC countries are participating: Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.

The project's objectives are to:

- Create a common hydrological data base for the region by bringing together existing data sets from participating countries. A total of 1 000 gauging stations will be presented in the data base.
- Analyse flood and low-flow data and to develop appropriate methods for the region.
- Develop and test rainfall-runoff models for more detailed design studies and to address the impact of land-use change.
- Provide training.

The project is centred at the University of Dar es Salaam, Tanzania, with active research aid from the Institute of Hydrology in Wallingford, UK. The South

African contribution is made up by the DWAF, that will supply all the necessary data, and the Institute for Water Research at Rhodes University, that will provide research capability.

## Dam siltation

On average, South Africa loses a dam with the storage capacity of the Hartbeespoort Dam every 2 to 4 years, because of siltation. Against this background and in order to determine the extent of the problem, the WRC tasked a firm of consulting engineers, Sigma Beta, to update an existing siltation map. The new map indicates the areas with the highest erosion potential, and therefore the highest siltation impact. Fortunately, South Africa has one of the best data sets in the world on dam siltation. Data on the problem have been collected since 1928.

The map assists planners to predetermine how much silt can be generated from a specific area in a given period – information that can be very important in planning the siting of new dams or indicating that special measures need to be taken to limit silting in a new dam. The map can also act as a guideline on where attention should be given in combating soil erosion.

## Encouragement for young water scientists

The Stander Commemorative Lecture is delivered biennially by a prominent person in the water field, under joint sponsorship of the Water Institute of Southern Africa (WISA), the Division of Water Technology (WATERTEK) of the CSIR, and the WRC. This year the commemorative lecture was delivered by Mr PGJ Meiring of the consulting engineering firm Wates, Meiring and Barnard Inc. and, as in previous years, a young scientist of WATERTEK, in this case Dr Heather MacKay, also delivered a presentation.

The WRC decided for the first time to avail itself of the opportunity to honour two young scientists (younger than 30 years) who had carried out outstanding research in WRC-supported projects. Rebecca Tharme of the Unit for Freshwater Research of the University of Cape Town, and James Meyer of the Department of Animal and Wildlife

On average, South Africa loses a dam with the storage capacity of the Hartbeespoort Dam every 2 to 4 years, because of siltation

Science of the University of Pretoria were the recipients of this honour. Rebecca Tharme has for some time been involved in research on the water requirements of ecosystems, specifically streamflow requirements. She has developed into a leading researcher in this field, nationally as well as internationally.

James Meyer's research is aimed at developing methods to evaluate the suitability of borehole water for animal production. He laid the basis for a unique index system integrating all the variables into a single-digit index. Measured against current outdated norms, it often happens that water from boreholes (for the best part sunk with state funds) is declared unsuitable, while it may in actual fact be suitable in the specific production situation. The savings effected as more boreholes are being utilised, are evident.

As a further initiative to develop and encourage young scientists, the WRC has since 1993 made available two bursaries annually. This year the bursaries for 1995 were awarded for research on the theme *Water for the People*. The recipients were Miss GM King of the DWAF in Durban and Mr MJ Mphahlele of Medunsa.

## Senior staff changes

Dr MJ Pieterse, Deputy Executive Director, retired in April. He had been with the WRC since 1976.

Dr OO Hart, Research Manager, retired in November. He had been with the WRC since 1978 and had been responsible for research relating to industrial water and effluent management.

Dr GC Green was appointed Deputy Executive Director as of 1 May. He has been with the WRC since 1983.

Mrs APM Oelofse joined the WRC in August as Research Manager responsible for research relating to potable water quality and health aspects. She was previously employed by Sasol's Waterworks Division, Secunda.

Mr ZT Ngcakani, previously from the Ontario Department of the Environment, Toronto, Canada, joined the WRC in November as Research Manager responsible for research relating to industrial water and effluent management.

# 2
# Developing communities

The RDP has created a new focus on water and a resolve to achieve an equitable and wholesome water supply to all and especially to the rural and peri-urban areas of South Africa. As a result the labours of researchers and others working in the area of water supply have taken on a new impetus which deserves sustained support.

Recently completed research has investigated the accessibility of both water and sanitation facilities to people living in the densely populated urban areas. Large numbers of backyard dwellers in these areas are often denied access to such facilities by the owners.

Shortcomings in water supply policies with regard to various consumers have also been identified.

Information gathered seems to indicate that a number of currently applied standards are unacceptable to certain consumers in some circumstances although they may be perfectly adequate in other circumstances. For drought relief, emergency supplies or temporary schemes, people may accept 20 *l* of potable water *per capita* per day. However, established villages, which may have existed for centuries in some cases, will definitely require a much higher *per capita* allocation. In cases where this has not been foreseen the systems fail. Reservoirs on the high ground never receive water as consumers in the areas closest to the borehole or source of water consume all of the water. Residents on the higher ground or outlying areas may have to buy water at as much as 50c for 25 *l* (R20 per k*l*).

Other institutional limitations also work against the interests of the smaller communities. These communities are very often the most desperate of all, due to the very small financial resource base.

During 1994 the WRC supported 25 projects directly related to developing communities of which 4 were completed during the year and 8 commenced.

## Completed projects

### Development of drought response policy options for the cost-effective provision of water supply to rural communities subject to recurring drought

(No 506) Division of Water Technology, CSIR

Drought policy formulation has come through an evolutionary process in the last 150 years in which 4 stages can be identified i.e. famine relief, scarcity relief, drought relief and drought management.

The objective of the project was to develop drought response policy options with regard to water supply to rural communities. The report relates drought susceptibility to both the physical and socio-economic framework in South Africa with in most cases, the socio-economic framework being even more important than the physical one. The report offers the reader a useful, though not exhaustive, guide to the process of developing strategies for coping with droughts.

*Cost:* *R90 000*
*Term:* *1993-1994*

### Water and sanitation in urban areas: Survey of on-site conditions

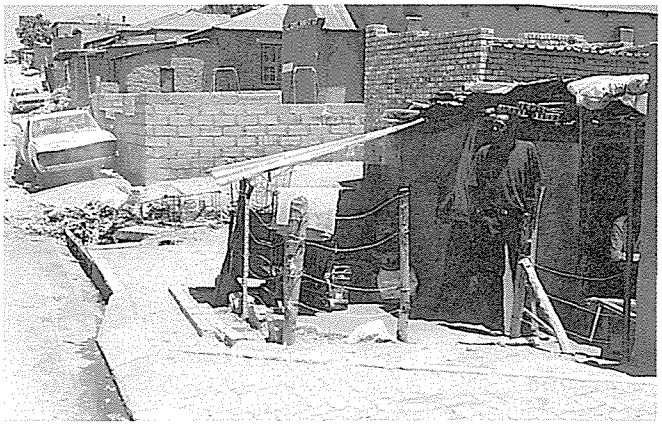
(No 561) Palmer Development Group

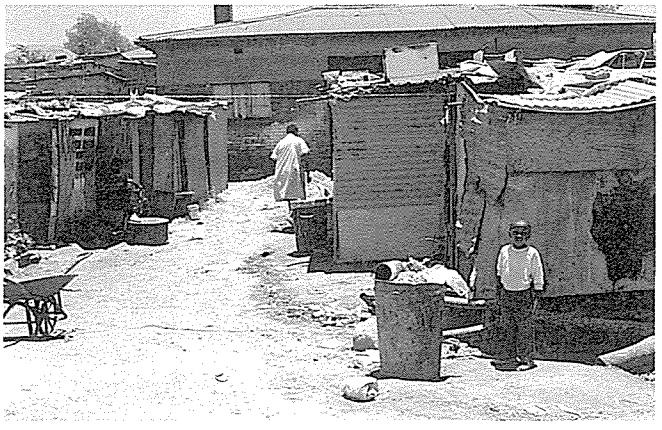
Access to water and sanitation facilities is largely influenced by the social conditions under which poorer people live in urban areas.

The project covered 6 township areas nation-wide, and found that, in the short to medium term, the number of backyard tenants is unlikely to decrease as tenants are an important source of income to the main household and by living closer to places of employment, tenants save on transport costs and time.

Although living conditions are far from ideal, most backyard dwellers enjoy access to better levels of services than the occupants of informal and squatter settlements. This does, however, place a burden on bulk services such as sanitation and water supply, which often fail under the excessive population densities. Authorities are reluctant to augment the existing bulk sewer and water supply services as the costs would be prohibitive. There is some speculation that as more land becomes available for housing development, coupled with improved economic activity, more and more of the backyard dwellers will move out to establish their own homes, thus relieving current overloading of facilities.

The generation of domestic refuse also easily exceeds the capacity of the local cleansing services and results in an unsightly environment, high pollution loading during storm runoff and health





The burgeoning problem of backyard dwellers is impacting heavily on the capacity of water supply and sanitation systems.

risks. A new project (see No 629 under **New Projects**), addressing this problem, commenced during the year.

*Cost:* *R75 000*
*Term:* *1993*

### SANPLAT: A simplified latrine system for rural and squatter areas

(No 563) Division of Water Technology, CSIR

The simplicity of the SANPLAT latrine and its success elsewhere in Africa prompted this project to investigate its applicability and acceptance in South Africa.

In its original form (Mozambique, Kenya, Malawi), SANPLAT comprised a domed concrete squat slab, with a keyhole-shaped access. Locally this type of arrangement was viewed unfavourably as being too primitive. Various types of pedestal seat were developed to make the system more acceptable to local users. In this form it now approximates an unimproved pit latrine and the primary advantages of the original SANPLAT concept have been largely negated. These were: simple on-site construction, cheap, easy to keep clean, very low maintenance, reusable, unnecessary to transport paraphernalia such as toilet seats and lids, vent pipes etc., over large distances.

*Cost:* *R94 600*
*Term:* *1993-1994*

### Water and sanitation in urban areas: Financial and institutional review

(No 571) Palmer Development Group

This ambitious project aimed to present and analyse water supply information to guide and promote the extension of services and reshape local authority structures to enable all people living in the urban areas to have adequate and appropriate water supply and sanitation services. In the short term, all local authorities will be undergoing major transformations and restructuring.

To assist them in making early investment decisions on the development and evaluation of investment scenarios and tariff policy, whilst maintaining the financial viability of the service, an investment-tariff model was developed. This model has been recommended by the Department of Finance as a guideline for all local governments to follow. Originally envisaged as a water supply model it was later adapted for sanitation services as well, largely with the assistance of the Durban Corporation.

The investigation resulted in the publication of 6 reports and 7 working papers, many of which have already been in great demand.

*Cost:* *R300 000*
*Term:* *1992-1993*

## New projects

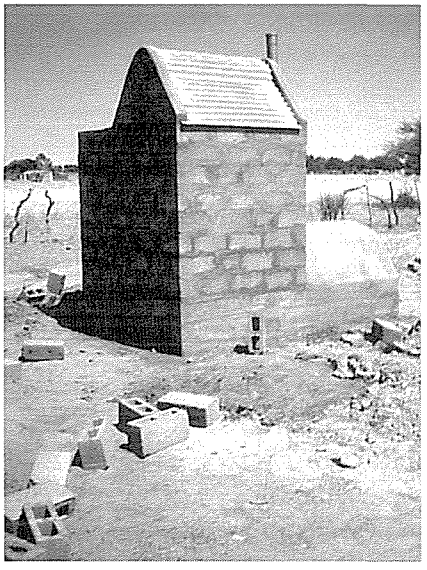
### Appropriate management of urban runoff in South Africa

(No 598) Water Systems Research Group, University of the Witwatersrand and Division of Water Technology, CSIR

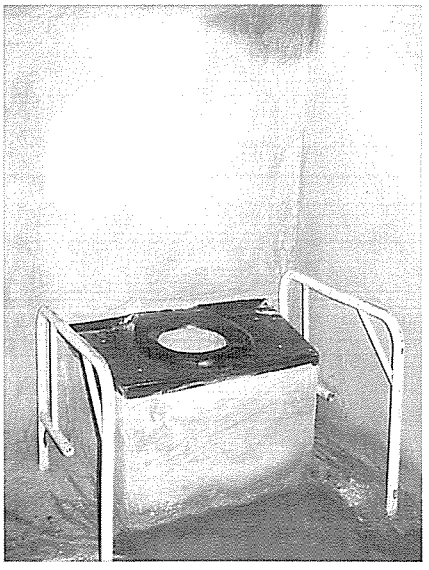
The application of wetlands as a treatment facility for diffuse or point-source runoff from developing urban areas is not a new concept, but is one which is fraught with uncertainties regarding physical, chemical, managerial and socio-cultural aspects. Wetlands also support a range of wildlife and an abundance of plant material, both of which could have, and in many areas of the world do have, commercial value. Other values often ascribed to wetlands are their educational value and their ability to attenuate flows. For these reasons they have been referred to as the "kidneys" on the landscape, and the potential advantages of wetlands render them desirable assets in developing urban areas in South Africa.

There are as yet no general guidelines to assist in identifying when and where wetlands will be most valuable or in what instances they may in fact be inappropriate in terms of cost-benefits. The main aims of this project, therefore, are to establish general guidelines to determine when and where wetland technology would be appropriate in developing urban communities. In order to achieve this, the performance of natural and constructed wetlands will be evaluated to ascertain whether urban runoff and domestic waste water can be treated so that the final effluent meets the standards of fitness for use for irrigation, recreation, aquaculture, domestic supply or discharge to surface waters in the catchment.

*Estimated cost:* *R532 600*
*Term:* *1994-1996*



A Phungalutho VIP toilet built by the local community – note the vent pipe on the "sunny" side.



Adaptation to a VIP toilet to facilitate use by handicapped people.

## Co-disposal and composting of septic tank and pit latrine sludges with municipal refuse

(No 599) Division of Water Technology, CSIR and La Trobe Ass.

In terms of an earlier project (No 341), the viability of co-composting night-soil and unsorted domestic waste was demonstrated at a plant at Rini, near Grahamstown. Whether the same excellent results could be achieved using the digested, stabilised sludges from pit latrines and septic tanks is, however, unclear. Should the experiment prove successful a double benefit of the joint disposal of 2 sources of waste, namely sanitation sludge and domestic waste and the production of a useful soil conditioner cum fertiliser could be realised.

For these new materials, therefore, the project aims to:

- Establish that co-composting can be a safe and low-cost disposal method
- Establish the operational parameters
- Assess the economic and environmental implications
- Assess the viability for developing communities in more remote areas.

*Estimated cost:* *R210 000*
*Term:* *1994-1996*

## Development of effective community water supply systems using deep- and shallow-well handpumps

(No 603) Division of Water Technology, CSIR

Deep- and shallow-well handpumps are used extensively for rural community water supplies over large parts of South Africa. Very often these installations fail due to poor pump selection, poor pump installation and inadequate maintenance.

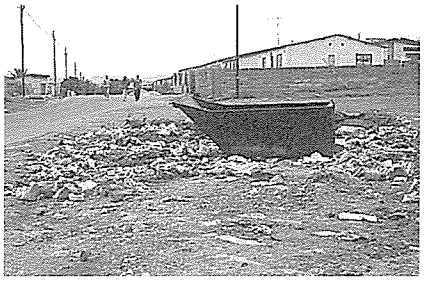
It has been demonstrated in other parts of the world that reliable low-cost solutions are possible through the adoption of the so-called "Village Level Operations and Maintenance" (VLOM) concept, a concept in terms of which appropriate design technologies and implementation policies are systematically included in the design and installation of handpump systems.

This project intends to:

- Survey and evaluate current installation practices
- Assess the economics and effectiveness of the current system of centralised maintenance
- Evaluate the handpumps currently available in South Africa
- Assess the potential of VLOM-type pumps for local use
- Assess the potential for training local community-based operation and maintenance staff.

*Estimated cost:* *R381 000*
*Term:* *1994-1996*


Local area initiatives are beginning to appear.



Inadequate solid waste collection adds to the pollution load from developing areas.

## Evaluation of solid waste practice in developing urban areas in South Africa

(No 629) Palmer Development Group

Stormwater runoff from urban areas carries pollutants from streets, stands and open space and is a major contributor to the diffuse pollution load on receiving rivers and impoundments.

To a large extent the resulting problem appears to be related to the solid waste management practice in the area concerned.

Solid waste removal practice also impacts on the functioning of sanitation systems since people may try to dispose of domestic wastes down toilets or manholes if waste removal is inadequate. Health, odours, fly and mosquito breeding are all affected by adequate waste removal.

The project aims to:

- Determine how effectively domestic solid waste is removed
- Determine the factors which influence solid waste removal
- Link solid waste management practices to stormwater runoff quality
- Estimate costs
- Propose methods for improving solid waste removal.

One product of the research project will be an information document giving suggestions for improving solid waste removal arrangements, for use by all levels of authority.

*Estimated cost:* *R221 000*
*Term:* *1994-1996*

## Community participation and education in water resources management and environmental awareness

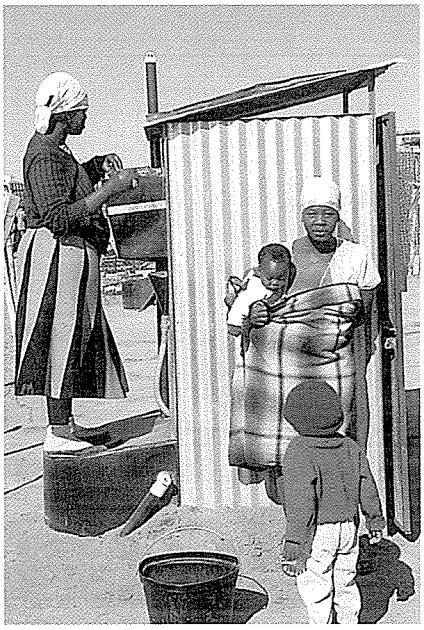
(No 630) Amanzi Esizwe

Development agencies responsible for water resources management and environmental awareness within communities need to be sensitive towards community aspirations, development needs and cultures. With this in mind, the project aims to determine the parameters which need to be considered by development agencies in order to understand the socio-economic, political and cultural factors pertinent to community participation. This will be achieved by assessing the factors which influence and motivate communities to participate actively in development programmes and by investigating the suitability of community structures as vehicles for community development.

The main product of the research will be to establish guidelines for promoting community participation through education programmes aimed at raising the level of environmental awareness among communities. This will make a positive contribution towards developing a better understanding of the environment in which the development agencies and the developing communities operate. The study will consequently help lay bare the variables that are pertinent to meaningful community development processes relating to the provision and use of water and its infrastructure.

The study will take place in a number of areas nation-wide.

*Estimated cost:* *R261 000*
*Term:* *1994-1995*



LOFLOS (low-flush on-site sanitation) is an alternative on-site sanitation system.

## Assignment of a financial cost to pollution from on-site sanitation, with particular reference to Gauteng

(No 631) Department of Civil Engineering, University of the Witwatersrand

Sanitation has always been a sensitive subject and the emergence of very dense urban settlements has escalated sanitation to one of the most emotional issues facing the new South Africa. One of the key decisions in a strategy to provide water and sanitation to the inhabitants of Gauteng (and elsewhere in the country), is whether to permit the use of on-site sanitation on a widespread scale.

The high cost of conventional water-borne sewerage compared to on-site sanitation systems makes this option virtually unattainable at present, given the country's limited financial resources. It has been estimated that the scenario in which full water-borne sewerage would be provided for all in the urban areas by the year 2000, together with the appropriate water supply, would cost some R30 bn. in capital costs (1990 Rands) and a further amount of R1,6 bn. annually. However, if 50% of sanitation systems in the urban areas of the country by the year 2000 would be ventilated improved pit (VIP) latrines, costs would come down to about one-third of the above.

The environmental impact of such widespread use of on-site sanitation may be significant and needs careful evaluation. More specifically the project aims to:

- Establish a generalised methodology for assigning a financial cost to water pollution
- Apply this methodology to pollution from on-site sanitation
- Apply the methodology to pollution from on-site sanitation in Gauteng to obtain a first estimate of the implications and financial costs of this pollution for various sanitation planning scenarios.

*Estimated cost:* *R155 100*
*Term:* *1994-1995*

## Common problems associated with drinking-water disinfection in the developing areas

(No 649) Division of Water Technology, CSIR

A lack of knowledge and applicable information exists on the reliability and operational problems associated with drinking-water disinfection units for rural and small users. Some problems encountered with installed units, such as intermittent disinfection, could have very serious health consequences.

The aims of this project are to:

- Establish the current status of drinking-water disinfection in developing areas
- Assess the efficiency and reliability of operation and to identify common problems and reliability of installed disinfection units
- Propose revised standards for disinfection systems and assess the value of alternative technologies to overcome the problems identified in the survey.

*Estimated cost:* *R40 000*
*Term:* *1994*

## Appropriate low-cost sewage treatment using the advanced algal high-rate oxidation pond

(No 651) Department of Microbiology and Biochemistry, Rhodes University

As new informal settlements mature into permanent township development, the provision of essential services, including water-borne sewerage, can be expected to become an important socio-political and funding problem.

Conventional sewage treatment plants will be unaffordable, therefore innovative technology and a re-evaluation of available cost-effective alternatives to current practice need to be investigated.

The advanced algal high rate oxidation pond (HROP) presents a low-cost option for sewage treatment.

This project aims to make low-cost sewage treatment technology available as an option for consideration by devel-

oping communities, new township developments or the upgrading of existing facilities by way of a demonstration plant.

*Estimated cost:* *R597 000*
*Term:* *1994-1995*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  (Health Aspects)
- **Mr G Offringa**
  (Water Treatment)

☎ **(012) 330-0340**


## Research projects

### Completed

- **506** Development of drought response policy options for the cost-effective provision of water supply to rural communities subject to recurring drought (CSIR – Division of Water Technology)
- **561** Water and sanitation in urban areas: Survey of on-site conditions (Palmer Development Group)
- **563** SANPLAT – a simplified latrine system for rural and squatter areas (CSIR – Division of Water Technology)
- **571** Water and sanitation in urban areas: Financial and institutional review (Palmer Development Group)

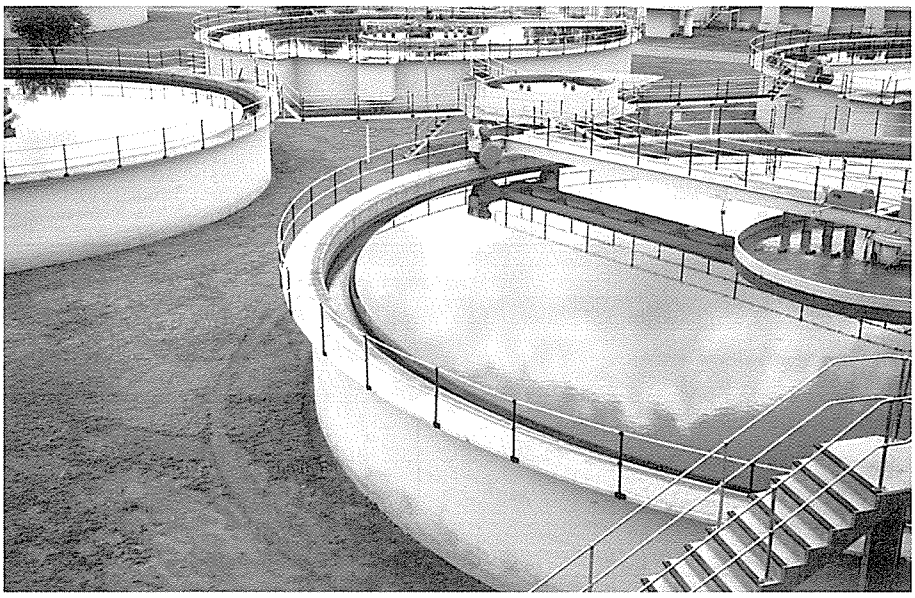
### Current

- **346** Study of the relationship between hydrological processes and water quality characteristics in the developing Zululand coastal region (University of Zululand – Department of Hydrology)
- **384** Water resources and sanitation systems source book with special reference to KwaZulu-Natal (Natal University – Department of Economics)
- **386** Development of a cross-flow microfilter for rural water supply (Umgeni Water and the University of Natal – Department of Chemical Engineering)
- **435** Development of a training programme on community water supply management for village water committees (CSIR – Division of Water Technology)
- **480** *Per capita* water demand in developing communities (Water Systems Management)
- **514** Groundwater contamination as a result of Third-World type urbanisation (CSIR – Division of Water Technology)
- **519** Development of programmes to combat diffuse sources of water pollution in residential areas of developing communities (Afrosearch CC)
- **520** Guidelines on appropriate technologies for water supply and sanitation in developing communities (CSIR – Division of Water Technology)
- **521** Water scheme cost recovery (Umgeni Water)
- **539** Dynamic cross-flow sand filter for rural water treatment (CSIR – Division of Water Technology)
- **544** Determination of sludge build-up rates in septic tanks, biological digesters and pit latrines in South Africa (CSIR – Division of Building Technology)
- **562** Effect of water supply, handling and usage on water quality in relation to health indices in developing communities (CSIR – Division of Water Technology)
- **586** Development of a decision support system for the selection of the most appropriate sanitation option for developing communities (Umgeni Water)

### New

- **598** Appropriate management of urban runoff in South Africa (University of the Witwatersrand – Water Systems Research Group and CSIR – Division of Water Technology)
- **599** Co-disposal and composting of septic tank and pit latrine sludges with municipal refuse (CSIR – Division of Water Technology and La Trobe Associates)
- **603** Development of effective community water supply systems using deep- and shallow-well handpumps (CSIR – Division of Water Technology)
- **629** Evaluation of solid waste practice in developing urban areas in South Africa (Palmer Development Group)
- **630** Community participation and education in water resources management and environmental awareness (Amanzi Esizwe)
- **631** Assignment of a financial cost to pollution from on-site sanitation, with particular reference to Gauteng (University of the Witwatersrand – Department of Civil Engineering)
- **649** Common problems associated with drinking-water disinfection in the developing areas (CSIR – Division of Water Technology)
- **651** Appropriate low-cost sewage treatment using the advanced algal high-rate oxidation pond (Rhodes University – Department of Biochemistry and Microbiology)

# 3
# Drinking water



Although approximately 12 million people, mostly rural, in South Africa do not have access to drinking water that has been purified to any acceptable standard, the remaining 28 million of the population receive potable water from treatment plants spread throughout the country.

Notwithstanding the fact that this treated water is regarded as potable, a number of issues still remain to be researched in order to ensure the continued well-being of South Africans who will now or in the future consume some form of treated water. These issues could be grouped into 2 main categories:

- **Costs to the consumer**: To ensure that potable water is made more affordable, especially to the lower income households, research is urgently required to develop less expensive treatment processes, plant and equipment, suitable for South African conditions, **without sacrificing water quality**. Producing an acceptable quality of drinking water from our eutrophied, and sometimes polluted, surface waters at reasonable cost poses a special challenge to research and innovation. Reducing the high costs of the installation of reticulation systems, their maintenance, and water losses experienced in these systems, also require special research attention.
- **Water quality and health aspects**: The water resources of South Africa are under a considerable and increasing demand pressure. Coupled to this, the growing population and expanding industrial activities are increasingly contributing toward the microbiological and chemical pollution of these resources. This causes growing concern regarding the adverse health effects of difficult-to-remove micro-organisms, and micropollutants such as disinfection by-products, pesticides and other organics.

Various research programmes and projects pertaining to drinking water are supported in the following main research areas, i.e. **Water Treatment and Reclamation, Drinking-Water Quality and Health Aspects** and **Urban and Rural Water Supply**.

## Water treatment and reclamation

The challenges facing South African water treatment utilities in treating water cost-effectively to a potable quality are increasing. A few reasons for this state of affairs are:

- Urbanisation is taking place at a rate much higher than the average birth rate. This leads to a higher demand for potable water in the urban areas and increased pollution due to increasing return flows of treated sewage effluents into surface water sources used for the production of potable water.
- Increased industrial activity adds to the burden.
- Settlement of people in the catchment areas and on the banks of surface water sources is on a fairly sharp incline, leading to diffuse pollution which already exceeds point-source pollution of these water resources in many instances.

The thrust in this research field therefore revolves around the development, improvement and selection of cost-effective plant and processes to continue supplying a safe drinking water that complies fully with guidelines for the treated water quality. Although a number of high priority goals in the Strategic Plan for Research on Potable Water Treatment are being addressed, the majority of goals still require attention.

## Drinking-water quality and health aspects

Ongoing research projects focus on the effects of micro-organisms and organic compound biodegradability on the quality of drinking water provided by

municipalities and water utilities equipped with high-level technology laboratories.

Field test kits which will enable water quality monitoring to be extended to all areas, should be investigated. Research is also required into the development of suitable methods for taking and transporting samples, the cost-effectiveness of field testing versus laboratory testing, and the involvement of the community overall.

Chemical water quality standards are high in terms of South African realities of available water and drought cycles and a more pragmatic approach to satisfying basic needs might be needed. Similar pragmatic standards for bacteriological quality, to take into account available sources and regional disease patterns, also require early attention. A recently completed project emphasises the need and recommends the establishment of a task group for the assessment and re-evaluation of drinking-water quality guidelines for South Africa (see **Completed Projects**).

The challenge to researchers is not only to relate health status to **chemical** quality of water but also to adapt techniques relating health to **bacteriological** water quality.

## Urban and rural water supply

The capital investment which local authorities have in underground pipelines remains considerable, especially in the larger diameter pipes, in spite of increasing use of plastics piping materials.

The causes, quantification and control of corrosion in all of its forms are therefore still major considerations and easily account for the lions' share of research investment into this sector. Leak detection is still receiving attention albeit at a much lower level than was the case a few years ago. The use of naturally occurring isotopes to "finger-print" the source of water flowing underground and making its way into basements, stormwater pipes or river courses, etc., could prove to be another world-first for South African researchers (see new project No 628).

## Completed projects

### Effects of varying water quality on the corrosion of different pipe materials in the Gauteng/ Klerksdorp areas

(No 254) Division of Materials Science and Technology, CSIR

The long-held belief that increasing total dissolved solids (TDS) in drinking water would lead to increased corrosion of the distribution system, was put to the test in this project and was found to be lacking in some respects. In fact the lowest corrosion rate of mild steel was measured at the Klerksdorp test site where the TDS was highest at ca. 700mg/*l*.

Arguably, the most profound finding in the report states that: "No correlation could be found between the Langelier Index and the corrosion rate of any alloy at any of the test sites. Similarly, none of the other prediction indices showed any correlation to the corrosion rate".

Sulphate reducing bacteria (SRB) were identified in all samples at all test sites, indicating that SRB is a problem which is not going to be easily solved. Dezincification, a controversial topic amongst brassware manufacturers, was also shown to be prevalent at all sites in both hot and cold water after only 3 months.

*Cost:* *R384 500*
*Term:* *1988-1993*

### Effect of water quality on the effectiveness of chlorine dioxide in drinking-water treatment

(No 281) Rand Water

Studies were carried out to determine the relative efficacies of chlorine and chlorine dioxide in the pre-oxidation of various algal species that are known to cause problems in the treatment of eutrophic water to potable standards. In addition, the effect of varying water chemistry on oxidant efficiency was also investigated.

It was found that chlorine dioxide was between 2 to 10 times more effective as an algaecide than chlorine for the algal species investigated. Increased organic pollution levels in the raw water had less effect on chlorine dioxide demand than on chlorine demand. In the case of chlorine, more trihalomethanes formed with increasing pollution levels, but no thrihalomethanes were formed when using chlorine dioxide – even at high pollution levels.

*Cost:* *R60 000*
*Term:* *1990-1991*

### Domestic meter replacement policy and testing of water meters

(No 400) Division of Building Technology, CSIR

The scope of the project involved an in-depth literature survey of water metering, to isolate the most significant factors contributing to the reduction in the accuracy of water meters.

This was necessary to provide a sound base from which to design and validate an accelerated test procedure. The broad outline of a project proposal to develop such a test procedure was appended to the project report.

Such a test procedure would enable local authorities to determine, before making any commitment to purchase and within a period of about 2 months, what the expected service life of a meter could be. Considering the millions of meters in service, a difference of only one year in the actual operating life could account for very large sums of money which could otherwise have been spent elsewhere or alternatively led to lower tariffs.

*Cost:* *R80 000*
*Term:* *1991-1993*

### Microbial corrosion of common piping materials in the Gauteng area

(No 432) Division of Materials Science and Technology, CSIR

Corrosion of potable water distribution pipelines not only affects the integrity of the system but can also influence water quality by the release of corrosion products into the system. Severe corrosion leads to leaks and bursts with the associated costs of water loss and pipe replacement. In a recent WRC project (No 254) the possibility of the involvement of bacteria in the corrosion process was reported.

The objectives of this study were thus to determine to what extent micro-organisms are involved in the corrosion of common piping materials in potable waters and how widespread the problem is in Gauteng and the Klerksdorp area. Furthermore, the stage during biofilm growth at which corrosion is initiated by micro-organisms was to be determined. If microbial corrosion did prove to be a problem, remedial and/or preventative measures were to be recommended. A better understanding of the failure mechanisms of potable water pipes in a widespread area would enable guidelines for material selection

and water treatment for various areas to be drawn up.

During the investigation it was found that biofilm developed on all alloy surfaces in both chlorinated and non-chlorinated waters. Tubercle formation and colonisation by SRB were only present on mild steel test and control coupons. Disinfection retarded biofilm and tubercle formation and colonisation, but did not eliminate them.

It was thus recommended that the use of lining systems for mild steel pipelines and non-metallic alternative materials be investigated. This would entail both chemical and microbiological tests to assess the suitability of these alternatives for potable water systems.

*Cost:* *R426 500*
*Term:* *1992-1993*

## Evaluating the long-term use of polypropylene for hot- and cold-water piping

(No 434) Division of Materials Science and Technology, CSIR

Despite widespread use of polypropylene pipes, little was known about the long-term behaviour and aging tendencies of such pipes, especially in hot-water installations. This uncertainty has led to reservations regarding its use being expressed by many authorities.

A number of problems which had been identified with locally manufactured pipes were addressed in terms of the project. This led to intense negotiations involving the main players from industry, the SABS, the research team and other interested parties, resulting in a code of practice for the manufacture of polypropylene pipes. Incorrect installation procedures and fittings were other aspects which were highlighted and which are now receiving attention separately.

*Cost:* *R296 300*
*Term:* *1992-1993*

## Removal of colour from Cape waters using ozonation and ultrafiltration

(No 445) Stewart Scott Inc.

Humic and fulvic substances often impart a brownish colour to natural waters of the South and Western Cape. Alum is commonly used as a coagulant for colour removal. This process does, however, have certain disadvantages – relatively high chemical dosages and sludge disposal being two of them.

Two alternative treatment methods, namely ozonation followed by biologically enhanced sand filtration, and nanofiltration were investigated. The former method achieved up to 95% colour removal, but the product quality varied. Nanofiltration demonstrated excellent colour removal. Membrane fouling, which necessitated frequent detergent washes, occurred due to the relatively high natural turbidity of the water.

*Cost:* *R272 000*
*Term:* *1992-1993*

## Improvement of injection nozzles for dissolved air flotation

(No 448) Department of Civil Engineering, Rand Afrikaans University

The aim of this project was to refine nozzle design in flotation systems for drinking-water purification to such an extent that bubbles of random size and distribution could be generated. In the past the prediction and control of bubble size had been uncertain and nozzle design had been mainly empirical.

The study gave rise to a bubble growth model to explain the behaviour of the bubbles originating from nozzles of varying geometric design. The use of this model, together with a few assumptions has thrown new light on the generation of micro-bubbles, and should lead to a more rational method for designing this kind of injection nozzle.

*Cost:* *R85 000*
*Term:* *1992-1993*

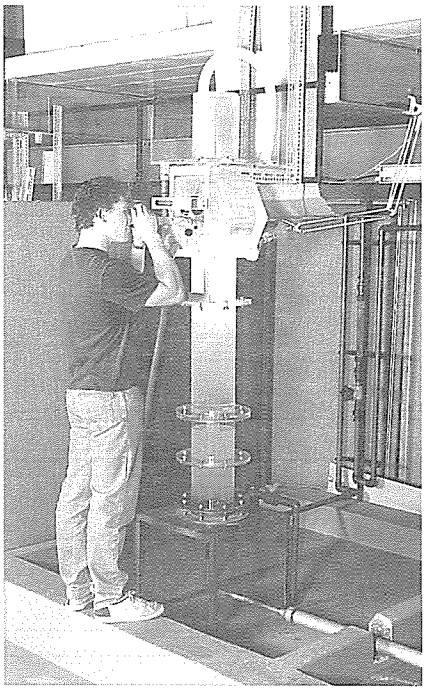
## Studies on microbiological drinking-water quality guidelines

(No 469) Division of Water Technology, CSIR

The aims of this study were to conduct an in-depth investigation of available data on microbial guidelines and standards which are used in different parts of the world and to study the applicability of various guideline scenarios to the present situation in South Africa. Matters such as water quality, microbiological and sampling issues, were addressed.

The project team recommends the establishment of a task group for the assessment and re-evaluation of drinking-water quality guidelines for South Africa. The task group should also examine the feasibility of establishing drinking-water standards for microbiological quality of drinking water in South Africa.

*Cost:* *R70 000*
*Term:* *1992*



Experimental flotation cell for the generation and measurement of microscopic air bubbles.

### Investigation of inorganic materials derived from water purification processes for ceramic applications

(No 538) Division of Water Technology, CSIR

Sludges and silts produced by waterworks often create disposal problems and can spoil land or foul waterways. The main objective was to study the technical and economic feasibility of using waterworks sludges for the production of bricks, blocks, tiles or other ceramics.

Production of bricks with small perforations counteracted their tendency to crack in the unfired state. Calcination and an optimised firing cycle were used to avoid cracking and warping of tiles. The sludge obtained from Wiggins Waterworks was found to be suitable for the production of rustic tiles and stock or face bricks, particularly for use in low-cost housing.

*Cost:* *R200 000*
*Term:* *1993*

## New projects

### Study for the provision of point-source water by air-gap membrane distillation

(No 591) Institute for Polymer Science, University of Stellenbosch

The main aim of the project is to develop a small, collapsible membrane distillation bag, which can be used in emergencies to produce small quantities of potable water for daily requirements.

A secondary aim is to develop a larger, mobile air-gap membrane distillation unit, operated by solar heat and air-cooling, to desalinate larger volumes of brackish borehole water on farms. Such a device should be able to deliver desalinated water continuously for extended periods of time for stock watering and household use in arid areas where salt concentrations in borehole water may at times reach 13 000 mg/*l*.

*Estimated cost:* *R98 000*
*Term:* *1994-1995*

### Evaluation of rapid methods for the detection of indicator organisms in water

(No 610) Division of Water Technology, CSIR

The detection and enumeration of indicator organisms are of primary importance for monitoring the sanitary and microbial quality of water.

The aim of this study is to evaluate the available new methodology (e.g. Colilert, Coliquich and MUG methods) for the enumeration of bacterial indicators and confirmation of *E. coli* bacteria, and to establish whether more rapid and practical methods exist which may be used as an alternative to the conventional methods.

These new methodologies will be compared with available methods which are presently used in South Africa. The feasibility of employing these methodologies as a basis for the reformulation of present microbial water quality guidelines for the various fitness for use categories of water in South Africa will also be investigated.

The project will, therefore, aim at recommending the most rapid and practical methodologies which can be successfully utilised by water boards, small and large municipalities and any other water users and suppliers in South Africa.

*Estimated cost:* *R90 000*
*Term:* *1994*

### Development of procedures for bio-degradability testing of organic chemical compounds

(No 611) Division of Water Technology, CSIR

In an area of acute awareness of the need for environmental and human health protection, there is an increasing need for organic chemicals reaching the aquatic environment to be completely degraded to harmless chemical components. In order to determine the extent and ease with which this is possible, bio-degradability tests should be carried out.

This project is aimed at evaluating short-term screening tests to test the bio-degradability of chemical products and pollutants in water and effluents and the modification of the most suitable tests for application in South Africa. Such tests will be of benefit to a wide range of water managers as tools for better decision-making.

*Estimated cost:* *R251 600*
*Term:* *1994-1995*

### Stabilisation of aggressive and corrosive waters

(No 613) Division of Water Technology, CSIR

Approximately 40% of the surface waters of South Africa are corrosive and aggressive to the water reticulation systems used in general. Early replacement of degenerated pipelines delivering these waters has significant cost implications to municipalities and water utilities, whereas currently used stabilisation chemicals constitute a substantial part of treatment plant running costs.

