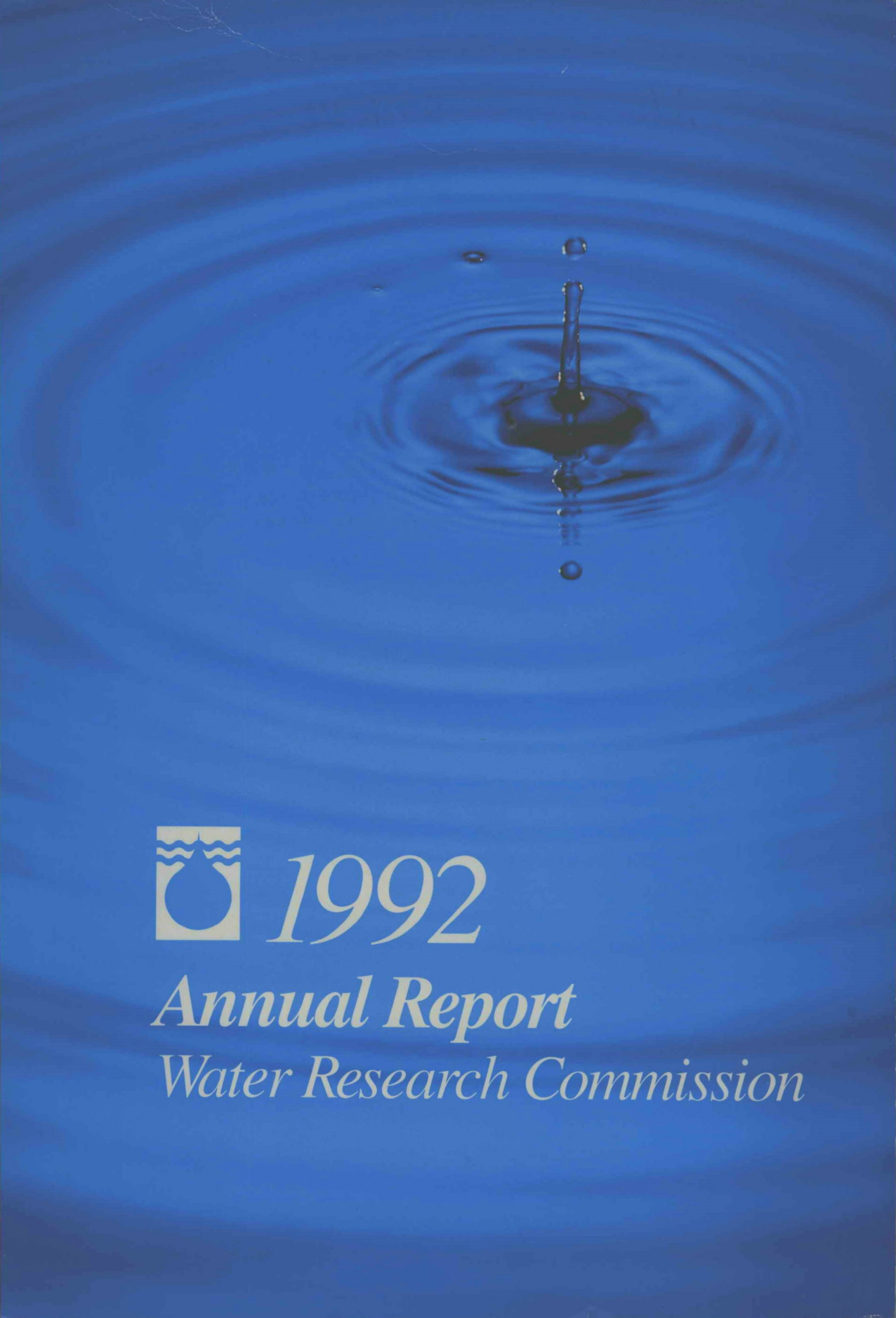

1992

Annual Report

Water Research Commission

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.*

RH

1992

Annual Report

Water Research Commission

ADDRESS:

491 18TH AVENUE
RIETFONTEIN
PRETORIA
0084

POSTAL ADDRESS:

✉ 824
PRETORIA
0001

TELEGRAPHIC ADDRESS: WATERKOM

☎ (012) 330-0340

F NATIONAL (012) 331-2565
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WATER RESEARCH COMMISSION
PO BOX 824
PRETORIA
0001
20 MARCH 1993

Dear Mr Van Wyk

We take pleasure in submitting to you, herewith, the report of the Water Research Commission for the period 1 January to 31 December 1992.

The balance sheet and statement of revenue and expenditure for the financial year to 31 December 1991, as certified by the Auditor General, as well as a receipts and payments account for the year ended 31 December 1992 and a budget for 1993, are furnished under ***Financial Statements*** *of this report.*

Yours respectfully

AJ Raubenheimer
CHAIRMAN

PE Odendaal
EXECUTIVE DIRECTOR

Mr JA van Wyk, MP
Minister of Environment Affairs and of Water Affairs
Private Bag X9052
CAPE TOWN
8000

Contents

Senior personnel

Professional

Deputy Executive Director

Dr MJ Pieterse

(Municipal effluents; industrial water and waste water; drinking water; treatment technology)

Deputy Executive Director

Mr DS van der Merwe

(Water sources; urban water reticulation; water utilisation for agricultural and ecological purposes)