This project aims to investigate the use of calcium carbonate pebbles (limestone) as an inexpensive means of stabilising treated potable water in order to prevent the early degradation and replacement of final water distribution systems. Both in-line pressure reactors, for small plants, and fluidised bed plants, for large plants, will be evaluated and developed.

*Estimated cost:* *R282 000*
*Term:* *1994-1995*

### Expert system for water treatment plant design and analysis

(No 614) Wates, Meiring and Barnard Inc., and Sutherland and Ass.

The project was initiated to further develop the potential of an expert system for water treatment plant design, compiled by Dr NA Patrick, previously of the Water Systems Research Group of the University of the Witwatersrand.

The program performs process selection using pre-programmed rule bases and subsequently designs the selected processes, allowing interactive "what-if" changes to any design.

The project aims to refine the process selection protocols, research and include further unit treatment processes in general use and develop a capital cost module which would allow the user to perform a comparative cost analysis for various selected process configurations.

*Estimated cost:* *R321 000*
*Term:* *1994-1995*

## Modelling the causes of algal blooms in impoundments of the Umgeni catchment and the consequences for potable water treatment

(No 615) Umgeni Water

This investigation aims to establish a predictive model relating problematic algae to the key environmental variables in the major impoundments of the Umgeni catchment, and to relate water treatment costs to the types and numbers of algae likely to be found in eutrophied impoundments.

Once these key environmental variables affecting algal distributions and abundance have been identified, methods to manipulate a dam's physico-chemistry to limit problematic algae, and the development of an expert system for use by catchment managers and planners, will be investigated. Although some re-calibration will be required, possible inter-regional applications of these models by other major catchments in South Africa are envisaged.

*Estimated cost:* *R293 000*
*Term:* *1994-1995*

## Balancing tank control application

(No 621) Watson Edwards Inc.

Unchecked large variations in both the pollutant concentration of waste water and its inflow into a treatment works not only complicate system control but also impair plant performance. In order to dampen out the effect of such feed variations it has become common practice to incorporate a balancing or equalisation tank upstream of reactors in the system. Tank control is implemented to provide a fairly constant outflow and to prevent it running dry or overflowing.

To overcome the limitations of currently used controllers based on mathematical models, the project will investigate the feasibility of using a fuzzy logic controller to control balancing tank outflow. The final product will be a PC software-based controller interfacing with the plant through a Process Logic Controller, which will be suitable for any treatment works incorporating balancing tanks.

*Estimated cost:* *R74 300*
*Term:* *1994-1995*

## Rapid quantitative evaluation of water quality using a modified biological test

(No 622) Department of Microbiology, University of the Witwatersrand

Biological water quality tests are becoming more widespread internationally as their usefulness becomes recognised. The value of biological tests is that toxins or synergy between effluent constituents can be detected rapidly without complete chemical analysis. Most of the available tests are both expensive and slow. During this project the sensitivity cell cultures will be investigated using a technique developed by the research team. This test is not only quick but has shown itself to be very sensitive to certain pollutants.

*Estimated cost:* *R38 000*
*Term:* *1994-1995*

## Leak detection from municipal mains water systems in the Gauteng area using environmental isotopes

(No 628) Schonland Research Centre for Nuclear Science, University of the Witwatersrand

The loss of large amounts of potable water leaking from municipal reticulation systems, constitutes a major economic problem. Often much of this water finds its way into the groundwater, later to be abstracted from private boreholes. Stormwater pipes also transfer leakage water to a local spruit or river. Basements of large buildings and excavations are often flooded if a major leak should occur nearby. Traditional leak detection methods are not always adequate to locate such leaks especially if the leakage water has travelled a long distance from its origin to the point of observation.

The stable isotope composition of water from Rand Water has a distinctive nature. By comparing the isotopic composition of the water in the borehole, stormwater drain or foundation, with the distinctive isotopic signal of water from Rand Water, it is hoped to be able to identify whether that water is of municipal origin or not.

*Estimated cost:* *R87 500*
*Term:* *1994*

Algae – a growing problem in the Umgeni system in KwaZulu-Natal.

## Application of computational fluid dynamics to improving the design and operation of water and waste-water treatment plants

(No 648) Department of Chemical Engineering, University of Natal

The performance of water and waste-water treatment plants depends, *inter alia*, on the flow distribution conditions within the constituent equipment, which if incorrect, impairs efficacy. Improving malfunctioning flow distributions will upgrade both treatment quality and capacity, thereby delaying the necessity to invest in new facilities.

The aim of the project is to improve the operation and performance of equipment used in treatment plants which have been identified as operating poorly. This will be effected by using computational fluid dynamics to simulate existing flow distributions in the equipment and thence to investigate ways in which the equipment may be modified to improve flow patterns. The emphasis of the project will be on the transfer of existing software technology into the water treatment field, and not the development of new computational methods or techniques.

*Estimated cost:* *R874 000*
*Term:* *1994-1997*

# Research projects

## Completed

- **254** Effects of varying water quality on the corrosion of different pipe materials in the Gauteng/Klerksdorp areas (CSIR – Division of Materials Science and Technology)
- **281** Effect of water quality on the effectiveness of chlorine dioxide in drinking-water treatment (Rand Water)
- **400** Domestic meter replacement policy and testing of water meters (CSIR – Division of Building Technology)
- **432** Microbiological corrosion of common piping materials in the Gauteng area (CSIR – Division of Materials Science and Technology)
- **434** Evaluating the long-term use of polypropylene for hot- and cold-water piping (CSIR – Division of Materials Science and Technology)
- **445** The removal of colour from Cape waters using ozonation and ultrafiltration (Stewart Scott Inc.)
- **448** Improvement of injection nozzles for dissolved air flotation (Rand Afrikaans University – Department of Civil Engineering)
- **469** Studies on microbiological drinking-water quality guidelines (CSIR – Division of Water Technology)
- **538** Investigation of inorganic materials derived from water purification processes for ceramic application (CSIR – Division of Materials Science and Technology)

## Current

- **259** Effect of water quality and chemical composition on corrosivity in mild steel pipelines (Rand Water)
- **280** Evaluation of full-scale flotation-filtration and chlorine dioxide plants (OFS Gold Fields Water Board)
- **282** Development of a combination of sedimentation, flotation and sand filtration processes for water treatment (SEDIDAFF) (CSIR – Division of Water Technology)
- **354** Evaluation and development of deep-bed filtration for the treatment of South African surface waters (CSIR – Division of Water Technology and Local Government Affairs Council)
- **358** Development of guidelines for toxicity bioassaying of drinking and environmental waters in South Africa (CSIR – Division of Water Technology)
- **363** Development and evaluation of small-scale potable water treatment equipment (University of Natal – Department of Chemical Engineering and Umgeni Water)
- 381 Corrosion performance of various non-metallic piping materials and coatings in potable water (CSIR – Division of Materials Science and Technology)
- **383** Holistic approach to affordable planning and maintenance of water and sewer systems (Water Management Services)
- **443** Compilation of guidelines for the use of peroxone and other oxidants in the treatment of eutrophic water (CSIR – Division of Water Technology)
- **446** Ozonation in the production of potable water from polluted surface water (University of Pretoria – Department of Chemical Engineering, Division of Water Utilisation Engineering and Rand Water)
- **449** Evaluation of non-conventional disinfection technologies for small water systems (CSIR – Division of Water Technology)
- **450** Performance criteria for package water treatment plants (Umgeni Water and University of Natal – Department of Chemical Engineering, Pollution Research Group)
- **451** Occurrence of protozoal parasites in South African drinking water (CSIR – Division of Water Technology)
- **470** Application of health risk assessment techniques to microbial monitoring data (CSIR – Division of Water Technology)
- **472** Characterisation of South African media for sand filtration (Rand Afrikaans University – Department of Civil Engineering)
- **488** Optimisation of the Rand Water system (University of the Witwatersrand – Water Systems Research Group)
- **489** Development of procedures for the control of unaccounted-for water in water distribution systems and for the reduction of water loss (De Leuw Cather Inc.)
- **504** Guide for water purification and plant design: Phases 2 and 3 (Dr FA van Duuren)
- **534** Guidelines for the treatment of Eastern and Southern Cape coloured water (CSIR – Division of Water Technology)
- **537** Guidelines to coagulation and flocculation for South African waters (Pavel Polasek Association)
- **540** Evaluation of the use of bacteriophages as indicators for water quality (University of Pretoria – Department of Medical Virology)

- **541** Bio-degradable organic compounds and microbial regrowth in drinking water (Rand Water)
- **549** Algal toxins in drinking-water supplies (CSIR – Division of Water Technology)
- **557** Optimal operation of combined flotation/filtration of eutrophic surface water (Rand Afrikaans University – Laboratory for Energy)
- **558** Algal rupture – further investigation (Umgeni Water)
- **567** Occurrence and distribution of algal species and related substances in a full-scale water purification plant (University of the OFS – Department of Botany and Genetics)
- **568** Development of an Exxpress unit for the production of potable water and the dewatering of waterworks sludges (Umgeni Water)
- **584** Atlas of potentially water-related disease in South Africa (University of Cape Town – Department of Community Health)
- **587** Evaluation of water pipe leaks in the Johannesburg municipal area (CSIR – Division of Material Science and Technology)

## New

- **591** Study for the provision of point-source water by air-gap membrane distillation (University of Stellenbosch – Institute for Polymer Science)
- **610** Evaluation of rapid methods for the detection of indicator organisms in water (CSIR – Division of Water Technology)
- **611** Development of procedures for biodegradability testing of organic chemical compounds (CSIR – Division of Water Technology)
- **613** Stabilisation of aggressive and corrosive waters (CSIR – Division of Water Technology)
- **614** Expert system for water treatment plant design and analysis (Wates, Meiring and Barnard Inc., Sutherland and Ass.)
- **615** Modelling the causes of algal blooms in impoundments of the Umgeni catchment and the consequences for potable water treatment (Umgeni Water)
- **621** Balancing tank control application (Watson Edwards Inc.)
- **622** Rapid quantitative evaluation of water quality using a modified biological test (University of the Witwatersrand – Department of Microbiology)
- **628** Leak detection from municipal mains water systems in the Gauteng area using environmental isotopes (University of the Witwatersrand – Schonland Research Centre for Nuclear Science)
- **648** Application of computational fluid dynamics to improving the design and operation of water and waste-water treatment plants (University of Natal – Department of Chemical Engineering)

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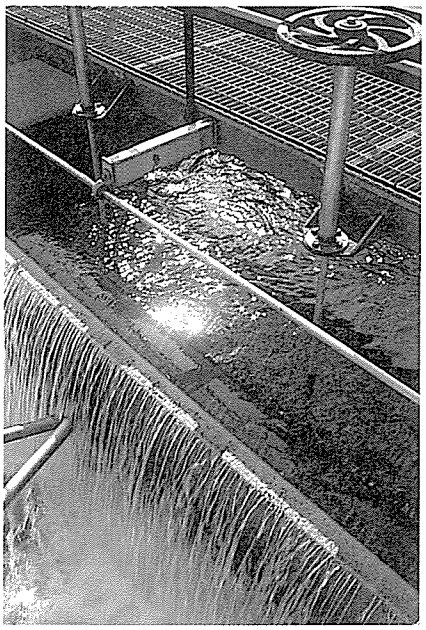
# 4
# Municipal effluents



The rehabilitation of waste water is of cardinal importance to South Africa. With much of the country semi-arid or arid, effluent has to be treated to a quality where it may be returned to the environment without doing any harm. This is all the more important in South Africa where a sector of the population is not provided with treated potable water, but relies on natural sources for their supplies. Enteric disease is high amongst people who use untreated water. Amongst the disease-causing organisms are viruses, bacteria and protozoa. These diseases are debilitating, leading to a loss of productivity amongst adults, and causing considerable infant mortality if unchecked. Effluents rich in phosphates will also cause cyanobacterial (blue-green algal) blooms which may become toxic. People, livestock and wildlife drinking from surface waters are directly exposed to this risk.

Research funded by the WRC has continued to improve the country's capacity for waste-water treatment. A process has been developed for the removal of algae from oxidation pond effluent (See **Chapter 1** – PETRO). In another project, the use of a biocatalyst is showing promising results in the rehabilitation of the Sipingo River, a heavily impacted river draining Umlazi and Prospecton south of Durban. Projects aimed specifically at transferring the technologies of sewage sludge drying beds and biological nutrient removal to plant operators have also been started.

In this field, which comprises **Sewage Treatment, Sewage Sludge Treatment and Disposal** and **Wetlands**, the WRC supported 29 projects during 1994, of which 8 commenced during the year, 19 are current and 2 were completed.

## Completed projects

### Preparation of engineering design guidelines for artificial wetlands for waste-water treatment

(No 232) Division of Water Technology, CSIR and Stewart Scott Inc.

The application of sewage and waste waters to land and natural wetlands is a long established tradition, in many cases representing the only means of disposing of a community's wastes.

Artificial or constructed wetlands are usually created either as a totally new and independent system or as an engineered modification of a natural system, to enhance the natural purification processes. Wetland systems should not be seen as "cheap" systems. They are not suitable for treating raw sewage and must be preceded by one or other primary treatment process. Engineering costs could be prohibitive if local resources are not freely available. Water losses from ponds can be significant and if this presents a problem the costs associated with the necessary ameliorative measures could become prohibitive.

The project results confirmed that artificial wetlands are complex biophysical systems that are, as yet, little understood. Experience overseas has also been highly erratic. Advantages are:

- Low maintenance, energy and operating costs
- A robust process requiring a low level of training
- An environmentally friendly facility offering considerable wildlife conservation opportunity.

*Cost:* *R50 000*
*Term:* *1988-1993*

### Development and evaluation of specific control methods for ameliorating low F/M bulking

(No 286) Department of Civil Engineering, University of Cape Town

The research conducted to date provides strong evidence that selectors are ineffective as bulking sludge control measures. As a result this project, the third in a series, had to take a new course. A broad range of investigations enabled the researchers to develop the hypothesis that sludge bulking was caused by incomplete denitrification in the anoxic

and anaerobic zones by the floc-forming bacteria, resulting in the floc-formers being inhibited by nitric oxide, a denitrification intermediate. The bulking organisms, although slower growing, can only denitrify from nitrate to nitrite, and are therefore not inhibited by nitric oxide in the cells, giving the bulking organisms a competitive advantage.

*Cost:* *R494 000*
*Term:* *1989-1993*

## New projects

### Technology adaptation for successful application of septic tank systems in the coastal zone

(No 597) Division of Water Technology, CSIR

Septic tank and soak-away systems are the most widely used systems of waste-water disposal in the South African coastal area. In view of the highly variable loadings linked to holiday seasons, few resorts have conventional water-borne sewerage and even many of the newer developments rely on septic tanks and a centralised waste-water soak-away system. The design and management of these systems varies from area to area and even within single municipalities, as different design criteria have been applied over the years. This *ad hoc* approach, coupled with often limited local technical expertise, has led to septic tank systems being the single most important pollution hazard in the region. Not only does it involve contamination of groundwater, but also storm-water runoff and ultimately the local lagoon, estuary or bay. Bacteria, viruses, nitrates and synthetic organic chemicals have all been identified as major pollutants.

The potential for serious pollution from septic tank systems is increased because:

- Many resorts, towns and settlements are located on unconfined sandy aquifers
- Groundwater levels are shallow and storm drainage during the wet winter season is poor in the Southern Cape.

In view of the above, the project aims to adapt internationally known technology on septic tank systems to the South African coastal environment and to develop a standard and user-friendly set of guidelines for the management of such systems by local authorities.

The results of the research will be published in a brief but comprehensive handbook for use by local authorities responsible for managing sanitation systems, and a condensed brochure, ideal for mass circulation aimed at providing a comprehensive but quick reference chart for home owners, minor entrepreneurs and smaller developments.

*Estimated cost:* *R196 000*
*Term:* *1994-1995*

### Application of chemical equilibrium to the control of struvite and calcite precipitation in waste-water treatment

(No 602) Department of Civil Engineering, University of Cape Town

The treatment of certain wastes, containing relatively high concentrations of orthophosphates and magnesium and calcium, can cause the minerals struvite and calcite to precipitate in the systems' pipe circuitry. The mass of precipitant formed can be so extensive that it may eventually lead to operational failure.

To counter such mishaps, the project aims to:

- Identify and evaluate the causes of struvite/calcite precipitation and fouling in waste-water treatment processes
- Develop strategies to either control (prevent) or effect struvite/calcite precipitation using chemical equilibrium modelling.

These findings will culminate in a flexible computer model addressing the water chemistry of the system to enable not only the prediction of where fouling is likely to occur, but also to give control strategies (i.e. effluent recycle, chemical dosing etc.) to minimise or prevent fouling.

*Estimated cost:* *R108 200*
*Term:* *1994-1995*

### Guidelines for the design and operation of sewage sludge drying beds

(No 604) GFJ Inc.

The South African climate is well suited to the use of sludge drying beds, but the design criteria used are empirical and the technology is not always correctly applied or used. As a result the Sludge Management Division of the Water Institute of Southern Africa (WISA) identified a need for proper guidelines on sludge drying beds. During this project rational design guidelines and guidelines for the efficient operation of drying beds will be developed. This will enable the technology to be effectively applied in the country.

*Estimated cost:* *R183 700*
*Term:* *1994-1995*

### Municipal sewage sludge disposal: Development of guidelines and expert systems

(No 605) Division of Water Technology, CSIR

There is universal pressure to provide better services at lower cost, and water resource and waste management have not escaped this. During this project expertise and knowledge will be incorporated into a decision support system. This system will be an aid to officials assessing permit applications for the disposal of sewage sludge to land and also for the establishment of design and planning constraints for impact assessments relating to the disposal of sewage sludge to land. Secondary aims include the ability to model current guidelines and administrative procedures for sludge disposal and to provide people involved in sewage sludge disposal with user-friendly software for regulatory compliance and impact-control purposes.

*Estimated cost:* *R193 600*
*Term:* *1994-1995*

The high temperatures reached during composting ensure a pathogen-free product.

## Practical application of special waste co-disposal with municipal refuse at the Coastal Park landfill bioreactor

(No 606) City Engineer's Department, Cape Town City Council

A vast array of special wastes with undesirable characteristics is produced by industry. These wastes need further processing or special disposal to render them acceptable in terms of both environmental impact and public health legislation.

The co-disposal of special waste with municipal refuse would provide an affordable waste disposal option which could be adapted for use in less affluent areas.

The main aims of this project are to determine the practical norms for the co-disposal of various special wastes, together with municipal refuse under Western Cape conditions, to establish if this co-disposal is an economic and environment-friendly concept, and to monitor the quality of the leachate produced and to estimate the possible effect on groundwater quality.

*Estimated cost:* *R334 400*
*Term:* *1994-1996*

## Compilation of an operating manual for biological nutrient removal waste-water treatment works

(No 607) Stewart Scott Inc.

South African biological nutrient removal (BNR) technology is good, but an aspect of technology transfer which is not always given the emphasis that it should be given is the training of plant operators to run these plants efficiently. At the moment there is no single manual covering the operation of BNR plants, and this was identified as a need by the Nutrient Removal Division of WISA. This manual will serve as the basic resource for the operation of BNR activated sludge plants, addressing the theory and practice of BNR.

*Estimated cost:* *R142 500*
*Term:* *1994-1995*

## Modelling, design and operation of secondary settling tanks

(No 620) Department of Civil Engineering, University of Cape Town

The performance of secondary settling tanks is often inadequate because their design is still being based primarily on empirical procedures to assess a critical design parameter, viz., sludge settleability.

Although the flux model adequately describes secondary settling tank behaviour, its tedious measurement requirements have led to the evolvement of empirical procedures to assess sludge settleability. As these characterise sludge settleability differently, no clear-cut link between their respective settleability descriptive coefficients, as well as how these relate to those of the flux model, exist as yet.

Realising the need to improve the performance and design of secondary settling tanks, this project aims to:

- Establish relationships between the various sludge settleability measures
- Effect comparison of design procedures for secondary settling tanks
- Formulate dynamic simulation modelling of secondary settling tanks and to use the knowledge so gained to develop a user-friendly interactive design program and to prepare its associated user manual and information document.

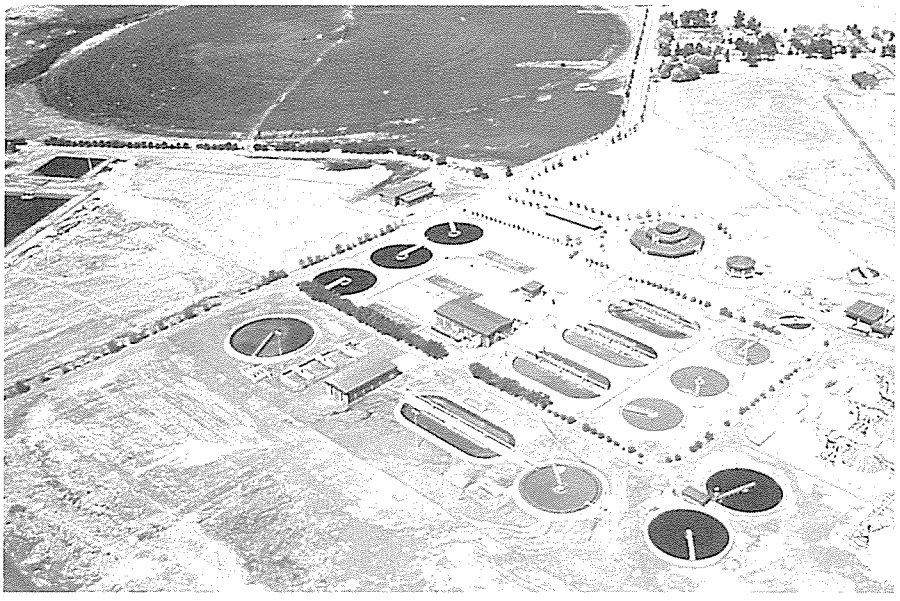
*Estimated cost:* *R143 000*
*Term:* *1994-1995*

## Bioremediation of a river system using the Alpha Biocatalyst

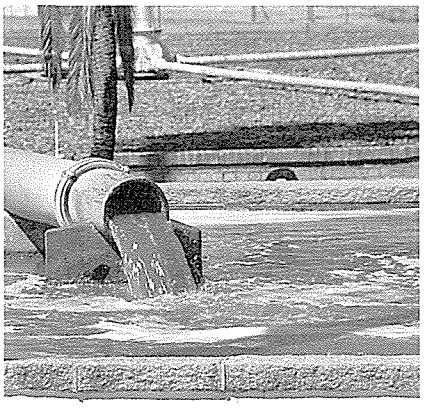
(No 623) Alpha Biotech CC

The Alpha Biocatalyst is a bioremediation or biostimulation technology which stimulates indigenous bacterial activity. In this way the indigenous bacterial fauna can remediate problems more effectively. The Alpha Biocatalyst has been used successfully to treat hydrocarbon spills and to enhance the performance of waste-water treatment plants, but has not before been used for the remediation of a watercourse. Some rivers have been severely impacted by South Africa's rapid urbanisation, and this project will evaluate the effectiveness of this technology to remediate such systems. This project will assess the effectiveness of the Alpha Biocatalyst in remediating a heavily impacted stream.

*Estimated cost:* *R69 300*
*Term:* *1994*



Aerial view of a biological nutrient removal works. The quality of the effluent depends on both the design of the works and the competence of the operating personnel.



Industrial effluent entering a sewage works for treatment.

**CONTACT PERSONS:**
- **Dr SA Mitchell**
  (Nutrient Removal and Sludge Treatment)
- **Mr HC Chapman**
  (Low-cost Sanitation)

☎ **(012) 330-0340**

## Research projects

### Complete

- **232** Preparation of engineering design guidelines for artificial wetlands for waste-water treatment (CSIR – Division of Water Technology and Stewart Scott Inc.)
- **286** Development and evaluation of specific control methods for ameliorating low F/M bulking (University of Cape Town – Department of Civil Engineering)

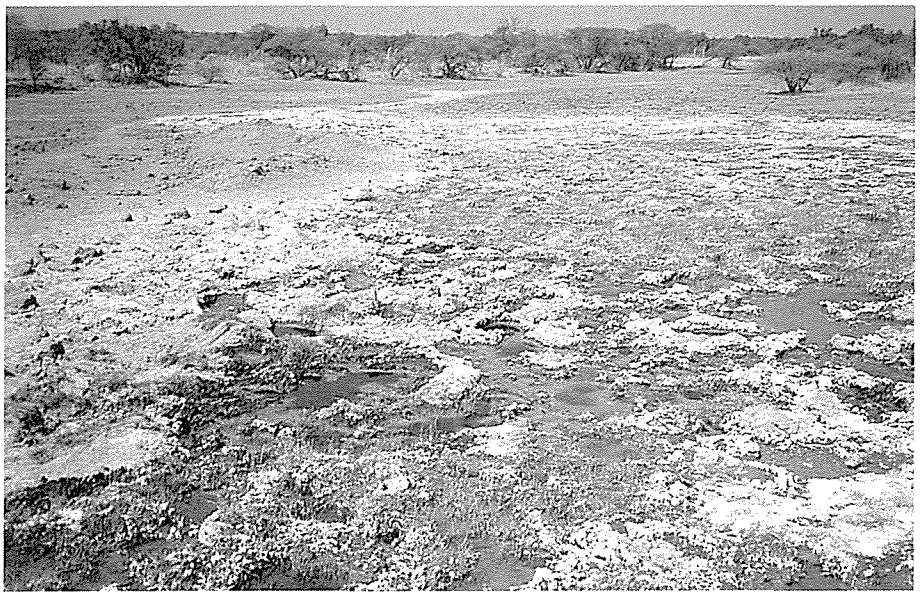
### Current

- **248** Chemical augmentation of biological phosphate removal (City Council of Johannesburg)
- **316** Aspects of sewage sludge treatment and disposal (City Council of Johannesburg)
- **328** Full-scale study of chemical sludge bulking control (University of Pretoria – Department of Chemical Engineering)
- **356** Consolidation of activated sludge research (University of Cape Town – Department of Civil Engineering)
- **366** Full-scale pilot plant studies on phosphate crystallisation in biological systems (CSIR – Division of Water Technology and City Council of Pretoria)
- **391** Co-disposal of sewage sludge and refuse (City Council of Cape Town)
- **416** Application and performance of full-scale constructed wetlands for waste-water treatment in South Africa (SRK Inc.)
- **427** Development of electro-osmotic sludge dewatering technology (CSIR – Division of Water Technology)
- **429** Bio-augmentation technology for waste-water treatment in South Africa (CSIR – Division of Water Technology)
- **462** Activated fixed and suspended cultures for nitrification (University of Pretoria – Department of Chemical Engineering)
- **491** Pond-enhanced trickling filter operation (PETRO) (Wates, Meiring and Barnard Inc. and CSIR – Division of Water Technology)
- **496** Human viruses in diffuse effluents and related water environments (University of Pretoria – Department of Medical Virology)
- **542** Causes and control of low A/A filament bulking in nutrient removal activated sludge systems (University of Cape Town – Department of Civil Engineering)
- **543** Bioremediation technology for the treatment of contaminated seepage water and soil in South Africa (CSIR – Division of Water Technology)
- **554** Study of activated sludge microbial population dynamics for the optimisation of biological phosphorus removal (University of Pretoria – Department of Microbiology and Plant Pathology)
- **555** Limitation of convection currents in clarifiers (University of Pretoria – Department of Chemical Engineering)
- **556** Refinement of design parameters for sludge thickening by dissolved air flotation (Rand Afrikaans University – Energy Laboratory)
- **560** Development of a cross-flow microfiltration unit to improve the performance of anaerobic digesters at waste-water treatment works (University of Natal – Department of Chemical Engineering, Pollution Research Group)
- **569** High-rate recirculation and solids contact optimisation of biological filtration plants (Wates, Meiring and Barnard Inc.)

### New

- **597** Technology adaption for successful application of septic tank systems in the coastal zone (CSIR – Division of Water Technology)
- **602** Application of chemical equilibrium to the control of struvite and calcite precipitation in waste-water treatment (University of Cape Town – Department of Civil Engineering)
- **604** Compilation of guidelines for the design and operation of sewage sludge drying beds (GFJ Inc.)
- **605** Municipal sewage sludge disposal: Development of guidelines and expert systems (CSIR – Division of Water Technology)
- **606** Practical application of special waste co-disposal with municipal refuse at the Coastal Park landfill bioreactor (Cape Town City Council – City Engineer's Department)
- **607** Compilation of an operating manual for biological nutrient removal waste-water treatment works (Stewart Scott Inc.)
- **620** The modelling, design and operation of secondary settling tanks (University of Cape Town – Department of Civil Engineering)
- **623** The bioremediation of a river system using the Alpha Biocatalyst (Alpha Biotech CC)

# 5
# Water pollution



As part of its RDP, the Government aims to meet the basic needs of the people of our country by, *inter alia*, providing access to clean water. Pollution of our water sources is one of the threats to achieving this goal on a sustainable basis. In addition to reducing the suitability of water for potable use, pollution also affects the suitability of water for practically all its uses – thereby posing a threat to sustainable industrial, agricultural and other development. In a water-poor country, such as ours, where surplus water is not available for the dilution of polluted waters, it is thus even more imperative than in water-rich countries to prevent and control pollution as far as possible. It thus comes as no surprise that some experts already view the problem of providing users with water of an acceptable quality as a greater long-term challenge than merely supplying water in adequate quantities. In order to be prepared to face the expected challenges in this regard a two-pronged research strategy is being followed: on one hand research is being carried out which will contribute to the reduction and prevention of pollution, while, on the other hand, the levels of pollution that users can tolerate are being determined. The WRC is funding high priority research in both categories. Non-point source pollution is increasingly being identified as the major cause of water quality degradation in many catchments. This fact and other aspects requiring attention are being reflected in identified research needs and priorities.

The WRC has been funding pollution-related research projects in the research fields of salinisation, eutrophication, water quality studies and marine disposal.

**Salinisation** remains one of the consequences of water pollution causing most problems in South Africa. It is the result of the addition of a variety of salts to the water environment which virtually inevitably results from the increasing use and reuse of water associated with development. With increasing salinity the water becomes less fit for most users, thereby incurring additional costs. During 1994 the WRC financed 9 salinisation projects of which 1 commenced during the year and 2 were completed.

**Eutrophication** is the enrichment of the water environment with plant nutrients and the consequent abundant growth of algae and aquatic plants. Serious problems pertaining to water purification and defacement of the water environment are consequently still being experienced, while certain algae also excrete toxins. During the year the WRC financed 5 current eutrophication projects.

The gradual deterioration of water quality and the growing awareness of water quality as a factor which determines the utilisation potential of water, have given rise to the identification of a number of research needs. The Commission currently finances 11 projects with regard to **water quality studies** of which 1 commenced during the year and 1 was completed.

**Marine disposal** often is more economical than the land-based treatment of effluents. As the sea's limited assimilation capacity is increasingly being recognised, and because marine disposal is sometimes abused for the disposal of substances detrimental to the marine environment, as well as the unfavourable publicity associated with pipelines which are poorly designed or operated, public resistance to marine disposal is increasingly being experienced worldwide. It is nevertheless a practice which is widely (also in South Africa) adopted by coastal communities to dispose of their effluents. The WRC currently finances 3 projects in order to enable the responsible consideration of marine disposal as an alternative to land-based effluent treatment.

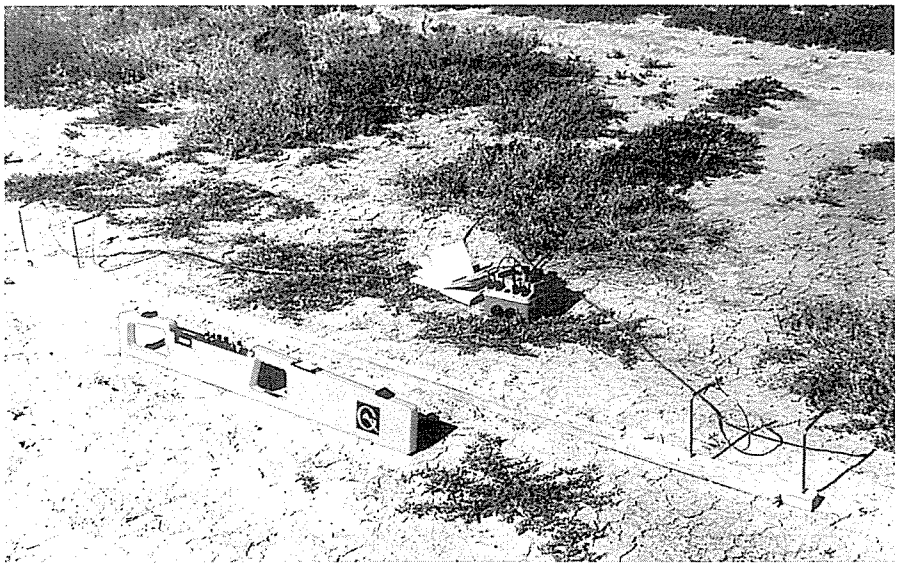
## Completed projects

### Four-electrode electrical conductivity and electromagnetic induction techniques of soil salinity measurement for use under South African conditions

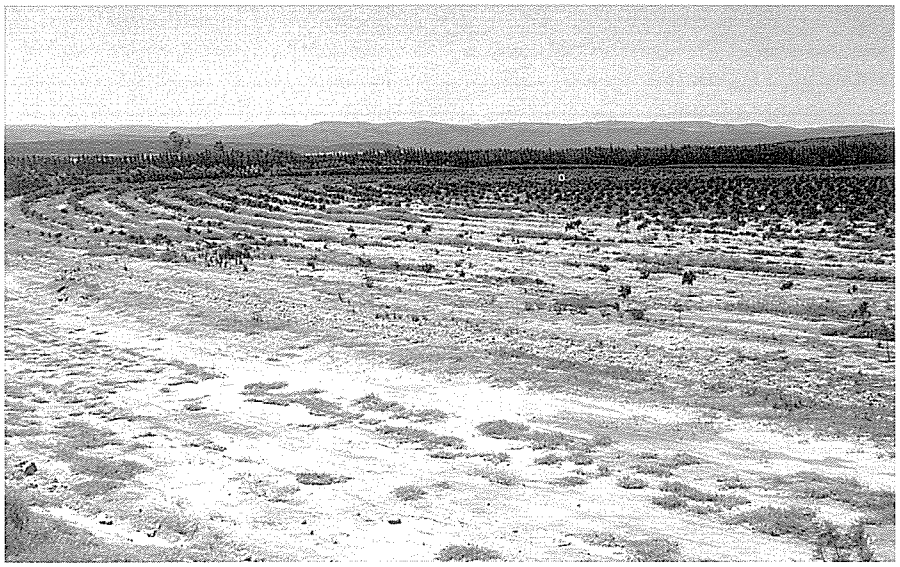
(No 269) Department of Agronomy, University of Natal

Salinisation of irrigation land is experienced to a greater or a lesser degree at virtually all irrigation schemes in South Africa. World-wide it is one of the major factors which impedes the sustainable utilisation of irrigation land. Determination of the extent of the problem and trends over time is hampered by the time-consuming nature of sampling and the cost of laboratory analyses required by traditional surveys of soil salinisation. The suitability of instruments and techniques developed overseas for the accelerated measurement of soil salinisation was evaluated during this project. Relationships were established between instrument readings and traditional laboratory determinations for a wide range of soils and were tried in practice. Good correlation was achieved between the accelerated and the traditional methods of measurement while mapping a piece of salinised land. The accelerated methods are, however, considerably less expensive.

*Cost:* *R236 000*
*Term:* *1989-1993*



The electromagnetic induction sensor and four-electrode array used for measuring soil salinity.



Orange orchard in the Eastern Cape severely affected by soil salinity.

### Concentration ratios of selected radionuclides in aquatic ecosystems affected by mine drainage effluents

(No 313) Department of Zoology, Rand Afrikaans University

The occurrence and concentration values of radium and uranium were investigated in gold and uranium mine polluted waters. The potential effects of these radionuclides on man were studied in relation to their concentration ratios in selected vegetable crops. The results were used in a dose assessment model to study the potential pathways of these radionuclides to man via the soil, drinking water, vegetables, cereals and fish.

The concentrations of the radionuclides were found to be an order of magnitude lower than those found in Japan, Germany and the USA, and were below the maximum recommended guideline values laid down by the SA Council for Nuclear Safety.

*Cost:* *R136 000*
*Term:* *1990-1993*

### The contribution of groundwater to the salt load of the Breë River using natural isotopes and chemical tracers

(No 344) Institute for Groundwater Studies, University of the OFS

Depending on the origin of the salts, various management options have to be exercised to combat salinisation of a river system. In the Breë River where irrigation is involved, the issue was to determine the respective contributions to the salinisation of the river by irrigation return flows and groundwater influx from various geological formations. The investigation indicated that groundwater plays a minor role in the salinisation of the Breë River. This conclusion was arrived at based on the strontium isotope relationships of different potential sources, and was supported by a calculation of the probable rate at which groundwater flows to the river.

*Cost:* *R179 000*
*Term:* *1990-1991*

## New projects

### Management of urban impoundments

(No 633) Municipality of Johannesburg and Stewart Scott Inc.

Urban impoundments are provided for the dual purpose of providing recreation and to control storm water. The need for these facilities increases as the standard of living of the man-in-the-street decreases and he needs to find an escape from the concrete jungle in close proximity from his home and work. Unfortunately these impoundments are fed predominantly by the often polluted normal and storm-water runoff from the urban catchments in which they nestle. The result can be a highly polluted impoundment which could turn into a public liability or even pose a safety and health risk. This 3-year project will investigate problems experienced by existing impoundments, identify and evaluate appropriate treatment processes, apply these on a few selected impoundments and compile a manual providing guidelines for their management.

*Estimated cost:* *R594 000*
*Term:* *1994-1996*

### Quantifying the impact of the salinisation of South Africa's water resources with special reference to economic effects. Phase I: Development of a generic model

(No 634) Urban-Econ, Development Economists

While the problem of high salinity water previously experienced by Rand Water customers, was solved by blending with low salinity Vaal Dam water, the Middle Vaal River now experiences a major salinisation problem. Uncertainties about important assumptions and the methodology used in an earlier attempt to quantify the monetary loss different water use sectors suffer as a result of increasing water salinity, made it risky to use the cost estimates of the earlier attempt to analyse the cost-benefit of alternative options for reducing the salinity in the Middle Vaal. As the first step towards obtaining an improved appraisal of the cost of salinity to water users, the WRC and the DWAF are now funding this 1-year project to develop a generic methodology to determine the financial, economic and social impacts associated with an increase in the salt concentration of water supplies.

*Estimated cost:* *R700 000*
*Term:* *1994-1996*

Urban impoundments can provide recreation for city dwellers or be polluted and unsightly.

## Research projects

### Completed

- **269** Four-electrode electrical conductivity and electromagnetic induction techniques of soil salinity measurement for use under South African conditions (University of Natal – Department of Agronomy)
- **313** Concentration ratios of selected radionuclides in aquatic ecosystems affected by mine drainage effluents (Rand Afrikaans University – Department of Zoology)
- **344** Contribution of groundwater to the salt load of the Breë River using natural isotopes and chemical tracers (University of the Orange Free State – Institute for Groundwater Studies)

### Current

- **195** Hydrosalinity studies in the Eastern Cape (Rhodes University – Institute for Water Research)
- **266** Extension of the management-orientated models for eutrophication control (CSIR – Division of Water Technology)
- **312** Occurrence and accumulation of selected heavy metals in freshwater ecosystems affected by mine and industrial polluted effluents (Rand Afrikaans University – Department of Zoology)
- **359** Phytoplankton blooms in the Vaal River and the environmental variables responsible for their development and decline (University of the Orange Free State – Department of Botany)
- **364** Field dilution studies on large offshore pipelines (CSIR – Division of Earth, Marine and Atmospheric Science and Technology)
- **369** Completion of research relating to the DISA model – A daily irrigation and salinity analysis system model (Ninham Shand (Cape) Inc.)
- **380** Investigation techniques for the determination of microbial aspects of water quality of South African rivers (CSIR – Division of Water Technology and Rand Water)
- **404** Manual for waste load allocations in South Africa (CSIR – Environmental Services)
- **405** Situation analysis of water quality in the Buffalo River, Eastern Cape, with special emphasis on the impact of low-cost high-density urban development on water quality (CSIR – Division of Water Technology)
- **411** Coastal pollution: Pathogenic microorganisms (University of Pretoria – Department of Medical Virology)
- **419** Water quality and quantity assessments in catchments with changing land uses in the Umzinto coastal area (SA Sugar Association Experiment Station)
- **420** Long-term salt balance of the Vaalharts irrigation scheme (Stewart Scott Inc.)
- **421** Relationship between atmospheric deposition and water quality in a small upland catchment (CSIR – Division of Water Technology)
- **443** Compilation of guidelines for the use of peroxone and other oxidants in the treatment of eutrophic water (CSIR – Division of Water Technology)
- **447** Optimising diffuser design for offshore pipelines – Laboratory experiments (CSIR – Division of Earth, Marine and Atmospheric Science and Technology)
- **465** Detergent phosphorus in South Africa: Impact on eutrophication with specific reference to the Umgeni catchment (University of Natal – Department of Chemical Engineering and Umgeni Water)
- **498** Collection and evaluation of runoff water quality data from a disused feedlot in Natal (CSIR – Division of Water Technology)
- **522** Pilot study to investigate alternative management options to enhance the use of saline water for irrigation purposes (University of Stellenbosch – Department of Soil and Agricultural Hydrology)
- **523** Lower Vet River water quality situation analysis with particular reference to the OFS gold-fields (Stewart Scott Ing.)
- **524** Development of a rule model for the design of stream water quality monitoring strategies in the forestry industry (CSIR – Division of Forestry Science)
- **536** Development of a dynamic model for the growth and bloom of algae in the Vaal River (University of the OFS – Department of Applied Science)
- **574** Potential for the use of economic instruments to protect the quality of water resources in South Africa (Economic Project Evaluation (Pty) Ltd)
- **583** Development of a laboratory river model to determine the environmental impacts of key zenobiotic compounds (University of Natal – International Centre for Waste Technology, and Umgeni Water)
- **588** Demonstrating the potential of geographical information systems technology in hydrosalinity modelling by using the DISA model (University of Stellenbosch – Institute for Geographical Information)

### New

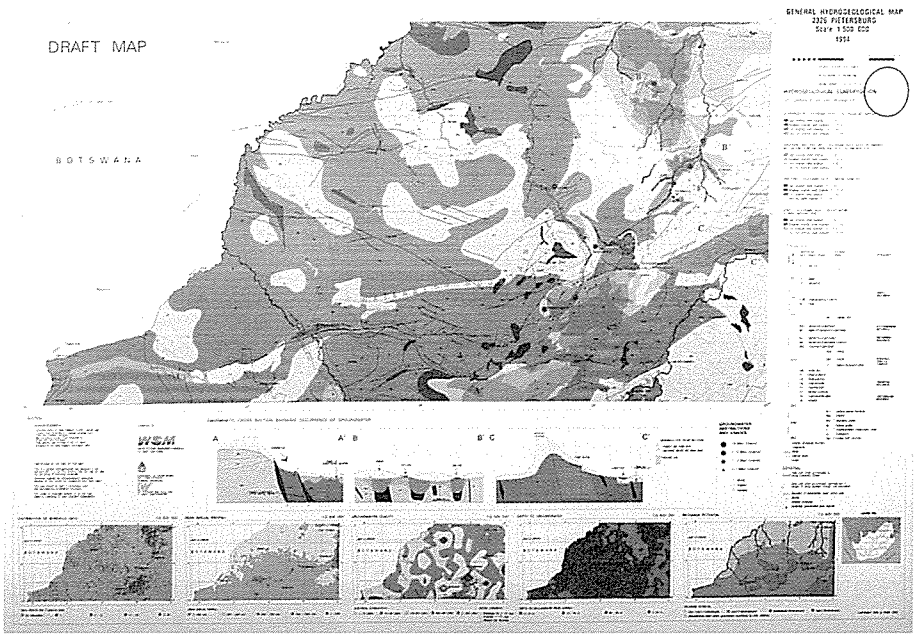
- **633** Management of urban impoundments (Johannesburg City Council and Stewart Scott Inc.)
- **634** Quantifying the impact of the salinisation of South Africa's water resources with special reference to economic effects. Phase 1: Development of a generic model (Department of Water Affairs and Forestry and Urban-Econ, Development Economists)

**CONTACT PERSONS**:

- **Mr HM du Plessis** (Salinisation, Eutrophication and Water Environment)
- **Dr HM Saayman** (Water Environment)
- **Mrs APM Oelofse** (Urban Runoff)
- **Mr G Offringa** (Eutrophication)
- **Dr TC Erasmus** (Marine Disposal)

☎ **(012) 330-0340**

# 6
# Groundwater




The Pietersburg 1:500 000 Hydrogeological Map Sheet 2326 is the first in a series of regional-scale hydrogeological maps.

For many years, groundwater in South Africa has been regarded as a cheap source of water supply requiring little or no treatment. A lack of understanding of the occurrence, movement and recharge of groundwater, and its private water status, have, however, led to this resource not being utilised optimally. The consequent failure of boreholes in some instances has unfortunately promoted the view that groundwater is an unreliable source of supply which should be replaced as soon as possible by more reliable surface water supplies.

Hopefully this perception will shortly be something of the past. The considerable emphasis on hydrogeological mapping, where the potential for groundwater development is depicted in a form that planners, decision-makers and the general public can understand, together with a better understanding of our fractured hard rock aquifers, is leading to greater confidence in the ability of groundwater to meet the water supply needs of some urban and many rural communities.

The fact that groundwater can meet drinking-water requirements at the point of need has resulted in hundreds of farms, small villages, schools, clinics and hospitals in rural areas being dependent upon untreated springs and boreholes which tap shallow groundwater reserves. The importance of groundwater in rural areas is bound to increase as attempts are made to realise the water supply objectives of the RDP. Fortunately both the national groundwater map of South Africa and the pilot regional-scale map of the Pietersburg 1:500 000 sheet are nearing completion. These maps will facilitate the provision of clean drinking-water supplies and through encouraging its use, will ensure the sustainable development of groundwater.

Economists have shown that in terms of sustainable development, the level of management of a resource is related to the value that society attaches to it. This has led to the hypothesis that a more realistic valuation of groundwater will establish a justifiable basis for its appropriate utilisation and management.

A workshop on groundwater valuation approaches based on the importance of the use to which the water is put, was held in September 1994. It is postulated that the economic value assigned to groundwater is likely to vary from one groundwater use activity to another and from one location to another, hence the need for methods which may not be comparable with surface water valuation approaches. The very valuable conclusions reached at this Workshop will be presented in the final report of project No 639, **The economics of groundwater usage: The importance of intrinsic value as a basis for sustainable development**.

During 1994 the WRC supported 26 projects related to groundwater of which 4 commenced during the year and 4 were completed.

## Completed projects

### Geohydrological investigation and evaluation of the Zululand coastal aquifer

(No 221) Division of Earth, Marine and Atmospheric Science and Technology, CSIR

The aquifer horizons below the Zululand coastal plain constitute South Africa's largest primary groundwater resource. Geohydrological, geological and geophysical information were combined to obtain a geohydrological model of the area and to determine the groundwater resources of the region. Extensive studies were conducted to calculate the recharge to the aquifer using a rainfall/groundwater chemistry approach. This assisted in calculating a much more accurate water balance for the region

than had been determined using earlier models. The finite element simulation model that was constructed highlighted the role and influence of groundwater in maintaining the many inland freshwater lakes occurring in the area.

Conclusions reached during this study will provide important baseline data for the current hydrogeological mapping programme of Kwazulu-Natal which is being conducted under the direction of the DWAF.

*Cost:* *R767 000*
*Term:* *1988-1992*

## Development of a method for the selection of suitable landfill sites, and of guidelines for sanitary landfill in municipal areas

(No 352) Division of Water Technology, CSIR

In many countries, South Africa being no exception, prime land for the expansion and development of urban areas is becoming scarce. This is particularly true for large metropolitan areas but is equally a problem for rapidly expanding coastal towns and industrial growth points. The result has been ever-increasing pressure for the location of municipal solid waste landfill sites in zones considered unsuitable or uneconomical for other kinds of development. Many such zones are, however, highly unsuitable for landfill.

At the commencement of this project, no standardised approach for the selection and evaluation of sanitary landfill sites existed in South Africa. The subsequent initiation of a study to prepare *Minimum Requirements for the Disposal of Waste by Landfill* by the DWAF meant that greater effort could be given to the potential of expert systems for this application in this research project.

As landfilling of waste is by its very nature multidisciplinary, and its potential impact on the environment multifaceted, no single expert can possibly consider in detail all the factors of relevance to the siting and evaluation of sanitary landfill sites. An *expert system*, on the other hand, which allows access to text (hypertext), photographs, engineering drawings, mathematical models and a powerful database of expert knowledge and opinion, can provide a permitting authority or a consultant with sufficient information with which to make informed decisions which will lead to minimum impact on the environment. A component-based procedure, called *Aquirisk*, which determines the risk to an aquifer from solid waste disposal, emanated from this project.

*Cost:* *R235 000*
*Term:* *1991-1993*

A methodology to determine site suitability for waste disposal based on geohydrological criteria has been developed.

## Development of a systematic method for evaluating site suitability for waste disposal based on geohydrological criteria

(No 485) Division of Water Technology, CSIR

If the expensive and technically difficult exercise of groundwater rehabilitation is to be avoided, waste facilities and aquifers must be kept apart. This separation concept is central to the method developed during the above project and led to the name Waste-Aquifer Separation Principle, abbreviated as WASP.

Three factors which form the basis of WASP were identified as being important in the assessment of site suitability for waste disposal, based on geohydrological criteria, namely:

- The threat factor
- The barrier factor
- The resource factor.

The procedure was developed and refined using information from the DWAF permit applications and associated reports. Following this, detailed investigations of 10 waste disposal sites covering a range of climatic and geological conditions across South Africa, were carried out. This involved the drilling of observation boreholes and monitoring of groundwater levels and water chemistry at these sites. The validity of WASP was assessed by comparing the WASP indices obtained for the 10 waste disposal sites with observed contamination patterns. All of the indices were found to provide accurate assessments of the prevailing conditions.

The procedure has 3 applications namely, initial site screening and ranking, defining further data needs and final site suitability determination. WASP can also be used for the evaluation of sites for permitting purposes.

As the methodology lends itself to computerisation, a software package to calculate the WASP Index has been written.

*Cost:* *R336 000*
*Term:* *1992-1994*

### Conversion of the software packages TRICON and BAYES from personal computers to machines using the UNIX operating system

(No 566) Institute for Groundwater Studies, University of the Orange Free State

The software packages TRICON and BAYES emanated from a WRC project entitled **A comparative study of two- and three-dimensional groundwater models**. They were originally developed for IBM-compatible personal computers, using the DOS operating system, with the following objectives in mind:

- To draw accurate and aesthetically acceptable contour maps of a regionalised variable, i.e. a variable that varies in space
- To estimate values of a regionalised variable, and its associated error at points where no measurements are available.

The restriction to IBM-compatible machines unfortunately limited their practical application considerably. Both packages were, therefore, converted to machines that use the UNIX operating system which has allowed incorporation into a GIS package, also under development by the Institute for Groundwater Studies.

*Cost:* *R80 000*
*Term:* *1993*

## New projects

### Economics of groundwater usage: The importance of intrinsic value as a basis for sustainable management

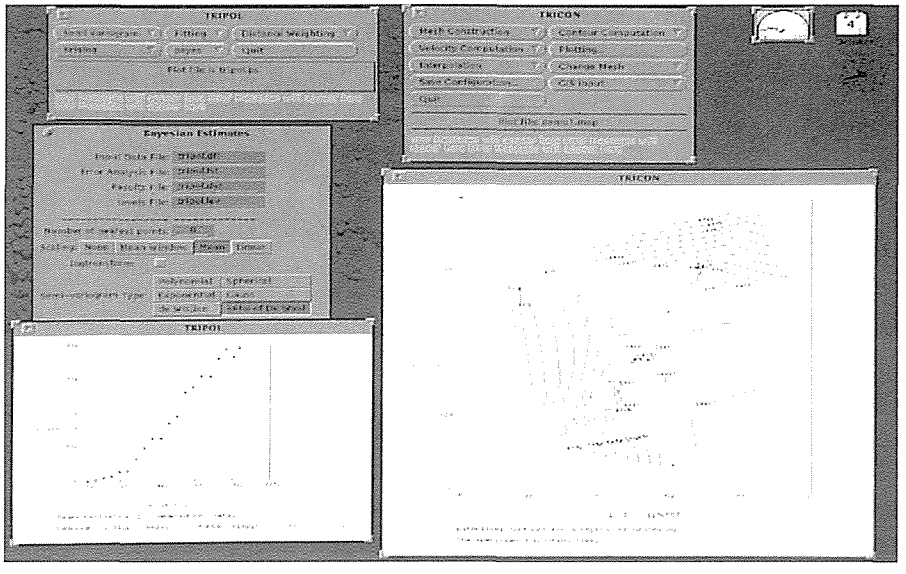
(No 639) Economic Project Evaluation (Pty) Ltd

The decision to improve water management systems is invariably prompted by the reduced utility value of the water supply. This is often a result of either a reduction in the assurance of supply or a decline in water quality. Although the utility value of water is seldom calculated with any degree of preciseness, the response from consumers claiming to be disadvantaged by its decline is usually sufficient to convince water managers of the need to allocate money and manpower to improve its management.

Economists have shown that the level of management accorded to a resource is related to the value society attaches to it. Consequently, the more realistic valuation of groundwater will establish a justifiable basis for its appropriate utilisation and management.

The overall objective of this project is to develop methodologies for placing a value on groundwater which is proportional to the importance of the use to which it is put. These values are likely to vary from one groundwater use activity to another, and from one location to another. Such values are critical in that they can indicate and justify the nature and extent of groundwater management systems.

*Estimated cost:* *R170 000*
*Term:* *1994*




Contour maps drawn by means of the TRICON and BAYES software packages.

### Extension and refinement of the AQUAMOD computer software package

(No 640) Institute for Groundwater Studies, University of the Orange Free State

The semi-arid conditions prevalent over much of South Africa have resulted in groundwater being utilised as a sole source of water, or in conjunction with surface water, to meet both rural and urban demands. A poor understanding of the occurrence, replenishment and behaviour of groundwater, however, has resulted in this resource being inadequately managed, not only in the semi-arid areas, but in the better watered parts as well, resulting in over-abstraction and pollution in some instances.

An increasing need to manage groundwater in a similar manner to surface water resulted in the initiation of a research project entitled **The development of techniques for risk analysis and groundwater management of Southern African aquifers** in January 1991. Over the past 3 years considerable progress has been made in the development and testing of computer software to simulate the flow of groundwater and the movement of pollutants therein. For the first time local hydrogeologists are in a position to manage South African aquifers on a scientific basis.

In order to ensure that the computer software, called AQUAMOD, is accepted and widely used by those responsible for planning and managing our groundwater resources on a sustainable basis, further development and refinement is required. For this reason a follow-up project, which will add considerable value to the recently completed study, has been initiated.

*Estimated cost:* *R269 000*
*Term:* *1994-1995*

## Assessment of the impact of agricultural practices on the quality of groundwater resources in South Africa

(No 641) Division of Water Technology, CSIR

Although the agricultural sector is the largest consumer of groundwater in South Africa, little is known about the status of groundwater used by the agricultural sector, and more significantly, the impact of agricultural practices on groundwater quality.

It is recognised world-wide that the agricultural sector contributes to diffuse contamination. Problems include irrigation practices, animal feedlots and the use of fertilisers, pesticides and herbicides. Point sources of pollution which exacerbate the problem include septic tanks and pit latrines and the disposal of household and agricultural waste products.

Although some research has been undertaken locally, little quantified information is available as to the impact of agricultural practices on groundwater resources and the status of such resources. This lack of information is viewed as an obstacle in the formulation of a groundwater quality protection strategy for South Africa. There is consequently a need to draw this information together and thereby focus attention on priority problem areas requiring further research.

Furthermore, it is recognised that much could be achieved in terms of protecting groundwater from contamination by agricultural activities through the process of education. The transfer of information from the groundwater community to the agricultural sector is urgently required. In addition to quantifying the extent of the problem in South Africa, the research effort can be used as a means of transferring this sort of information through preparation of best management practices.

*Estimated cost:* *R838 200*
*Term:* *1994-1997*

## Regional characterisation and mapping of Karoo fractured aquifer systems – An integrated approach using a geographical information system and digital image processing

(No 653) Directorate of Geohydrology, DWAF and the Council for Geoscience

One of the potential bottlenecks in a regional hydrogeological mapping programme is the poor distribution of groundwater data and information across South Africa. This is evidenced in the availability of high quality data for specific hydrogeological units, with vast areas containing little or no documented data on groundwater occurrence. Satellite remote sensing, together with other digital data sets, especially when linked to a geographic information system (GIS), offers a cost-effective opportunity of extrapolating such groundwater data and information from areas of known groundwater occurrence to those areas yet to be explored.

The aim of this research project is consequently to assess the potential of satellite image processing as a tool within the GIS environment for the characterisation and mapping of Karoo aquifers on a regional scale.

The research is complementing the DWAF hydrogeological mapping programme and will be carried out in conjunction with the production of the Beaufort-West (3222) hydrogeological map at a scale of 1:500 000.

*Estimated cost:* *R277 575*
*Term:* *1994-1996*

## Research projects

### Completed

- **221** Geohydrological investigation and evaluation of the Zululand coastal aquifer (CSIR – Division of Earth, Marine and Atmospheric Science and Technology)
- **352** Development of a method for the selection of suitable landfill sites, and of guidelines for sanitary landfill in municipal areas (CSIR – Division of Water Technology)
- **485** Development of a systematic method for evaluating site suitability for waste disposal based on geohydrological criteria (CSIR – Division of Water Technology)
- **566** Conversion of the software packages TRICON and BAYES from personal computers to machines using the UNIX operating system (University of the Orange Free State – Institute for Groundwater Studies)

### Current

- **273** Investigation of the potential use of NOAA satellite remotely sensed data for identification of regional-scale fracture zones for groundwater supply purposes in Southern Africa (SRK (CE) Inc.)
- **291** Regional investigation into groundwater quality deterioration in the Olifants River catchment above the Loskop Dam, with specialised investigations in the Witbank Dam subcatchment (University of the Orange Free State – Institute for Groundwater Studies)
- **311** Development and evaluation of geohydrological and isotope hydrological methodologies for the identification of areas potentially suitable for waste disposal (University of the Witwatersrand – Schonland Research Centre, and Atomic Energy Corporation of South Africa Ltd)
- **353** Preparation of a manual on quantitative estimation of groundwater recharge and aquifer storativity (Department of Water Affairs and Forestry)
- **377** Use of geographic information systems and other computer-aided drafting facilities for the production of geohydrological maps (University of the Orange Free State – Institute for Groundwater Studies)
- **378** Development of techniques for risk analysis and groundwater management of Southern African aquifers (University of the Orange Free State – Institute for Groundwater Studies and CSIR – Division of Earth, Marine and Atmospheric Science and Technology)
- **481** Geochemistry and isotopes for resource evaluation in the fractured rock aquifers of the Table Mountain Group (CSIR – Division of Water Technology)
- **483** Compilation of a hydrogeological map of South Africa (JR Vegter Esq. and the Department of Water Affairs and Forestry)
- **484** Integrated multidisciplinary geodynamic/geophysical approach to groundwater exploration around the South African coastline (Atomic Energy Corporation of South Africa Ltd)
- **486** Catchment water quality deterioration as a result of water-level recovery in abandoned gold mines on the eastern and central Witwatersrand (University of the Orange Free State – Institute for Groundwater Studies)
- **487** Analysis and interpretation of aquifer tests in secondary aquifers (University of the Orange Free State – Institute for Groundwater Studies)
- **515** Groundwater abstraction in the Port Elizabeth municipal area (SRK (CE) Inc. and the Municipality of Port Elizabeth)
- **516** Application of seismic tomography and ground-penetrating radar for the detection of fractures and the determination of hydraulic properties of fractured rock aquifers (CSIR – Division of Earth, Marine and Atmospheric Science and Technology)
- **517** Production of the Pietersburg 1:500 000 hydrogeological map sheet 2326 (Water Systems Management and the Department of Water Affairs and Forestry – Directorate of Geohydrology)
- **526** Distribution of fluoride-rich groundwater in the eastern and Mogwase regions of Bophuthatswana: Influence of bedrock and soils and constraints on utilisable drinking-water supplies (University of Cape Town – Department of Geology)
- **564** Review of approaches and methodologies for determining recharge and leachate generation rates at waste disposal sites (CSIR – Division of Water Technology)
- **565** Hydrogeological, isotopic and hydrochemical assessment of the response of a fractured multi-layered aquifer to long-term abstraction (University of the Witwatersrand – Schonland Research Centre)
- **572** Investigation of the contaminant attenuation capacity of the soil/aquifer system with special emphasis on the vadose zone (CSIR – Division of Water Technology and the University of Stellenbosch – Department of Soil and Agricultural Water Science)

### New

- **639** Economics of groundwater usage: The importance of intrinsic value as a basis for sustainable management (Economic Project Evaluation (Pty) Ltd)
- **640** Extension and refinement of the AQUAMOD computer software package (University of the Orange Free State – Institute for Groundwater Studies)
- **641** Assessment of the impact of agricultural practices on the quality of groundwater resources in South Africa (CSIR – Division of Water Technology)
- **653** Regional characterisation and mapping of Karoo fractured aquifer systems – An integrated approach using a geographical information system and digital image processing (Department of Water Affairs and Forestry – Directorate of Geohydrology, and the Council for Geoscience)

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# 7
# Agricultural water utilisation

Agricultural water utilisation, comprising water used for irrigation purposes and stock watering, in 1965 accounted for 70% of the total water consumption. In 1980 this percentage decreased to 53,8% (52,2 and 1,6% respectively for the two subsections) and these figures will, according to estimation, be 45,8% and 1,4% respectively in the year 2010.

These figures clearly illustrate that agricultural water utilisation will come under increasing pressure, as it will be expected of the industry to maintain the current production and even better it, using less water. This increasing pressure will be felt by the irrigation utilisation sector in particular.

It is against this background that the WRC had already during the early stages of its existence realised the need to stimulate research in the irrigation field, and started making real contributions in this regard. The majority of the irrigation research projects was aimed at the needs of large commercial agricultural undertakings, although one of the very first WRC irrigation research projects (titled **Soil factors affecting the optimal utilisation of irrigation water in the national states**, executed by the University of Fort Hare), had already investigated facets of developing irrigation agriculture. Although much of the data and technologies thus generated, are also of value to developing agriculture, the specific needs of this sector have not been addressed in depth.

Following a recommendation by the Co-ordinating Committee for Irrigation Research in 1991, the WRC contracted the consulting engineering firm Murray, Biesenbach and Badenhorst Inc. in 1992 to evaluate the existing irrigation techniques of subsistence and emergent farmers and to draw up design guidelines for irrigation under these circumstances.

Although this research project has at this stage not yet been completed, it is already clear that small-scale cultivation of vegetables under irrigation (also known as "community gardens") is contributing significantly to the food security of households in the rural and peri-urban areas of South Africa. This security not only centres in vegetables for own use, but also in income generated by the sale of vegetables. It is estimated that approximately 150 000 vegetable farmers (mostly women) are involved in this activity and are providing a livelihood for approximately 1 million people.

Furthermore it is also evident that community gardens afford individuals the opportunity to develop virtually a full range of entrepreneurial and farming skills through a small enterprise. In their own right these individuals are in a position to make decisions on crops and marketing, although they have to co-operate within an organisational structure with regard to water supply, equipment and other infrastructure.

In this regard these supplementary results of the current WRC projects have strongly emphasised the scope and importance of small-scale irrigation ventures in emergent agriculture. At the same time, additional gaps in the current state of knowledge have also been identified, which, seen against the background of future developments in the field of small-scale irrigation agriculture, will necessitate in-depth attention. The WRC will focus its attention on some of these identified gaps in the foreseeable future, but it is also clear that the extent of the WRC's involvement in research on emergent irrigation agriculture, will have to be developed substantially. In this respect the revision of the existing strategic plan for irrigation research will be directional.

During 1994 the WRC financed 35 research projects in the field of agricultural water utilisation. Of these projects, 4 were completed during the year, while 8 new research agreements were concluded.

## Workshop on crop water requirements and irrigation scheduling

Following a recommendation of a previous project that a PC-based program SAPWAT (Southern African Procedure for estimating irrigation WATer requirements) be developed to the stage where it will be acceptable as the standard procedure for estimating crop irrigation requirements in Southern Africa, the WRC entered into an agreement with the consulting engineering firm Murray, Biesenbach and Badenhorst Inc. (MBB) to attend to this task. MBB Inc. was also responsible for the initial development of SAPWAT.

Although SAPWAT is required to be compatible with South African conditions and databases, it is desirable that it should nevertheless conform to the maximum extent with "standard" procedures in the rest of the world. The FAO of the UNO is currently in the forefront of the standardisation effort. In order to bring SAPWAT in line with the other procedures, a workshop in this regard took place in June 1994 involving Mr Martin Smith of the FAO. Mr Smith heads the FAO's activities as far as standardisation is concerned, and was invited to participate in and guide the workshop in the discussions on the refinement of the SAPWAT concept and the further development thereof.

The workshop *inter alia* identified fields for future co-operation including the following:

- Involving researchers and scientists from South Africa in the FAO Working Group on Crop Water Requirements, and the introduction of FAO methodologies in established procedures in South Africa for irrigation planning and management.
- Participation of South African scientists in the ICID/FAO Irrigation Scheduling Seminar in 1995 and the water-use research network of the joint FAO/IAEA (International Atomic Energy Agency) division.
- Co-operation with FAO in the formulation and implementation of national development priorities, in particular in relation to assistance programmes for small farmers to improve agricultural production and rural welfare by the introduction of improved cultural practices including irrigation.

The workshop met the expectations of all involved and solicited comments from Mr Smith on the excellent standard of research and practical application of the various scheduling techniques developed in South Africa.

## Completed projects

### Water-use efficiency of certain irrigated temperate pasture species

(No 257) Department of Plant Production, University of Pretoria

The main aim of the research was to determine the water consumption and water-use efficiency of different pasture species, and to establish irrigation standards for the species.

A field test was conducted under a rain shelter to accurately determine water consumption for 10 pasture species.

The conclusion arrived at was that a single set of irrigation criteria for pasture species was inadequate for efficient irrigation management and water utilisation. The species were found to have considerably deeper root systems than had generally been accepted. The rooting depth of 300 mm which had in the past been used for planning purposes can be increased for all the species. The rooting depths of the various species showed definite variations.

*Cost:* *R484 100*
*Term:* *1988-1993*

### Quality of water for animal production

(No 301) Department of Animal and Wildlife Sciences, University of Pretoria

This project was initiated at the request of the Department of Agriculture due to the reservations expressed regarding the validity of the guidelines presently used in South Africa in assessing the quality of water for livestock production.

Datasets of borehole water samples indicated that fluoride (F), total dissolved salts (TDS), chloride (Cl) and sulphate ($SO_4$) were the variables of major importance to livestock production based on the incidence of potential toxicity assessed according to international guidelines.

The effects of five different levels of F in drinking water on the growth and health of SA Mutton Merino (SAMM) wethers to market weight, were investigated. From these investigations recommendations followed regarding the ingestion levels of F for SAMM wethers for growth to market weight without any adverse effects on growth and health occurring. A similar fluoride level (20 mg/*l*) had no negative effects on Bonsmara steers during growth to market weight, and neither did it have any negative effects on Ross broilers up to an age of 49 days, nor on Silver Grey Hy-line layers over a period of 74 weeks.

Regarding the effect of Cl and $SO_4$ on the palatability of water, it was found that both variables had a significant adverse effect on the palatability of water, judged by a decrease in the water intake for both variables and a decrease in the feed intake for the Cl variable. However, no significant treatment effects were found on growth to market weight or health.

The project concluded that since the guidelines currently used in South Africa to assess the suitability of a groundwater source, are based largely on international data, it may result in the rejection of many sources that under local conditions might be quite acceptable for animal production. International guidelines are based on extremely conservative time limits, and in actual fact animals are slaughtered well ahead of the point in time when accumulation of a certain toxic substance reaches levels unacceptable for human consumption. Climate, fodder and the end product (e.g. milk or meat) need all to be considered in the evaluation of the suitability of water for animal production.

*Cost:* *R434 000*
*Term:* *1990-1993*

### Development of an effective and environmentally safe larviciding programme for the control of the blackfly, *Simulium chutteri* along the Orange River

(No 343) Onderstepoort Veterinary Institute, Agricultural Research Council

This project was initiated in July 1991 in response to complaints from farmers whose stock were being affected by the biting of pest blackflies.

In addition to the determination of the efficacy of commercially available formulations of *Bacillus thuringiensis* var. *israelensis* (Bti) against blackfly larvae in the Orange River, the project also included the testing of the organophosphate, temephos. Both proved to be effective in controlling blackflies, although Bti was better suited for use in clear water, whereas temephos was suited for use in turbid water. Downstream "carry" of these larvicides was highly variable e.g. for Bti 5 km at flows of 60 – 143 $m^3/s$ and 20 km at flows of 180 $m^3/s$. The "carry" of temephos was usually 3 times further than Bti.

The project indicated that the development rates of larval *S. chutteri* largely depend on water temperature and food quality, ranging from 7 days in mid-summer to 37 days in mid-winter. Consequently the recommended time intervals between treatments ranged from 6 to 32 days.

Utilising a novel method of estimating the abundance of immature blackflies, surveys showed that larval numbers were generally higher in winter than in summer with the lowest numbers occurring in autumn during algal blooms. This observation suggests that blackfly populations may be controlled by naturally occurring toxic algae.

Regarding the effects of these larvicides on non-target organisms, trials indicated that blackfly larvae were the most sensitive taxa in the stones-in-current biotope to both Bti and temephos. High-dosage applications indicated that Bti has a wide margin of safety, whereas temephos has a narrow margin of safety. It was concluded that good control of blackflies may be obtained with minimal direct impact on the non-target fauna, provided recommended dosages of temephos are not exceeded. Overdosing with temephos should be strictly avoided.

*Cost:* *R332 000*
*Term:* *1991-1994*

### Evaluation of the interdependent factors which determine the viability of irrigation farming

(No 382) Murray, Biesenbach and Badenhorst Inc.

The objective of this project was to assess the ways and means of incorporating qualitative research techniques in the "toolbox" used by technical specialists with a view to developing a practical system for acquiring, analysing and presenting data and information relevant to the viability of irrigation farming.

Utilisation and presentation of information gathered were achieved through the development of a computer program SAPFACT (South African Procedure for assessing farming FACTors).

The project clearly indicated that there is a place for qualitative research in agriculture and engineering with specific reference to irrigation. It also emphasised the potential role of the individual farmer in contributing to the design of new technology and development programmes. The following perceptions by irrigation farmers need to be taken into consideration in the development of proposals:

- Irrigation is a chore to most irrigation farmers and is nowhere near the top of their priority list
- Water wastage is a consequence of anxiety about under-watering and not an irresponsible disregard for natural resources
- Irrigation increases rather than decreases the risk factor in farming
- Farmers may have good reasons not to accept the recommendations of engineers and scientists
- It is not true that a farmer values equipment or services only if he pays for them
- Irrigation farming is labour-intensive, placing a premium on developing present labourers to be active participants in the organisation and management of the irrigation function.

The increasing attention being given to small-scale farmers who operate in circumstances unfamiliar to many specialists has revealed that farmers' perceptions are as important as "facts" available to the specialist. The project also revealed the lower priority that most farmers place on irrigation management, and the almost complete dearth of effective irrigation extension.

*Cost:* *R228 000*
*Term:* *1991-1993*

## New projects

### Water-use efficiency of cultivated subtropical forage and pasture crops

(No 573) Department of Plant and Soil Sciences, University of Pretoria

The primary aim of the project is to develop irrigation standards for cultivated subtropical forage and pasture crops as well as to develop concomitant water production functions. Comparisons will also be possible with the results obtained with a similar project on temperate pastures, to determine whether water must be used on temperate pastures during the winter months or rather on subtropical pastures in the summer months when potential yields, and water consumption, are higher.

The results emanating from this project, together with those of the project on temperate forage and pasture species, will lead to the establishment of scientific irrigation standards for the entire forage and pasture crop spectrum.

*Estimated costs:* *R677 600*
*Term:* *1994-1998*

### Problem blooms of macro-algae: Investigation of causal factors, seasonality of recruitment and growth, and efficiency of control methods

(No 600) Department of Botany, University of Cape Town

Control of macro-algae is enforced and currently consists of either extremely intensive manual/mechanical control or chemical control. Manual control is labour-intensive (and thus expensive), difficult and continuous throughout the period of infestation. Chemical control, although also expensive, has a longer residual effect. Treatment is, however, complex and usually requires acidification of the water prior to treatment. Environmental problems associated with such treatments are also increasingly negative attributes. This study will attempt to establish guidelines for either more efficient and/or environmentally acceptable control measures.

It is expected that this project will produce an environmentally acceptable and more cost-effective method of algal weed control in canal systems.

*Estimated cost:* *R569 000*
*Term:* *1994-1997*

## Personal computer-based procedure for the estimation of irrigation requirements of crops in Southern Africa

(No 624) Murray, Biesenbach and Badenhorst Inc.

A pilot project recently completed by MBB Inc. yielded a PC-based program which demonstrated that by linking existing data, procedures and sub-programs, and by incorporating recent international recommendations, it is possible to provide an updated and effective successor to the "Green Book" for the calculation of cropwater requirements. There is now a need, however, to develop this program (SAPWAT) beyond the demonstration stage to the stage where it is accepted as the standard procedure for estimating irrigation requirements of crops in South Africa. After necessary developments and refinements, SAPWAT will be thoroughly evaluated and a comprehensive user's manual produced.

*Estimated cost:* *R632 000*
*Term:* *1994-1996*

## Use of computer models for agricultural water management at farm level

(No 625) Department of Soil Science, University of the OFS

This project aims to establish 2 types of agricultural water management models which can be used for global farming purposes, viz. firstly for the planning and management at regional level and secondly for agricultural water management and planning at ecotope level. The project will be executed in 2 phases, namely, firstly the modelling phase and secondly, the testing phase. The data systems comprise detailed crop and field ecotope classification as well as soil-water balance and production detail.

The integration of the existing data sets and relevant subroutines of existing models ought to make a significant contribution to the scientific utilisation of and decision-making concerning agricultural water in the semi-arid climatic regions of the RSA.

*Estimated cost:* *R755 500*
*Term:* *1994-1996*

## Quality of water for livestock production with emphasis on subterranean water and the development of a water quality guideline index system

(No 644) Department of Animal and Wildlife Science, University of Pretoria

During the project preceding this project it had been ascertained that the current guidelines for the evaluation of borehole water for animal husbandry were unnecessarily conservative. The guidelines currently in use set only maximum allowable limits for certain variables while the guidelines in actual fact need to take into account the individual and collective effects of, among others, the following:

- Tolerance of the relevant animal species to maximum values
- Impact of the relevant macro- and micro-climates on the relevant animals
- The production system being used
- The production phase of the relevant animals
- The economic impact of exposure to harmful substances.

From the previous project it was clear that, in view of the complex nature of the interaction between the various variables and the importance of these interactions, the most realistic manner in which to integrate the influences, would be an index system. The intention is that the index system will summarise the major variables and the role which they play in the global suitability of water for animal husbandry, in such a manner that it will provide a "weighted" decision on the suitability of the water. In addition to integrating the impact of the variables at an acceptable level of accuracy, the index system has to be flexible and user-friendly.

*Estimated cost:* *R851 000*
*Term:* *1994-1996*

## Optimal management of uncertain water availability at farm and regional level with due allowance for risk and the environment

(No 645) Department of Agricultural Economics, University of the OFS

Both short- and long-term strategies are required for farm management under conditions of uncertain irrigation water availability. In addition, problems are being experienced in taking the stochastic nature of irrigation farming into account, consequently restricting the economic and financial analyses of alternative water supply and utilisation at farm and regional level. As short- and long-term economic adjustments to varying water supplies are not being made, the economic survival of irrigation entrepreneurs is being jeopardised.

The aim of this project is to develop procedures to evaluate the economic impact of irrigation farming on the environment, as well as procedures to determine the detrimental effects of irrigation management strategies at regional level, and to evaluate irrigation water utilisation economically at regional level. In addition the models generated during the previous project to evaluate water supply and water utilisation strategies at farm level, will be expanded to include long-term economic and financial analyses.

*Estimated cost:* *R1 499 000*
*Term:* *1995-1998*

## Maximisation of economic water-use efficiency of processing tomatoes

(No 646) Department of Plant Production, University of Pretoria

An emerging cost saving trend in the tomato processing industry is the setting of stricter quality standards as regards the total soluble solids (TSS) content of tomatoes. The higher the TSS, the lower the water content of the fruit and hence the lower the energy cost in evaporating off the water in the paste-making process. The tomato producer will thus have to grow a product of acceptable TSS standard. To date, however, farmers have geared their whole production and irrigation philosophy on maximum yield and not maximum TSS. Therefore, in order to comply with the TSS requirements, new irrigation strategies, focusing on substantially lower water usage, will have to be followed.

The major objectives of the research project are thus the following:

- The establishment of an irrigation management tool for the optimum yield and quality combination which will maximise income and water-use efficiency
- The establishment of a management tool for scheduling planting dates in order to make optimum use of processing facilities.

*Estimated cost:* *R440 000*
*Term:* *1994-1996*

## Integrated control of blackflies along the Orange River

(No 650) Onderstepoort Veterinary Institute, Agricultural Research Council

Earlier in this chapter completion of a project on the development of an effective and environmentally safe larviciding programme for the control of the blackfly (with special reference to the microbial larvicide *Bacillus thuringiensis* var. *israelensis* (Bti)) was reported on. The report made recommendations on the use of Bti and an organophosphate larvicide for optimal pest control.

Larvicidal control, employing these two larvicides, remains a costly undertaking, both in terms of monetary and environmental costs. For this reason the best option still is to minimise the number of treatments, which may be achieved by integrating larvicide applications with other methods of control. Against this background this follow-up project aims to integrate the use of larvicides, flow manipulation and predators, in the control of blackflies along the Orange River so as to minimise larvicide applications. Furthermore the aim is to define the annoyance level at which larviciding is necessary – again with a view to reducing the number of applications. Concentrating on the middle Orange River, the project will investigate the relationship between river discharge and habitat availability for blackflies, and the probabilities of blackfly outbreaks under different environmental and biological conditions.

*Estimated cost:* *R535 000*
*Term:* *1994-1997*

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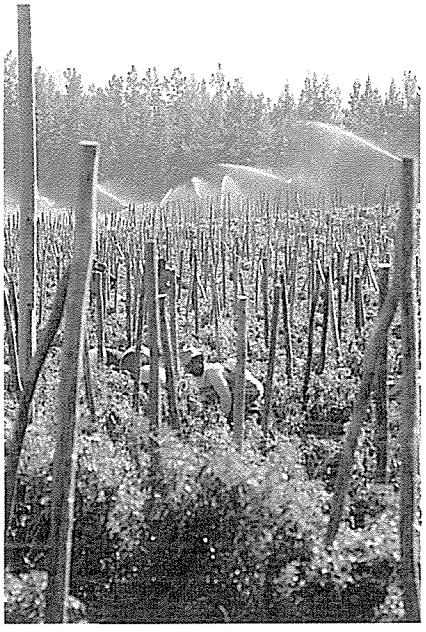


New irrigation strategies for the production of factory tomatoes will have to be developed.

One of the irrigation techniques employed by developing communities.

## Research projects

### Completed

- **257** Water-use efficiency of certain irrigated temperate pasture species (University of Pretoria – Department of Plant Production)
- **301** Investigation into the quality of water for animal production (University of Pretoria – Department of Animal and Wildlife Science)
- **343** Development of an effective and environmentally safe larviciding programme for the control of the blackfly, *Simulium chutteri*, along the Orange River (Agricultural Research Council – Onderstepoort Veterinary Institute)
- **382** Evaluation of the interdependent factors which determine the viability of irrigation farming (Murray, Biesenbach and Badenhorst Inc.)