Research Managers

Dr TC Erasmus
Dr OO Hart
Mr G Offringa
Dr HM Saayman
Dr SA Mitchell

Research Managers

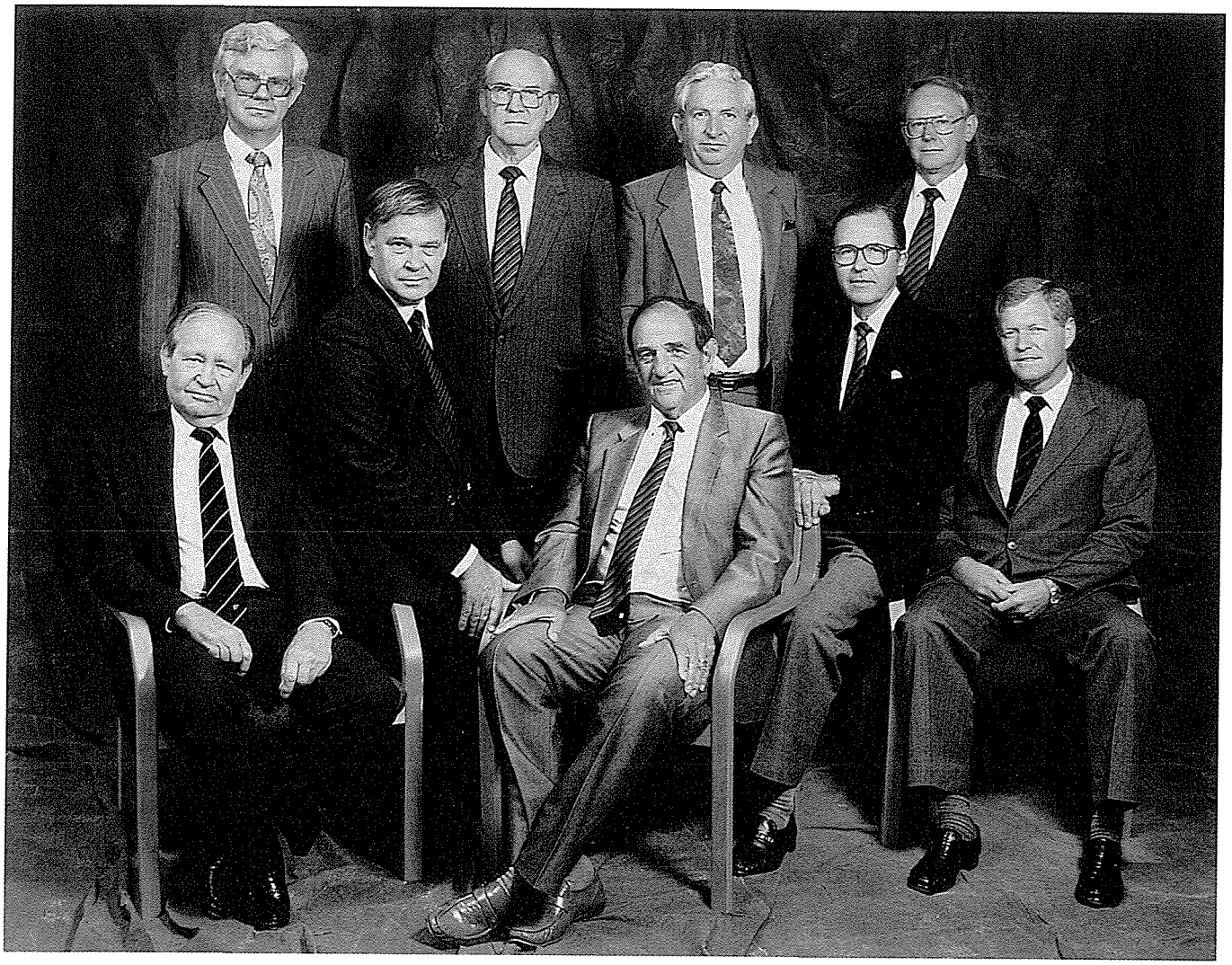
Mr HC Chapman
Mr HM du Plessis
Dr GC Green
Mr H Maaren
Dr PCM Reid
Mr AG Reynders

Administrative

Director: Administration

Mr PM van der Schyff

Members of the Water Research Commission
as on 31 December 1992



Back row from left to right:

Prof T Erasmus - Vice-Principal: University of Pretoria
Mr DH Marx - Chairman: Magalies Water Board
Mr AJ Clayton (Co-opted member) - City Engineer: Cape Town
Mr M Erasmus (Co-opted member) - Deputy Director-General: Department of Water Affairs and Forestry

Front row from left to right:

Dr WL van Wyk - Former Deputy Director-General: Department of Mineral and Energy Affairs
Mr PE Odendaal - Executive Director: Water Research Commission
The Honourable AJ Raubenheimer (DMS) (Chairman) - Former Minister of Water Affairs
Prof PD Tyson - Vice-Principal: University of the Witwatersrand
Mr VJ Bath - Chief Executive: Rand Water Board

Absent:

Mr GCD Claassens (Vice-Chairman) - Director-General: Department of Water Affairs and Forestry
Mr DW Steyn - Former Minister of Economic Affairs and Technology; Chairman: Roadfix Africa Ltd; and Chairman: Prisma Food CC

1 The year under review

The multidisciplinary approach to water research is evidenced by the variety of research areas supported by the Water Research Commission (WRC). The research fields and allocation of funds to the various areas for 1992 are reflected 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 responsible for the research are listed, as well as the extent of their involvement:

RESEARCH SECTOR	*NUMBER OF TIMES INVOLVED*	*%*
Universities	*119*	*49*
CSIR	*54*	*22*
Consulting engineers	*22*	*9*
Government departments	*3*	*1*
Local authorities	*5*	*2*
Water boards	*9*	*4*
Private companies	*16*	*7*
Other organisations	*15*	*6*
Total	***243***	***100***

From the figures it is evident that universities are involved in 49% of the total number of contracts. The number of times that organisations are involved, namely 243, 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 1992 the WRC financially supported 225 projects at a budgeted amount of R33 661 748.

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

- The South African 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 1992

WRC reconstituted

The simplicity of the PETRO process means that it can operate successfully with minimal supervision

In terms of the Water Research Act (Act No 34 of 1971), the WRC consists of 9 members. They are the Director-General of Water Affairs and Forestry *(ex officio)*, the Executive Director *(ex officio)* and 7 other members appointed by the Minister of Water Affairs and Forestry by virtue of their expertise in some aspect of the WRC activities.

The term of office of the appointed members ended on 31 July 1992. The following members were reappointed: The Honourable AJ Raubenheimer (DMS), Dr WL van Wyk, Mr DH Marx, Prof PD Tyson, Mr M Erasmus (co-opted) and Mr D Steyn. Two members retired: Dr AJ Heyns and Mr EJ Hall. New appointments are Prof T Erasmus (Vice-Principal, University of Pretoria), Mr VJ Bath (Chief Executive, Rand Water Board) and Mr AJ Clayton (City Engineer, Cape Town) (co-opted). Mr GCD Claassens (Director-General of the Department of Water Affairs and Forestry) and Mr PE Odendaal (Executive Director, WRC) are *ex officio* members. Mr Raubenheimer was reappointed as Chairman, and Mr Claassens as Vice-Chairman.