### Current

- **227** Storage and utilisation of rain water in the soil for the stabilisation of plant production in semi-arid areas (University of the OFS – Department of Soil Science)
- **228** Factors affecting the water-use efficiency of irrigated crops with special reference to the physiological responses of these crops (University of the OFS – Department of Agronomy and Horticulture)
- **261** Soil/plant/water relations in the upper reaches of plant available soil water (University of Pretoria – Department of Soil Science)
- **262** Moisture sensors to facilitate water management (University of Stellenbosch – Institute of Polymer Science)
- **290** Flood and furrow irrigation: A critical evaluation of design procedures and the computerisation of the most suitable approaches (University of Pretoria – Department of Agricultural Engineering)
- **303** Use of saline water for irrigation purposes and an assessment of salt tolerance criteria of crops (University of Stellenbosch – Department of Soil and Agricultural Water Science)
- **307** Influence of different water-nitrogen regimes on crop canopy development, water flow resistance and crop yield, with a view to improvement of irrigation models (Agricultural Research Council – Institute for Soil, Climate and Water)
- **347** Global farm approach to enhancing the economic efficiency of water and energy use for irrigation in the central RSA (University of the OFS – Department of Agricultural Economics)
- **348** Root development and water usage of commercial timber species (University of Natal – Department of Agronomy)
- **372** Assessing the impacts of varying rainfall conditions on vegetation dynamics, production and certain hydrological properties of natural grassland, using a system modelling approach (Potchefstroom University for CHE – Department of Plant and Soil Sciences)
- **389** Scheduling irrigation of tuber crops with specific reference to potatoes (Agricultural Research Council – Vegetable and Ornamental Plant Institute)
- **417** Optimal water utilisation by turf (Potchefstroom University for CHE – Department of Plant and Soil Sciences)
- **423** Effect of pre-programmed deficit irrigation on crop reaction (University of the OFS – Department of Soil Science)
- **440** Identification of irrigated land in an intensively cultivated agricultural area in the South-Western Cape by means of satellite remote sensing (University of Stellenbosch – Institute for Cartographic Analysis)
- **441** Determination of the relationship between transpiration rate and declining available soil water for *Eucalyptus grandis* (CSIR – Division of Forest Science and Technology)
- **476** Transfer of research results on the irrigation of vegetable crops into practice (University of Pretoria – Department of Plant Production)
- **479** Molecular approach to drought tolerance (Agricultural Research Council – Institute for Plant Biotechnology)
- **499** Effect of exchangeable sodium percentage and clay mineralogy on the infiltration capacity of soils already sealed due to cyclic irrigation (Potchefstroom University for CHE – Department of Plant and Soil Sciences)
- **507** Improved estimation of plant and soil evaporation from cropped lands (University of the OFS – Department of Agrometeorology)
- **508** Modelling the water balance on benchmark ecotopes (Agricultural Research Council – Institute for Soil, Climate and Water)
- **513** The development of a computerised management system for irrigation projects (Rand Afrikaans University – Department of Civil Engineering)
- **578** The evaluation of irrigation techniques used by subsistence and emergent farmers (Murray, Biesenbach and Badenhorst Inc.)
- **581** A computerised weather-based irrigation water management system (University of the Orange Free State – Department of Agrometeorology)

### New

- **573** Water-use efficiency of cultivated subtropical forage and pasture crops (University of Pretoria – Department of Plant and Soil Sciences)
- **600** Problem blooms of macro-algae: Investigation of causal factors, seasonality of recruitment and growth, and efficiency of control methods (University of Cape Town – Department of Botany)
- **624** Personal computer-based procedure for the estimation of irrigation requirements of crops in Southern Africa (Murray, Biesenbach & Badenhorst Inc.)
- **625** Use of computer models for agricultural water management at farm level (University of the Orange Free State – Department of Soil Science)
- **644** Quality of water for livestock production with emphasis on subterranean water and the development of a water quality guideline index system (University of Pretoria – Department of Animal and Wildlife Science)
- **645** Optimal management of uncertain water availability at farm and regional level with due allowance for risk and the environment (University of the Orange Free State – Department Agricultural Economics)
- **646** Maximisation of economic water-use efficiency of processing tomatoes (University of Pretoria – Department of Plant Production)
- **650** Integrated control of blackflies along the Orange River (Agricultural Research Council – Onderstepoort Veterinary Institute)

# 8
# Industrial effluents

The underlying principle reflected in WRC sponsored industrial effluent research projects is to minimise the pollution load leaving a factory and at the same time to ensure a higher degree of water reuse within a factory premises.

In the short term the WRC gives attention to the large consumers of water such as the textile, fruit and vegetable processing, hides and skin and fish and meat industries. Research is aimed at developing and implementing the necessary expertise for sound water management and treatment of effluents, and manuals are compiled.

A medium-term strategy was precipitated by the severe drought in 1982 to 1983 when it was realised that all industries, not only the large ones, were being severely affected by water restrictions of up to 30% of their normal intake. This resulted in the WRC sponsoring a National Industrial Water and Waste-water Survey (NATSURV). Results from this survey have been reported in the form of short information guides for each of 14 industries that were identified as either major water consumers or polluters of the environment.

As far as the long term is concerned, it is fully realised by the WRC that a country's economic and social growth is to a very large degree dependent on its industrial activities. Since there is a direct connection between economic and industrial growth, the implication is that there will be an increase in industrial water use and a resultant increase in effluent volumes from industry.

While significant strides have been made by research into "high-tech" solutions for the treatment of industrial effluents such as cross-flow microfiltration, ultrafiltration and reverse osmosis, the WRC has for some years now accepted the fact that there are natural environmentally friendly processes that can effectively treat organically rich effluents to a standard acceptable to the environment.

To this end the WRC is presently sponsoring projects aimed at low-cost, novel, but natural technologies such as algal systems for the treatment of domestic, tannery and abattoir effluents.

Proposed new projects in this field deal specifically with low-cost, low-technology processes for the treatment of small rural abattoir effluents, feed-lot wastes, piggery effluents or any high organic content effluent.

During this year 8 new projects commenced in this category, 7 were completed while 29 are ongoing. A brief summary of the completed and new projects follows.

## Completed projects

### Treatment of wool scouring effluents

(No 161) Department of Chemical Engineering, University of Natal, SRK (CE) Inc. and Gubb and Inggs (Pty) Ltd

The scouring of raw wool leads to the production of an extraordinarily stable effluent which is both unsuitable for discharge to the environment and very difficult to deal with. The report addresses the area of dynamic ultrafiltration as a potential contender of interest to the South African scene.

The main aims were to determine the technical feasibility of an ultrafiltration system to treat the scouring effluent for water reuse purposes and to develop a detailed design for the full-scale treatment of wool scouring effluents.

In spite of positive technological aspects, this specific membrane technology application has proved to be non-viable from an economic point of view due to excessive running costs.

*Cost:* *R1 152 800*
*Term:* *1985-1992*

## Evaluation of various factors affecting dry-wet cooling

(No 285) Bureau of Mechanical Engineering, University of Stellenbosch and Eskom

Being a relatively arid country, South Africa is fortunate in having three of the world's largest dry-cooled power stations at its disposal. Because of the complex interaction of the relevant parameters, performance improvement options for such large dry-cooling systems are best evaluated by means of suitable computer programs. This project was aimed at refining and augmenting the computer programs that had been developed by the University during a preceding research project.

Aspects that were studied analytically, by means of simulation apparatus, and through field trials include:

- The rate of steam condensation and the corresponding change in pressure drop in the dephlegmator
- The cooling-air flow rate through the heat exchanger array
- The influence of disturbed inlet flows on fan performance
- The influence of wind and ambient temperature inversions on cooling-tower performance.

Although useful computer programs were developed, the study revealed that certain system characteristics are as yet not fully understood and, therefore, warrant further in-depth study to enable improvement of the computer programs. These are being addressed in a follow-up project, entitled **Saving of water with air-cooled heat exchangers**.

*Cost:* *R835 000*
*Term:* *1989-1992*

## Phase diagrams of complex precipitants

(No 309) Department of Chemical Engineering, University of Natal

Many industries are employing some form of desalination measure in order to recover and reuse water and chemicals and to reduce the volume of effluent requiring disposal. Regardless of the desalination technology used, fouling and scaling of heat or mass transfer surfaces is a common problem which often results in equipment being used below design specifications, in order to avoid the precipitation of unwanted solid phases.

The main aims were to develop techniques for the determination of a phase diagram of complex precipitates and to generate data which could assist in the verification of computer models of aquatic equilibria. Two major water users are already benefiting from the expertise gained during this project.

A large number of workshops were held to bring this computer model to the attention of various organisations in the water field.

*Cost:* *R192 500*
*Term:* *1990-1992*

## Optimisation of biofouling control programmes

(No 318) Department of Microbiology, University of Pretoria

Microbial growth in water-cooling systems results in fouling of pipelines, biocorrosion of metals and reduction in heat transfer. Industry spends millions of rands annually to combat these problems. The objective was to develop techniques to control biofouling.

Five industrial bactericides were evaluated to determine their optimum concentrations to prevent biofouling. The "Sterikon" bio-indicator proved to be the most suitable. Sulphate-reducing bacteria (SRB) were identified in industrial cooling-water systems and organisms, other than SRB, are also involved in corrosion. It was found that bacteria often develop a resistance to bactericides, leading to the induction of cross-resistance to other bactericides. Oxidising biocides such as hydrogen peroxide or hypochlorous aid, may be used to counteract this bacterial resistance.

Conductance changes occurring during microbially induced corrosion were used instead of conventional media for enumerating SRB, which were found to behave very differently in a biofilm than when in suspension.

*Cost:* *R376 194*
*Term:* *1990-1993*

## Neutralisation of water containing high concentrations of sulphuric acid with calcium carbonate

(No 355) Division of Water Technology, CSIR

Acid mine waters contain high concentrations of dissolved heavy metals and sulphate, and can have pH values as low as 2,5. These conditions may prohibit discharge of untreated acid mine waters into public streams, as they have a detrimental effect on aquatic plant and fish life. Chemicals such as lime, sodium hydroxide and sodium carbonate are used for the neutralisation of acid water but limestone can also be used which has certain advantages, such as more accurate dosage control, availability, cost-effectiveness and producing a sludge of higher density. Limestone is also easy to store and safe to handle.

The main aims were to undertake pilot-plant studies to determine the technical feasibility of neutralising acid mine water with limestone and to determine the economic feasibility of a fluidised-bed limestone neutralisation process. The main contribution from this study is that it was demonstrated that acid water can be neutralised effectively in a fluidised-bed reactor.

*Cost:* *R200 000*
*Term:* *1991-1992*

## Microbiological transformation of metal-contaminated effluents

(No 357) Department of Microbiology, University of Durban-Westville

Many industrial processes discharge metal-laden effluents, which are toxic when released into the environment due to the process of bioaccumulation. Hence metals should be removed from waste water before it may be safely recycled.

Ten sludges were exposed to 6 metals to determine their biosorptive capacities for these metals. The sludges were then exposed to desorbing agents, such as acetic or hydrochloric acids. Desorbents were found to selectively remove metals from sludge surfaces.

This study showed that waste activated sludges were efficient metal biosorbents from industrial effluents. These metals could be desorbed later and safely disposed of, or recovered for reuse.

*Cost:* *R479 300*
*Term:* *1991-1993*

### Use of yeast biomass and yeast products to accumulate toxic and valuable heavy metals from waste water

(No 464) Department of Biochemistry and Microbiology, Rhodes University

Metal ions contribute significantly to water pollution. Some are very toxic and may be concentrated in certain organisms with the danger of being passed on to humans. Surface waters originating from mine drainage areas often contain significant levels of metals which may be reclaimed.

The main aims of the project were to devise methods to use yeast biomass to accumulate heavy metal ions and to identify components of the biomass responsible for such accumulation. Yeasts were found to accumulate zinc, lead and chromium effectively from industrial effluents. The biomass could be harvested by tangential filtration or in a fixed-bed cartridge.

*Cost:* *R54 334*
*Term:* *1992-1993*

## New projects

### Development of management strategies and recovery systems for heavy metal wastes

(No 589) SRK (CE) Inc.

Heavy metal discharges in industrial effluents concentrate in the sludges at sewage works, making them unsuitable for composting or land conditioning in terms of the relevant legislation. The WRC commissioned SRK Inc. to conduct an investigation into the problem, and to evaluate potential solutions.

An effective solution to this widespread problem may include a low-cost or no-cost collection service for metal sludges and concentrated solutions, a municipal or privatised centralised treatment facility for recovery of heavy metals and safe disposal of residual wastes and a register and manifest tracing system for all concentrated heavy metal tanks.

*Estimated cost:* *R70 000*
*Term:* *1994*

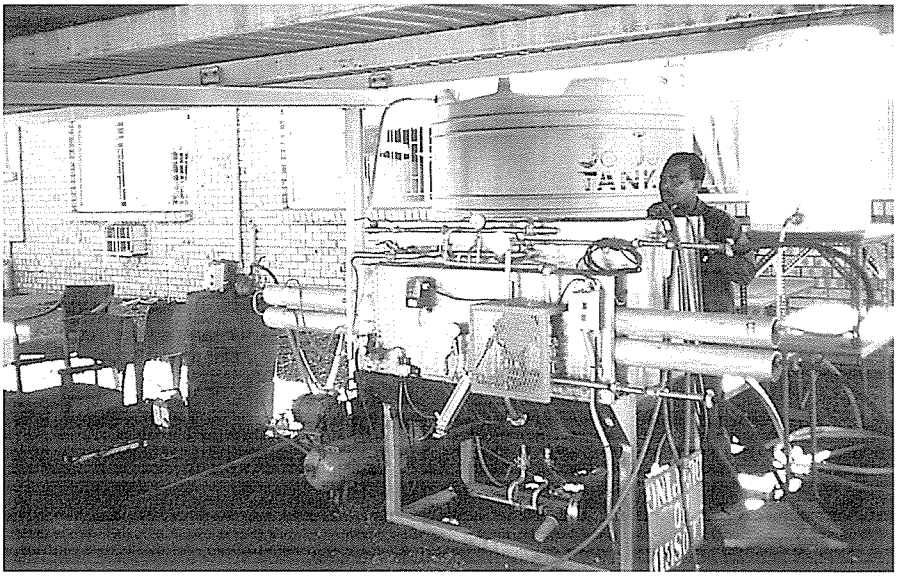
### Membrane technology for the treatment of industrial effluents

(No 590) Division of Water Technology, CSIR

Effluent discharges from tanneries to municipal water treatment works are generally unacceptable because of high salinity levels. Such effluents also contain very high concentrations of organic materials. Hence there is a need to desalinate tannery effluents prior to discharge to municipal sewers.

This project aims to evaluate ultrafiltration and reverse osmosis for the removal of organic substances and salts from various tannery operations, such as washing of hides and skins, liming and deliming processes, tanning and dyeing. Process design criteria will be developed for effluent volume reduction and pollution control with the aid of the above membrane techniques.

*Estimated cost:* *R99 000*
*Term:* *1994*




Industrial effluent from steel manufacture.

### Investigation into the use of biodispersants available for biofouling control in industrial water systems

(No 592) Department of Microbiology and Plant Pathology, University of Pretoria

Large quantities of dissolved or suspended substances are present in industrial cooling-water systems. The cooling water forms an ideal medium for microbial growth which leads to biofouling of surfaces with attendant decreases in flow rates, metallic corrosion and a reduction in heat transfer rates.

Most cooling-water systems are currently treated with biocides, but bacteria sometimes develop a resistance to such biocides, which means that higher than normal concentrations have to be applied.

The overall aim of the project is to study the dispersing activity of biodispersants which are added to decrease the adherence of substances to surfaces, thus counteracting biofouling.

*Estimated cost:* *R96 000*
*Term:* *1994-1995*

### Application of the anaerobic digestion/ultrafiltration (ADUF) process for the treatment of metal-cutting-fluid waste water

(No 593) Membratek (Pty) Ltd

The disposal of raw metal-cutting-fluid waste water, generated by the automotive and metal machining industries, can have a detrimental impact on the country's water resources. The fact that water-based metal-cutting-fluids are amenable to anaerobic digestion suggests that the anaerobic digestion/ultrafiltration (ADUF) process, capable of high quality effluent production, may be a viable means of treating such waste waters at the point of origin.

The viability of the envisaged treatment process will be studied during this project using a laboratory set-up and, if practicable, the study will be extended to generate the design data necessary for scale-up to process-plant level.

*Estimated cost:* *R60 000*
*Term:* *1994*

## Reduction of scaling in industrial water-cooling circuits by means of magnetic and electrostatic treatment

(No 612) Energy Laboratory and Department of Chemistry, Rand Afrikaans University

Although magnetic water treatment has been applied in South Africa for more than a decade, there are no scientific indications on whether it is successful and no guidelines on its use.

The primary objective of this project is to attempt to prove or disprove the value of electromagnetic scale-prevention devices in the prevention of scale in industrial water-cooled systems. The project team will investigate under which circumstances such units may be effective and ascertain whether any beneficial effects experienced are due to the electromagnetic treatment or simply ascribable to more conventional physical or chemical variables.

An expert in this field from the Ukraine, Dr Vladimir Kochmarsky, will also be involved in certain aspects of the project execution.

*Estimated cost:* *R351 000*
*Term:* *1994-1996*

## Use of algal and yeast biomass to accumulate toxic and valuable heavy metals from waste water

(No 616) Department of Biochemistry and Microbiology, Rhodes University

Many industrial processes produce waste waters which contain toxic heavy metals. In the case of the mining industry, there is a loss of valuable metals. Removal of these metal ions is vital if the effluent is to be recycled without significant contamination of watercourses.

The aims of this follow-up project are to determine the efficiency and capacity of algal and yeast biomass to remove heavy metals from industrial waste waters. Hollow-fibre membranes will be evaluated for biomass retention and immobilisation. Methods will be investigated to desorb heavy metals from biomass to concentrate the metals and to reuse the biomass.

*Estimated cost:* *R573 200*
*Term:* *1994-1996*

## Extractive purification of industrial effluents

(No 617) Department of Chemical Engineering, Potchefstroom University for CHE

Membrane technology has relied traditionally on the development of membranes which have to be evaluated and characterised experimentally. A need exists, however, to find easily measurable and reliable parameters for the optimal design of membranes.

This project aims to optimise the containment within which the membrane has to operate, the dynamic deformation of the membrane, the optimal operating cycle and the flow, pressure and temperature characteristics in the membrane.

Electrochemical impedance spectroscopy of a membrane may characterise it under dynamic conditions. Flow in and through a membrane can be optimised with computational flow mechanics.

*Estimated cost:* *R266 300*
*Term:* *1994-1995*

## Purification of abattoir effluents by means of the protein reclamation process

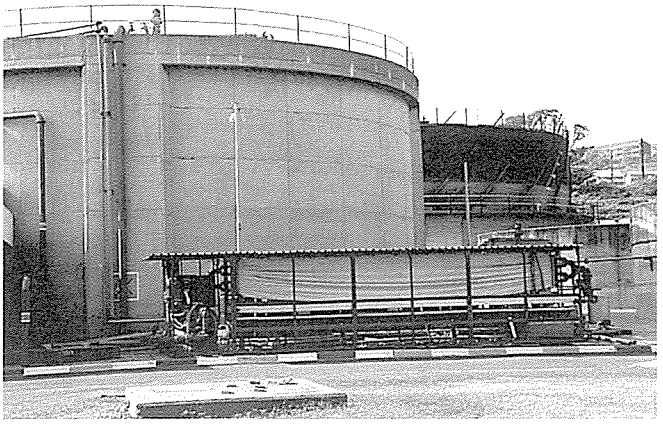
(No 652) Abakor Ltd

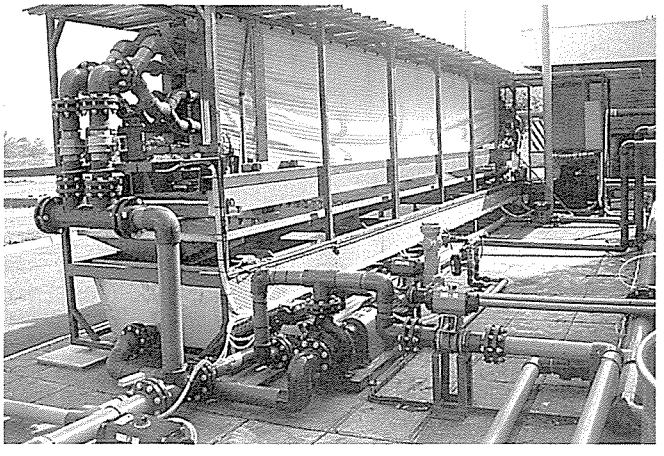
One of the major problems confronting abattoirs is coping with the effluent. Physical-chemical techniques, as well as biological processes, are normally employed to treat the effluent. Both types of processes, however, suffer from the drawback of being either relatively expensive or of still discharging a pollution load to the environment.

An alternative treatment process is the culture of single-cell protein in the effluent. This process has the advantage of being environment-friendly, of relieving the pollution load to existing municipal sewage treatment plants and of being an additional source of protein.

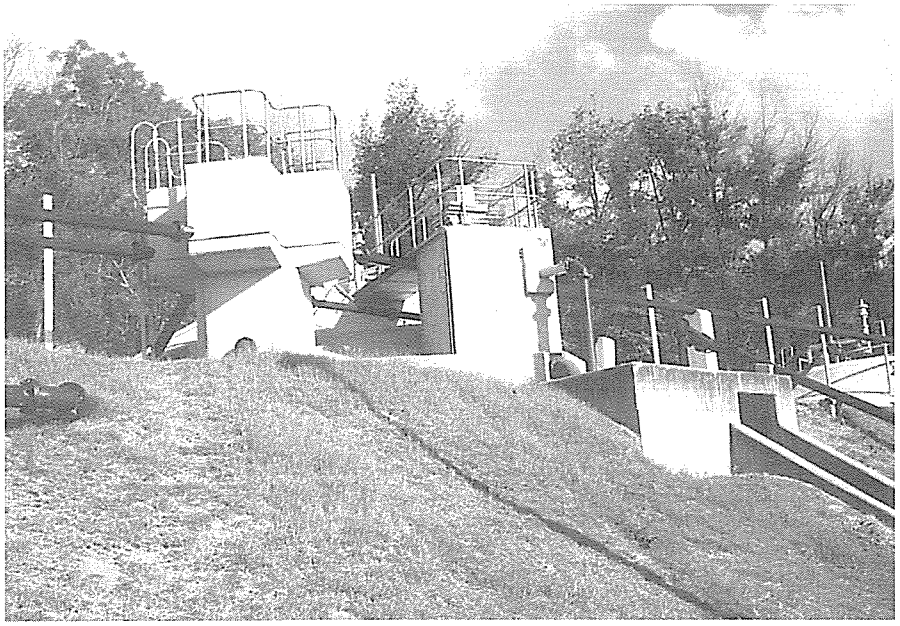
The purpose of this project is to transfer single-cell protein technology to a full-scale plant at the Johannesburg Abattoir.

*Estimated cost:* *R300 000*
*Term:* *1994*





Dewatering municipal sewage effluent.



General view of the earth-covered digester at Umbilo Sewage Purification Works in which concentrated dye effluent is being treated.

Feeding concentrated dye effluent into the anaerobic digesters at the Umbilo Sewage Purification Works at Pinetown, Durban. The digester is in the background.

## Research projects

### Completed

- **161** Treatment of wool scouring effluents (University of Natal – Department of Chemical Engineering, SRK (CE) Inc. and Gubb and Inggs (Pty) Ltd)
- **285** Evaluation of various factors affecting dry-wet cooling (Eskom and University of Stellenbosch – Bureau of Mechanical Engineering)
- **309** Phase diagrams of complex precipitants (University of Natal – Department of Chemical Engineering)
- **318** Optimisation of biofouling control programmes (University of Pretoria – Department of Microbiology)
- **355** Neutralisation of water containing high concentrations of sulphuric acid with calcium carbonate (CSIR – Division of Water Technology)
- **357** Microbiological transformations of metal-contaminated effluents (University of Durban-Westville – Department of Microbiology)
- **464** Use of yeast biomass and yeast products to accumulate toxic and valuable heavy metals from waste water (Rhodes University – Department of Biochemistry and Microbiology)

### Current

- **239** Transfer of waste-water management technology to the meat processing industry (SRK (CE) Inc. and Abakor Ltd.
- **241** Dewatering of compressible filter cakes (University of Natal – Department of Chemical Engineering)
- **263** Biological treatment of industrial water with the simultaneous production of single-cell protein (University of Pretoria – Department of Chemical Engineering)
- **308** Recovery of water and chemicals from ion-exchange regeneration effluents (University of Natal – Department of Chemical Engineering)
- **315** Utilisation of the fungus *Geotrichum* in waste water (University of Pretoria – Department of Chemical Engineering)
- **322** Study of a mine-water reclamation test plant (CSIR – Division of Mining Technology)

- **331** Improved oxygen transfer for high biosludge concentrations (University of Pretoria – Department of Chemical Engineering)
- **333** Removal of suspended solids from pulp and paper effluents by employing a combined sedimentation, flotation and sand filtration process (CSIR – Division of Water Technology)
- **342** Improvement in water usage control and waste-water treatment in the sorghum beer industry (University of Pretoria – Department of Chemical Engineering)
- **365** Evaluation and improvement of the anaerobic digestion/ultrafiltration (ADUF) effluent treatment process (CSIR – Division of Water Technology)
- **388** Evaluation of various methods for the forming of free radicals for the oxidation of molecules in industrial effluents and potable water (University of Natal – Department of Chemical Engineering, Pollution Research Group)
- **393** Use of algae to bioassay for toxic substances in water (University of the Orange Free State – Department of Botany and Genetics)
- **408** Fats and oils in effluents (University of Pretoria – Department of Chemical Engineering, Division of Water Utilisation Engineering)
- **409** Phenols in the steel industry waste water: Origin, prevention and removal (University of Pretoria – Department of Chemical Engineering, Division of Water Utilisation Engineering)
- **410** Biological approach to the removal of organics from saline effluents (Rhodes University – Department of Biochemistry and Microbiology)
- **453** Development of procedures to assess whole effluent toxicity (CSIR – Division of Water Technology)
- **455** Anaerobic digestion of dairy factory effluents (Irene Animal Production Institute, Agricultural Research Council)
- **456** Regional treatment of textile and industrial effluents (University of Natal – Department of Chemical Engineering)
- **457** Monitoring and optimisation study of high-rate biofiltration, aerobic biological treatment processes for tannery and fellmongery waste water (LIRI Technologies)
- **458** Development of an expert systems approach to water management in the fruit and vegetable processing industry (SRK (CE) Inc.)
- **478** Saving of water with air-cooled heat exchangers (University of Stellenbosch – Department of Mechanical Engineering and Eskom)
- **495** Biotechnological approach to the removal of organics from saline effluents (Rhodes University – Department of Biochemistry and Microbiology)
- **530** Technology transfer of aquatic chemical speciation modelling (University of Natal – Department of Chemical Engineering, Pollution Research Group)
- **533** Extractive purification of industrial effluent (Potchefstroom University for CHO – Department of Chemical Engineering)
- **535** Use of filamentous micro-organisms for the purification of industrial effluents (University of Pretoria – Department of Chemical Engineering, Division of Water Utilisation Engineering)
- **546** Development and demonstration of effluent treatment systems appropriate to the needs of the red meat abattoir industry (SRK (CE) Inc.)
- **551** Evaluation of the potential quantity of methane gas from 85 anaerobic household digesters (BE La Trobe)
- **552** Evaluation of immobilised semi-conductor particles for the photo-catalytic oxidation of organic pollutants in industrial and municipal waste water (University of Stellenbosch – Department of Chemistry)
- **553** Application of capillary membranes in the biotechnological treatment of industrial effluents (University of Stellenbosch – Institute of Polymer Science)

## New

- **589** Development of management strategies and recovery systems for heavy metal wastes (SRK (CE) Inc.)
- **590** Membrane technology for the treatment of industrial effluents (CSIR – Division for Water Technology)
- **592** Investigation into the use of biodispersants available for biofouling control in industrial water systems (University of Pretoria – Department of Microbiology and Plant Pathology)
- **593** Application of the anaerobic digestion/ultrafiltration (ADUF) process for the treatment of metal-cutting-fluid waste water (Membratek (Pty) Ltd)
- **612** Reduction of scaling in industrial water-cooling circuits by means of magnetic and electrostatic treatment (Rand Afrikaans University – Energy Laboratory and Department of Chemistry)
- **616** The use of algal and yeast biomass to accumulate toxic and valuable heavy metals from waste water (Rhodes University – Department of Biochemistry and Microbiology)
- **617** Extractive purification of industrial effluents (Potchefstroom University for CHE – Department of Chemical Engineering)
- **652** Purification of abattoir effluents by means of the protein reclamation process (Abakor Ltd)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# 9
# Membrane technology

Membranes are being used to an increasing extent in the purification of potable water sources as well as in the treatment of industrial and municipal effluents. Membrane systems have emerged as effective unit processes which may be used in a wide variety of applications. The technical and commercial importance of membrane separation processes is not only relevant to first-world conditions, but also has great potential for water supply to remote, rural as well as peri-urban communities.

Research and development work, currently under way on membranes which are more tolerant of various chemicals and new membrane module systems, has resulted in the granting of 3 new patents to the WRC.

The development of "A Strategic Plan for Water Related Membrane Research in South Africa" was taken a step further when a small task group met to review certain aspects of the proposed master plan. The aims, vision and mission statements were re-examined and finalised. Attention was given to key factors which are necessary to guarantee success of membrane research, the requisite criteria to achieve certain research goals and the existence of potential niches for water-related membrane research in this country.

The most important goal to emerge was "Research for Sustainable Development", which highlighted the need to supply potable water to disadvantaged communities, the abatement of pollution in the aquatic environment and industrial reuse of water. These subgoals all address relevant issues raised in the government's recently announced RDP and as such can have a major role to play in ensuring an adequate supply of good quality water for all South Africans into the next century.

The newly developed master plan formed the basis for the evaluation of new research proposals received by the WRC in the membrane technology, potable water and industrial water fields.

During the year under review 7 projects were finalised, 3 commenced and 9 were ongoing in this field.

## Completed projects

### Technical support for the application of dynamic membrane plants for the treatment of industrial effluents

(No 274) Pollution Research Group, University of Natal

Technical support was given to dynamic membrane plants treating wool-scouring waste waters, dyehouse effluent and emulsion polymerisation wash waters.

It was shown that suitably formed dynamic membranes are capable of treating effluents which would irreversibly foul conventional membranes. The effectivity of the dynamic membrane system is governed by the pore size distribution of the membrane support substrate, which has a significant effect on membrane performance. Fumed silica and hydrous zirconium (IV) oxide proved capable of modifying the pore size of the porous stainless steel substrate and was successfully implemented to effect improved membrane performance.

*Cost:* *R431 100*
*Term:* *1989-1992*

### Evaluation of membrane technology for electroplating effluent treatment

(No 275) Division of Water Technology, CSIR

Approximately 80% of the water used in the electroplating industry is disposed of as metal-laden effluent to the sewers. The metals often inhibit conventional biological sewage treatment processes and are also undesirable in sludges destined for land disposal.

The main aims of the project were to evaluate reverse osmosis, electrodialysis and diffusion dialysis for the recovery of metals and water from electroplating effluents.

Nickel, chromium and zinc-containing effluents could be treated effectively with reverse osmosis and electrodialysis to recover these metals, as well as up to 90% of the water used. Spent acids, such as hydrochloric and sulphuric acids, were recovered from electroplating waste waters by means of diffusion dialysis.

*Cost:* *R285 000*
*Term:* *1989-1993*

### Modelling of tubular reverse osmosis systems

(No 325) Pollution Research Group, University of Natal

The main objective of the project was to develop computer software and modelling methodology to support tubular membrane separation technology for waste-water treatment. This would allow an insight into causes of operational problems in large tubular reverse osmosis plants.

Single-solute and multi-solute membrane transport models were created to run on IBM-compatible personal computers. In order to validate these models, case studies were conducted of tubular reverse osmosis plants at the Lethabo Power Station, Sasol's Secunda Plant, Cato Ridge Abattoir and Huletts Sugar Refinery. In all cases valuable recommendations could be made to optimise the running of the plants and certain operational problems could be pinpointed.

*Cost:* *R751 500*
*Term:* *1990-1994*

### Development of tolerant membranes

(No 361) Institute for Polymer Science, University of Stellenbosch

This project was designed to generate a family of low-pressure, thin-film membranes which could be used for the purification of industrial effluents. Two membrane types were considered - a medium to high salt-retention reverse osmosis membrane and a low to medium salt-retention nanofiltration membrane.

Polyvinyl alcohol membranes were produced in tubular and flat sheet configurations, using 3 different cross-linking agents. Useful medium retention, medium flux reverse osmosis and nanofiltration membranes were manufactured. The latter type was evaluated in industrial effluents and also used to purify cooling tower blow-down water at the Sasol II plant.

*Cost:* *R553 900*
*Term:* *1991-1993*

### Development and production of membrane systems

(No 387) Institute for Polymer Science, University of Stellenbosch

The project proposed to develop novel tubular ultrafiltration membranes having extended molecular mass cut-off ranges in the case of polyether sulphone and polysulphone membranes. New materials, such as polyacrylonitrile and polyvinylidene fluoride, would also be used for membrane manufacture.

Unsupported polysulphone and polyether sulphone membranes were developed and commercialised. Two novel modules were designed to house axial-flow and transverse-flow capillary membranes and these were patented. A shell-and-tube cartridge module, to house internally skinned membranes, was also patented. Tubular cellulose acetate nanofiltration membranes were produced to remove colour from surface waters, to polish secondary sewage effluent and to remove bitartrate from wine lees.

*Cost:* *R1 280 000*
*Term:* *1991-1993*

### Fluoro-carbon coating of ion-exchange membrane surfaces to overcome fouling and general scaling

(No 466) Eskom

Currently the incoming waters into industrial installations contain higher concentrations of organic contaminants than before. Tubular reverse osmosis and electrodialysis membranes are often fouled irreversibly due to substances in the raw waters.

To overcome this fouling potential of membranes it was proposed to coat the surfaces of ion-exchange membranes with a limited range of fluorinated carbon compounds.

Such coatings tended to decrease the flux of the membrane and hence its capacity to desalinate effluents by ion-exchange. A limited resistance to fouling was exhibited in certain cases, but the coatings did not improve mechanical cleaning requirements.

*Cost:* *R50 000*
*Term:* *1992*

### Feasibility study for the provision of point-source water by enhanced solar distillation

(No 468) Institute for Polymer Science, University of Stellenbosch

The concept of producing potable water by enhanced solar distillation is fairly simple – sunlight enters a bag through a clear polymer film and is absorbed in a black bag, containing water, which will allow water vapour to escape freely. The vapour is finally condensed and collected for use.

The feasibility was investigated to develop a small-scale still for emergency use and a larger-scale solar still for rural household use and for stock watering.

A prototype single-effect unit was constructed and results obtained with it were found to compare favourably with computer simulation results. A prototype double-effect unit was then constructed. This was 60% more effective than the earlier unit. Various membrane materials and design aspects were evaluated.

*Cost:* *R52 500*
*Term:* *1992*

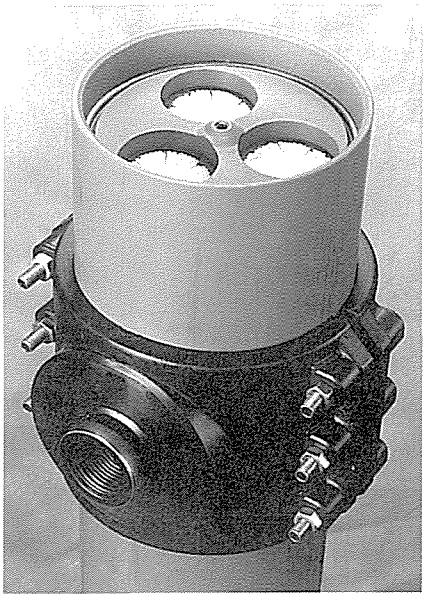
## New projects

### Development of specialised cross- and transverse-flow capillary membrane modules

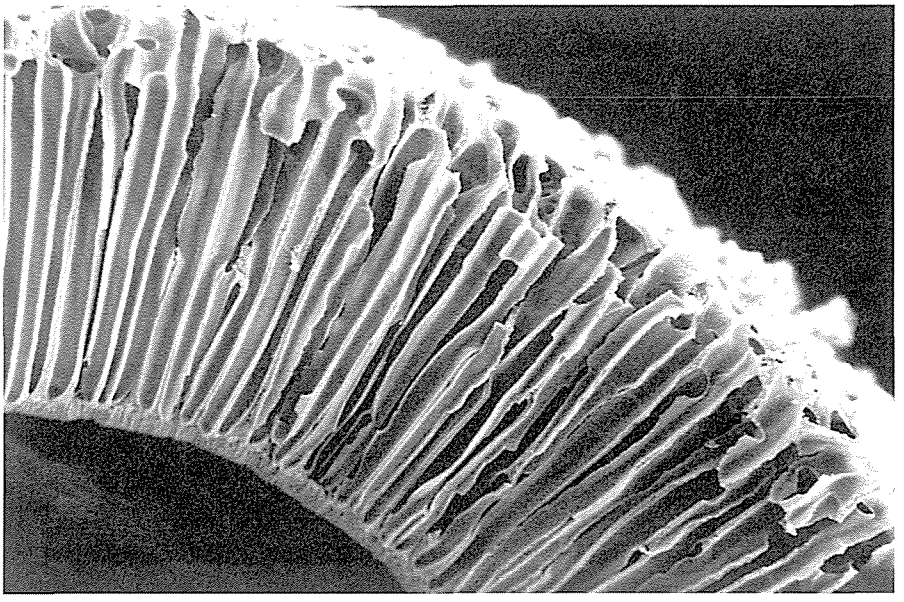
(No 618) Institute for Polymer Science, University of Stellenbosch

Membranes having capillary geometry are ideally suited for use in macrofiltration to clarify potable waters; in ultrafiltration for disinfection of drinking water; and in nanofiltration for softening of waters or colour removal from effluents.

The main aims of this membrane pro-



Prototype cartridge filter for water treatment.



Cross-section of an internally skinned capillary membrane for ultrafiltration.

duction and development project are to produce microfiltration membranes from polymers which are known for their chemical, hydrolytic and mechanical stabilities; to develop hydrophilic ultrafiltration membranes from cellulose acetate for large-scale filtration of surface waters for potable or industrial use; to create thermally precipitated polypropylene microfiltration membranes; and to prepare ceramic membranes on carbon fibre supports.

*Estimated cost:* *R558 700*
*Term:* *1994-1996*

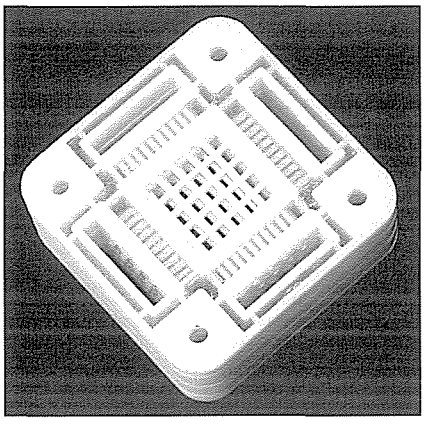
### Tolerant membranes

(No 619) Institute for Polymer Science, University of Stellenbosch

Novel membrane materials need to be created and new membrane applications have to be developed if we are to preserve current standards of living and to protect the aquatic environment.

The main objectives of the project are to develop membranes that show a greater tolerance to chemicals and solvents; and to devise post-treatment operations for the production of potable water, desalination of brackish water or seawater, effluent treatment, ozone distribution and bioreactors. Improved membranes are needed for potable water treatment, to prevent or correct environmental problems and to improve the handling of industrial discharges.

*Estimated cost:* *R599 000*
*Term:* *1994-1996*



A transverse flow capillary membrane module.