Important new waste-water treatment process

PETRO (pond-enhanced trickling filter operation) is a patented process whereby oxidation pond systems may be upgraded by the addition of trickling filters to substantially increase the capacity of the system, at a reasonable cost, in order to produce a consistently good quality effluent. The simplicity of the process means that it can operate successfully with minimal supervision. Although a few full-scale plants are already incorporating the principle, the firm Wates, Meiring and Barnard Inc. and the CSIR are now investigating the refinement of the process and the rationalisation of design criteria. The process has great potential for application in countries or areas where oxidation ponds are currently used.

Operating guide for the anaerobic digestion of waste-water sludge

This guide has been developed in collaboration with the Water Institute of Southern Africa (WISA). The anaerobic treatment of waste-water sludges is practised at virtually all municipal waste-water treatment plants in the RSA. The Sludge Management Division and the Water Care Division of WISA recognised that in many instances the operation and control of the anaerobic digestion process was far from satisfactory. They, therefore, approached the WRC to fund the production of a guide which can be used to upgrade current sludge digestion practices by providing training material for operating staff. The guide has been well received and a number of training workshops, based on the guide, have already followed.

Sanitation for developing communities

The intensification of research into the problems of developing communities continued during the year. Various aspects of alternative sanitation systems were looked at and a series of 6 workshops addressed a total audience of 400 interested persons. This work has led to the compilation of an important new guideline for the selection and provision of affordable and robust sanitation, but which will still provide the same level of health standards as the less robust full water-borne system. The main aim of this research is to improve the quality of life in developing communities and to reduce the very high pollution loads emanating from many of the urban and squatter areas. Such pollution reaches surface- and ground-water resources, constituting a serious health problem.

Forced aeration composting for developing communities and industry

In rural communities, and in over-populated outskirts of urban areas where many people are settling in search of better work opportunities, adequate disposal systems for sanitary wastes and domestic refuse are generally lacking because of demographic, sociological and economic factors. This situation has resulted in an urgent need for low-cost waste management technologies. Sanitary waste disposal is often by means of the bucket system, with the night soil disposed of in lagoons situated some distance from the communities to avoid odours and fly-breeding problems. At the same time, domestic refuse is mostly disposed of by uncontrolled landfilling, which adversely affects the environment.

To address at least some of these problems the WRC initiated research with the Grahamstown Municipality on the forced aeration composting of night soil with unpulverised and unsorted refuse as a bulking and filtering agent. The research established the chemical, physical, biological, thermo-

dynamic and kinetic criteria for controlling the process. It was also demonstrated that the process could yield safe and valuable compost and saleable glass, metal and plastic. It offers a cost-effective technology for stabilising, disinfecting and recovering usable products from 2 polluting waste streams. The process is now applied full-scale at Rini Township outside Grahamstown.

It offers a cost-effective technology for stabilising, disinfecting and recovering usable products from 2 polluting waste streams

IAWQ technical tour

During October 1992 the South African National Committee of the International Association on Water Quality (IAWQ) hosted a technical tour to the RSA. The tour focused on 2 fields in which South Africa has, from an international perspective, contributed extensively to research and development, namely the biological removal of nutrients from waste water and the anaerobic treatment of waste water and sludges. WRC-supported research played a major role in developing the South African technology and expertise in these fields.

More than 30 delegates from 12 countries participated in the tour, which was launched as an experiment on behalf of IAWQ, in order to test the viability of technical tours as a feature of future IAWQ activities. Feedback by questionnaire at the end of the tour, indicated that the venture had been outstandingly successful.

Mr RD Reardon (Vice-President of Camp, Dresser and McKee, Orlando, Florida, USA) in conversation with Mr PE Odendaal (Executive Director, WRC) during the IAWQ tour

IAWQ technical tour participants enjoying Kirstenbosch Botanical Gardens in Cape Town

Work emanating from WRC research featured prominently in the conference programme, and also in the associated pre-conference technical tour

Visit by expert on anaerobic processes

Prof Fred G Pohland from the University of Pittsburgh, USA, was a guest of the WRC during July 1992. Prof Pohland is Chairman of the Specialist Group on Anaerobic Digestion of the IAWQ and has extensive experience in the anaerobic treatment of solid and liquid wastes. During his visit he was the keynote speaker at the 3rd South African Anaerobic Digestion Symposium in Pietermaritzburg. After the symposium he visited the various research programmes on anaerobic digestion on-going in South Africa, and gave valuable advice.

International conference on membrane technology

The IAWQ held its first specialised conference on Membrane Technology in Waste-water Management in Cape Town in March 1992. Work emanating from WRC research featured prominently in the conference programme, and also in the associated pre-conference technical tour. Facilities visited during the technical tour included an anaerobic digestion ultrafiltration plant treating maize processing effluent; the treatment of cooling tower blow- down at 2 large power stations, the one using tubular reverse osmosis, and the other electrodialysis reversal; the dewatering of waterworks sludge with a tubular filter press; the treatment of abattoir effluent with ultrafiltration and reverse osmosis; and the treatment of wool scouring effluent with dynamic ultrafiltration. The plants were all based on membrane technology developed or evaluated in WRC-funded research projects.

During the conference an IAWQ Specialist Group on Membrane Technology was established. An interim management committee was formed with members from 12 countries. The standing of South African membrane technology researchers was evident from the fact that 2 South African scientists were elected chairman and secretary of the interim management committee.

Commercialisation of membrane technology

Research on the development of reverse osmosis and ultrafiltration membrane systems for the desalination and treatment of water and waste water, has now for many years been funded at the Institute for Polymer Science, University of Stellenbosch. The manufacture and commercialisation of these systems are being done by Membratek (Pty) Ltd. In a significant development, the latter and Debex (Pty) Ltd, a subsidiary of the De Beers Group, formed a joint venture company, called Debex Desalination (Pty) Ltd on 1 June 1992. The objective is to provide improved infrastrucure and service to the membrane manufacturing industry and to ensure growth and development of local desalination technology.