### Capillary membrane production development

(No 632) Institute for Polymer Science, University of Stellenbosch

Local development of capillary membrane technology has reached an advanced stage and is nearly ready for commercialisation. This technology needs to be improved further and a module device has to be developed for effective large-scale application of capillary filtration.

Specialised cross- and transverse-flow membrane modules will be developed during this project for cost-effective application in the large-scale treatment of surface waters to potable standard; the filtration of seawater as pretreatment for desalination by reverse osmosis; and upgrading the quality of industrial or municipal effluents by filtration or biofiltration.

*Estimated cost:* *R878 000*
*Term:* *1994-1996*

## Research projects

### Completed

- **274** Technical support for the application of dynamic membrane plants for the treatment of industrial effluents (University of Natal – Pollution Research Group)
- **275** Evaluation of membrane technology for electroplating effluent treatment (CSIR – Division of Water Technology)
- **325** Modelling of tubular reverse osmosis systems (University of Natal – Pollution Research Group)
- **361** Development of tolerant membranes (University of Stellenbosch – Institute for Polymer Science)
- **387** Development and production of membrane systems (University of Stellenbosch – Institute for Polymer Science)
- **466** Fluoro-carbon coating of ion-exchange membrane surfaces to overcome fouling and general scaling (Eskom)
- **468** Feasibility study for the provision of point-source water by enhanced solar distillation (University of Stellenbosch – Institute for Polymer Science)

### Current projects

- **201** Treatment of inorganic brines and concentrates (University of Natal – Pollution Research Group)
- **238** Design criteria for crossflow microfiltration (University of Natal – Pollution Research Group)
- **362** Industrial application of membranes (University of Stellenbosch – Institute for Polymer Science)
- **529** Membrane characterisation by electrochemical measurements and membrane optimisation with computational fluid mechanics (Potchefstroom University for CHE – Department of Chemical Engineering)
- **531** Development of characterising and cleaning techniques to classify foulants and to remove them from ultra- and microfiltration membranes by biochemical means (University of Stellenbosch – Department of Biochemistry)
- **532** Electrically driven membrane separation processes for the treatment of industrial effluents (CSIR – Division of Water Technology)
- **547** Synthesis of organic precursors for the development of novel tubular membranes for the treatment of industrial effluents (University of Stellenbosch – Department of Chemistry)
- **548** An investigation into the upgrading of Orange River water and secondary sewage effluent by means of ultra- and nanofiltration (University of Stellenbosch – Institute for Polymer Science)
- **585** Modelling flow through porous media (University of Stellenbosch – Department of Applied Mathematics)

### New

- **618** Development of specialised cross- and transverse-flow capillary membrane modules (University of Stellenbosch – Institute for Polymer Science)
- **619** Tolerant membranes (University of Stellenbosch – Institute for Polymer Science)
- **632** Capillary membrane production development (University of Stellenbosch – Institute for Polymer Science)

**CONTACT PERSONS**:
- **Dr HM Saayman**
(Development and Application of Membranes)
- **Dr TC Erasmus**
(Engineering Aspects of Membranes)

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# 10 Hydrometeorology

The new double wavelength (S- and X-band) radar system which has been installed at Bethlehem in the Free State.

The consequences of the large spatial variability of South Africa's rainfall have, over the past year, been expressed forcibly by the intensification of drought conditions in the extreme eastern and northern areas at a time when a large part of South Africa experienced some welcome relief. Water resources are extremely sensitive to such variability. Consequently, understanding and predicting climate variability at meaningful spatial and temporal scales remains an important goal of the hydrometeorological research which the WRC supports.

There is growing evidence that, over the long term, South Africa's water resources will be increasingly affected by global climate change. It seems all the more likely that the country's climate will in future experience an even greater temporal variability probably reflected in a higher frequency of wet and dry episodes and extreme events. Furthermore, changes in climate, and therefore also the impacts of such changes, are unlikely to be uniform from region to region within South Africa.

General circulation models, which are used to predict climate change on a global scale, provide little information which is relevant to predicting the regional consequences in terms of changing rainfall patterns and water resources impacts. Consequently, it has become necessary to develop methods of "downscaling", from the global to regional and even sub-regional scales. A new project which commenced during 1994 and aims at a short-term solution, is using a novel "neural net" approach to achieving the necessary downscaling. An alternative, longer-term approach would be to nest a suitable mesoscale climate model within a general circulation model. This presupposes that the mesoscale model is in a position to accurately simulate the behaviour and consequences, in terms of rainfall production, of dominant South-African rain-producing circulation systems such as tropical-temperate troughs. Another new WRC project is currently assessing the suitability of the Colorado State University's RAMS model for this purpose.

The better measurement and representation of daily rainfields (spatially distributed or areal rainfall) for water resources applications remains a challenge which is being addressed in WRC projects from both a remote-sensing and a modelling perspective. Ground-based weather radars are an essential component of the remote-sensing facet of the research. To facilitate this, the WRC purchased a dual-wavelength (S- and X-band) radar in 1994 and installed it at a site near Bethlehem in the Free State, where it is being operated by personnel attached to the Weather Bureau. Since the radar is intended to form the nucleus of a national radar research facility, researchers who have an interest in hydrological applications of weather radar are encouraged to establish contact with a view to participating in the forthcoming radar research programme.

During 1994 the WRC supported 12 hydrometeorological projects of which 2 were completed and 3 commenced.

## Completed projects

### Prediction of South African summer rainfall variability from ocean surface temperatures

(No 278) Department of Oceanography, University of Cape Town

Predictions of rainfall anomalies would, if feasible, have enormous benefits for water resources management and other socio-economic activities. The principal goal of this project was to provide an objective, statistical basis for the prediction of South African summer rainfall anomalies on monthly to seasonal time scales. To achieve this goal, South African rainfall fluctuations were analysed in association with fluctuations of sea surface temperature (SST) and

other appropriate meteorological variables in a belt extending around the globe between 20°N and 40°S. Key ocean areas in which SST was strongly associated with subsequent summer monthly rainfall over South Africa were identified. The research revealed a range of indicators having potential for use in an empirical model for predicting summer rainfall anomalies. Indicators especially favouring dry summer conditions include a negative southern oscillation index (SOI), positive SST anomalies in the central equatorial Indian (CEI) and east equatorial Pacific Oceans (El Ninõ), strengthening of regional-scale surface cyclonic circulations in the CEI and decreased upper westerlies in the subtropics over South Africa.

*Cost:* *R343 684*
*Term:* *1989-1992*

### Interpolation and mapping of daily rainfall model parameters for South Africa

(No 305) Department of Mathematical Statistics, University of Cape Town

The main objective of the project was, through interpolation, to provide estimates of the parameters at sites throughout South Africa at which there are little or no rainfall data available. The interpolation methodology selected was kriging. Model parameters fall into two classes, viz. amplitude and circular (or phase) parameters, each of which had to be treated differently. The topography-dependency of the amplitude parameters was accounted for by using a technique known as "kriging with external drift". A kriging technique for circular variables was not available initially but was successfully developed by the project. As a result, parameter values could be interpolated on a regular grid of one minute of a degree covering approximately 500 000 sites over Southern Africa at a resolution of about 1,5 km.

It is now possible to use the model to generate daily rainfall sequences and to deduce a wide range of rainfall characteristics at any location in Southern Africa.

*Cost:* *R267 372*
*Term:* *1990-1993*

## New projects

### Regional climate change scenarios for precipitation and temperature from general circulation models

(No 594) Department of Environmental and Geographical Science, University of Cape Town

Increasing levels of $CO_2$ and other greenhouse gases are changing the energy balance of the earth system. Resulting changes in temperature expected over the earth's surface will probably be accompanied by shifts in precipitation patterns and also enhanced precipitation variability. Corresponding changes in runoff and streamflow will in all probability be amplified owing to the nature of the hydrological system. This implies that South Africa's water resources will be sensitive to regional climate changes associated with expected global climate change.

Simulation and prediction of climate change using general circulation models (GCMs) is, because of their coarse resolution, less viable at the regional than the global scale. Special procedures are therefore needed to derive justifiable regional predictions from GCM data. The primary aim of this project is to initiate the regionalisation of climate change scenarios for Southern Africa by developing a non-linear cross-scale methodology for relating the general circulation to local climates. The product of the research, besides this methodology, will be quantified provisional estimates of regional changes in temperature and precipitation for use as inputs to hydrological and agricultural models.

*Estimated cost:* *R125 200*
*Term:* *1994-1995*

### Modelling rainfall-producing systems over Southern Africa

(No 595) Climatology Research Group, University of the Witwatersrand

The problem of limited water resources in semi-arid Southern Africa is further exacerbated by the inter- and intra-annual rainfall variability over the region. Tropical-temperate troughs have been identified as contributing substantially more to the annual rainfall over Southern Africa than any other rainfall-producing system. These troughs form a connection between tropics and mid-latitudes and result in ideal conditions for strong vertical uplift and the formation of cloud bands.

The project aims to model the thermodynamic and kinematic structure of tropical-temperate troughs and their rainfall production over Southern Africa using the Colorado State University Regional Atmospheric Modelling System (CSU RAMS). The model will also be used to test hypotheses concerning large-scale circulation controls over tropical-temperate troughs as well as the moisture sources and rainfall distributions of these systems.

*Estimated cost:* *R449 000*
*Term:* *1994-1996*

### Development of a real-time non-conventional rainfall mapping system for coastal zone cloud systems

(No 596) Department of Civil Engineering, University of Pretoria

The non-availability of spatial rainfall data in near-real time presents hydrologists with obstacles to making optimal use of distributed hydrological models for water resources management and flood warning purposes. Whereas rain-gauge networks display serious sampling inadequacies, indirect measurement systems such as satellite and radar also have deficiencies. However, by combining rain gauges, satellite and radar into a single measuring system for spatially distributed rainfall, many of the deficiencies can, theoretically, be overcome. It was to test this assumption and to develop a prototype of an integrated rain-gauge-satellite-radar rainfall measuring system that a pilot project was, with WRC support, launched at the University of Pretoria in 1992. The pilot project focuses on the summer rainfall area only. However, criteria for estimating rainfall from coastal clouds differ radically from those of continental clouds.

The proposed new project, therefore, addresses the need to extend the pilot project, now nearing completion, to the coastal zones so that limitations to mapping daily rainfall can, as far as possible, be overcome for all areas in Southern Africa.

*Estimated cost:* *R123 000*
*Term:* *1994-1995*

## Research projects

### Completed

- **278** Prediction of South African summer rainfall variability from ocean surface temperatures (University of Cape Town – Department of Oceanography)
- **305** Interpolation and mapping of daily rainfall model parameters for South Africa (University of Cape Town – Department of Mathematical Statistics)

### Current

- **306** Techniques for seasonal and long-term rainfall forecasting in South Africa (University of Pretoria – Department of Civil Engineering (Chair of Meteorology))
- **349** Evaporation measurements above vegetated surfaces using micro-meteorological techniques (University of Natal – Department of Agronomy)
- **374** The Southern Agulhas Current and its influence on the weather and climate of Southern Africa (University of Cape Town – Department of Oceanography)
- **436** Mechanisms of short-term rainfall variability (University of Cape Town – Department of Oceanography)
- **437** Assessment of the potential for using stable carbon isotope ratios of wood charcoal as a climate indicator (South African Museum, Cape Town)
- **438** Development of a real-time, non-conventional rainfall mapping system (University of Pretoria – Department of Civil Engineering (Chair of Meteorology))
- **550** Development of models to stochastically generate spatially distributed daily rainfields (University of Natal – Department of Civil Engineering)

### New

- **594** Regional climate change scenarios for precipitation and temperature from general circulation models (University of Cape Town – Department of Environmental and Geographical Science)
- **595** Modelling rainfall-producing systems over Southern Africa (University of the Witwatersrand – Climatology Research Group)
- **596** Development of a real-time non-conventional rainfall mapping system for coastal zone cloud systems (University of Pretoria – Department of Civil Engineering)

**CONTACT PERSON:**
- **Dr GC Green**

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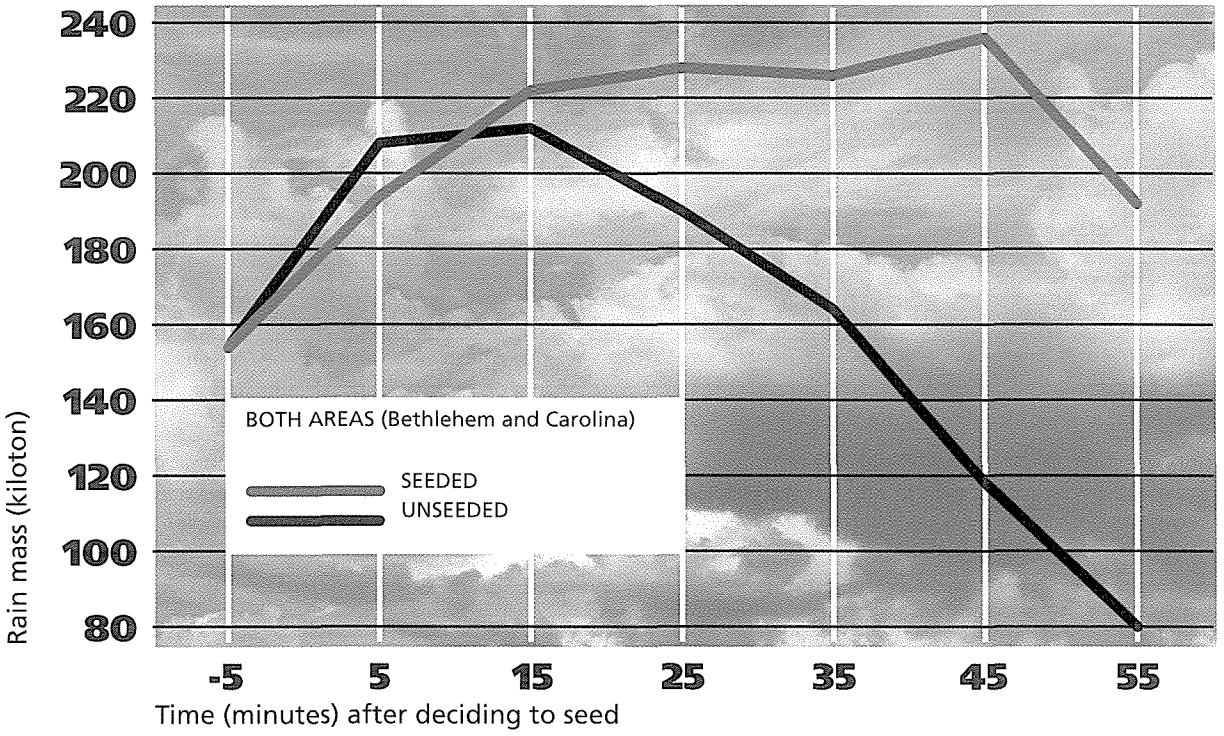
# 11
# Rainfall stimulation




Prospects of developing new water sources in South Africa are very slim. By contrast, the demand for water is constantly increasing owing to population growth and development. This may in future give rise to serious water shortages and conflict situations concerning water provision.

The largest potential source of additional good quality water which has not yet been exploited is the atmosphere. At present only a very small portion of the water vapour present in the atmosphere is eventually converted into rainfall which reaches the earth. In nature it is often found that the water droplets and ice crystals which make up clouds are very reluctant to grow fast enough and large enough in order to produce rain. As a result of this inertia, particles are more likely to evaporate and a cloud therefore produces much less rain than when cloud particles coalesce efficiently and grow rapidly.

Before 1990 the WRC and the Weather Bureau separately supported cloud-seeding experiments in the Eastern Transvaal and North-Eastern Free State with a view to enhancing rainfall from treated thunderclouds. Various seeding agents and methods were tested experimentally. Promising results were, for example, obtained when using dry-ice pellets released by means of a seeding aircraft high up in a thundercloud at the -10°C level. Although promising, this treatment turned out not to be optimal, as revealed by a whole host of measurements made using radar and instrumented aircraft. Knowledge gained also indicated that rather than stimulate the growth of ice particles in the cold area of the cloud with dry-ice, it would be far more effective to seed with a substance which would promote the coalescence of water droplets in the lowest, warmest part of the cloud. Common table salt is hygroscopic and is therefore such a substance.

Consequently, in 1990 the WRC and the Weather Bureau joined forces and started experimenting with a brand-new seeding technique. Flares which release hygroscopic salt particles (mainly table salt and potassium chloride) during burning were designed. These flares are deployed in the humid air just below a thundercloud where the updraughts are strongest. Released particles are then rapidly drawn into the cloud while deliquescence, followed by dispersion and interaction with natural cloud particles, takes place. Since 1991 research teams of the Weather Bureau and the company CloudQuest have been experimenting with these flares. Unisa statisticians have, however, also been involved to ensure that experiments are planned and analysed in accordance with strict statistical principles.

Randomised experiments were conducted in 2 circular areas of radius 90 km centred on Carolina in the Eastern Transvaal and Bethlehem in the North-Eastern Free State from 1991/92 to 1993/94. Results have shown that a noteworthy reaction to seeding only becomes evident 25 to 35 minutes after commencement of seeding. Seeding, on average, tends to increase the rain production rate in the seeded clouds slightly or to maintain it at a constant level. Rain production in untreated clouds decreases fairly rapidly, while seeded clouds produce rain over a longer period. On average seeded clouds produced approximately 30% more rain than unseeded clouds.

To sum up, research to date has provided sufficient statistical evidence that

individual thunderclouds, when seeded by means of hygroscopic flares, produce significantly more rain. What has, however, not been tested yet, is whether systematic seeding of scattered thunderclouds in an area will enhance the areal rainfall significantly. Preliminary calculations show that it will indeed be the case. It also seems likely that the additional river flow which might be obtained will be substantially cheaper than the cheapest alternative option to supplement water supplies.

In pursuit of further rainfall stimulation research, a new phase will have to be entered. The new objectives will be to prove that through cloud seeding not only rainfall from single clouds, but also areal rainfall and streamflow, can be increased significantly. This new phase also offers many new challenges and compels us to use the 1994/95 season to facilitate the transition from the old to the new phase. The expectation is that exploratory studies concluded during this season will serve as a sound basis for planning a formal "area experiment" with the objectives as set out above. This planning should, if at all possible, ensure that the formal area experiment will yield adequate and meaningful results within 3 seasons, from 1995/96 onwards.

## Completed project

### Potential impacts of rainfall augmentation on water resources and forestry in the Nelspruit-Bethlehem target zone

(No 439) Ninham Shand (Cape) Inc.

Ongoing research has provided strong evidence that increases in convective storm rainfall can be brought about by appropriate cloud-seeding. The objective of this particular project was to examine, via a desk study, possible impacts of an operational cloud-seeding programme on water resources and forestry in parts of the Eastern Transvaal highveld and adjacent escarpment region. For this purpose, the ACRU model was configured and verified for 13 catchments in the region. Inputs for model runs comprised a large number of paired areal rainfall sequences comprising stochastically generated daily rainfall and corresponding daily rainfall values as plausibly augmented by cloud-seeding. For a rainfall augmentation scenario corresponding to a 7% increase in mean annual rainfall, the model predicted increases of 20 to 48% (average 32%) for catchment runoff, 14 to 42% (average 27%) for reservoir yield and 16 to 30% (average 22%) for timber yield.

*Cost:* *R395 000*
*Term:* *1992-1993*

## Research projects

### Completed

- **439** Potential impacts of rainfall augmentation on water resources and forestry in the Nelspruit-Bethlehem target zone (Ninham Shand (Cape) Inc.)

### Current

- **133** National precipitation research programme with a view to rainfall enhancement (Company for Research on Atmospheric Water Supply and Department of Environment Affairs (Weather Bureau), subcontracting CloudQuest (Pty) Ltd and Unisa)

CONTACT PERSON:
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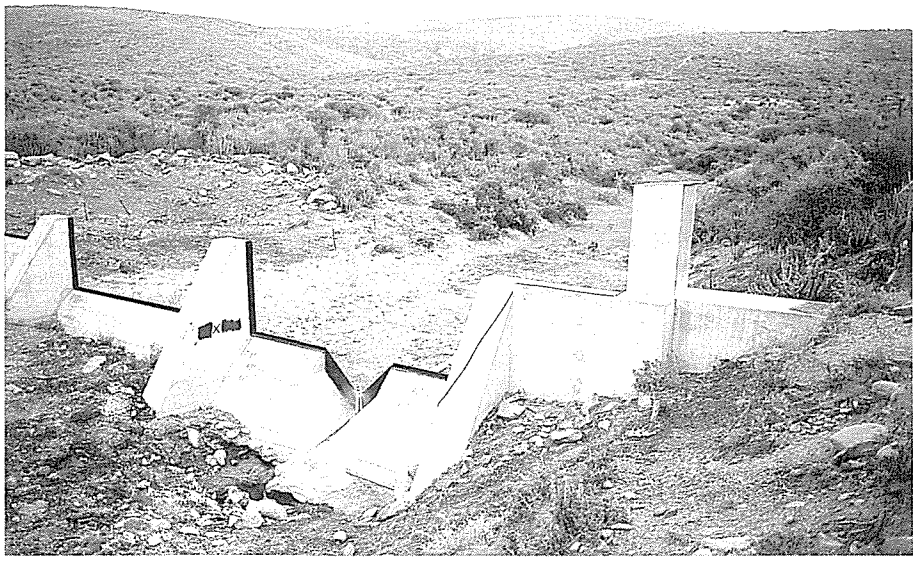
# 12
# Surface hydrology and water resource management



Two important developments are affecting research in the field of surface hydrology and water resources management:

- Firstly the government's RDP places a much greater emphasis on small water supply schemes which necessitates a much more detailed assessment of our available water resources. In many areas permanent springs provide excellent opportunities for clean water supply, but our knowledge on the occurrence, reliability, vulnerability and variability of spring-water supplies on a country-wide basis is virtually non-existent. Knowledge concerning links between groundwater resources and surface flows is becoming even more necessary than was the case in the past.
- Secondly with the readmission of South Africa into the United Nations the isolation of the past is over. On the one hand South Africa has much to offer the world in terms of water technology and bulk water management. On the other hand we now have the opportunity to bring our research and management approaches into line with the latest international thinking. The enormous amounts of expert man years that have gone into UN and other overseas research development provide a rich source of knowledge and approaches which can be adapted to our South African conditions with its unique blend of developing communities and extremely variable hydrology.

The road to integrated water development and management lies in **water policy research**. The time has come to systematically aggregate a variety of ideas about integrated catchment management into realistic and effective management tools with the purpose of improving the quality of life of the less privileged people. In other words, a priority is to do research on how best to use the enormous amounts of information available to us.

There is a particular need for a generic methodology on integrated water management which must include a proper assessment of the resource and a detailed projection of the demand for water. Indicators of satisfaction levels for all user sectors, including the environment, must be developed to form bridges between the managers and the public in a process of transparent decision support.

The WRC supported 29 projects during this year of which 9 were completed and 6 commenced.

## Completed projects

### Hydrological modelling studies in the Eastern Cape Province

(No 235) Department of Geography, Rhodes University

Three main issues were researched:

- Rain-water infiltration in response to vegetation cover dynamics.
- River channel transmission losses. In a 40 km$^2$ catchment the results indicate that over 75% of the runoff is likely to be lost for events up to a 5-year return period.
- Groundwater recharge has been studied using geochemistry methods. The application of such techniques in the Bedford catchments produced an area-weighted mean annual recharge of 5 mm per annum. It was also found that groundwater recharge varies strongly with soil depth conditions.

A modelling system for a PC, called HYMAS (hydrological model application system) has been developed. At present there are 7 models that can be run from within HYMAS:

- A semi-distributed variable time interval model of catchment hydrology which includes groundwater-surface water interaction

- A semi-distributed version of the Pitman monthly model
- A monthly multiple reservoir water balance model
- A daily model to simulate stormwater runoff and associated nutrient washoff from developing (informal) areas
- A daily version of the RAFLES model, developed originally by the Water Systems Research Programme of the University of the Witwatersrand
- A daily roof rain-water tank model
- A simple flood routing model based on the Muskinghen routing procedures.

*Cost:* *R1 582 170*
*Term:* *1988-1993*

## Hydrological systems model development

(No 270) Department of Agricultural Engineering, University of Natal

The final results of this project have culminated in a report entitled *Hydrology and Agrohydrology: A Text Accompanying the ACRU Modelling System*. This treatise is gradually developing into a sound reference work for hydrology in South Africa. Extensive reference to the theory of hydrological processes and the verification of model components under local conditions make for an excellent foundation from which to work.

One of the strengths of the modelling system is the fact that plausible default values can be selected for many of the variables used in the models. For instance, reference to soils is based on the official soil classification of South Africa and the associated land-type maps produced by the Institute for Soil, Climate and Water (Agricultural Research Council). Digital terrain model (DTM) technology is used to interpret these land-type maps for hydrological purposes. Land-use hydrology is a strong component of the modelling system. Although the use of realistic physically based model variables is no guarantee for absolute accuracy, the chances are good that relative response of catchments to land-use change can be estimated fairly accurately, at least well within the requirements of present catchment management decision-making.

*Cost:* *R2 511 288*
*Term:* *1989-1994*

## Surface water resources of South Africa 1990

(No 298) Consortium of consulting engineers

The main purpose of this research was to generate suitable information for preliminary water resource planning for the entire South Africa. All suitable flow measurements up to 1990 were analysed and some 2 000 quaternary subcatchments were demarcated for this purpose.

The work is presented in the following reports:

- A **manual** on procedures, explaining what has been done and, with the help of worked examples, how the data should be used. This report also contains a warning on pitfalls explaining how the data should not be used.
- A detailed summary of **data** for 6 different regions of the country, following primary catchment boundaries as determined by the DWAF. One volume, for instance, covers drainage region A and B which is the Northern Transvaal. For the purpose of easy data access the country has been subdivided up to quaternary catchment level, the numbering of which has been approved by the DWAF as "official".
- A **book of maps**. The entire country is represented on 24 maps (average about 4 per region) of A3 size and a scale of 1:1 000 000. Ten themes are represented on these maps. The main purpose of the maps is to allow the user to see his particular water resources planning problem in the context of regional relevant information.

Data and maps will be available in electronic format via the CCWR and on CD-ROM.

*Cost:* *R3 360 000*
*Term:* *1990-1994*

Small springs are useful water-supply sources – the occurrence, reliability and vulnerability of these sources must receive attention.

### Utilisation of geographical information systems (GIS) and integrated environmental management (IEM) in the planning and management of water resources within river catchments

(No 300) Department of Landscape Architecture, University of Pretoria

The project's main objective was the development of procedures and methodologies to integrate GIS and IEM. The steps that are normally required in IEM have been analysed and linked to GIS data sources. The results are presented in two forms:

- Several reports and manuals
- A large electronic data set covering the Sabie-Sand and Letaba catchments. Linked to this data set are a number of computer procedures.

Some of the hydrological model test results include the effects on streamflow of afforestation, deforestation, building a large dam and consolidating urban growth in one large city. These results serve as examples of effects which may be assessed for different development scenarios.

*Cost:* *R686 175*
*Term:* *1990-1993*

### Application of resource economics to water management decision-making in South Africa

(No 415) Institute of Natural Resources, University of Natal

There is a vast, largely untapped, reservoir of economic measures that can be used in our complex water management situation.

After extensive research it was concluded that the most promising contribution of economics to South African water management lies in the provision of the following:

- An alternative (to the traditional supply) macro-management approach to deal with water quantity (allocation) problems
- An alternative (to the traditional command-and-control) macro-management approach to deal with water quality (pollution) problems
- Methods to assist in the piecemeal implementation of macro-economic approaches, such as cost-benefit analysis and resource valuation.

This report is not aimed specifically at economists. The methodologies it contains will likely prove somewhat conventional to practitioners of this discipline. It is primarily intended for water managers and decision-makers, particularly those who have had limited exposure to economic concepts.

*Cost:* *R536 000*
*Term:* *1991-1993*

### Development of an integrated catchment management system for the Crocodile River catchment

(No 425) Division of Forest Science and Technology, CSIR

The project developed a generic catchment-centred resource assessment and management system, using the Crocodile catchment in the Eastern Transvaal as a case study area. In particular, the focus was on the integration of:

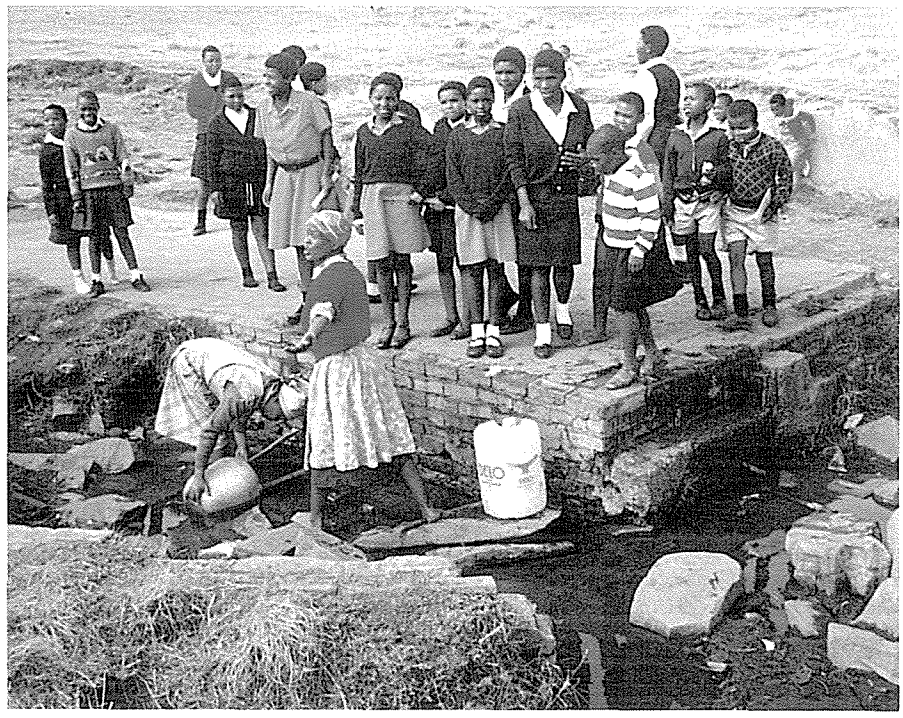
- Economic models
- Hydrological models
- Afforestation models
- Socio-political models
- Other land-use models.

The generic system is able to:

- Integrate information bases and outputs from predictive models
- Predict consequences of given patterns of use in terms of water flows, water quality, economic yield and social and environmental scores
- Compare different options.

The final report consists of a report on the background of the project and the theory followed, and a user manual accompanied by the necessary software.

*Cost:* *R520 000*
*Term:* *1992-1993*



## Development of improved flow gauging structures for South African rivers

(No 442) Sigma Beta (CE)

Since South Africa is not richly endowed with stable river reaches which could be calibrated for flow measuring purposes, local hydrologists have to rely heavily on specially constructed flow gauging structures to obtain flow data required for various purposes. The accuracy of the data generated by these structures is often questioned though, as is the structure's ability to handle sediment-laden runoffs. The objectives of this project consequently were the upgrading of existing flow gauging structures to improve the quality of the runoff data, and the development of a structure requiring little maintenance and yet being able to provide accurate data on a sustainable basis.

In a report entitled *Laboratory Calibration of Compound Sharp-crested and Crump Weirs*, the effects of the absence of dividing walls (as prescribed by British Standards BS3680), of pool depth, overflow height, step heights between adjacent weir crests and relative lengths of adject crests were reported on. The project proved conclusively that accurate flow measurements are possible with sharp-crested and Crump weirs without dividing walls. Traditional discharge coefficients can be adapted to improve the accuracy of discharge calculations for this type of weir. Where dividing walls are not used, the step heights should be limited to ensure that the ratio of step height to pool depth does not exceed 0,5.

In a second report entitled *River Discharge Measurement in South African Rivers: The Development of Improved Measuring Techniques*, a new gauging structure (Fig. 1) is discussed. This structure meets a number of pre-set criteria and requirements, and has the following characteristics:

- It is a compound structure in order to deal with extreme variations in discharge magnitudes.
- The lowest weir section consists of a flume-type structure which forms a control by means of horizontal, rather than vertical contraction and thus allows unrestricted passage of sediment. Two symmetrical adjoining Crump weirs form an integral part of the structure. These weirs are not separated from the flume by dividing walls, i.e. the crests of the weirs are at the same level as the top of the flume walls. By integrating the lower Crump weirs with the flume, a smooth transition between low notch measurements and the established practices for discharge measurements over different weir sections at higher water levels is established.

*Cost:* *R480 000*
*Term:* *1992-1994*

## Development of rigorous engineering methodology for designing vegetative erosion protection systems

(No 444) SRK (CE) Inc.

South Africa is confronted with a very serious soil erosion problem which is not only detrimental to the soil resources of the country, but also results in sedimen-

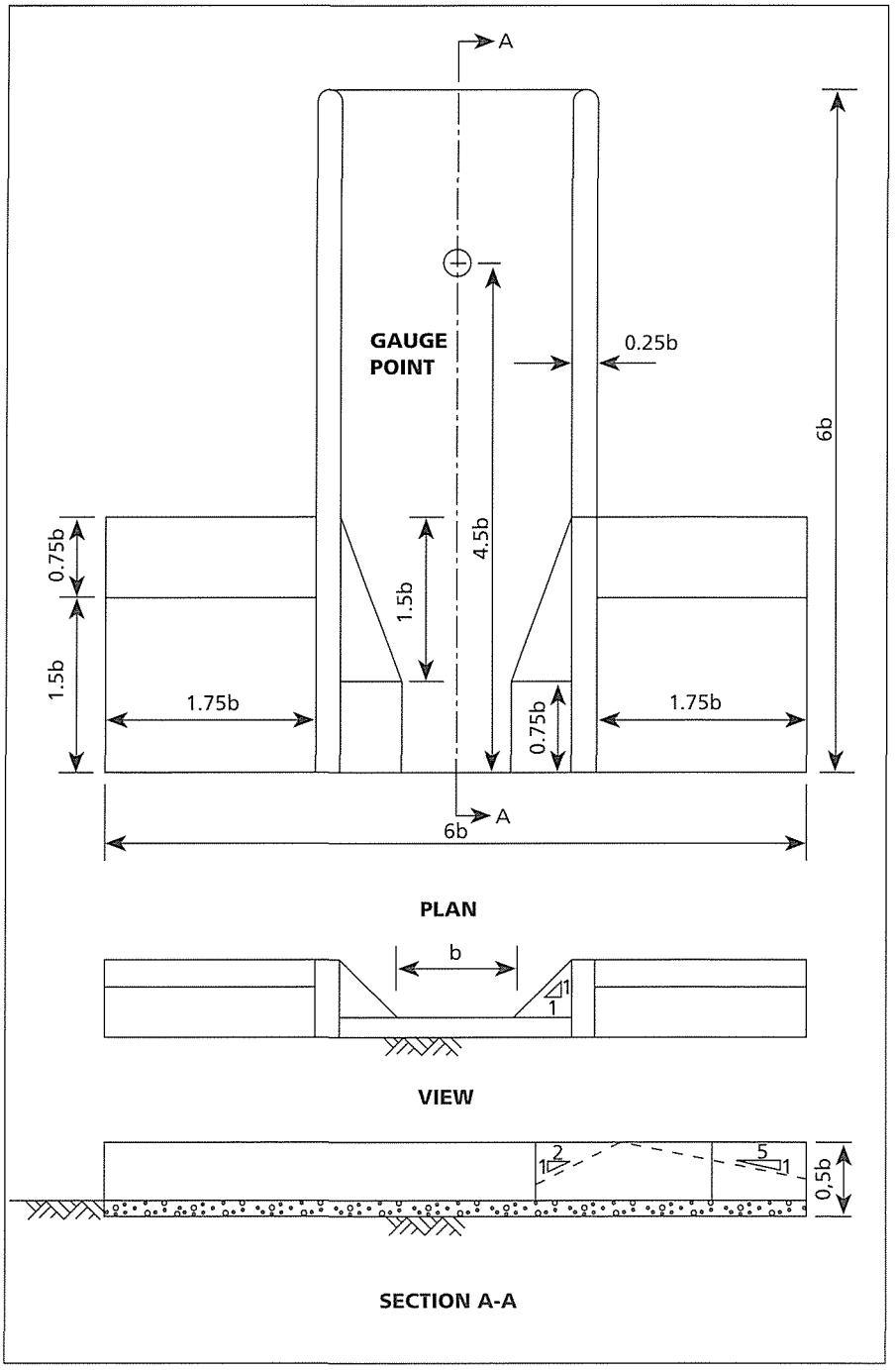



Figure 1: Layout of sluicing flume.

tation of dams and estuaries. Suitable well-established plant growth is still one of the most cost-effective pro-active erosion control measures. Experience in this regard clearly identified the need for a more rigorous engineering approach to selecting suitable plants for a specific erosion control situation, and this project has made a significant contribution in this regard.

Root morphological surveys, together with triaxial tests on 3 grass species and 2 soil types, confirmed the proposed root reinforcement theory remarkably accurately. The applicability of the erodibility criterion to particulate materials, the multifaceted erosional resistence of root-reinforced particulate materials and the occurrence of root interlinking, intertwining and anchorage were confirmed by flume tests.

Based on the recommendations which emanated from this project (dealing with root tensile strengths of more grass species; including more soil types in the flume experiments as well as non-uniform plant densities; larger ultimate specific stream power in the flume tests and more in-depth investigation of the effects of root interlinking and intertwining), a follow-up project (No 643) commenced during 1994.

*Cost:* *R344 000*
*Term:* *1992-1993*

### Evaluation of river losses from the Orange River downstream of Vanderkloof Dam

(No 510) BKS Inc.

A conceptual framework of how river losses should be approached has been developed.

From the results obtained during the course of this project it was concluded that:

- The evaporation losses occurring from the Orange River are likely to be higher than the 800 x $10^6$ $m^3/a$ initially estimated using the Symons pan evaporation values.
- From the water balance analysis carried out using the gauged flows it is clear that the irrigation return flows are significant and must be included in any river loss evaluation. These return flows had been disregarded in the original loss estimate and will more than compensate for the higher evaporation.
- The analyses indicate that aerial photographs can be used to provide realistic estimates of both the water surface areas as well as the areas of sandbanks and riparian vegetation. By analysing photographs of the same river reach at different flow rates it is also possible to evaluate the influence of flow rate on surface area.
- Losses as a result of transpiration from riparian vegetation are significant and the total area of such vegetation is estimated to be more than 80 $km^2$ (i.e. 25% of the water surface).

*Cost:* *R271 813*
*Term:* *1993*

## New projects

### Flow regimes from international experimental and network data (FRIEND) for Southern Africa

(No 635) Institute for Water Research, Rhodes University

At a Steering Committee meeting held in Dar es Salaam, Tanzania, on 16 to 18 February 1994 the official participation of South Africa in the Southern African FRIEND project was ratified. The project involves 11 countries namely Tanzania, Zambia, Malawi, Zimbabwe, Swaziland, Botswana, Lesotho, Namibia, South Africa, Mozambique and hopefully Angola.

The objectives of the project are briefly as follows:

- Establishment of databases including:
  - A master register of all Southern African streamflow gauging stations
  - A database of daily streamflow and catchment characteristics of approximately 1 000 catchments
- Development of software for data processing and analysis including rainfall-runoff modelling for land-use effects
- Research on spatial and temporal variability of runoff, low flows and floods.
- Development of design procedures.

The project is being carried out in close co-operation with the DWAF within the framework of UNESCO's International Hydrological Programme.

*Estimated cost:* *R901 000*
*Term:* *1994-1996*

### Hydrological systems modelling research programme: ACRU model development and user support

(No 636) Department of Agricultural Engineering, University of Natal

The effect of changing land use on water resources has for a long time been recognised as an important issue. The WRC has over the years invested considerably in the development of the ACRU hydrological modelling system at the Department of Agricultural Engineering of the University of Natal. This model has found a fair amount of acceptance in the hydrological and agricultural community with the result that the "ACRU team" operates the model at the request of public and private bodies many hundreds of times annually. Rendering the model user-friendly, internally more "foolproof", easily accessible (including a PC version with defaults) and with enhanced output capabilities will ensure that the investment in the modelling system reaps its appropriate benefits.