Debex Desalination aims to extend the current product range and to offer improved technical assistance for the desalination of brackish and sea water. Membratek will continue to operate as a separate company specialising in the production of a wider range of membrane products, process development and the application of membrane technology in all projects not directly related to desalination.

Modelling of tubular reverse osmosis systems

The Pollution Research Group at the University of Natal has developed a computer model which can simulate the operation of a tubular reverse osmosis plant. The model has been used to analyse data from a pilot plant treating cooling water blowdown at the Lethabo Power Station. The model was able to significantly enhance the quality of the information obtained from the plant data. During May 1992 the first of a series of workshops was held at Eskom where the model was demonstrated to interested parties. This was followed by further workshops and discussions and the model has already found direct application in industry.

Optimisation of dry-cooling systems

Dry cooling in power generation can save enormous quantities of water, but it is more capital intensive than wet cooling and the power generation process also becomes less efficient. The optimisation of dry-cooling technology can, therefore, effect major cost reductions. Pursuing this objec-

Programs developed for evaluating the thermal performance of dry- and wet-cooling towers have been tested and applied successfully by Eskom

tive the WRC has been funding research on dry cooling for many years. Research so far has found application in what will be, on completion, the world's largest air-cooled condensers (Matimba and Majuba) and dry-cooling towers (Kendal).

The Department of Mechanical Engineering at the University of Stellenbosch was commissioned to develop computer programs with which various cooling systems could be evaluated. The results of the previous research by the University, the CSIR and Eskom, as well as practical field measurements, are incorporated in the programs. Programs developed for evaluating the thermal performance of dry- and wet-cooling towers have been tested and applied successfully by Eskom. Programs for evaluating the performance of direct air-cooled condensers are also being used by Eskom to monitor the performance of existing systems and to devise possible modifications for improved performance. On-going refinements of the programs, to include the effects of deluge, spray and adiabatic cooling, will make them even more generally applicable.

A strategic plan for research on potable water treatment

This strategic research plan was completed towards the end of 1992. The objective is to provide guidance to the research community as to perceived priorities in this field. The basis of the plan was laid by the WRC's Co-ordinating Committee for Research on Potable Water Treatment, during a 3-day strategic planning session. Utilising expert groups, 4 subsequent workshops were held to finalise and prioritise the goals and sub-goals of the plan.

The main thrust areas (broken down further into weighted secondary and tertiary goals) are in sequence of priority:

- Cost-effective provision of water to the unserved communities in South Africa
- Addressing the deterioration in source water quality
- Cost-effective treatment of water for the currently served communities
- Development of acceptable treated water quality guidelines.

The complete plan has been released to the water research community and is available on request from the WRC.

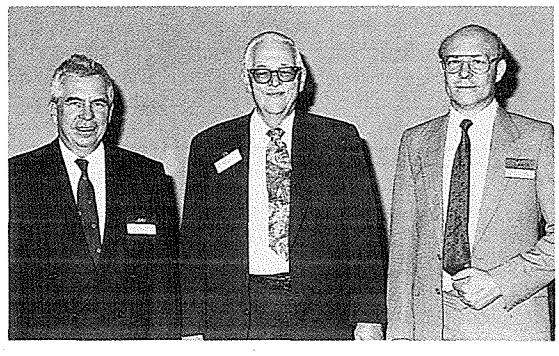
Model for the prediction of algal blooms in the lower Vaal River

The Department of Applied Mathematics and the Department of Botany and Genetics of the University of the OFS have joined forces to develop a mathematical model which can model blooms of green algae and diatoms in the lower Vaal River. Although the model is still in a development phase, good results are already being obtained, as reflected in the monitoring results of the Western Transvaal Water Supply Co. Several overseas models were tested beforehand but the desired results could not be attained. These predictions are of great value in that water treatment strategy can be adapted in good time.

In the lower Vaal River the nutrients are not limiting to algal growth, but light is. Initially therefore only light penetration, water temperature and silicon concentrations were used as parameters in the model. These 3 parameters have already succeeded very well in modelling the blooms and peak values of chlorophyll, both for green algae and diatoms. Currently the model is being refined further by also incorporating dissolved oxygen, carbon dioxide, carbonates, pH, phosphates, nitrogen compounds and dissolved salts.

Foreign consultant on oxidants in drinking-water treatment

Dr W Masschelein, a Belgian consultant and formerly technical head of the "Compagnie Intercommunale Bruxelloise des Eaux", visited South Africa from 24 October to 3 November 1992 on the invitation of the WRC. He is a world expert on the use of ozone, chlorine dioxide, ultraviolet and other oxidants in water treatment. He was a keynote speaker at the Second Southern African



Seen at the 2nd Southern African Conference of the International Ozone Association are from left: Dr W Masschelein (a Belgian consultant), Dr R Rice (USA) and Mr G Offringa of the WRC

Conference of the International Ozone Society which was held on 27 and 28 October at Warmbaths. In addition he undertook general counselling regarding oxidants in water treatment.

Dr Masschelein, together with Dr R Rice, an ozone expert from the USA, also participated in a technology transfer session at the WRC where ideas were exchanged on the role of a number of oxidants in water and effluent treatment.

There is renewed interest in the presence of parasites in water

Parasites in water

There is renewed interest in the presence of parasites in water. This follows on several outbreaks of diarrhoea which recently occurred world-wide and which were related to the presence of the parasites *Giardia* and *Cryptosporidium* in drinking-water supplies. The alarming aspect is that in a number of the outbreaks, the water quality conformed to microbiological criteria for potable water. In some cases these parasites were also found to be more resistant to certain purification processes than bacterial indicators. The CSIR's Division of Water Technology will evaluate and develop detection methods for these water-borne parasites, study the occurrence of the parasites in raw and treated water, investigate the effects of water treatment processes on the parasites, and develop suitable indicator organisms.

Problems associated with chemical equilibrium in water

The Pollution Research Group (PRG) of the University of Natal has for several years been using a program, called MINTEQA2 and developed by the US EPA, on WRC projects to analyse problems as diverse as fouling in reverse osmosis systems, ground-water pollution and heavy metal removal from effluents. MINTEQA2 is a geochemical speciation program which can be used to calculate chemical equilibrium in aquatic systems.

In carrying out this work contact was maintained with the developers in the EPA and during the year two of the PRG researchers attended an advanced course presented by the EPA in the USA. This will now enable them to present a series of workshops to promote the practical application of the program in the South African water industry.

Water quality criteria for the South African coastal zone

Water quality criteria for the South African coastal zone (WQCSA) were first formulated in 1984. They proved particularly useful for evaluating the impact of effluent discharges on the marine environment and for the design of new outfalls. Since then relevant research - locally and internationally - has made considerable progress, discharge policies have been reviewed in many countries while, generally, there has been a major upsurge in environmental awareness. It therefore became necessary to produce updated WQCSA which would be acceptable not only to the scientific community, regulating authorities and industry, but also to environmental groups and the public at large.

The CSIR's Division of Earth, Marine and Atmospheric Science and Technology was entrusted with the task. The first draft WQCSA was submitted to expert opinion at a workshop in Stellenbosch during August 1992, and the final document will be available early in 1993.

Polypropylene pipes investigated

There is a major swing away from steel and copper piping for potable water distribution towards plastics materials. This motivated a project to develop a reliable, yet quick and inexpensive test procedure, specifically for polypropylene pipes. Serious problems in the plastics pipe industry were discovered and at one point no products were able to pass the elementary test procedure developed by the Joint Acceptance Scheme for Water Installation Components (JASWIC) and undertaken by the SABS. This development placed severe pressure on the entire industry and the WRC arranged a trouble-shooting session during September 1992, involving all the polypropylene pipe manufacturers, JASWIC, the SABS and the CSIR. From this emanated a set of rules which, if adhered to, should ensure a quality product which will perform well over the design life of 30 to 50 years.

Irrigation scheduling/crop growth model

It is foreseen that this range of software, together with other relevant computer software, will greatly aid the planning and design of efficient irrigation projects

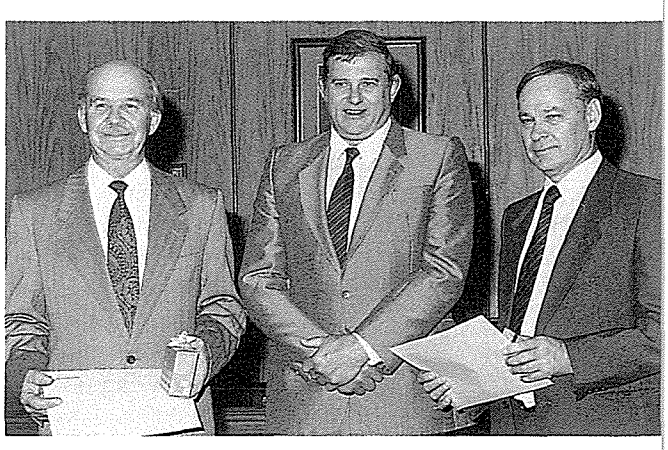
The PUTU irrigation models, conceptualised by the Department of Agricultural Meteorology, University of the OFS, have now been upgraded and made user friendly. By means of the relevant model version, irrigation scheduling, crop growth and yield potential can be effectively simulated. It is foreseen that this range of software, together with other relevant computer software, will greatly aid the planning and design of efficient irrigation projects.

Strategic plan for irrigation research

The strategic plan was finalised during the year and accepted by the interested organisations. This plan is the first in the agricultural water research field that is goal- and objective- oriented, as opposed to the subject orientation of previous plans. It is intended to guide future research in this field, and the plan will be regularly reviewed and updated in the light of progress made and of new problems that may emerge.

Irrigation return flow

For several years now the WRC has been aware of the potential contribution of irrigation return flow to water quality deterioration. Several research projects have therefore been funded to develop a better understanding of the processes involved in irrigation return flow, to predict the nature and extent of return flow, and to investigate possibilities of reducing return flow. Substantial progress has been made in reaching these objectives and several of the projects in this regard have recently been completed or will be concluded in the near future. A workshop with the researchers concerned and other interested parties is being planned for next year in order to take stock and to determine the need for and direction of further research.



Prof J de Jager of the Department of Agricultural Meteorology, UOFS, presents the PUTU computer model to Mr PE Odendaal (Executive Director, WRC) and to Dr Frans van der Merwe (Director-General of the Department of Agriculture)

Synergy in forest hydrology research

A situation has developed at the University of Natal, where water research and forestry research have found common ground, and synergy is developing to mutual benefit. The groups involved are the Department of Agricultural Engineering (which has for many years been conducting research for the WRC) and the Institute for Commercial Forestry Research (funded by the forestry industry). A joint project is being conducted at the Institute's Bloemendal experimental site, aimed at establishing tree growth, tree water usage and soil losses under different site preparations. Common interest lies in the recognition that the management and understanding of soil water budgets in plantations form the key to successful silviculture and forest hydrology. In a further area of collaboration, the ACRU hydrological model developed by the Department and containing a forest hydrology component, is used extensively by the Institute through the Computing Centre for Water Research.

The national precipitation research programme

The focus of this research has shifted from dry ice towards the development of a hygroscopic seeding technique for the enhancement of coalescence in typical summer convective storms. This led to the manufacture of pyrotechnic flares by means of which hygroscopic particles could be dispersed from an aircraft flying just below cloud base.