Furthermore, as a specialist "service" organisation to hydrology in Southern Africa, the Department has found it necessary to employ an experienced person to co-ordinate and carry out important user-support functions. Some form of cost recovery for this service will be investigated as part of this project.

*Estimated cost:* *R1 739 400*
*Term:* *1994-1999*

### Hydrological systems modelling research programme: Hydrological process research

(No 637) Department of Agricultural Engineering, University of Natal

The Department of Agricultural Engineering at the University of Natal has over the years systematically been developing the ACRU hydrological model based on knowledge obtained locally in well-executed catchment studies and field experiments.

However, there are a number of important hydrological processes that in the light of future hydrological problems in Southern Africa are not adequately understood and modelled and therefore need further research.

Associated with improved understanding of hydrological processes is the continuation of research catchments

and field monitoring, with special emphasis being placed on soil water movement, solute fate in soils and wetland process studies.

*Estimated cost:* *R2 593 400*
*Term:* *1994-1999*

### Studies on river losses: Phase 2

(No 638) BKS Inc.

During the execution of the Orange River System Analysis which BKS Inc. undertook for the DWAF, the losses downstream of Vanderkloof Dam were evaluated. The first estimate indicated that losses could be as high as 800 x $10^6$ $m^3/a$, which is 16% of the current mean annual runoff at Vanderkloof Dam. Because the surplus water resources of the Orange River are becoming limited, the uncertainty in this estimate has the effect that the available yield from Vanderkloof Dam becomes highly speculative and has a serious effect on the entire phased planning of the Lesotho Highland Water Project.

Knowledge of losses in other rivers is just as important, especially for those river stretches that are used as channels to transfer water between various storage facilities. Full understanding of the extent of river losses, and knowledge of how they can be minimised, will facilitate the optimum utilisation of scarce water resources. This will be established in this project.

*Estimated cost:* *R1 350 000*
*Term:* *1994-1997*

### Development of a water information management database system for data capture and processing at local authority level

(No 642) Institute for Groundwater Studies, University of the Orange Free State

Regional and local authorities generate considerable quantities of valuable water-related data which are of great interest to the DWAF and other organisations involved in water resources management. However, in their current form these data are generally of little use to these organisations, as they are stored either in paper files or in a variety of incompatible electronic formats.

A front-end software package will be developed during this project to allow data gathering. Although groundwater data will be used as the forerunner, the software will eventually be used for all local authority water management data.

To make the software package attractive to local authorities, limited graphics and other reporting facilities will be included to allow for the processing of their data. The most important benefit of the system will, however, be the simple data transfer facility for batch "downloading" of data onto the DWAF's databases.

*Estimated cost:* *R705 000*
*Term:* *1994-1996*

### Development of rigorous engineering methodology for designing vegetative erosion protection systems: Phase 2

(No 643) SRK (CE) Inc.

The project preceding this follow-up project (Project No 444), laid the foundation for the development of an engineering methodology for the design of vegetative erosion protection measures, the approach being the reinforcement of soil by plant roots. In the process the root morphology of selected types of grass was investigated, strength tests were conducted, as well as erosion tests under simulated flow conditions. Up to this stage only ideal uniform plant conditions were investigated and the need was identified to generalise the theory, which also called for the investigation of relatively non-uniform conditions of natural vegetation as well as the complexities which characterise it.

The main objective of this project is to determine how variables which play a role in the root reinforcement of soils, can be determined in practice for large areas by means of remote sensing and geographical information systems. This will require that the developed theory be tested on natural vegetation, following which the theory will be expanded to the general situation. In order to meet the requirements of effectively combating vegetative erosion, a design manual and recommendations regarding the planning and management of plant cover are envisaged.

*Estimated cost:* *R490 200*
*Term:* *1994-1996*

## Research projects

### Completed

- **235** Hydrological modelling studies in the Eastern Cape Province (Rhodes University – Department of Geography)
- **270** Hydrological systems model development (University of Natal – Department of Agricultural Engineering)
- **298** Surface water resources of South Africa 1990 (Consortium of consulting engineers)
- **300** Utilisation of geographical information systems (GIS) and integrated environmental management (IEM) in the planning and management of water resources within river catchments (University of Pretoria – Department of Landscape Architecture)
- **415** Application of resource economics to water management decision-making in South Africa (University of Natal – Institute of Natural Resources)
- **425** Development of an integrated catchment management system for the Crocodile River catchment (CSIR – Division of Forest Science and Technology)
- **442** Development of improved flow gauging structures for South African rivers (Sigma Beta (CE))
- **444** Development of rigorous engineering methodology for designing vegetative erosion protection systems (SRK (CE) Inc.)
- **510** Evaluation of river losses from the Orange River downstream of Vanderkloof Dam (BKS Inc.)

### Current

- **299** Adaption and calibration of an urban runoff quality model (CSIR – Division of Water Technology)
- **317** Urban catchment monitoring (Welkom City Council and SRK (CE) Inc.)
- **319** Monitoring the effect of catchment development on urban runoff and water balance (University of the Witwatersrand – Department of Civil Engineering, Water Systems Research Group)
- **375** Development of a distributed hydrological modelling system to assist with water quantity and quality management in the Mgeni catchment, Phase II (University of Natal – Department of Agricultural Engineering)
- **424** Development of an urban component for the ACRU model (University of Durban-Westville – Department of Geography)
- **490** Development of flood damage functions and a computer program to determine the advantages of flood and flood damage control measures (University of the Orange Free State – Department of Agricultural Economics)
- **492** Effect of the agricultural environment on water resources (University of Natal – Department of Agricultural Engineering)
- **493** Development and testing of a water balance model for a grassland catchment in the summer rainfall area of South Africa (CSIR – Division of Forest Science and Technology)
- **494** Classification and hydrological modelling of low flows in Southern Africa (Rhodes University – Institute for Water Research)
- **509** Palaeoflood hydrological analysis for selected South African rivers (Geological Survey)
- **511** Hydrological implications of afforestation in the North-Eastern Cape (CSIR – Division of Forest Science and Technology)
- **512** Development of procedures for decision support in water resources management (University of Cape Town – Department of Statistical Sciences)
- **518** Case study of storm-water pollution control in a representative valley (Wates, Meiring and Barnard Inc.)
- **580** Control of dam siltation in South Africa (BKS Inc.)

### New

- **635** Flow regimes from international experimental and network data (FRIEND) for Southern Africa (Rhodes University – Institute for Water Research)
- **636** Hydrological systems modelling research programme: ACRU model development and user support (University of Natal – Department of Agricultural Engineering)
- **637** Hydrological systems modelling research programme: Hydrological process research (University of Natal – Department of Agricultural Engineering)
- **638** Studies on river losses: Phase 2 (BKS Inc.)
- **642** Development of a water information management database system for data capture and processing at local authority level (University of the Orange Free State – Institute for Groundwater Studies)
- **643** Development of rigorous engineering methodology for designing vegetative erosion protection systems: Phase 2 (SRK (CE) Inc.)

**CONTACT PERSONS**:
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- **Mr HC Chapman** (Urban Water Balance)
- **Mr DS van der Merwe** (Flow Measurement and Sediment)

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# 13
# Conservation of water ecosystems

A number of years ago the DWAF initiated the policy for the management of water quality by developing instream water quality objectives instead of relying on effluent water quality standards.

As very little local knowledge existed with regard to aquatic ecosystem water quality requirements, the WRC initiated research efforts in this regard to gather the specific information required by the DWAF to institute the new policy.

The highlight of the year was undoubtedly a visit to SA by 13 Australian aquatic scientists, environmental academics and water resource managers. They took part in site visits to, *inter alia*, the Kruger National Park (KNP) and overviewed the KNP Rivers Research Programme, and also visited the Institute of Water Research, Rhodes University and the Freshwater Research Unit, University of Cape Town. The group thereafter participated in a 5-day workshop which reviewed progress on river classification and environmental health indicators. This workshop took place in Cape Town and over 60 South African scientists and managers took part.

The reconstituted Co-ordinating Committee for Water Ecosystems Research (CCWER) met once during the year. A subcommittee of the CCWER, inclusive of an invited social scientist, reviewed the research Masterplan/Guideline and found the major aims and objectives of the Plan to be still valid. The 2 major programmes which receive WRC funding, *inter alia*, namely the estuaries and rivers research programmes, have both contributed substantially to furthering the major goals and objectives as indicated in the Masterplan/Guideline.

In the year under review the WRC supported 27 projects of which 5 were completed and 6 commenced.

## Completed projects

### Freshwater requirements of estuarine plants

(No 292) Department of Botany, University of Port Elizabeth

The project had as overall objective the understanding of the manner in which freshwater controls the plant ecology of estuaries.

It was found that estuarine plants are sensitive to both salinity and water-level changes and that such sensitivity is caused by limiting normal freshwater catchment discharges. The project also demonstrated that the amount of chlorophyll *a* in the benthic component exceeded that in the water of most Southern Cape systems by orders of magnitude.

The findings have led to the development of a decision-support system that is available for use by water managers for the prediction of estuarine plant responses to different freshwater runoff scenarios.

*Cost:* *R253 600*
*Term:* *1990-1993*

### Effect of pollution on the physiology of fish in the Olifants River (Eastern Transvaal)

(No 350) Department of Zoology, Rand Afrikaans University

The main aim of this project was the determination of the effects of pollutants on the physiology of fish.

The research illustrated the hitherto unknown sublethal effects of, especially, metal pollution on fish life. In the one metal studied in some detail, namely copper, it was shown that rather severe sublethal damage to fishes occurred at copper concentrations well within existing water quality guideline standards. The research also showed that metals affect different organs in fish and that these metals could act synergistically.

The results of this research will greatly assist water resource managers in their efforts to lay down guidelines of water quality standards for aquatic ecosystems.

*Cost:* *R207 000*
*Term:* *1991-1993*

### Effects of water quality variables on riverine biota

(No 351) Department of Zoology, University of Cape Town

The major objective of this project was the establishment, on a first approximation level, of water quality guidelines for aquatic ecosystems.

During the course of the project a detailed literature review (the first of its kind in South Africa) was produced as well as a database on the available literature. A preliminary classification of South African rivers for management of the aquatic ecosystem was suggested and clarification, of methods for the field verification of water quality guidelines for aquatic biotas, obtained. These research results are currently assisting the DWAF in the establishment of water quality guidelines for aquatic environments.

*Cost:* *R479 000*
*Term:* *1991-1994*

Prof HH du Preez and his assistants actively involved in field work on fish from the Olifants River in the Kruger National Park.

### Preliminary investigation into algal weeds in South African inland waters

(No 426) Department of Botany, University of Cape Town

The main aim of this project was to investigate the occurrence of macroalgae in canal systems and to begin to develop management techniques for the control of these algae.

The main problem algal weed was found to be *Cladophora*, especially in the Transvaal and Free State, with *Oedogonium* dominating in the Western Cape canal systems. Problem algal growths were not necessarily associated with the most obviously polluted systems and the different algal species have different requirements for rapid growth. An identification guide to common and potential problem algal weeds in South Africa was also produced. The results will be used to focus efforts on the management and control of these weeds in canal systems via life cycle studies and possibly, biological control.

*Cost:* *R135 800*
*Term:* *1992-1993*

### Continuing research into the wetlands of KwaZulu-Natal

(No 501) Institute of Natural Resources, University of Natal

Even though wetlands have been widely shown to have many important values (e.g. water purification), the destruction and mismanagement of this resource continues. In the Mfolozi catchment, for example, 58% of the original wetland area has been lost. Presently the use of wetlands tends to be planned from the restricted perspectives of individual landowners with specific interests. Generally speaking, little attention is given to the effects on wetland functional values, such as flood attenuation, which benefit society at large. During the course of the project, management plans for priority wetlands were produced and a wetland management decision support system, termed WETLAND-USE, was developed. The primary objective of WETLAND-USE is to assist agricultural and nature conservation extension workers in providing sound management and land-use advice for wetland areas.

The field application involved applying the system to 2 case studies on wetlands, namely Blood River Vlei and Boschoff Vlei, with management guidelines being produced for both. The prototype was also applied to Aloeboom Vlei by a team including representatives from the Department of Agriculture and the Natal Parks Board. In addition, components of the system are being used by the Renfreight Wetlands Campaign for field-training sessions with extension workers.

With the objective of identifying the key management issues and characterising the decision-making process in wetlands, it is hoped that the results of this project will not only contribute towards improving the current management of wetlands, but will also assist in designing relevant research programmes that satisfactorily enhance resource management, by focusing on the more important knowledge gaps.

Some important wetland management-related research needs were identified in the report.

*Cost:* *R82 850*
*Term:* *1992-1993*

## New projects

### Freshwater requirements of plant communities in different types of estuaries

(No 601) Department of Botany, University of Port Elizabeth

The different types of estuaries and the plant communities within them respond differently to droughts, floods and mouth closure. Plant communities should therefore be ranked in order of their sensitivity to a lack of freshwater and it is also important to identify the changes that can occur in plant communities as they drive the faunal food chain. Without this knowledge base, managers are unable to make decisions regarding the absolute freshwater requirements of estuaries.

Against this background the objective of the project is the identification of estuarine plant communities, and their freshwater requirements in different types of South African estuaries. This information will be linked directly to a major decision-support system for estuary management.

*Estimated cost:* *R180 000*
*Term:* *1994-1995*

### Lethal and sublethal effects of metals on fish physiology in the Republic of South Africa

(No 608) Department of Zoology, Rand Afrikaans University

Certain anthropogenic influences create extreme environmental conditions in rivers such as the Olifants River in the Eastern Transvaal. Our current ability to estimate the effect of chronic exposure to sublethal conditions is based on factors derived empirically. The aim of this project is to investigate the effect of exposure to sublethal levels of heavy metals on the blood physiology of fishes in an attempt to find a better method of investigating the effects of chronic exposure of fish to toxins.

This project will be carried out both in the laboratory and in the field so that the two may be correlated.

*Estimated cost:* *R560 000*
*Term:* *1994-1996*

### Water quality requirements for riverine biotas

(No 626) Department of Zoology, University of Cape Town

Water quality guidelines for the natural environment are not universally applicable, varying from continent to continent and from region to region; furthermore, very little local information is available.

The objectives of the project are therefore the establishment of interim guidelines, in conjunction with the DWAF, for all water quality variables that vary site-specifically, as well as protocols for the verification of these guidelines. In addition, and also in collaboration with the DWAF, environmental water-quality management plans for the Berg and Mgeni Rivers will be drawn up and verified.

*Estimated cost:* *R644 000*
*Term:* *1994-1997*

### Integrated modelling system for predicting the impacts of changes in water quantity and quality brought about by upstream development

(No 627) Sigma Beta (CE)

The Kruger National Park Rivers Research Programme (KNPRRP) entered a new 3-year phase at the beginning of 1994. The Programme has now been restructured into 4 Subprogrammes, one of which is for Decision Support Systems Development and Management

(DSSDM). The aim of the DSSDM is to provide methodologies for integrating information and expert opinion into structural decision-support systems, directed at achieving the best possible answers at the time and at informing researchers of the information needs required to improve answers in the future.

This project addresses a core need of such a decision-support environment, i.e. establishment of a quantitative catchment modelling system. Such a modelling system would serve to integrate the currently disparate predictive capabilities in hydrology, hydraulics, water quality, sediment production and transport, channel morphology and ecological functioning. The intention is to test and refine this modelling system in a case study on the Sabie River, and to demonstrate the utility of the modelling system, linking "what if" catchment development scenarios to protocols for evaluating the acceptability of predicted changes.

*Estimated cost:* *R266 000*
*Term:* *1994-1996*

### Development of a modelling system which will provide a common currency for integration of the results and data emanating from the Kruger National Park Rivers Research Programme

(No 654) Department of Landscape Architecture, University of Pretoria

This research project is aimed at using GIS, existing modelling systems and interactive graphical displays of spatial and time series information in a manner which will enhance the level of scientific communication between researchers of the KNPRRP. The intention is to provide input to the Decision Support System which is the basis of Phase 2 of the KNPRRP. The GIS provides a powerful framework within which to organise and present spatial information both to the modelling system and to the users of the modelling system.

Against this background this project has as its objectives:

- To develop a modelling system framework incorporating ARC/INFO, Hydrological Simulation Programme Fortran (HSPF) and Watershed Data Management System (WDMS) into a flexible and versatile aid to researchers
- To demonstrate that the product of the above development can serve as a catalyst to elicit meaningful interaction, communication and integration amongst KNPRRP researchers.

*Estimated cost:* *R113 000*
*Term:* *1994-1995*

### Establishment of an effective information management system for the Kruger National Park Rivers Research Programme (KNPRRP)

(No 655) National Parks Board in collaboration with the Institute of Natural Resources, University of Natal

Over the years a vast volume of excellent research has been undertaken by the KNPRRP, and although good line-function products exist (mainly in the form of information), there is a need for lateral linkage of source data (and applied information) across projects and study themes. This Subprogramme addresses the problem at the source data level, while the Decision Support Subprogramme addresses it at the applied level.

Typically researchers and managers spend a great deal of time searching for data and information, mainly because no comprehensive listing exists of all available data and information. Very often access to available data and information is difficult due to poor data organisation. This Subprogramme aims to significantly improve the situation by constructing a versatile control reference database which will allow all relevant information pertaining to the KNPRRP to be easily traceable and readily accessible.

*Estimated cost:* *R277 000*
*Term:* *1994-1996*

## Research projects

### Complete

- **292** Freshwater requirements of estuarine plants (University of Port Elizabeth – Department of Botany)
- **350** Effect of pollution on the physiology of fishes in the Olifants River (E. Transvaal) (Rand Afrikaans University – Department of Zoology)
- **351** Effect of water quality variables on riverine biota (University of Cape Town – Department of Zoology)
- **426** Preliminary investigation of algal weeds in South African inland waters (University of Cape Town – Department of Botany)
- **501** Continuing research into the wetlands of KwaZulu-Natal (University of Natal – Institute of Natural Resources)

### Current

- **294** Pre-impoundment study of the Sabie-Sand River system, Eastern Transvaal, with special reference to predicted impacts on the Kruger National Park (University of Cape Town – Freshwater Research Unit, and Rhodes University – Institute of Freshwater Studies)
- **376** Geomorphological response to changing flow regimes of the Sabie and Letaba River system (University of the Witwatersrand – Department of Botany)
- **406** Structural analysis of the water apportionment mechanisms in the Water Act 54/1956, in view of the requirements of competing user sectors (Advocate M Uys)
- **418** Effects of catchment parameters and land use on runoff quality and estuary ecology (University of Fort Hare – Department of Zoology)
- **422** Rapid biological assessment of water quality impacts in streams and rivers (CSIR – Division of Water Technology)
- **428** Overview of the pesticide and heavy metal levels present in populations of the larger indigenous fish species of selected South African rivers (CSIR – Division of Water Technology)
- **463** Diversity and productivity of biotic communities in relation to fresh-water inputs in Eastern Cape estuaries (University of Port Elizabeth – Department of Zoology)
- **474** Developing an integrated approach to predicting the water use of riparian vegetation (University of the Witwatersrand – Department of Botany)
- **475** Development of a recirculating experimental stream system (Rhodes University – Institute for Water Research)
- **497** Geomorphological classification system for South African river systems (Rhodes University – Department of Geography)
- **503** Effect of soil utilisation on water quality of the Gamtoos estuary (University of Port Elizabeth – Department of Oceanography)
- **505** Environmental status of the Orange River mouth as reflected by the fish community (University of the OFS – Department of Zoology and Entomology)
- **525** Natural and unnatural factors regulating the structure and functioning of estuarine systems (University of Natal – Institute of Natural Resources)
- **545** Standard laboratory organisms for water quality studies (Rhodes University – Institute for Water Research)
- **576** Effects of different magnitude flows on riverine ecosystems (University of Cape Town – Freshwater Research Unit)
- **577** Decision support system for the integrated management and conservation of estuaries (University of Natal – Institute of Natural Resources)

### New

- **601** Freshwater requirements of plant communities in different types of estuaries (University of Port Elizabeth – Department of Botany)
- **608** Lethal and sublethal effects of metals on fish physiology in the Republic of South Africa (Rand Afrikaans University – Department of Zoology)
- **626** Water quality requirements for riverine biotas (University of Cape Town – Department of Zoology)
- **627** Integrated modelling system for predicting the impacts of changes in water quantity and quality brought about by upstream development (Sigma Beta (CE))
- **654** Development of a modelling system which will provide a common currency for integration of the results and data emanating from the Kruger National Park Rivers Research Programme (KNPRRP) (University of Pretoria – Department of Landscape Architecture)
- **655** Establishment of an effective information management system for the Kruger National Park Rivers Research Programme (KNPRRP) (National Parks Board in collaboration with the University of Natal – Institute of Natural Resources)

**CONTACT PERSONS:**
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- **Mr HM du Plessis** (Irrigation Return Flow)
- **Mr HC Chapman** (Natural Wetlands)
- **Dr SA Mitchell** (Stream Fauna and Flora)
- **Mr DS van der Merwe** (Facets of the KNP Rivers Research Programme)

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# 14
# Mine water

Mining was one of the primary driving forces behind the development of South Africa. The areas in which development and progress are currently centred were mainly determined by the relative paucity and disproportionate distribution of our water sources on the one hand, and by the relative abundance and location of our mineral resources on the other hand. Mining remains the single, most important industry in our country.

Due to the scope and extent of its activities, mining, however, also has considerable potential to impact negatively on the water environment. Despite the fact that gold-mines already recirculate 80% of their water, it is estimated that they annually release approximately 360 000 t of salts to the surface and groundwater environment. Salts in mine water originate mainly from saline underground water (which has to be pumped) and sulphuric acid which forms when pyrite (which often occurs in ores and in geological layers) is exposed to oxygen and water during mining activities.

Since the main part of the impact of mining on the aquatic environment is diffuse in nature and therefore difficult to quantify and to control, the regulatory authorities only fairly recently started paying attention to the problem of how to regulate this impact. Recent steps taken in this regard created new research needs. Mines are currently expected to present the authorities with an environmental management programme in which it should be indicated among others, what the background environmental conditions were before the commencement of mining activities and how these activities will influence the environment during and after completion of the activities. It also needs to be shown how the environmental impact will be managed. Our ability to predict these effects quantitatively and to indicate the efficacy of alleviating measures, is still inadequate and requires further research. During a work session in November 1993 to prioritise research needs, it was found that the most pressing need was for research on the identification, evaluation and development of cost-effective strategies and technology for the management of the impact of mining activities. The secondary research needs were identified as being the quantification of the current use and contamination of water sources by mining activitities, determination of economic, socio-political and regulatory issues relating to water sources, and formulation of the best available technology which would not incur excessive costs.

During 1994 the WRC funded 12 mining related projects, of which 2 commenced during the year and 1 was completed.

## Completed project

### Preliminary assessment and review of integrated passive water treatment systems for mine effluent streams

(No 570) Division of Water Technology, CSIR

The development of passive treatment systems, capable of ameliorating the various forms of mine effluent on a long-term self-sustaining basis, was identified as a high priority research need. However, prior to embarking on a very costly research project into all aspects of various passive treatment alternatives, it was necessary to determine the full extent of the problem and the depth of knowledge world-wide. It was found that the quality and quantities of mining effluent were of such a nature that they indeed presented a problem of national importance. It was further found that sufficient know-how and

examples of successful applications existed for a number of the water quality problems experienced with mine effluents to warrant further investigation in a more substantial project.

*Cost:* *R150 000*
*Term:* *1993-1994*

## New projects

### Underground neutralisation of mine water with limestone

(No 609) Division of Water Technology, CSIR

The CSIR has developed a fluidised-bed reactor using limestone to neutralise acidic effluents. The inherent advantages of the process, viz. lower operating costs and simpler and safer operation, render it an attractive alternative to conventional lime dosing for the underground neutralisation of mine water. Acid mine water usually contains iron which reduces the rate of limestone neutralisation. To counter this problem, this project will investigate the feasibility of adding a biological oxidation stage as pretreatment to the fluidised-bed limestone neutralisation reactor. The resulting integrated pilot plant will be operated underground on a continuous basis to generate the design data necessary for the construction of a full-scale underground facility.

*Estimated cost:* *R440 000*
*Term:* *1994-1995*

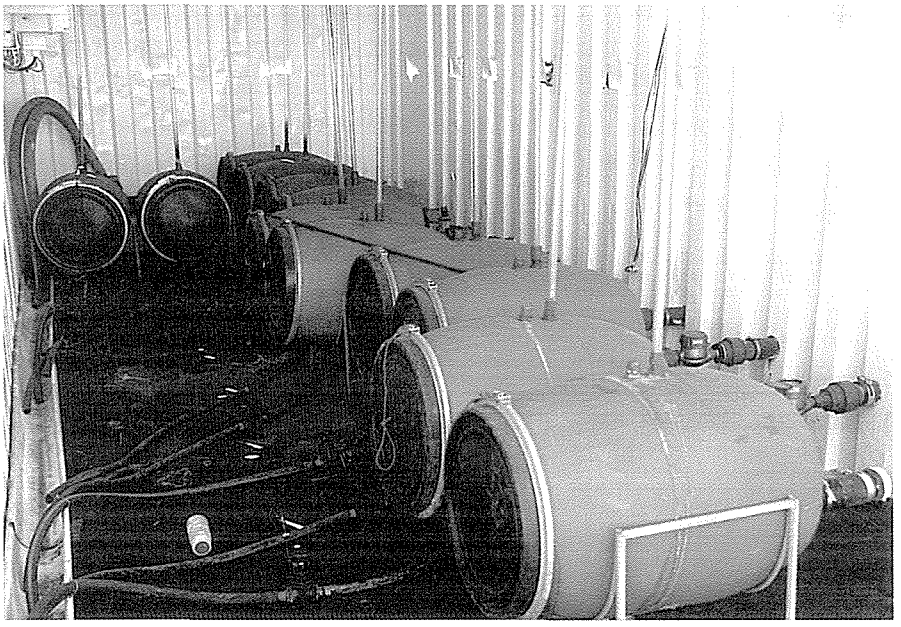
### Application of isotope chemistry to quantify the contribution of gold and coal mines to salt pollution load in groundwater and rivers

(No 647) Division of Earth, Marine and Atmospheric Science and Technology, CSIR

Isotope chemistry offers promising possibilities at improved quantification of the impact of non-point pollution on the water environment. Standard chemical investigations suffer, for example, from the problem that the different elements are invariably prone to precipitation or adsorption onto clay particles. In contrast, the "radiogenic" isotope ratios only change as a result of the introduction of new material with a different isotopic ratio. The specialised knowledge, experience and equipment required in isotope chemistry has resulted in the potential of these techniques remaining largely unexploited. Consequently this project intends to determine and illustrate the potential of radiogenic isotopes for quantifying the contribution of non-point sources to the salt pollution load in groundwater and rivers in 2 case studies – one downstream of a coal mine pollution source and the other associated with a gold mining environment.

*Estimated cost:* *R133 000*
*Term:* *1994-1995*


Evaluating the irrigability of various agricultural crops with neutralised acid mine water.



Collection drums for drainage material emanating from coal waste dumps covered with different soils.

## Research projects

### Completed

- **570** Preliminary assessment and review of integrated passive water treatment systems for mine effluent streams (CSIR – Division for Mining Technology)

### Current

- **413** Use of vegetation in the amelioration of the impact of mining on water quality – An assessment of species and water use (CSIR – Division of Forest Science and Technology)
- **454** Occurrence of bacteria causing acid mine drainage in the outer layers of coal waste dumps (University of Stellenbosch – Department of Microbiology)
- **471** Optimisation of mine service water disinfection (University of Pretoria – Department of Chemical and Environmental Engineering, Division of Water Utilisation)
- **477** *Guidelines and procedures to assess* and ameliorate the impact of gold mining operations on the water environment (Chamber of Mines Research Organisation (COMRO))
- **527** Survey of current water management and treatment practices in the South African gold and coal mining industries (Chamber of Mines of South Africa)
- **528** Development of an integrated and generic water quality simulation model for open-cast coal mining water circuits (Wates, Meiring and Barnard Inc.)
- **559** *Prediction of pollution loads from* coarse sulphide containing rock materials (SRK (CE) Inc.)
- **575** Calibration of models for the design of covers for open-cast mine and waste dump rehabilitation (Wates, Meiring and Barnard Inc.)
- **582** Screening of crop, pasture and wetland species for tolerance of polluted water originating in coal mines (University of Pretoria – Department of Plant and Soil Science)

### New

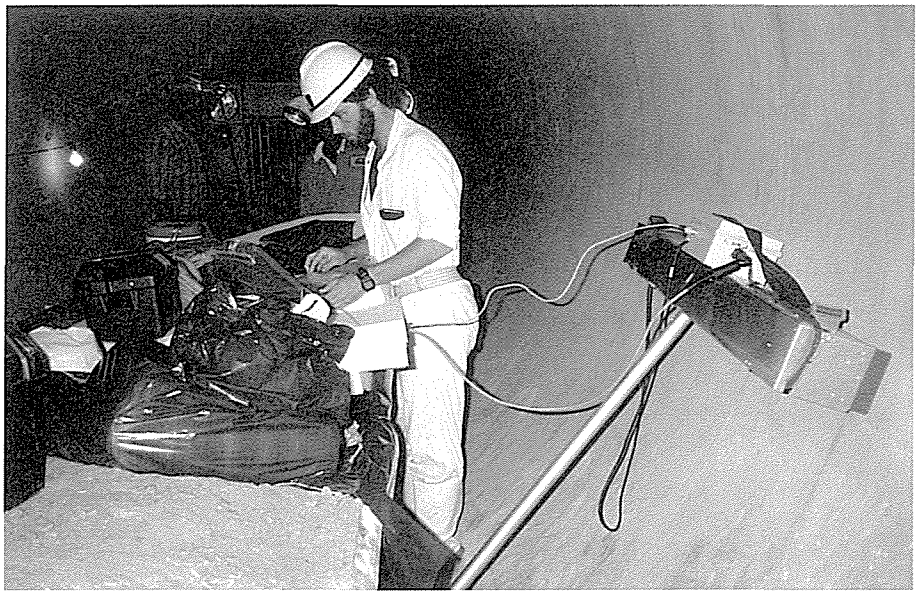
- **609** Underground neutralisation of mine water with limestone (CSIR – Division for Water Technology)
- **647** Application of isotope chemistry to quantify the contribution of gold and coal mines to salt pollution load in groundwater and rivers (CSIR – Division for Earth, Marine and Atmospheric Science and Technology)


CONTACT PERSONS:

- **Mr HM du Plessis** (Impact Studies and Mitigation of Effects)
- **Dr TC Erasmus** (Acid Mine Water)
- **Mr HC Chapman** (Passive Treatment)

☎ **(012) 330-0340**

# 15
# General



## Geological aspects

During 1994 the WRC funded 4 research projects in this field of which 1 was completed and 3 are continuing.

## Completed project

### Erodibility of different rock formations under varying flow conditions

(No 302) Department of Geology – University of Pretoria

Current methods to enable the prediction of the extent of erosion damage in various rock formations in unclad dam spillways and areas downstream, are unsatisfactory and often incur unnecessary costs due to the cladding of good quality rock, while in other cases, serious damage is caused by erosion of unclad spillways.

Against this background the project aimed at identifying the engineering geological and hydraulic parameters which influence the erodibility of a rock formation. Furthermore the development of a procedure to characterise a rock mass in terms of erodibility, as well as development of a correction between flow speed and the degree as well as rate of erosion which could be expected, would also be investigated.

A series of model tests were carried out in a flow channel in order to study the mechanism of erosion on softer materials which imitate seamfilling in a rock formation. A relatively good correlation was found between the clay content and cohesion of the samples and the threshold speed and threshold unit power at which erosion starts taking place. A correlation also exists between clay content and erosion rate when the tests are carried out at flow speeds higher than the threshold values.

By conducting a large number of case studies of erosion damage at existing dam spillways, an attempt was made to obtain a suitable correlation between selected parameters of the rock mass, stream flow and observed erosion. In most cases no or poor correlation existed when single or combinations of rock mass parameters were employed. The only clear distinction between the various degrees of erosion occurred where unit stream power was plotted against the Kirsten Index on a log-log scale. With the aid of this an evaluation chart was drawn up (see Figure 1) by means of which a prediction can be made of the degree of erosion in an unclad spillway. The distribution of observed data points on the evaluation chart indicates that the chosen erosion parameters (Kirsten Index, unit power and erosion depth) are possibly not equally suited to all conditions. The evaluation limits were, however, drawn so conservatively that the map can be used confidently as a preliminary design guideline.

*Cost:* *R210 000*
*Term:* *1990-1994*

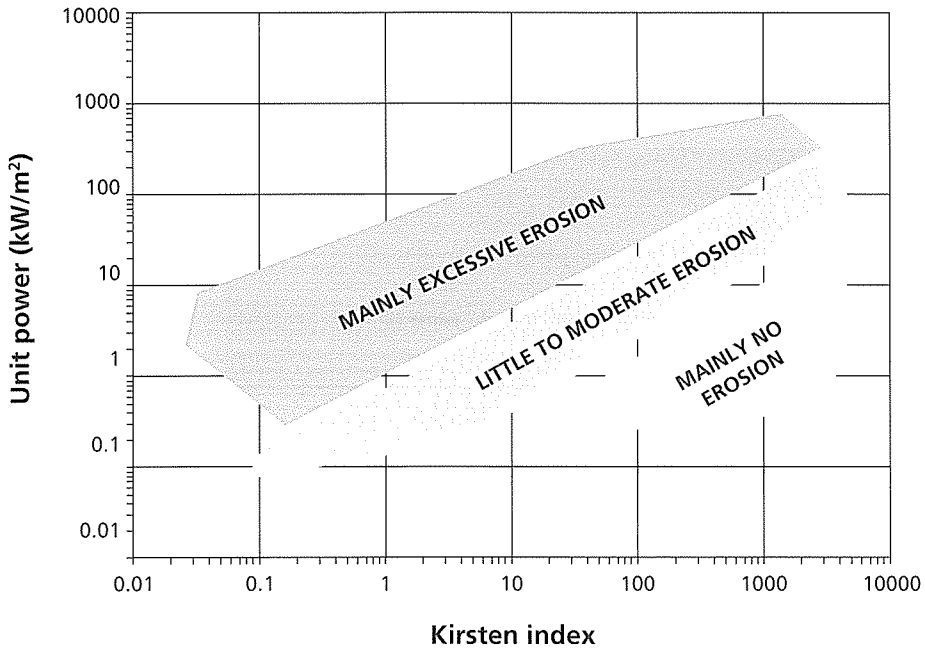
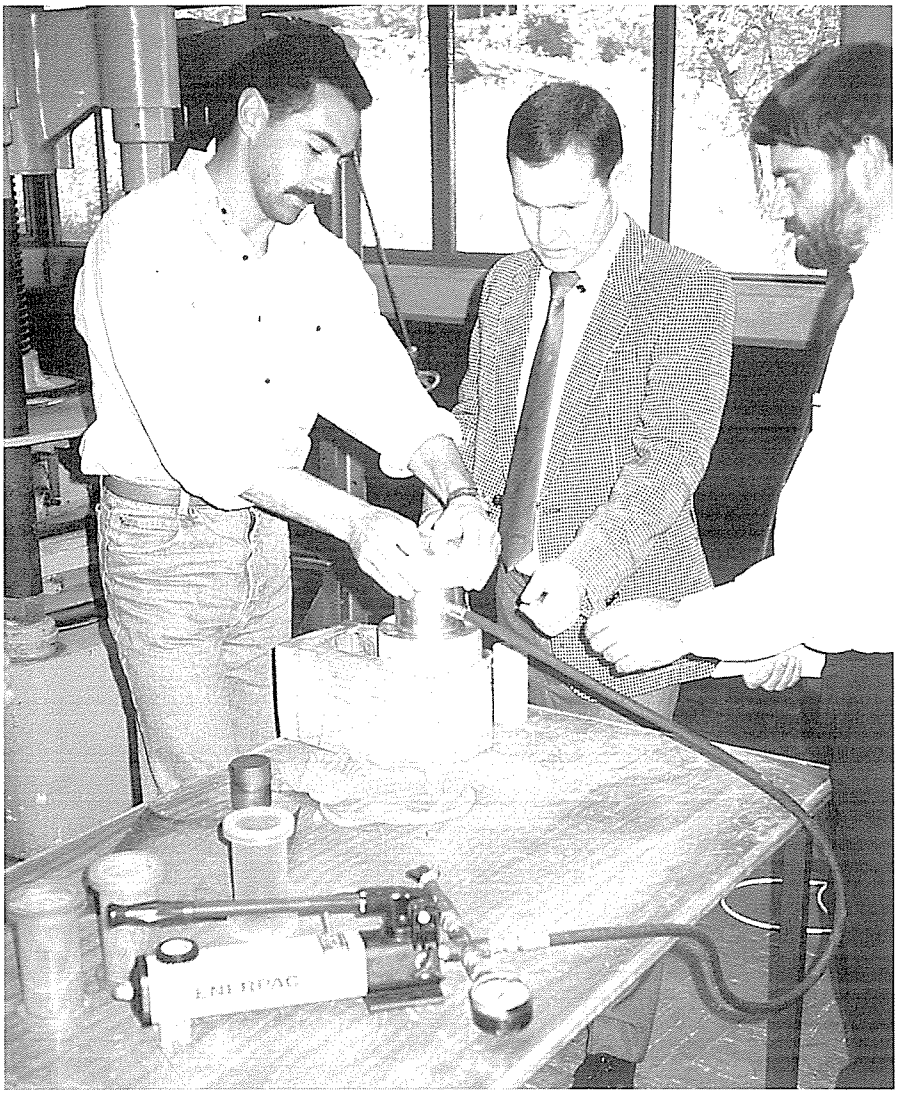



Figure 1: Evaluation chart



Testing the engineering properties of important South African rock types.

## Research projects

### Completed

- **302** Erodibility of different rock formations under varying flow conditions (University of Pretoria – Department of Geology)

### Current

- **433** Engineering properties of important Southern African rock types with special reference to the shearing strength of concrete dam wall foundations (Technicon Pretoria – School for Civil Engineering)
- **502** Plunge pool scour reproduction in hydraulic models (CSIR – Division for Earth, Marine and Atmospheric Science and Technology)
- **579** Hydraulic roughness of tunnels bored by machine through various rock-types (University of Natal – Department of Civil Engineering)

**CONTACT PERSONS:**
- **Mr DS van der Merwe** (Hydraulics)
- **Mr AG Reynders** (Geological Aspects)

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# 16
# Research support services

## South African Water Information Centre

The WRC, as part of its commitment to technology transfer, established the South African Water Information Centre (SAWIC) in 1974 to provide bibliographic information on water and to act as a comprehensive referral centre for water-related enquiries.

Development of the WATERLIT database started in 1975. Prior to this no database existed which covered the specific information requirements of South African researchers and much of the information relevant to Southern Africa and developing countries was not readily available. The services which were available from overseas, apart from not fulfilling the requirements of researchers, were extremely expensive.

Increasing at the rate of over 1 000 references per month, WATERLIT currently contains more than 230 000 references to articles in technical and scientific publications, including reports and conference proceedings. More than 650 local and international journals are scanned for relevant information each month.

SAWIC offers a range of services which includes:

- Conducting comprehensive literature reviews on request
- Providing regular alerting services to keep users abreast of the latest publications and developments in their fields
- Referral to other sources of relevant information
- Dealing with general enquiries about water and related topics
- Building and managing relevant databases:
  - WATERLIT
  - The Database of Water-related Research Projects
  - The Database of Water-related Information Sources
- Training users to search WATERLIT
- Indexing publications on behalf of organisations
- Advising users on the management of their information and the construction of personal databases
- Developing specific bibliographies on request.

Although intended primarily for the research community, SAWIC services are increasingly being used in the industrial and private sectors, by government departments, local authorities, water boards, consulting engineers and staff and students at technikons and universities.

Staff are continuously investigating ways of increasing the efficiency and cost-effectiveness of the services and keeping abreast of new developments. Co-operation with other organisations has made it possible for users to access WATERLIT from their personal computers using either a modem or a CD-ROM and the systems are constantly being improved. Impending changes to the computer system will facilitate the electronic transmission of references from literature surveys and alerting services to a user's personal computer.

The importance of comprehensive literature reviews at the planning stage of research projects cannot be overemphasised and the experienced water information specialists at SAWIC are the people best qualified to carry these out on behalf of researchers.