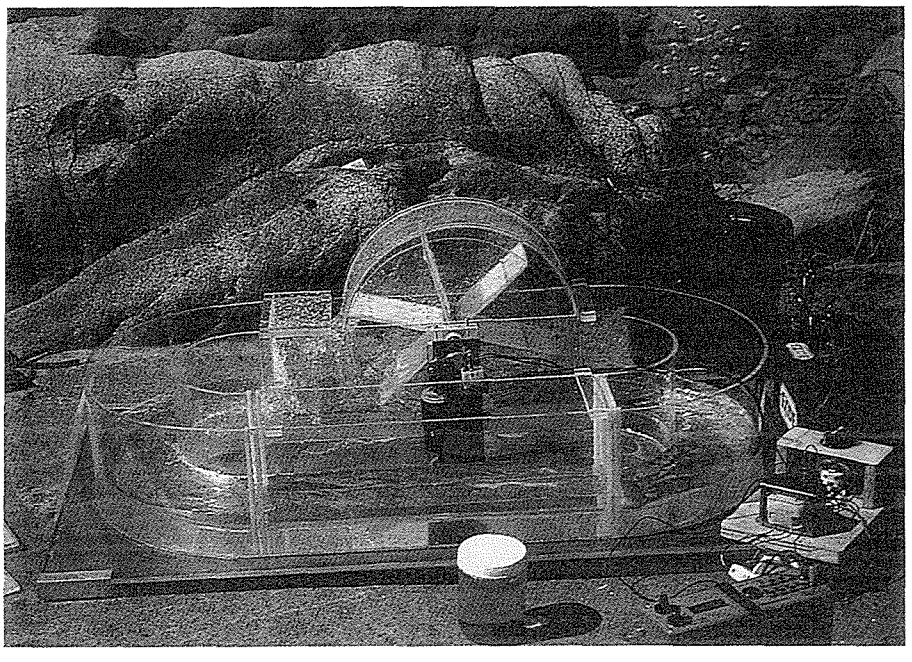
The nature and size distributions of particles produced by burning the flares in laboratory con-

Despite the small size of the data base, the average response of seeded clouds in terms of additional radar measured rain 30 min after seeding, has already proved to be substantial and statistically significant

ditions and in the atmosphere are being studied to obtain data for numerical modelling of the coalescence growth process. In addition, a randomised cloud seeding experiment using these flares, yielded data for 49 clouds, 25 of which were seeded and 24 unseeded. Despite the small size of the data base, the average response of seeded clouds in terms of additional radar measured rain 30 min after seeding, has already proved to be substantial and statistically significant. Results were also consistent between the 2 experimental areas. Further experimentation is, however, necessary to establish the repeatability of results and to confirm hypotheses concerning mechanisms whereby hygroscopic seeding leads to enhanced precipitation in summer convective clouds.

Mining pollution

Non-point sources of pollution are of major importance in certain catchments. This realisation comes to the fore particularly in the light of the new approach of the Department of Water Affairs and Forestry to integrated catchment management. Mining, in particular, has been identified as a potential important non-point source of pollution on which more information is essential. Against this background, in collaboration with the Chamber of Mines of South Africa, the establishment of guidelines and procedures to determine and counteract the impact of gold mine activities on the water environment was initiated during the year. A project to study the occurrence of bacteria causing acid mine drainage in the outer layers of coal waste-dumps has also been initiated. The WRC foresees that the significance and extent of mining-related water research both inside and outside the Commission will increase to such an extent that it has been decided in principle to establish a Co-ordinating Research Committee for Mining Research.



Small, portable artificial stream system being used at the Institute for Water Research, Rhodes University, to determine the effect of flow on riverine biota

Atmospheric pollution and salinisation

Preliminary estimates suggest that air pollution in the Eastern Transvaal Highveld and the concomitant precipitation of salts can double the saline load from the Vaal Dam catchment in the long run. This will inevitably have far-reaching effects on Vaal Dam water users.

At this stage the WRC finances 2 projects aimed at eliminating uncertainties associated with the above-mentioned estimates. Attempts are being made to quantify the extent to which soil sorption slows down the movement of salts to surface water, and to obtain a better indication of the absolute and relative quantities of wet and dry precipitation in the catchment. The results should indicate whether a hydrosalinity model should be developed to enable the prediction of salinisation of the Vaal Dam resulting from atmospheric pollution.

Consultant on the instream flow requirements of rivers

The principal author of a computer simulation model for the assessment of instream flow requirements, Dr Bob Milhous of the US Fish and Wildlife Services, visited South Africa in order to assess South African expertise in the use of his model. During his stay of one month, Dr Milhous took part in and led a number of intensive workshop sessions at which a multitude of data- and computer- oriented problems were resolved. The researchers concerned were also able to judge their level of expertise in the field. The highly successful visit will greatly assist the successful completion of 3 years of relevant research being funded by the WRC.

Planning for water ecosystems research

The fact that more than 80 packages are being utilised extensively in the RSA and a further 23 packages overseas, bears testimony to the wide interest HydroCom has attracted locally and overseas

The WRC's Co-ordinating Committee for Water Ecosystems Research agreed, during an intensive 2-day workshop, on a first draft of a strategic plan for water ecosystems research. The plan will be presented for acceptance to the relevant authorities during 1993. In the light of the growing environmental awareness generally, and the declared policy of the Department of Water Affairs and Forestry concerning the allocation of water for the maintenance of aquatic ecosystems specifically, this field of research has become of increasing importance over the last few years. It has, therefore, become essential to establish a strategic research plan focusing on needs and priorities.

Ground-water data base marketed internationally

During the development of the National Groundwater Data Base (NGDB) facility, the Institute for Ground-water Studies at the University of the OFS perceived a need to develop a ground-water data base for personal computers. From this need developed HydroCom, a comprehensive user-friendly software package incorporating both an advanced data management and powerful CAD system. Close co-operation with the user and consulting ground-water communities, resulted in many variables, over and above those found in the NGDB, being incorporated into the software. The inclusion of surface hydrology, full weather station data and water quality data provided an opportunity to evaluate ground water as a vital part of the hydrological cycle.

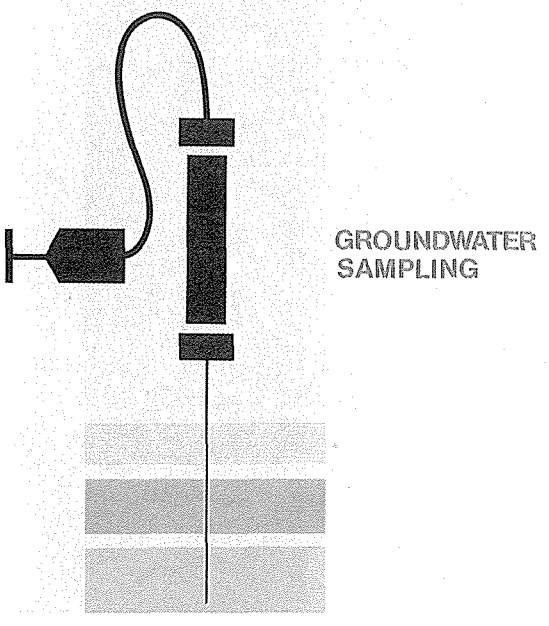
Although developed primarily as a means of up- and downloading and processing ground-water data resident in the NGDB, HydroCom can operate as a data base and data-processing facility on its own. The fact that more than 80 packages are being utilised extensively in the RSA and a further 23 packages overseas, bears testimony to the wide interest HydroCom has attracted locally and overseas.

Guide for ground-water sampling

In the past little or no standard protocol had been followed for ground-water sampling in South Africa. Each organisation depended on in-house procedures. Consequently, samples collected at various times and by different institutions cannot be compared in a meaningful way, frequently leading to doubts in terms of data reliability.

Therefore the compilation of the document *Ground-water Sampling: A Comprehensive Guide for Sampling Methods* by the CSIR's Division of Water Technology, aroused a great deal of interest in the ground-water community. The guide outlines determinand selection, quality assurance, sample containers, sample presentation, and sample collection devices, and provides information on the planning of a sample run and sampling procedures. It is envisaged that the guide will standardise ground-water sampling in the RSA, thereby ensuring that all ground-water quality data collected are representative of *in situ* ground-water conditions, and that data can confidently be used for comparative purposes.

John M.C.Weaver



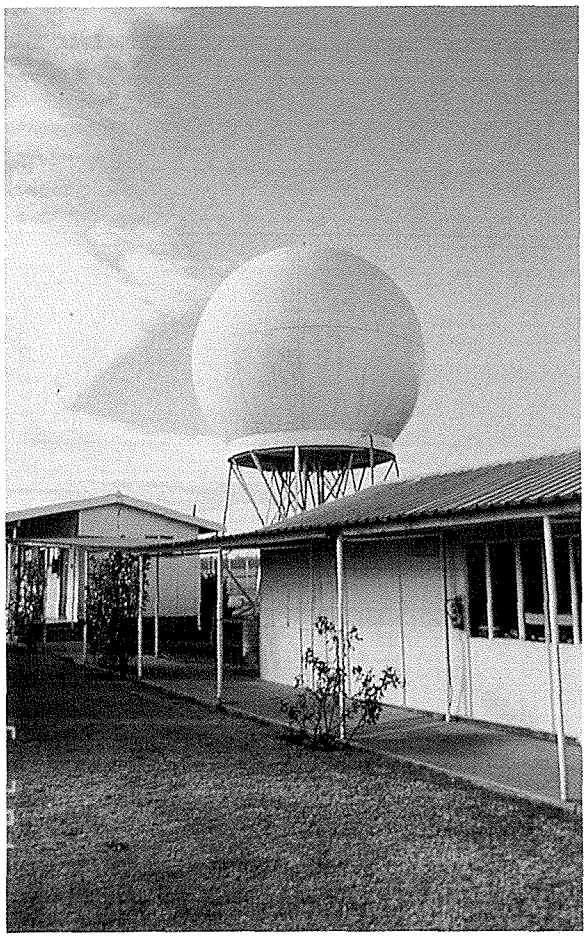
A local ground-water sampling guide was published this year

2 Hydrometeorology

Research on hydrometeorology is largely focused on understanding rainfall variability

The availability, management and use of water resources in South Africa are highly sensitive to variations in climate and particularly precipitation. The WRC, therefore, has a responsibility to support research into matters such as more adequate rainfall measurement, the spatial and temporal variability of South Africa's rainfall and medium- and long-range forecasting of precipitation conditions.

Although approximately 3 000 rain gauges are deployed throughout South Africa, inadequate spatial distribution and reporting frequency limit the usefulness of the rain-gauge data for many water resources applications. For instance, rain gauges are extremely sparsely distributed in the rugged mountainous terrain where most of the rain falls. A potential remedy lies in the complementary use of remote sensors such as satellite sensors and ground-based radar. Preliminary research now under way will throw more light on this potential and indicate what remaining issues will have to be addressed to successfully institute an integrated rain-gauge-radar-satellite system for rainfall measurement in South Africa.



Radar installation at Bethlehem used to study spatial distribution of rainfall (Photo - Weather Bureau)

In recent years research has provided much insight into the stochastic nature of the variability of South African rainfall. This research, now in its final stages, has given rise to versatile models which provide useful insight into rainfall probabilities, and especially probabilities of extreme events such as droughts and floods. Valuable as they are, these models have two major limitations which are commanding increasing attention. Firstly, they convey no information about the spatial distribution of rainfall in the area around each location for which rainfall is modelled. Secondly, because models make the assumption that rainfall variability as observed over the period of meteorological records (typically about 60 years) will essentially remain stable, model validity would be adversely affected by any occurrence of a longer term climatic trend or global climate change. For this reason, it is important to know the extent and rate of climatic change over, say, the past 2 000 years. Wood charcoal in archaeological deposits which span this period of time contains hidden information about precipitation regimes under which the wood was formed. Research supported by the WRC is becoming increasingly successful in revealing some of this information.

Another compelling reason for researching present-day rainfall variability and, in addition, ocean-atmosphere mechanisms responsible for such variability, is the contribution which will be made to the development of methods for medium- and long-range precipitation forecasting. Research efforts in this regard by meteorologists and oceanographers are in large measure being co-ordinated and supported by the WRC. Obviously, the greater the degree of foreknowledge of seasonal precipitation conditions, the greater the confidence with which water resources management decisions can be made.

During 1992 the WRC financially supported 10 hydrometeorological projects. Of these, 3 were new research agreements.

New projects

Mechanisms of short-term rainfall variability *(No 436) Department of Oceanography, University of Cape Town*

With techniques for short-term precipitation forecasting already well established, and with the intensification of efforts to understand year-to-year variations in summer rainfall over Southern

Africa, the need remains to develop a better understanding of mechanisms which cause intraseasonal fluctuations of the water balance over Southern Africa and the surrounding oceans. The fluctuations of interest typically occur over periods of 10 to 20 and 30 to 50 days and have relevance for the development of flood and drought conditions. Better understanding of mechanisms would contribute to refinement of forecasting techniques and better management of water and agricultural resources. In this 3-year project, the University of Cape Town will follow up findings of a previous WRC-supported project on relationships between sea surface temperatures and summer rainfall variability. The development, duration, evolution and termination of wet and dry spells will be analysed and linked to heating patterns and fluctuations in circulation patterns over a wide latitudinal range south of the equator.