## Computing Centre for Water Research

During the mid-1980s the WRC and IBM took the strategic initiative to enhance communication and hence co-operation between water researchers in South Africa by founding the Computing Centre for Water Research (CCWR) at the University of Natal.

The mission of the CCWR is to support collaboration and the dissemination of knowledge, data and information amongst researchers and practitioners through advanced computing and communication technology in order to enhance water resources management.

Japanese business people have a saying that it takes 25 years to grow a tree. The WRC's strategic initiative, 9 years ago, in founding and funding the CCWR is now, like the proverbial Japanese tree, paying dividends.

One indication of this success is the extent to which the CCWR has empowered researchers and practitioners from diverse disciplines to work together despite their geographic separation. The following table indicates the level of success achieved in this regard during 1994.

| User's field of interest | Number of users |
|---|---|
| Agrohydrology | 10 |
| Groundwater | 11 |
| Chemical and salinity | 33 |
| Hydrology | 43 |
| Climate change | 11 |
| Irrigation | 7 |
| Climatology | 24 |
| Limnology | 15 |
| Crop yield | 10 |
| Soil | 9 |
| Ecology | 17 |
| Water treatment | 5 |
| Economics | 4 |
| Urban hydrology | 3 |
| Forestry | 10 |
| Water consumption | 1 |
| Floods | 1 |
| Wetlands | 9 |
| Geographic information systems | 13 |

The specific benefits of this empowerment are manifold. However, 2 key areas of benefit where considerable progress has been made, and which are worthy of mention, are presented below:

- The process of institutional capacity building which is so necessary for integrated catchment management
- Operationally active links with large state organisations.

Part of the institutional capacity building referred to above entails the link between large state organisations such as the SA Weather Bureau (SAWB), DWAF, Agricultural Research Council (ARC) and the CCWR. The fact that persons at these organisations are now accessible on the Internet has led to exciting new opportunities for this kind of co-operation between research, state and practitioners. However, technical connections alone do not suffice. Strong inter-personal bonds have been forged. It is these bonds which the WRC has so profoundly influenced, and the CCWR so actively promoted over the years and particularly in the year under review. The above-mentioned state departments are a major avenue for the transfer of WRC research technology. In turn the basic data sets accumulated by these state institutions form a primary platform for research, the accessibility of which is critical.

**CONTACT PERSONS:**
- **Mr AG Reynders** (WATERLIT)
- **Mr H Maaren** (CCWR)

☎ **(012) 330-0340**

# 17
# Transfer of information and technology

The promotion of information and technology transfer is one of the most important objectives of the WRC. This is very clearly defined in the Water Research Act, namely to "accumulate, assimilate and disseminate knowledge in regard to the results of such research and the application thereof, and promote development work for the purpose of such application".

For the promotion of its programme of information and technology transfer, the WRC has developed a number of activities. Although some of these activities are directed at the transfer of information, the emphasis falls mainly on technology transfer, i.e. the application of research results, since this will always represent the final dividend of the research investment.

## Partnership research

Partnership research is regarded as a very effective method of enhancing technology transfer. The partnership principle is incorporated, as far as possible, in research projects, and means that the end user of the results participates in the planning and execution of the research.

## Publications

The WRC's publications cater for three levels, viz. pure scientific, popular scientific and practical scientific.

### *Water SA*

*Water SA* is the WRC's scientific journal which contains original research articles and review articles on all aspects of water science, technology and engineering. The journal appears quarterly and the first edition was launched in April 1975.

*Water SA* has a strict refereeing system whereby all articles submitted for publication are first referred to referees, whereafter a decision is taken on publication.

*Water SA* has an extensive local as well as overseas readership. It also enjoys world-wide coverage in the sense that it is covered by more than 20 international abstracting services who publish and distribute summaries of articles which appear in *Water SA*.

### *SA Waterbulletin*

*SA Waterbulletin* is a bilingual bi-monthly periodical. Within the broad spectrum of water research it aims to:

- Furnish information on water and water research in a popular scientific manner to the different interest groups in the water field
- Promote the transfer of technology by announcing the availability of reports, manuals, guides etc. which emanate from water research
- Promote communication between the WRC and authorities and individuals, such as researchers, engineers, technicians, government departments, local authorities and the industrial and agricultural sectors
- Convey social news and matters of interest (e.g. about conferences and personalities) to the water research community.

## Manuals, guidelines and reports

At the conclusion of a project, and also while research is still under way, results are evaluated in respect of possible use and application and depending on the nature of the results a decision is taken on publication, dissemination and application thereof. More information on these publications appears in the relevant chapters and in the **Annexure**.

## List of WRC publications

The **Annexure** to this annual report contains a list of publications (articles, papers and published reports) which appeared during 1994 and which emanated from research supported wholly or in part by the WRC.

## Conferences, seminars, workshops and demonstrations

From time to time the WRC, on its own or in co-operation with other organisations, arranges such meetings. These afford ideal opportunities for promoting personal contact between research scientists or between research scientists and the users of research results. In this way the transfer of information and technology is greatly enhanced. More information on meetings held during the year is contained in the individual chapters.

## Mass media

In this regard the accent falls on information transfer, and press releases, radio and television are used to this end.

## Utilisation of overseas expertise

It is in the national interest that overseas expertise and knowledge be used where these are not available locally, and the WRC has developed various methods to achieve this. Overseas specialists, for example, are engaged as consultants and the WRC from time to time sends personnel and other experts overseas in order to obtain information on a particular problem area. More information in this regard appears in the individual chapters.

## Commercialisation

In the future the WRC will focus increasingly on a further aspect of technology transfer, which is in progress already, viz. the commercialisation of research results by e.g. the private sector. The patenting of research results and the sale of publications and computer programs would be classified as such. In this way the WRC earns royalties, locally as well as abroad.

# Financial statements

The accounts of the Water Research Commission have been audited in terms of section 5 of the Auditor-General Act, No. 52 of 1989, read with section 14(1) of the Water Research Act, No. 34 of 1971, and in my opinion the annual financial statements are a fair representation of the financial position of the Commission as at 31 December 1993 and the results of its operations for the year then ended.

Auditor-General

## Statement 1
### Balance sheet as at 31 December 1993

| | Notes | 1993 R | 1992 R |
|---|---|---|---|
| **Capital employed** | | | |
| Accumulated fund | | **60 559 419** | **63 838 991** |
| **Employment of capital** | | | |
| Fixed assets | 3 | **701 727** | 771 246 |
| Investments and loans | 4 | **39 528 587** | 28 435 214 |
| **Current assets** | | | |
| Debtors | 5 | **14 988 946** | 15 655 836 |
| Deposits and amounts immediately recoverable | | **4 203 241** | 19 186 523 |
| Bank balance and cash | | **1 487 904** | 150 |
| **Total current assets** | | **20 680 091** | 34 842 509 |
| **Current liabilities** | | | |
| Creditors | | **338 582** | 198 669 |
| Income received in advance | | **12 404** | 3 486 |
| Bank overdraft | | **-** | 7 823 |
| **Total current liabilities** | | **350 986** | 209 978 |
| Net current assets | | **20 329 105** | 34 632 531 |
| | | **R60 559 419** | **R63 838 991** |

(Signed PE Odendaal)
Executive Director

Pretoria, 16/6/94

## Statement 2
### Income statement for the year ended 31 December 1993

| | Notes | 1993<br>R | 1992<br>R |
|---|---|---|---|
| Net income/(deficit) | 6 | **(3 279 572)** | 5 468 814 |
| Accumulated fund at beginning of year | | **63 838 991** | 58 370 177 |
| Accumulated fund at end of year | | **R60 559 419** | **R63 838 991** |

## Statement 3
### Cash flow statement for the year ended 31 December 1993

| | Notes | 1993<br>R | 1992<br>R |
|---|---|---|---|
| **Cash retained from (employed in) operations** | | **(2 292 353)** | **4 381 950** |
| Net income/(deficit) before non-cash items | 1 | **(5 930 999)** | 3 076 563 |
| Employed to increase operating capital | 2 | **815 721** | (1 262 773) |
| Investment income | | **2 822 925** | 2 568 160 |
| **Cash employed in investment operations** | | | |
| Additions to investments | | **(11 497 877)** | - |
| Additions to fixed assets | 3 | **(101 979)** | (302 392) |
| | | **R(13 892 209)** | **R4 079 558** |
| **Cash effects of financing operations** | | | |
| (Decrease)/increase in loans granted | 4 | **404 504** | (3 391 784) |
| Decrease/(increase) in short-term loans | 5 | **13 487 705** | (687 774) |
| | | **R13 892 209** | **R(4 079 558)** |

## Schedule A
### Notes to the financial statements

**1. Accounting policy**

The annual financial statements have been compiled according to the historic cost principle. The principal accounting policy is reflected hereunder and is consistent with that of previous years, unless stated otherwise.

**1.1 Fixed assets and depreciation**

Unless otherwise indicated, fixed assets are shown at cost and where appropriate, are depreciated at rates which will result in each asset being written off over its useful life. The basis and rates of depreciation are shown for each category of assets. No provision is made for depreciation on land.

**1.2 Research projects and research support services**

Payments made in respect of research projects prior to the submission of audited statements shall be brought to account as advances and expenditure may only be charged against projects upon receipt of audited statements.

**1.3 Investments**

Listed investments with insurance companies are shown at book value and unlisted investments are shown at cost.

**1.4 Acknowledgement of income in general**

Income is acknowledged on the accrued basis.

**2. Comparative figures**

Certain comparative figures have been restated to correspond with the presentation in the current year.

| | **1993** R | 1992 R |
|---|---|---|
| **3. Fixed assets** | | |
| Land at cost | **5 000#** | 5 000# |
| Motor vehicles, at cost | **167 682** | 167 682 |
| Less: Accrued depreciation | **160 089** | 140 609 |
| | **7 593** | 27 073 |
| Computer equipment at cost | **372 900** | 359 760 |
| Less: Accrued depreciation | **106 378** | 41 129 |
| | **266 522** | 318 631 |
| Office equipment at cost | **402 762** | 387 030 |
| Less: Accrued depreciation | **131 572** | 119 078 |
| | **271 190** | 267 952 |
| Office furniture at cost | **213 036** | 203 748 |
| Less: Accrued depreciation | **61 614** | 51 158 |
| | **151 422** | 152 590 |
| Total fixed assets | **701 727*** | 771 246* |

Depreciation on motor vehicles is written-off on a pro-rata basis calculated on annual kilometres travelled and the life expectancy in kilometres of the vehicles. Depreciation on computer equipment is being calculated on the straight line method at a rate of 25% annually. Depreciation on office furniture and office equipment is being calculated on the straight line method at a rate of 5% annually.

\# Purchased on 25 March 1975 and situated at Schaap Kraal, Site 477.

* Capital assets purchased by organisations with research grants are not included.

# Schedule A
## Notes to the financial statements

| | 1992<br>R | 1992<br>R |
|---|---|---|
| **4. Investments and loans** | | |
| Company for Research on Atmospheric Water Supply | **23 444 991** | 23 444 991 |
| The loan to the Company for Research on Atmospheric Water Supply may not be wholly recoverable. Upon termination of the finance contract the *amount of the loan minus the amount realised on the capital assets purchased* with contract funds is written off as current expenditure. Since 1993 expenditure on this project was set-off against operating expenditure and not treated as a loan. | | |
| Erf Sewe-Nul-Ses Rietfontein (Pty.) Ltd. | **3 829 780** | 4 234 284 |
| Unsecured loan repayable over 30 years with interest at 15% calculated on monthly balance. | | |
| Noted investments | | |
| Old Mutual | **4 370 958** | - |
| SANLAM | **4 269 112** | - |
| UAL Merchant Bank | **2 857 807** | - |
| Unlisted shares in Erf Sewe-Nul-Ses Rietfontein (Pty.) Ltd. | **755 939** | 755 939 |
| **Total investments and loans** | **39 528 587** | 28 435 214 |

| | 1993<br>R | 1993<br>R |
|---|---|---|
| **5. Debtors** | | |
| Water research levies | **12 187 415** | 13 351 647 |
| Other | **2 801 531** | 2 304 189 |
| **Total debtors** | **14 988 946** | 15 655 836 |

# Schedule A
## Notes to the financial statements

| | Budget 1993 | 1993 R | Budget 1992 | 1992 R |
|---|---|---|---|---|
| **6. Net income** | | | | |
| **Income** | | | | |
| Investment income | | **2 822 925** | | 2 568 160 |
| Water research levies | | **39 024 077** | | 39 710 785 |
| Other income | | **149 492** | | 172 099 |
| **Total income** | | **41 996 494** | | 42 451 044 |
| **Expenditure** | | | | |
| Administrative services | **1 849 500** | **1 833 194** | 1 703 000 | 1 766 461 |
| Audit fees | **65 000** | **59 370** | 45 000 | 41 649 |
| Rental and maintenance | **965 000** | **898 490** | 948 500 | 897 450 |
| Staff expenditure | **4 914 000** | **4 934 246** | 4 369 600 | 4 272 318 |
| Depreciation of fixed assets | **157 500** | **168 489** | 80 000 | 72 721 |
| Fixed assets written off | **-** | **3 009** | - | 103 188 |
| Water research levies written off | **-** | **2 936** | - | - |
| Technology transfer | **1 054 000** | **948 694** | 770 000 | 698 750 |
| Research projects and research support services | **44 735 634** | **36 427 638** | 35 760 142 | 29 129 693 |
| **Total expenditure** | **53 740 634** | **45 276 066** | 43 676 242 | 36 982 230 |
| **Net (Shortage)/Surplus** | | **(3 279 572)** | | 5 468 814 |

Change in accounting estimate

Depreciation method

The method of providing for depreciation on office furniture and office and computer equipment has changed from the reducing balance method to the straight line method. This change was brought about due to the fact that the reducing balance method does not reflect the actual useful life of an asset whereas the straight line method is more representative of the actual useful life of an asset.

| The effect on the current year is as follows: | **Old method (Reducing balance)** | New method (Straight line) |
|---|---|---|
| Computer equipment | **17 711** | 99 176 |
| Office equipment | **14 511** | 39 112 |
| Office furniture | **7 929** | 10 720 |
| | **40 151** | 149 008 |
| Motor vechiles (No change in method) | **19 481** | 19 481 |
| | **R59 632** | R168 489 |

The change in depreciation method increases the net deficit with R108 857

## Schedule B
### Notes to the cash flow statement

| | 1993<br>R | 1992<br>R |
|---|---|---|
| **1. Net income/(deficit) before non-cash items** | | |
| Net income/(deficit) according to income statement | **(3 279 572)** | 5 468 814 |
| Adjustments for: | | |
| Depreciation | **168 489** | 72 721 |
| Fixed assets written off | **3 009** | 103 188 |
| Interest on investments and loans | **(2 822 925)** | (2 568 160) |
| | **(5 930 999)** | 3 076 563 |
| **2. Employed to increase operating capital** | | |
| Decrease/(increase) in debtors | **666 890** | (1 425 288) |
| Decrease/(increase) in creditors | **148 831** | 162 515 |
| | **815 721** | (1 262 773) |
| **3. Additions to fixed assets** | | |
| Computer equipment | **(62 512)** | (99 744) |
| Office equipment | **(29 874)** | (191 896) |
| Office furniture | **(9 593)** | (10 753) |
| | **(101 979)** | (302 393) |
| **4. (Decrease)/increase in loans granted** | | |
| Company for Research on Atmospheric Water Supply | **-** | (3 761 726) |
| Erf Sewe-Nul-Ses Rietfontein (Pty.) Ltd. | **404 504** | 369 942 |
| | **404 504** | (3 391 784) |
| **5. Decrease/(increase) in short-term loans** | | |
| Corporation for Public Deposits and other deposits | **14 983 282** | (1 173 920) |
| Cash on hand and bank overdraft | **(1 495 577)** | 486 146 |
| | **13 487 705** | (687 774) |

# Statement 4

## Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1993

| | Project | Expenditure 1993 R | Expenditure Total to 31/12/93 R | Total advances outstanding as at 31/12/93 R |
|---|---|---|---|---|
| 1. | **Research projects** | | | |
| 133 | CRAWS | 3 438 017,39 | 3 438 017,39 | 45 000,00 |
| 183 | Research on the effects of urbanisation on catchment water balance | 75 200,00 | 1 249 956,23 | *(56 350,43) |
| 208 | Research on the development of criteria for sprinkler irrigation systems to combat surface sealing of soils | - | 414 939,02 | 3 344,92 |
| 211 | Research on groundwater abstraction in residential areas | - | 185 289,64 | 15 710,36 |
| 212 | Research on the use of electromagnetic exploration techniques for the development of ground-water resources | - | 216 000,00 | 15 251,95 |
| 218 | Research on economic evaluation of alternative irrigation scheduling strategies for wheat in the irrigated area of the Orange Free State region | - | 300 505,95 | 277,47 |
| 219 | The development of fixed and dynamic membrane systems for the treatment of brackish water and effluents | 40 583,31 | 1 791 860,11 | - |
| 221 | Research on geohydrological investigation and evaluation of the Zululand coastal aquifer | - | 766 406,46 | 71 924,28 |
| 222 | Research on the reconstruction of the climatic history of the last 2000 years in the summer rainfall regions of Southern Africa | - | 214 993,11 | 1 025,89 |
| 226 | Research on maximizing irrigation project efficiency in different soil-climate-irrigation situations | 51 917,16 | 970 806,77 | *(27 064,23) |
| 227 | Research on the storage and utilisation of rain water in soil for the stabilisation of plant production in semi-arid regions | 239 500,00 | 1 261 227,84 | *(11 498,62) |
| 228 | Research on the factors affecting the water-use efficiency of irrigated crops, with special reference to the physiological responses of these crops | 175 365,74 | 1 439 049,83 | *(13 327,00) |
| 229 | Research on the estimation and evaporation of moisture stress in crops by means of remote control aerial surveillance | - | 278 952,01 | 40 397,00 |
| 235 | Hydrological modelling studies in the Eastern Cape | 328 690,61 | 1 582 169,91 | *(92 350,25) |
| 236 | The development of a model to simulate flow in alluvial rivers | 30 000,00 | 378 534,16 | 0,02 |
| 238 | Research on the design criteria for crossflow microfiltration | 188 311,67 | 1 252 845,89 | 7 475,51 |
| 239 | Transfer of waste-water treatment management technology to the meat processing industry | 3 787,64 | 161 566,21 | 7 715,84 |
| 248 | Research on chemical augmentation of biological phosphate removal | - | 69 388,91 | 17 611,09 |
| 249 | Research on pelletisation in upflow anaerobic sludge bed (UASB) systems | - | 253 189,59 | 4 306,46 |
| 255 | Research on the development and testing of data-logging equipment for the monitoring of water consumption patterns | - | 86 120,77 | 12 379,23 |
| 257 | Research on the water-use efficiency of certain irrigated temperate pasture species | 90 699,78 | 504 080,33 | 11 938,22 |
| 259 | Research on the effect of water quality and chemical composition on the corrosivity in mild steel pipelines | 32 083,25 | 98 545,13 | 616,75 |
| 260 | Research on the relationship between climate and crop factors | - | 179 037,41 | 22 604,41 |
| 261 | Research on soil-plant-water relations in the upper reaches of plant available soil water | 116 008,14 | 552 684,44 | 23 491,86 |
| 263 | Research on the biological treatment of industrial water with the simultaneous production of single-cell protein | - | 67 027,75 | 21 572,25 |
| 265 | Research on human viruses in water | 17 542,00 | 352 399,66 | - |
| 267 | Research on the evaluation and development of geophysical techniques for characterising the extent and degree of ground-water pollution | - | 437 258,00 | 25 942,00 |
| 269 | Research on the evaluation of the four-electrode electrical conductivity and electromagnetic induction techniques of soil salinity measurement for use under South African conditions | 21 537,00 | 235 982,00 | 58,00 |
| 270 | Research on hydrological systems model development | 535 307,00 | 2 205 288,00 | *(32 288,00) |
| 275 | The investigation into the evaluation of membrane technology for electroplating effluent treatment | 68 499,56 | 283 499,67 | 1 499,44 |
| 285 | Research on and evaluation of various factors affecting dry-wet cooling | 6 578,35 | 835 049,24 | - |
| 290 | Research on flood and furrow irrigation: A critical evaluation of design procedures and the computerisation of the most suitable procedures | 105 000,00 | 264 653,78 | - |
| 291 | A regional investigation into groundwater quality deterioration in the Olifants River catchment above the Loskop Dam, with specialized investigations in the Witbank Dam subcatchment | 379 968,50 | 1 547 272,24 | *(646,24) |
| 292 | Research on the freshwater requirements of estuarine plants | 70 297,32 | 249 687,85 | 201,97 |
| 294 | Research on a pre-impoundment study of the Sabie-Sand River system, Eastern Transvaal, with special reference to predicted impacts on the Kruger National Park | 152 330,71 | 1 038 349,02 | *(30 686,87) |
| 295 | Research on assessment of the instream flow requirements of rivers | 23 595,00 | 452 999,52 | *(23 595,00) |
| 297 | Research on the preparation of a review document on sediment transport in South Africa including revision of the sediment production map of Southern Africa | 8 654,74 | 349 465,92 | - |

## Statement 4 (continued)

### Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1993

| | Project | Expenditure 1993 R | Expenditure Total to 31/12/93 R | Total advances outstanding as at 31/12/93 R |
|---|---|---|---|---|
| 298 | Research on the surface water resources of South Africa 1990 | 790 000,02 | 2 729 898,64 | - |
| 299 | Research on the adaption and calibration of an urban runoff quality model | 123 057,64 | 544 297,19 | *(13 446,79) |
| 300 | Research on the utilisation of geographical information systems (GIS) and integrated environmental management (IEM) in the planning and management of water resources within river catchments | 95 526,06 | 493 474,94 | 5 473,94 |
| 301 | An investigation into the quality of water for animal production | 179 075,00 | 434 175,67 | - |
| 302 | Research on the erodibility of different rock formations under varying flow conditions | 16 421,68 | 183 573,05 | 1 578,32 |
| 303 | Research on the use of saline water for irrigation purposes and an assessment of salt tolerance criteria of crops | 221 043,16 | 1 052 198,75 | *(33 043,16) |
| 304 | Research on the applicability of hydrodynamic reservoir models for water quality management in stratified water bodies in South Africa | 119 641,92 | 396 915,83 | *(40 648,84) |
| 305 | Research on interpolation and mapping of daily rainfall model parameters for South Africa | 60 939,88 | 267 371,51 | 9 060,12 |
| 306 | Research on techniques for seasonal and long-term rainfall forecasting in South Africa | 114 802,32 | 326 950,38 | 22 897,68 |
| 307 | Research on the influence of different water nitrogen regimes on crop canopy development, water flow resistance and crops yield, with a view to improvement of irrigation models | 162 822,00 | 458 469,57 | 46 282,00 |
| 308 | Research into the recovery of water and chemicals from ion-exchange regeneration effluents | 25 045,83 | 223 380,40 | 42 954,17 |
| 311 | Research on the development and evaluation of geohydrological and isotope hydrological methodologies for the identification of areas potentially suitable for waste disposal | 79 560,00 | 424 557,54 | *(42 810,00) |
| 312 | Research on the occurrence and accumulation of selected heavy metals in freshwater ecosystems affected by mine and industrial effluents | 80 932,00 | 187 999,58 | - |
| 313 | Research on the concentration ratios of selected radionuclides in aquatic ecosystems affected by mine drainage effluents | 42 363,91 | 135 999,76 | - |
| 314 | Research on biological phosphate removal mechanisms in the activated sludge process | 10 600,00 | 152 538,98 | - |
| 316 | Research on aspects of sewage sludge treatment and disposal | - | 34 181,81 | 3 074,69 |
| 317 | Research on urban catchment monitoring | 49 596,05 | 144 747,00 | - |
| 318 | Research on the optimization of biofouling control programmes | 100 670,03 | 376 193,08 | 9 805,97 |
| 319 | Research on monitoring the effect of catchment development on urban runoff and water balance | 300 000,00 | 980 040,72 | *(61 000,00) |
| 321 | Research on bacteriophages as water quality indicators | 13 000,00 | 197 710,23 | - |
| 325 | Research on modelling of tubular reverse osmosis systems | 214 852,24 | 730 879,77 | *(24 979,77) |
| 331 | Research on improved oxygen transfer for high biosludge concentrations | - | 51 651,42 | 23 348,58 |
| 333 | Research on the removal of suspended solids from pulp and paper effluents by employing a combined sedimentation, flotation and sand filtration process | - | 49 107,29 | 5 892,92 |
| 341 | Research on forced aeration composting of sewage sludge for rural communities | 9 800,00 | 54 120,00 | - |
| 342 | Research on improvement in water usage control and waste-water treatment in the sorghum beer industry | - | 46 999,17 | 22 000,00 |
| 343 | Research on the development of an effective and environmentally safe larviciding programme for the control of the blackfly, *Simulium chutteri*, along the Orange River | 108 730,39 | 250 699,57 | 37 387,00 |
| 345 | The development of seeded reverse osmosis technology | - | 40 000,00 | 10 000,00 |
| 346 | A study of the relationship between hydrological processes and water quality characteristics in the developing Zululand coastal region | 169 282,01 | 386 704,17 | 7 117,99 |
| 347 | A global farm approach to enhancing the economic efficiency of water and energy use for irrigation in the central RSA | 167 383,95 | 421 912,37 | *(52 933,60) |
| 348 | Root development and water usage of commercial timber species | 54 055,00 | 326 344,00 | 19 145,00 |
| 349 | Evaporation measurements above vegetated surfaces using micro-meteorological techniques | 41 229,00 | 319 454,00 | 29 546,00 |
| 350 | The effect of pollution on the physiology of fishes in the Olifants River (Eastern Transvaal) | 84 000,27 | 207 000,00 | - |
| 351 | The effect of water quality variables on riverine biotas | 102 139,44 | 289 030,51 | 46 060,56 |
| 352 | Development of a method for the selection of suitable landfill sites, and of guidelines for sanitary landfill in municipal areas | 90 000,00 | 234 686,71 | - |
| 353 | Preparation of a manual on quantitative estimation of groundwater recharge and aquifer storativity | - | 43 435,44 | *(14 556,37) |
| 354 | Research on the evaluation and development of deep-bed filtration for the treatment of South African surface waters | 29 025,00 | 135 999,76 | 18,24 |
| 356 | The consolidation of activated sludge research | 88 833,05 | 233 032,30 | 99 095,95 |
| 357 | Research on the microbiological transformations of metal-contaminated effluents | 144 803,93 | 431 653,32 | 1 915,83 |
| 358 | The development of guidelines for toxicity bio-assaying of drinking and environmental waters in South Africa | 130 000,00 | 374 000,00 | - |
| 359 | An investigation into phytoplankton blooms in the Vaal River and the environmental variables responsible for their development and decline | 60 614,00 | 255 398,57 | 13 171,54 |
| 361 | Research on the development of tolerant membranes | 247 500,00 | 545 931,04 | *(141 931,04) |

## Statement 4 (continued)

### Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1993

| | Project | Expenditure 1993 R | Expenditure Total to 31/12/93 R | Total advances outstanding as at 31/12/93 R |
|---|---|---|---|---|
| 362 | Research on industrial application of membranes | 182 100,00 | 356 274,37 | *(122 774,37) |
| 363 | The development and evaluation of small-scale potable water treatment equipment | 166 047,41 | 331 256,95 | 4 743,05 |
| 364 | Research on field dilution studies on large off-shore pipelines | 61 500,00 | 178 228,73 | *(47 768,43) |
| 366 | Research on full-scale pilot plant studies on phosphate crystallization in biological systems | 146 214,82 | 329 753,67 | 14 985,18 |
| 372 | Assessing the impacts of varying rainfall conditions on vegetation dynamics, production and certain hydrological properties of natural grassland, using a system modelling approach | 195 900,00 | 352 641,19 | - |
| 374 | The Southern Agulhas current and its influence on the weather and climate of Southern Africa | 255 689,20 | 271 492,07 | 33 310,80 |
| 375 | The development of a distributed hydrological modelling system to assist with water quantity and quality management in the Mgeni catchment, Phase II | 357 339,00 | 743 020,00 | 166 980,00 |
| 376 | The geomorphological response to changing flow regimes of the Sabie and Letaba River systems | 249 705,61 | 522 022,75 | 40 941,15 |
| 377 | The use of geographic information systems and other computer-aided drafting facilities for the production of geohydrological maps | 205 455,51 | 719 834,25 | 27 544,49 |
| 378 | The development of techniques for risk analysis and ground-water management of Southern African aquifers | 266 879,93 | 834 966,90 | 22 078,62 |
| 380 | Techniques for microbial aspects of water quality investigation of South African rivers | 332 997,82 | 969 013,62 | 70 460,09 |
| 381 | The corrosion performance of various non-metallic piping materials and coatings in potable water | 157 500,00 | 589 636,42 | *(166 636,42) |
| 382 | The evaluation of the interdependent factors which determine the viability of irrigation farming | 48 000,00 | 228 000,00 | *(48 000,00) |
| 384 | A water resources and sanitation systems sourcebook with special reference to KwaZulu-Natal | 117 824,00 | 315 616,00 | *(2 198,96) |
| 385 | Technical, socio-economic and environmental evaluation of sanitation systems for developing urban areas in South Africa | 75 722,54 | 280 271,09 | 328,46 |
| 386 | Research on development of a crossflow microfilter for rural water supply | 294 180,25 | 816 834,23 | *(14 934,23) |
| 387 | Research on the development and production of membrane systems | 414 312,00 | 1 279 999,72 | *(24 312,00) |
| 388 | The evaluation of various methods for the forming of free radicals for the oxidation of molecules in industrial effluents and potable water | 219 603,57 | 591 321,74 | 35 078,26 |
| 389 | Scheduling irrigation of tuberous crops with specific reference to potatoes | 19 823,00 | 165 332,99 | 52 229,00 |
| 391 | Co-disposal of sewage sludge and refuse | 24 000,00 | 69 000,00 | 1 000,00 |
| 393 | The use of algae to bioassay for toxic substances in water | 13 143,00 | 59 499,52 | 1 250,48 |
| 398 | The degradation of mortar linings and concrete by micro-organisms in industrial water systems | 20 000,00 | 100 000,00 | - |
| 403 | Research on nitrate removal from potable water | - | 33 482,01 | 10 517,99 |
| 404 | The preparation of a manual for waste load allocation in South Africa | 356 700,00 | 630 341,36 | *(241 138,05) |
| 405 | A situation analysis of water quality in the Buffalo River, Eastern Cape, with special emphasis on the impact of low-cost, high density urban development on water quality | 126 539,38 | 509 241,42 | 3 728,14 |
| 406 | A structural analysis of the water apportionment mechanisms in the Water Act 54/1956, in view of the requirements of competing user sectors | 110 000,00 | 389 500,00 | - |
| 408 | Fats and oils in effluents | 6 976,43 | 13 000,00 | - |
| 409 | Phenols in the steel industry waste water: Origin, prevention and removal | 27 128,37 | 39 000,00 | - |
| 411 | Marine pollution: Pathogenic micro-organisms | 91 600,00 | 207 731,63 | *(32,00) |
| 412 | Contribution to the estuaries research programme | (50 000,00) | 50 000,00 | - |
| 413 | The use of vegetation in the amelioration of the impacts of mining on water quality - An assessment of species and water use | 224 321,82 | 474 998,46 | *(92 518,57) |
| 414 | Soil buffering of rain-water salinity in the Vaal Dam catchment | 11 600,00 | 142 277,00 | *(2 164,87) |
| 415 | The application of resource economics to water management decision-making in South Africa | 110 249,00 | 462 152,00 | 12 848,00 |
| 416 | The application and performance of full-scale artificial wetlands for waste-water treatment in South Africa | 119 895,06 | 193 962,94 | *(19 123,10) |
| 417 | Optimal water utilisation by turf | 27 408,20 | 65 598,50 | 1 091,80 |
| 418 | Catchment and land use: Effects on water quality and estuaries | - | - | 7 250,00 |
| 419 | Water quality and quantity assessments in catchments with changing land uses in the Umzinto coastal area | 54 200,00 | 230 655,96 | - |
| 420 | The long-term salt balance of the Vaalharts irrigation scheme | 99 996,65 | 199 996,65 | *(17 853,90) |
| 421 | The relationship between atmospheric deposition and water quality in a small upland catchment | 196 765,88 | 329 364,90 | 61 734,12 |
| 422 | The rapid biological assessment of water quality impacts in streams and rivers | 162 098,53 | 347 339,58 | 29 601,47 |
| 423 | The effect of pre-programmed deficit irrigation on crop reaction | 197 000,00 | 197 000,00 | - |
| 424 | The development of an urban component for the ACRU model | 121 514,64 | 121 514,64 | 3 018,09 |
| 425 | The development of an integrated catchment management system for the Crocodile River catchment | - | 272 100,00 | 61 975,00 |
| 426 | Preliminary investigation of algal weeds in South African inland waters | 71 300,00 | 134 900,00 | - |

## Statement 4 (continued)

### Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1993

| | Project | Expenditure 1993 R | Expenditure Total to 31/12/93 R | Total advances outstanding as at 31/12/93 R |
|---|---|---|---|---|
| 427 | The development of electro-osmotic sludge dewatering technology | 256 400,00 | 396 498,46 | - |
| 428 | An overview of the pesticide and heavy metal levels present in populations of the larger indigenous fish species of selected South African rivers | 87 007,72 | 202 796,20 | 92 492,78 |
| 429 | Research on bio-augmentation technology for waste water treatment in South Africa | 130 500,00 | 228 500,00 | - |
| 431 | A feasibility study of membrane characterisation by electrochemical measurements and membrane optimisation with computational fluid mechanics | 77 000,00 | 82 787,71 | *(12,71) |
| 432 | Microbiological corrosion of common piping materials in the PWV area | 130 893,00 | 258 443,00 | *(81 443,00) |
| 433 | Engineering properties of important Southern African rock types with special reference to the shearing strength of concrete dam wall foundations | 123 357,68 | 263 605,45 | 20 742,32 |
| 434 | Evaluating the long-term use of polypropylene for hot and cold water piping | 122 300,00 | 122 300,00 | 54 000,00 |
| 435 | Development of a training programme on community water supply management for village water committees | 54 998,93 | 134 998,93 | - |
| 436 | Mechanisms of short-term rainfall variability | 137 431,88 | 217 331,88 | 6 068,12 |
| 437 | An assessment of the potential for using stable carbon isotope ratios of wood charcoal as a climate indicator | 117 000,00 | 163 700,41 | 30 691,56 |
| 438 | The development of a real-time, non-conventional rainfall mapping system | 142 200,00 | 302 761,60 | - |
| 439 | Potential impacts of rainfall stimulation on water resources and forestry in the Nelspruit-Bethlehem target zone | 220 284,55 | 395 000,00 | *(37 993,68) |
| 440 | Identification of irrigation land in an intensively cultivated agricultural area in the South-Western Cape by means of satellite remote sensing | 46 993,30 | 64 941,71 | 6,70 |
| 441 | Determination of the relationship between transpiration rate and declining available water for *Eucalyptus grandis* | 131 800,00 | 264 496,85 | *(28 309,35) |
| 442 | Development of improved flow gauging structures for South African rivers | 159 520,88 | 269 687,29 | *(17 133,94) |
| 443 | The compilation of guidelines for the use of peroxone and other oxidants in the treatment of eutrophic water | 88 171,13 | 186 657,03 | 7 328,87 |
| 444 | Development of rigorous engineering methodology for designing vegetative erosion protection systems | 254 202,11 | 343 453,79 | *(15 466,91) |
| 445 | The removal of colour from Cape waters using ozonation and ultrafiltration | 85 660,00 | 272 000,00 | - |
| 446 | Ozonation in the production of potable water from polluted surface water | - | - | 8 000,00 |
| 448 | The improvement of injection nozzles for dissolved air flotation | 50 000,00 | 84 900,71 | - |
| 449 | Evaluation of non-conventional disinfection technologies for small water systems | 58 370,00 | 129 997,35 | - |
| 450 | Research on performance criteria for package water treatment plants | 163 755,64 | 212 937,40 | *(37 505,58) |
| 451 | The occurrence of protozoan parasites in South African drinking water | 120 500,00 | 237 500,00 | - |
| 453 | Development of procedures to assess whole effluent toxicity | 199 700,00 | 359 700,00 | - |
| 454 | An investigation of the occurrence of bacteria causing acid mine drainage in the outer layers of coal waste dumps | 34 979,92 | 65 239,55 | *(1 039,55) |
| 455 | Research on the anaerobic digestion of dairy factory effluents | 20 506,00 | 65 606,00 | 9 494,00 |
| 456 | The regional treatment of textile and industrial effluents | 170 000,00 | 251 667,51 | *(17 967,51) |
| 457 | Monitoring and optimization study of high-rate biofiltration, aerobic biological treatment processes for tannery and fellmongery waste-water | 141 549,67 | 201 000,00 | - |
| 458 | Research on the development of an expert systems approach to water management in the fruit and vegetable processing industry | 75 794,65 | 208 558,40 | *(1 213,37) |
| 462 | Activated fixed and suspended cultures for nitrification | 30 000,00 | 30 000,00 | - |
| 463 | Diversity and productivity of biotic communities in relation to freshwater inputs in Eastern Cape estuaries | 12 475,76 | 12 475,76 | 8 849,24 |
| 464 | The use of yeast biomass and yeast products to accumulate toxic and valuable heavy metals from waste water | 34 298,17 | 54 333,79 | 101,83 |
| 465 | Detergent phosphorus in South Africa: Impact on eutrophication with specific reference to the Umgeni catchment | 550,00 | 6 050,00 | 51 518,18 |
| 472 | The characterisation of South African media for sand filtration | 32 772,69 | 64 589,42 | *(589,42) |
| 473 | Magnetite as flocculant in water purification processes | - | 3 482,59 | 16 517,41 |
| 474 | Developing an integrated approach to predicting the water use of riparian vegetation | 289 300,00 | 393 542,71 | 169 732,29 |
| 475 | The development of a recirculating experimental stream system | 300 674,30 | 489 780,94 | 109 149,86 |
| 476 | The transfer of research results on the irrigation of vegetable crops into practice | 351 219,90 | 588 514,37 | 1 180,10 |
| 478 | Research on the saving of water with air-cooled heat exchangers | 149 376,82 | 336 776,82 | 67 123,18 |
| 479 | Research on a molecular approach to drought tolerance | 153 437,00 | 290 052,00 | 2 663,00 |
| 480 | *Per capita* water demand in developing communities | 58 716,42 | 126 076,96 | *(10 209,62) |

## Statement 4 (continued)

### Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1993

| | Project | Expenditure 1993 R | Expenditure Total to 31/12/93 R | Total advances outstanding as at 31/12/93 R |
|---|---|---|---|---|
| 481 | Research on geochemistry and isotopes for resource evaluation in the fractured rock aquifers of the Table Mountain Group | 124 337,34 | 152 937,34 | 662,66 |
| 482 | The development of a strategy to monitor groundwater quality on a national scale | 47 487,00 | 149 999,41 | 2 513,00 |
| 483 | The compilation of a hydrogeological map of South Africa | 189 594,11 | 260 474,41 | *(40 733,10) |
| 484 | An integrated multidisciplinary geodynamic/geophysical approach to groundwater exploration around the South African coastline | 254 000,00 | 370 100,00 | *(115 247,00) |
| 485 | Development of a systematic method for evaluating site suitability for waste disposal based on geohydrological criteria | 157 180,69 | 293 227,33 | 42 919,31 |
| 486 | Catchment water quality deterioration as a result of water level recovery in abandoned gold mines on the eastern and central Witwatersrand | 201 562,42 | 389 187,43 | *(55 937,43) |
| 487 | Analysis and interpretation of aquifer tests in secondary aquifers | 298 296,72 | 621 171,05 | 31 003,27 |
| 488 | Optimisation of the Rand Water system | 139 435,68 | 243 351,64 | 18 648,36 |
| 489 | The development of procedures for the control of unaccounted-for water in water distribution systems and for the reduction of water loss | 371 055,49 | 587 464,23 | - |
| 490 | The development of flood damage functions and a computer program to determine the advantages of flood and flood damage control measures | 217 528,15 | 303 427,74 | 14 971,85 |
| 491 | Research on pond-enhanced trickling filter operation (PETRO) | 457 300,00 | 592 300,00 | - |
| 492 | Research on the effect of the agricultural environment on water resources | 207 763,00 | 336 418,00 | 50 682,00 |
| 493 | The development and testing of a water balance model for a grassland catchment in the summer rainfall area of South Africa | 305 468,74 | 522 642,62 | (118 635,48) |
| 494 | Classification and hydrological modelling of low flows in Southern Africa | 144 629,60 | 144 629,60 | *(15 529,60) |
| 495 | Biotechnological approach to the removal of organics from saline effluents | 154 386,14 | 365 547,89 | 36 692,11 |
| 496 | Research on human viruses in diffuse effluents and related water environments | 279 877,32 | 334 151,88 | 53 122,68 |
| 497 | Research on a geomorphological classification system for South African river systems | 144 221,02 | 210 615,03 | 4 884,97 |
| 498 | Collection and evaluation of runoff water quality data from a disused feedlot in Natal | 11 870,61 | 55 000,00 | - |
| 499 | The effect of exchangeable sodium percentage and clay mineralogy on the infiltration capacity of soils already sealed due to cyclic irrigation | 26 009,82 | 80 801,09 | 8 998,91 |
| 501 | Continuing research into the wetlands of KwaZulu-Natal | 43 594,00 | 73 312,00 | 9 538,00 |
| 502 | Plunge pool scour reproduction in hydraulic models | 96 800,85 | 143 332,85 | *(17 960,75) |
| 503 | The effect of land use on Gamtoos Estuary quality | 34 500,00 | 54 648,95 | - |
| 504 | A manual on water purification and plant design. Phases 2 and 3: A design guide for water purification | 151 027,10 | 173 154,60 | 21 332,90 |
| 505 | The environmental status of the Orange River Mouth as reflected by the fish community | 47 700,79 | 47 700,79 | 299,21 |
| 506 | The development of drought response policy options for the cost-effective provision of water supply to rural communities subject to recurring drought | 48 713,56 | 48 713,56 | 41 286,44 |
| 507 | Improved estimation of plant and soil evaporation from cropped lands | 39 768,24 | 39 768,24 | 16 231,76 |
| 508 | Modelling the water balance on benchmark ecotopes | 187 000,00 | 187 000,00 | - |
| 509 | Palaeoflood hydrological analysis for selected South African rivers | 38 290,98 | 38 290,98 | *(32 589,23) |
| 510 | Evaluation of river losses from the Orange River downstream of Vanderkloof Dam | 271 812,89 | 271 812,89 | *(30 286,59) |
| 511 | The hydrological implications of afforestation in the North-Eastern Cape | - | - | 7 823,60 |
| 512 | Development of procedures for decision support in water resources management | 111 453,41 | 111 453,41 | 60 546,59 |
| 513 | The development of a computerized management system for irrigation projects | 7 651,02 | 7 651,02 | 46 648,98 |
| 514 | Ground-water contamination as a result of Third World type urbanization | 9 250,67 | 9 250,67 | 50 749,33 |
| 515 | Ground-water abstraction in the Port Elizabeth municipal area | 76 000,00 | 76 000,00 | 3 077,34 |
| 516 | The application of seismic tomography and ground-penetrating radar for the detection of fractures and the determination of hydraulic properties of fractured rock aquifers | 129 512,52 | 129 512,52 | 70 487,48 |
| 517 | The production of the Pietersburg 1:500 000 hydrogeological map sheet 2326 | 131 686,81 | 131 686,81 | *(68 241,50) |
| 518 | A case study of stormwater pollution control in a representative valley | 120 371,41 | 120 371,41 | - |
| 519 | The development of programmes to combat diffuse sources of water pollution in residential areas of developing communities | 217 800,00 | 217 800,00 | 2 375,44 |
| 520 | Guidelines on appropriate technologies for water supply and sanitation in developing communities | 56 651,94 | 56 651,94 | 48 348,06 |
| 522 | A pilot study to investigate alternative management options to enhance the use of saline water for irrigation purposes | 169 340,91 | 169 340,91 | 18 759,09 |
| 523 | The Lower Vet River water quality situation analysis with particular reference to the OFS gold-fields | 283 999,99 | 283 999,99 | - |
| 524 | Development of a rule model for the design of stream water quality monitoring strategies in the forestry industry | 94 929,58 | 94 929,58 | *(90 929,58) |
| 525 | Natural and unnatural factors regulating the structure and functioning of estuarine systems | 100 000,00 | 100 000,00 | - |

## Statement 4 (continued)

### Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1993

| | Project | Expenditure 1993 R | Expenditure Total to 31/12/93 R | Total advances outstanding as at 31/12/93 R |
|---|---|---|---|---|
| 526 | Distribution of fluoride-rich ground-water in the Eastern and Mogwase regions of Bophuthatswana: Influence of bedrock and soils, and constraints on utilisable drinking water supplies | 32 800,00 | 32 800,00 | - |
| 527 | A survey of current water management and treatment practices in the South African gold and coal mining industries | 179 311,60 | 179 311,60 | 59 688,40 |
| 528 | The development of an integrated and generic water quality simulation model for opencast coal mining water circuits | 166 021,32 | 166 021,32 | - |
| 529 | Membrane characterisation by electrochemical measurements and membrane optimisation with computational fluid mechanics | 82 484,37 | 82 484,37 | 106 615,63 |
| 530 | Technology transfer of aquatic chemical speciation modelling | 147 461,96 | 147 461,96 | *(15 536,96) |
| 531 | The development of characterising and cleaning techniques to classify foulants and to remove them from ultra- and microfiltration membranes by biochemical means | 40 396,63 | 40 396,63 | 20 103,37 |
| 532 | Electrically driven membrane separation processes for the treatment of industrial effluents | 98 000,00 | 98 000,00 | - |
| 533 | Extractive purification of industrial effluents | - | - | 90 000,00 |
| 534 | Guidelines for the treatment of Eastern and Southern Cape coloured water | 61 000,00 | 61 000,00 | - |
| 535 | The use of filamentous micro-organisms for the purification of industrial effluents | 61 189,88 | 61 189,88 | 20 810,12 |
| 536 | The development of a dynamic model for the growth and bloom of algae in the Vaal River | 31 290,39 | 31 290,39 | 6 709,61 |
| 537 | Guidelines to coagulation and flocculation for South African waters | 325 800,00 | 325 800,00 | - |
| 538 | The investigation of inorganic materials derived from water purification processes for ceramic applications | - | - | 200 000,00 |
| 539 | The development of a dynamic cross-flow sand filter for rural water treatment | 49 507,34 | 49 507,34 | 18 492,66 |
| 540 | Evaluation of the use of bacteriophages as indicators for water quality | 123 329,55 | 123 329,55 | 18 670,45 |
| 541 | Bio-degradation organic compounds and microbiological regrowth in drinking water | 107 758,26 | 107 758,26 | 42 741,74 |
| 542 | Causes and control of A/A filament bulking in nutrient removal activated sludge systems | 83 018,19 | 83 018,19 | 34 981,81 |
| 543 | Bioremediation technology for the treatment of contaminated seepage water and soil in South Africa | 152 053,46 | 152 053,46 | 13 946,54 |
| 544 | The determination of sludge build-up rates in septic tanks, biological digesters and pit latrines in South Africa | 53 135,38 | 53 135,38 | *(53 135,38) |
| 545 | Standard laboratory organisms for water quality studies | 110 000,00 | 110 000,00 | - |
| 546 | The development and demonstration of effluent treatment systems appropriate to the needs of the red meat abattoir industry | 296 342,02 | 296 342,02 | *(21 811,50) |
| 547 | Synthesis of organic precursors for the development of novel tubular membranes for the treatment of industrial effluents | 19 504,20 | 19 504,20 | 521,80 |
| 548 | An investigation into the upgrading of Orange River water and secondary sewage effluent by means of ultra- and nanofiltration | 19 900,00 | 19 900,00 | 6 180,00 |
| 549 | Algal toxins in drinking-water supplies | 96 167,03 | 96 167,03 | *(1 669,58) |
| 550 | The development of models to stochastically generate spatially distributed daily rainfields | - | - | 8 771,93 |
| 552 | Evaluation of immobilised semi-conductor particles for the photo-catalytic oxidation of organic pollutants in industrial and municipal waste water | 49 697,52 | 49 697,52 | 502,48 |
| 553 | The application of capillary membranes in the biotechnological treatment of industrial effluents | 27 100,00 | 27 100,00 | 180,00 |
| 554 | A study of activated sludge microbial population dynamics for the optimization of biological phosphorus removal | 85 670,28 | 85 670,28 | *(2 329,20) |
| 556 | Refinement of design parameters for sludge thickening by dissolved air flotation | 49 200,00 | 49 200,00 | - |
| 557 | The optimal operation of combined flotation/filtration of eutrophic surface water | 53 501,78 | 53 501,78 | *(29 001,78) |
| 558 | Algal rupture - further investigation | 38 510,85 | 38 510,85 | *(7 169,93) |
| 559 | The prediction of pollution loads from coarse sulphide-containing rock materials | 250 000,00 | 250 000,00 | *(153 701,49) |
| 560 | The development of a cross-flow microfiltration unit to improve the performance of anaerobic digesters at waste-water treatment works | 120 343,62 | 120 343,62 | 156,38 |
| 561 | Water and sanitation in urban areas: Survey of on-site conditions | 75 000,00 | 75 000,00 | *(8 300,00) |
| 562 | The effect of water supply, handling and usage on water quality in relation to health indices in developing communities | 207 582,90 | 207 582,90 | 42 417,10 |
| 563 | SANPLAT - a simplified latrine system for rural and squatter areas | 94 600,00 | 94 600,00 | - |
| 564 | Review of approaches and methodologies for determining recharge and leachate generation rates at waste disposal sites | 49 070,48 | 49 070,48 | 43 929,52 |
| 565 | Hydrogeological, isotopic and hydrochemical assessment of the response of a fractured multi-layered aquifer to long-term abstraction | 28 939,34 | 28 939,34 | 31 060,66 |

## Statement 4 (continued)

### Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1993

| | Project | Expenditure 1993 R | Expenditure Total to 31/12/93 R | Total advances outstanding as at 31/12/93 R |
|---|---|---|---|---|
| 566 | Conversion of the software packages TRICON and BAYES from personal computers to machines using the UNIX operating system | 79 305,65 | 79 305,65 | 6 694,35 |
| 567 | The occurrence and distribution of algal species and related substances in a full-scale water purification plant | 52 000,00 | 52 000,00 | 20 000,00 |
| 568 | The development of an Exxpress unit for the production of potable water and the dewatering of waterworks sludges | 534,03 | 534,03 | 70 518,60 |
| 569 | Investigation into high rate recirculation and solids contact optimisation of biological filtration plants | 98 526,74 | 98 526,74 | - |
| 571 | Water and sanitation in urban areas: Financial and institutional review | 173 770,72 | 173 770,72 | *(17 000,00) |
| 572 | An investigation of the contaminant attenuation cacity of the soil/aquifer system with special emphasis on the vadose zone | 53 641,41 | 53 641,41 | 33 358,59 |
| 574 | The potential for the use of economic instruments to protect the quality of water resources in South Africa | 104 780,00 | 104 780,00 | *(11 130,00) |
| 575 | Calibration of models for the design of covers for opencast mine and waste dump rehabilitation | 162 000,49 | 162 000,49 | *(13 402,16) |
| 576 | The effects of different magnitude flows on South African riverine ecosystems | 180 599,24 | 180 599,24 | 99 500,76 |
| 577 | Decision support for the integrated management and conservation of estuaries | 171 000,00 | 171 000,00 | - |
| 578 | The evaluation of irrigation techniques used by subsistence and emergent farmers | 300 000,00 | 300 000,00 | - |
| 579 | Hydraulic roughness of tunnels bored by machine through various rock-types | - | - | 13 158,89 |
| 580 | The control of dam siltation in South Africa | 138 839,38 | 138 839,38 | *(11 620,30) |
| 581 | A computerised weather-based irrigation water management system | 271 000,00 | 271 000,00 | - |
| 582 | The screening of crop, pasture and wetland species for tolerance of polluted water originating in coal mines | 23 607,23 | 23 607,23 | 33 892,77 |
| 583 | The development of a laboratory river model to determine the environmental impacts of key zenobiotic compounds | 51 746,00 | 51 746,00 | 4 754,00 |
| 584 | An atlas of potentially water-related disease in South Africa | 86 000,00 | 86 000,00 | - |
| 585 | Modelling flow through porous media | 43 000,00 | 43 000,00 | - |
| 586 | The development of a decision support system for the selection of the most appropriate sanitation option for developing communities | 26 263,19 | 26 263,19 | 34 191,36 |
| 587 | Evaluation of water pipe leaks in the Johannesburg municipal area | 59 527,00 | 59 527,00 | *(34 727,00) |
| 588 | Demonstrating the potential of geographical information systems technology in hydrosalinity modelling by using the Disa model | 26 100,00 | 26 100,00 | *(100,00) |
| | SUB TOTAL | 32 997 540,34 | 78 836 488,89 | 1 141 456,62 |
| | **2. Research support services** | | | |
| | South African Water Information Centre | 976 000,00 | 2 542 000,00 | - |
| | Establishment of a Computing Centre for Water Research | 913 500,00 | 3 620 200,00 | *(299 114,33) |
| | SUB TOTAL | 1 889 500,00 | 6 162 200,00 | *(299 114,33) |
| | **TOTAL** | 34 887 040,34 | 84 998 688,89 | 842 342,29 |

* Excess expenditure over advances for projects

# Statement 5
## Budget 1995

| | |
|---|---|
| ESTIMATED INCOME | 53 063 000 |
| Rates and charges in terms of Section 11 of the Water Research Act | 51 561 000 |
| Interest on investments | 1 050 000 |
| Erf Sewe-Nul-Ses Rietfontein (Pty) Ltd | 452 000 |
| TOTAL ESTIMATED INCOME | 53 063 000 |
| ESTIMATED EXPENDITURE | |
| Administrative expenses | 9 895 200 |
| Salaries and allowances | 6 172 000 |
| Subsistence and transport | 944 200 |
| Postal, telegraph and telephone services | 144 000 |
| Printing, stationery and advertisements | 120 000 |
| General expenses | 2 445 000 |
| Purchases: Fixed assets | 70 000 |
| | 1 312 000 |
| Technology and information transfer | 1 312 000 |
| Approved projects | 23 793 300 |
| 133 CRAWS | 3 661 000 |
| 303 Research on the use of saline water for irrigation purposes and an assessment of salt tolerance criteria of crops | 97 900 |
| 319 Research on monitoring the effect of catchment development on urban runoff and water balance | 245 700 |
| 346 A study of the relationship between hydrological processes and water quality characteristics in the developing Zululand coastal region | 163 800 |
| 359 An investigation into phytoplankton blooms in the Vaal River and the environmental variables responsible for their development and decline | 45 500 |
| 363 The development and evaluation of small-scale potable water treatment equipment | 53 700 |
| 372 Assessing the impacts of varying rainfall conditions on vegetation dynamics, production and certain hydrological properties of natural grassland, using a system modelling approach | 120 000 |
| 374 The Southern Agulhas current and its influence on the weather and climate of Southern Africa | 164 700 |
| 376 The geomorphological response to changing flow regimes of the Sabie and Letaba River systems | 275 600 |
| 381 The corrosion performance of various non-metallic piping materials and coatings in potable water | 31 900 |
| 388 The evaluation of various methods for the forming of free radicals for the oxidation of molecules in industrial effluents and potable water | 48 200 |
| 389 Scheduling irrigation of tuberous crops with specific reference to potatoes | 21 800 |
| 413 The use of vegetation in the amelioration of the impacts of mining on water quality – An assessment of species and water use | 91 000 |
| 417 Optimal water utilisation by turf | 10 000 |
| 419 Water quality and quantity assessments in catchments with changing land uses in the Umzinto coastal area | 65 300 |
| 423 The effect of pre-programmed deficit irrigation on crop reaction | 167 400 |
| 432 Microbiological corrosion of common piping materials in the PWV area | 48 300 |
| 433 Engineering properties of important Southern African rock types with special reference to the shearing strength of concrete dam wall foundations | 110 400 |
| 436 Mechanisms of short-term rainfall variability | 27 300 |
| 437 An assessment of the potential for using stable carbon isotope ratios of wood charcoal as a climate indicator | 71 000 |
| 441 Determination of the relationship between transpiration rate and declining available water for *Eucalyptus grandis* | 95 000 |
| 446 Osonation in the production of potable water from polluted surface water | 31 900 |
| 454 An investigation of the occurrence of bacteria causing acid mine drainage in the outer layers of coal waste dumps | 51 000 |
| 456 The regional treatment of textile and industrial effluents | 44 600 |
| 457 Monitoring and optimization study of high-rate biofiltration, aerobic biological treatment processes for tannery and fellmongery wastewater | 422 000 |
| 474 Developing an integrated approach to predicting the water use of riparian vegetation | 353 200 |
| 475 The development of a recirculating experimental stream system | 137 400 |
| 479 Research on a molecular approach to drought tolerance | 130 200 |
| 481 Research on geochemistry and isotopes for resource evaluation in the fractured rock aquifers of the Table Mountain Group | 155 000 |
| 484 An integrated multidisciplinary geodynamic/geophysical approach to groundwater exploration around the South African coastline | 120 000 |

# Statement 5
## Budget 1995 (continued)

| | | |
|---|---|---|
| 487 | Analysis and interpretation of aquifer tests in secondary aquifers | 398 600 |
| 489 | The development of procedures for the control of unaccounted-for water in water distribution systems and for the reduction of water loss | 555 100 |
| 492 | Research on the effect of the agricultural environment on water resources | 542 400 |
| 493 | The development and testing of a water balance model for a grassland catchment in the summer rainfall area of South Africa | 242 000 |
| 494 | *Classification and hydrological modelling of low flows in Southern Africa* | 339 400 |
| 495 | Biotechnological approach to the removal of organics from saline effluents | 154 900 |
| 497 | Research on a geomorphological classification system for South African River Systems | 169 300 |
| 507 | Improved estimation of plant and soil evaporation from cropped lands | 4 800 |
| 508 | Modelling the water balance on benchmark ecotopes | 24 600 |
| 511 | The hydrological implications of afforestation in the North-Eastern Cape | 154 700 |
| 512 | Development of procedures for decision support in water resources management | 186 500 |
| 514 | Groundwater contamination as a result of Third World type urbanization | 200 200 |
| 515 | Groundwater abstraction in the Port Elizabeth municipal area | 23 000 |
| 516 | The application of seismic tomography and ground-penetrating radar for the detection of fractures and the determination of hydraulic properties of fractured rock aquifers | 145 600 |
| 520 | Guidelines on appropriate technologies for water supply and sanitation in developing communities | 154 700 |
| 522 | A pilot study to investigate alternative management options to enhance the use of saline water for irrigation purposes | 97 800 |
| 526 | Distribution of fluoride-rich groundwater in the Eastern and Mogwase regions of Bophuthatswana: Influence of bedrock and soils, and constraints on utilisable drinking-water supplies | 29 900 |
| 527 | A survey of current water management and treatment practices in the South African gold- and coal-mining industries | 33 200 |
| 528 | The development of an integrated and generic water quality simulation model for opencast coal mining water circuits | 42 700 |
| 529 | Membrane characterisation by electrochemical measurements and membrane optimisation with computational fluid mechanics | 205 600 |
| 536 | The development of a dynamic model for the growth and bloom of algae in the Vaal River | 48 200 |
| 539 | The development of a dynamic cross-flow sand filter for rural water treatment | 28 200 |
| 540 | Evaluation of the use of bacteriophages as indicators for water quality | 141 700 |
| 541 | Bio-degradable organic compounds and microbial regrowth in drinking water | 133 000 |
| 542 | Causes and control of low A/A filament bulking in nutrient removal activated sludge systems | 133 800 |
| 544 | The determination of sludge build-up rates in septic tanks, biological digesters and pit latrines in South Africa | 50 000 |
| 545 | Standard laboratory organisms for water quality studies | 182 900 |
| 549 | Algal toxins in drinking-water supplies | 161 200 |
| 550 | *The development of models to stochastically generate spatially distributed daily rainfields* | 35 000 |
| 551 | Evaluation of the potential quantity of methane gas from 85 anaerobic household digesters | 30 000 |
| 553 | The application of capillary membranes in the biotechnological treatment of industrial effluents | 7 100 |
| 554 | A study of activated sludge microbial population dynamics for the optimization of biological phosphorus removal | 94 500 |
| 559 | The prediction of pollution loads from coarse sulphide-containing rock materials | 182 000 |
| 560 | Development of a cross-flow microfiltration unit to improve the performance of anaerobic digesters at waste-water treatment works | 195 600 |
| 562 | The effect of water supply, handling and usage on water quality in relation to health indices in developing communities | 301 400 |
| 567 | The occurrence and distribution of algal species and related substances in a full-scale water purification plant | 136 500 |
| 568 | The development of an Exxpress unit for the production of potable water and the dewatering of waterworks sludges | 241 100 |
| 572 | An investigation of the contaminant attenuation capacity of the soil/aquifer system with special emphasis on the vadose zone | 327 200 |
| 573 | *Water use efficiency of cultivated subtropical forage and pasture crops* | 106 900 |
| 575 | Calibration of models for the design of covers for opencast mine and waste dump rehabilitation | 143 900 |
| 576 | The effects of different magnitude flows on South African riverine ecosystems | 323 500 |
| 577 | Decision support systems for the integrated management and conservation of estuaries | 173 300 |
| 578 | The evaluation of irrigation techniques used by subsistence and emergent farmers | 250 000 |
| 579 | Hydraulic roughness of tunnels bored by machine through various rock-types | 45 500 |
| 580 | The control of dam siltation in South Africa | 124 700 |
| 581 | A computerised weather-based irrigation water management system | 245 700 |
| 582 | The screening of crop, pasture and wetland species for tolerance of polluted water originating in coal mines | 103 300 |
| 583 | The development of a laboratory river model to determine the environmental impacts of key zenobiotic compounds | 29 000 |
| 586 | The development of a decision support system for the selection of the most appropriate sanitation option for developing communities | 91 000 |
| 587 | Evaluation of water pipe leaks in the Johannesburg municipal area | 21 900 |
| 591 | A study for the provision of point-source water by air-gap membrane distillation | 30 900 |
| 592 | An investigation into the use of biodispersants available for biofouling control in industrial water systems | 43 000 |
| 594 | Regional climate change scenarios for precipitation and temperature from general circulation models | 43 400 |
| 595 | Modelling rainfall-producing systems over Southern Africa | 121 000 |
| 596 | The development of a realtime non-conventional rainfall mapping system for coastal zone cloud systems | 56 400 |
| 597 | Technology adaption for successful application of septic tank systems in the coastal zone | 77 300 |
| 598 | Research on the appropriate management of urban runoff in South Africa | 250 300 |
| 599 | Co-disposal and composting of septic tank and pit latrine sludges with municipal refuse | 76 400 |

# Statement 5
## Budget 1995 (continued)

| | | |
|---|---|---|
| 600 | Problem blooms of macro-algae: Investigation of causal factors, seasonality of recruitment and growth, and efficiency of control methods | 116 100 |
| 601 | The freshwater requirements of plant communities in different types of estuaries | 95 500 |
| 602 | The application of chemical equilibrium to the control of struvite and calcite precipitation in waste-water treatment | 51 900 |
| 603 | The development of effective community water supply systems using deep and shallow well handpumps | 167 400 |
| 604 | The compilation of guidelines for the design and operation of sewage sludge drying beds | 88 300 |
| 605 | Municipal sewage sludge disposal: Development of guidelines and expert systems | 91 700 |
| 606 | The practical application of special waste co-disposal with municipal refuse at the Coastal Park landfill bioreactor | 93 600 |
| 607 | The compilation of an operating manual for biological nutrient removal wastewater treatment works | 12 700 |
| 608 | Lethal and sublethal effects of metals on fish physiology in the Republic of South Africa | 167 400 |
| 609 | Underground neutralisation of mine water with limestone | 236 600 |
| 611 | The development of procedures for bio-degradability testing of organic chemical compounds | 73 800 |
| 612 | Reduction of scaling in industrial water cooling circuits by means of magnetic and electrostatic treatment | 110 100 |
| 613 | Stabilisation of aggressive and corrosive waters | 138 300 |
| 614 | An expert system for water treatment plant design and analysis | 157 400 |
| 615 | Modelling the causes of algal blooms in impoundments of the Umgeni catchment and the consequences for potable water treatment | 121 000 |
| 616 | The use of algal and yeast biomass to accumulate toxic and valuable heavy metals from waste water | 165 800 |
| 617 | Extractive purification of industrial effluents | 128 800 |
| 618 | Capillary membrane production development | 171 200 |
| 619 | Tolerant membranes | 182 000 |
| 620 | The modelling, design and operation of secondary settling tanks | 80 000 |
| 621 | Balancing tank control application | 41 400 |
| 622 | Rapid quantitative evaluation of water quality using a modified biological test | 6 600 |
| 624 | A personal computer-based procedure for the estimation of irrigation requirements of crops in Southern Africa | 300 300 |
| 625 | The use of computer models for agricultural water management at farm level | 211 100 |
| 626 | Water quality requirements for riverine biotas | 183 000 |
| 627 | An integrated modelling system for predicting the impacts of changes in water quantity and quality brought about by upstream development | 81 900 |
| 629 | Evaluation of solid waste practice in developing urban areas in South Africa | 70 400 |
| 630 | Community participation and education in water resources management and environmental awareness | 116 300 |
| 631 | Assignment of a financial cost to pollution from on-site sanitation, with particular reference to the PWV | 72 500 |
| 632 | The development of specialised cross- and transverse-flow capillary membrane modules | 257 600 |
| 633 | Research on the management of urban impoundments | 108 300 |
| 634 | Quantifying the impact of the salinisation of South Africa's water resources with special reference to economic effects. Phase 1: Development of a generic model | 200 000 |
| 635 | Flow regimes from international experimental and network data (FRIEND) for Southern Africa | 252 000 |
| 636 | Hydrological systems modelling research programme: ACRU model development and user support | 295 700 |
| 637 | Hydrological systems modelling research programme: Hydrological process research | 502 300 |
| 638 | Studies on river losses: Phase 2 | 309 400 |
| 640 | Extension and refinement of the Aquamod Computer Software package | 128 300 |
| 641 | An assessment of the impact of agricultural practices on the quality of groundwater resources in South Africa | 309 700 |
| 642 | The development of a water information management database system for data capture and processing at local authority level | 215 900 |
| 643 | Development of rigorous engineering methodology for designing vegetative erosion protection systems: Phase 2 | 242 900 |
| 644 | The quality of water for livestock production with emphasis on subterranean water and the development of a water quality guideline index system | 319 400 |
| 645 | Optimal management of uncertain water availability at farm and regional level with due allowance for risk and the environment | 273 000 |
| 646 | Maximisation of economic water-use efficiency of processing tomatoes | 200 200 |
| 647 | The application of isotope chemistry to quantify the contribution of gold and coal mines to salt pollution load in groundwater and rivers | 68 900 |
| 648 | The application of computational fluid dynamics to improving the design and operation of water and wastewater treatment plants | 271 100 |
| 650 | Integrated control of blackflies along the Orange River | 149 600 |
| 651 | Appropriate low-cost sewage treatment using the advanced algal high rate oxidation pond | 400 000 |
| 653 | Regional characterisation and mapping of Karoo fractured aquifer systems - an integrated approach using a geographical information system and digital image processing | 91 200 |
| 654 | The development of a modelling system which will provide a common currency for integration of the results and data emanating from the Kruger National Park Rivers Research Program (KNPRRP) | 25 700 |
| 655 | The establishment of an effective information management system for the Kruger National Park Rivers Research Programme (KNPRRP) | 86 400 |

# Statement 5
## Budget 1995 (continued)

| | | |
|---|---|---|
| | | 8 057 100 |
| **New commitments** | | 8 057 100 |
| | | 2 500 000 |
| **Capacity building program** | | 2 500 000 |
| **Other** | | 4 424 600 |
| Research and other grants | | 130 000 |
| Specialist and Consultation Services | | 1 500 000 |
| Research Support Services and Facilities | | 2 794 600 |
| **TOTAL ESTIMATED EXPENDITURE** | | 49 982 200 |
| **ESTIMATED INVESTMENT BALANCE** | | 3 080 800 |
| | | 53 063 000 |

# Statement 6
## Statement of receipts and payments for the year ended 31 December 1994

| Receipts | 1994 R | Payments | 1994 R |
|---|---|---|---|
| **Balance on 1 January 1994** | 16 445 984 | **Administrative services and staff expenditure** | 8 867 817 |
| Fixed investments | 10 000 000 | Salaries and allowances | 5 877 633 |
| Investment at Corporation for Public Deposits | 4 958 080 | Motor transport | 26 057 |
| Cash on hand | 150 | Subsistence and transport expenses | 403 497 |
| Cash in bank | 1 487 754 | General transport | 376 807 |
| | | Postal and telecommunication services | 42 233 |
| **Rates** | 1 546 173 | Telephone services | 67 720 |
| | | Printing | 6 678 |
| Government irrigation schemes with canal systems | 295 039 | Stationery | 81 656 |
| Irrigation Board Schemes | 1 251 134 | Advertisements | 54 023 |
| | | Computerisation | 92 515 |
| **Charges** | 38 919 843 | Rental and maintenance | 856 036 |
| | | Entertainment | 36 473 |
| Metered water from Government schemes | 29 444 539 | Office complex | 75 734 |
| Municipalities | 9 461 948 | Services rendered | 17 683 |
| Interest on charges in arrear | 13 356 | Insurance | 25 603 |
| | | Collection services | 439 732 |
| **Other** | 269 059 | Audit fees | 105 844 |
| | | Patent registrations and legal advice | 95 199 |
| Interest on investment: Corporation for Public Deposits | 109 257 | Registration and subscriptions | 64 867 |
| Sundry income | 159 802 | Miscellaneous expenses | 50 200 |
| | | Bank costs | 71 627 |
| **Sundry debitors** | 3 324 999 | **Purchases: Fixed assets** | 141 947 |
| | | Motor vehicles | 56 913 |
| | | Computer equipment | 48 925 |
| | | Office equipment | 34 933 |
| | | Office furniture | 1 176 |
| | | **Technology and information transfer** | 963 174 |
| | | Publications | 627 262 |
| | | Conferences | 160 646 |
| | | Publicity | 175 266 |
| | | **Research expenses** | 43 378 591 |
| | | Project advances | 36 070 136 |
| | | Research projects | 3 803 856 |
| | | Research and other grants | 127 446 |
| | | Specialist and consultation services | 1 329 872 |
| | | Research support services and facilities | 2 047 221 |
| | | **Sundry creditors** | 712 906 |
| | | **Balance as at 31 December 1994** | 6 441 683 |
| | | Fixed investments | 11 497 877 |
| | | Investment at Corporation for Public Deposits | 102 788 |
| | | Cash on hand | 150 |
| | | Bank overdraft | (5 159 132) |
| | 60 506 058 | | R60 506 058 |

Water Research Commission
Pretoria, 9/2/1995

(Signed) PE Odendaal
Executive Director

# Annexure

**Publications emanating from research financed wholly or partially by the WRC**

This **Appendix** contains a list of publications released in 1994, as well as a complementary list of 1993. Requests for publications should be directed, as far as possible, to the authors.

## Developing communities

### Articles and papers (1994)

- *Fourie, AB and Van Ryneveld, MB (1994) Sub-surface impact of low flush* on-site anaerobic digesters in Ivory Park. In: Palmer Development Group in association with University of Cape Town Water Research Group (eds.) Technical, Socio-Economic and Environmental Evaluation of Sanitation for Developing Urban Areas in South Africa. Working Paper B3.4 of WRC Report No. 385/1/93.
- Van Ryneveld, MB (1994) The current extent of coverage and the costs of water supply and sanitation provision in the urban areas of South Africa. *Water SA* **20** (2) 99-106.

### Reports (1994)

- Fourie, AB and Van Ryneveld, MB (1994) Environmental Impact of On-Site Sanitation: A Literature Review with Particular Application to South Africa. WRC Report No. KV 57/94.
- *Hazelton, DG, Pearson, I and Kariuki, AW (1994) Development of* Drought Response Policy Options for the Cost-effective Provision of Water Supply to Rural Communities Subject to Recurring Droughts. WRC Report No. 506/1/94.
- La Trobe and Associates (1994) Forced Aeration Composting of Sewage Sludge for Rural Communities. WRC Report No. 341/1/94.
- Palmer Development Group (1994) Water and Sanitation in Urban Areas: Financial and Institutional Review. Report 1: Overview of Institutional and Financial Arrangements in Water Supply and Sanitation. WRC Report No. 571/1/94.
- Palmer Development Group (1994) Water and Sanitation in Urban Areas: Financial and Institutional Review. Report 2: Overview of the Demand for and Cost of Water Supply and Sanitation Services in South Africa. WRC Report No. 571/2/94.
- Palmer Development Group (1994) Water and Sanitation in Urban Areas: Financial and Institutional Review. Report 3: Meeting the Demand for Water and Sanitation Services: Getting it Right in the Transition. WRC Report No. 571/3/94.
- *Palmer Development Group (1984) Water and Sanitation in Urban Areas:* Financial and Institutional Review. Report 4: International Perspectives. Some Lessons for South Africa from England, France, Italy, Brazil and Botswana and Some Information on External Funding Agencies. WRC Report No. 571/4/94.
- Palmer Development Group (1994) Water and Sanitation in Urban Areas: Financial and Institutional Review. Report 5: Macro-economic Sketch – A Sketch of the Macro-economic Implications of Major Investment in the (Domestic) Urban Water and Sanitation Sector. WRC Report No. 571/5/94.
- Palmer Development Group (1994) Water and Sanitation in Urban Areas: Financial and Institutional Review. Report 6: Summary Report. WRC Report No. 571/6/94.

### Reports (1993)

- Coleman, T (1993) Effects of Urbanization on Catchment Water Balance 10: Urban Runoff Quality and Modelling Methods. WRC Report No. 183/10/93.
- Coleman, TJ and Stephenson, D (1993) Effects of Urbanization on Catchment Water Balance 8: Runoff Management Modelling. WRC Report No. 183/8/93.
- Holden, A (1993) Effects of Urbanization on Catchment Water Balance 6: *A Physically Based Hydrological Model for Continuous Simulation of* Catchment Runoff. WRC Report No. 183/6/93.
- Kolovopoulos, P (1993) Effects of Urbanization on Catchment Water Balance 7: Streamflow Modelling. WRC Report No. 183/7/93.
- *Lambourne, JJ, Coleman, TJ and Stephenson, D (1993) Effects of* Urbanization on Catchment Water Balance 9: Catchment Water Balance. WRC Report No. 183/9/93.
- Lambourne, JJ (1993) Effects of Urbanization on Catchment Water Balance 4: A Hydrometeorological Data Management Package: Wits Data Management System (WITDMS). WRC Report No. 183/4/93.
- Lambourne, JJ and Coleman, TJ (1993) Effects of Urbanization on Catchment Water Balance 2: Description of Catchments and Methodology. WRC Report No. 183/2/93.
- *Paling, WAJ and Stephenson, D (1993) Effects of Urbanization on* Catchment Water Balance 3: Geohydrology of Catchments. WRC Report No. 183/3/93.
- Patrick, NA (1993) Effects of Urbanization on Catchment Water Balance 5: The Effects of Storm Patterns on Runoff. WRC Report No. 183/5/93.
- Water Systems Research Group, University of the Witwatersrand (1993) Effects of Urbanization on Catchment Water Balance 11: Compendium of Papers Published by the Water Systems Research Group. WRC Report No. 183/11/93.
- Wright, A, Kloppers, W and Fricke, A (1993) A Hydrological Investigation of the Stormwater Runoff from the Khayelitsha Urban Catchment in the False Bay Area, South Western Cape. WRC Report No. 323/1/93.

## Drinking water

### Articles and papers (1994)

- Bondonno, A, Ramotlhola, J and Ringas, C (1994) Study of microbiologically induced corrosion of mild steel exposed to potable water in the PWV area. Paper presented at the Afriwater 1994 Conf.
- Botha, CJ and Buckley, CA (1994) Disinfection of potable water – The role of hydrodynamic cavitation. Paper presented at WISA Int. Spec. Conf. on Disinfection of Potable Water, Kruger National Park. 13-18 March.
- Haarhoff, J and Rykaart, EM (1994) Rational design of packed saturators. Paper presented at Spec. Conf. on Flotation Processes in Water and Sludge Treatment, Orlando, Florida, USA. 26-28 April.
- Haarhoff, J and Van Vuuren, LRJ (1994) Design parameters for dissolved air flotation in South Africa. Paper presented at Spec. Conf. on Flotation Processes in Water and Sludge Treatment, Orlando, Florida, USA. 26-28 April.
- *Jordaan, R en Pieterse, AJH (1994) Algspesies wat eenheidsprosesse by* watersuiwering vermy. Referaat gelewer by Vergadering S.A. Akad. vir Wet. en Kuns (Afd. Biol.), Bloemfontein.

- Offringa, G (1994) Dissolved air flotation in Southern Africa. Paper presented at IAWQ-IWSA-AWWA Joint Spec. Conf. on Flotation Processes in Water and Sludge Treatment, Orlando, Florida, USA. 26-28 April.
- Pieterse, AJH and Basson, N (1994) The effects of oxidants and coagulant-flocculants on the sedimentation of algal species and suspended particles from turbid water in a full-scale water treatment plant. Paper presented at Workshop on Optimal Dosing of Coagulants and Flocculants held by the IWSA-IAWQ Joint Specialist Group on Coagulation, Flocculation, Filtration, Sedimentation and Flotation in Water Treatment, Mülheim an der Ruhr, Germany. 12-13 January.
- Pieterse, AJH and Janse van Vuuren, S (1994) Ecology and diversity of centric diatoms of the Vaal River, South Africa. Paper presented at 13th Symp. of the Int. Diatom Ass., Maratea, Italy. 1-7 September.
- Ringas, C and Gnoinski, J (1994) Corrosion in water reticulation systems. Corrosion and Coatings. Metallurgical and Corrosion Services, Div. of Materials Sci. and Technol., CSIR.
- Rykaart, EM and Haarhoff, J (1994) Behaviour of air injection nozzles in dissolved air flotation. Paper presented at Spec. Conf. on Flotation Processes in Water and Sludge Treatment, Orlando, Florida, USA. 26-28 April.
- Traut, DF, Jordaan, R en Pieterse, AJH (1994) Die invloed van flokkuleermiddels op die groei- en fotosintesetempo's van algsoorte uit die Vaalrivier. Referaat gelewer by Vergadering, S.A. Akad. vir Wet. en Kuns (Afd. Biol.), Bloemfontein.
- Voortman, WJ, Bailey, IW, Reddy, CD and Rencken, GE (1994) Disinfection methods for package water treatment plants. Paper presented at IWSA Conf. "Disinfection, the Total Spectrum", Kruger National Park. 13-18 March.

### Reports (1994)

- Ceronio, AD en Haarhoff, J (1994) Die Evaluasie van Suid-Afrikaanse Filtermedia vir Diepbedfiltrasie. WNK Verslagno. 472/1/94.
- Palmer Development Group (1994) Water and Sanitation in Urban Areas: Survey of On-site Conditions. WRC Report No. 561/1/94.
- Pretorius, CJ, Van der Merwe, RB, Van Niekerk, IE en Viljoen, MF (1994) Die Ontwikkeling van 'n Model vir die Projeksie van Waterbehoeftes in die Belangegebied van Bloemarea Waterraad tot die Jaar 2020. WNK Verslagno. KV 52/94.
- Simes, CE, Lings, RJ and Tshivhase, T (1994) Prepayment Water Metering for South Africa. WRC Report No. KV 56/94.
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# Water ecosystems

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# Mission statement

To contribute effectively to the best possible quality of life for the people of South Africa, by promoting water research and the application of research findings.

Therefore, the WRC endeavours dynamically and purposefully to:

- Promote co-ordination, communication and co-operation in the field of water research
- Establish water research needs and priorities
- Fund water research on a priority basis
- Promote effective transfer of information and technology.