Assessment of the potential for using stable carbon isotope ratios of wood charcoal as a climate indicator *(No 437)*

South African Museum, Cape Town

Since much of our present understanding of climatic variability is based on relatively short meteorological records, every opportunity needs to be exploited to obtain a broader perspective of longer term variability through the reconstruction of past climatic and particularly rainfall conditions. Over the past 4 years the SA Museum has successfully developed a methodology whereby changes in climatic conditions of the past 2 000 years may be inferred from measurements of certain wood xylem anatomical variables made on charcoal samples of specific tree species from dated archaeological deposits. During the course of the research it became apparent that the ratio of the stable carbon isotopes ^{12}C and ^{13}C in charcoal also showed promise as a climate indicator. The SA Museum has consequently launched a 3-year project with the aim of developing the carbon isotope technique and investigating its potential for extending and verifying climatic reconstructions previously done with the xylem anatomical technique.

Development of a real-time, non-conventional rainfall mapping system

(No 438) Department of Civil Engineering, University of Pretoria

Many potentially important applications of rainfall data in water resources management require the data to be available in near-real time and also to reflect the spatial distribution of the rainfall. Examples are:

- Distributed hydrological modelling for predicting runoff and sediment transport
- Monitoring the potential for floods
- Delineating drought-stricken areas
- Assessing drought intensity.

Since sparsely spaced rain gauges alone cannot provide this information, the University of Pretoria, in collaboration with the Weather Bureau and the Department of Water Affairs and Forestry, has initiated a 2-year pilot project to assess the feasibility of producing daily maps of spatially distributed rainfall. The project is being undertaken in the Wilge and Upper Vaal catchment areas and will attempt to integrate available data from 3 sources, viz. rain gauges, weather radar and satellite.

Research projects

Current

- **222** Reconstruction of the climatic history of the last 2 000 years in the summer rainfall regions of Southern Africa (South African Museum, Cape Town)
- **278** Prediction of South African summer rainfall variability from ocean surface temperatures (University of Cape Town - Department of Oceanography)
- **279** Relationships between lightning and precipitation (CSIR - Division of Earth, Marine and Atmospheric Science and Technology)
- **305** Interpolation and mapping of daily rainfall model parameters for South Africa (University of Cape Town - Department of Mathematical Statistics)
- **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)

New

- **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))

3 Rainfall stimulation

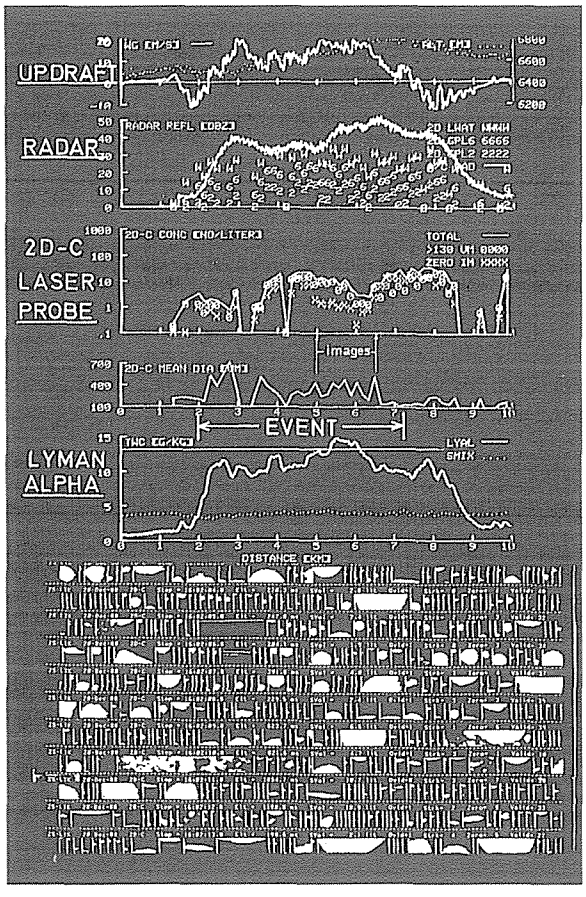
A randomised cloud seeding experiment using hygroscopic flares was initiated

Enhancing the supply of good quality water from the atmosphere is a potential economical option for augmenting South Africa's scarce water resources. For this reason, research on the feasibility of stimulating more rain in summer convective clouds has been strongly supported by the WRC for the past decade. Over the last 3 years, research has been undertaken in partnership with the Weather Bureau (Department of Environment Affairs) under the banner of the National Precipitation Research Programme (NPRP). During the second half of November 1992, Dr WA Cooper and Dr RT Bruintjes, cloud physicists attached to the National Center for Atmospheric Research in Boulder, Colorado, visited the NPRP to briefly participate in the research, to evaluate it and to make recommendations for its continuation.

Based on observations made over several seasons, there is strong evidence to suggest that the most effective means of increasing precipitation in cumulus clouds over the eastern highveld and escarpment regions of South Africa will be either to initiate or enhance early coalescence growth of cloud droplets near the base of the clouds. To promote coalescence growth of drops, hygroscopic seeding flares for mounting on aircraft have been developed. When fired, these flares produce hygroscopic particles consisting mainly of KCl, NaCl and MgO. Deliquescence of these particles results in the formation of droplets, some of which are sufficiently large to broaden the natural size distribution of droplets in the updraft regions of the cloud, thereby promoting coalescence growth.

During the 1991/92 summer season, a randomised cloud seeding experiment using the hygroscopic flares was initiated in the vicinity of Carolina (Eastern Transvaal) and Bethlehem (North-Eastern Orange Free State). Even though the number of cases which could be studied during this initial season was relatively small, a strong tendency emerged for seeded clouds in both areas to produce more precipitation than unseeded clouds in the period from approximately 25 min after seeding until the clouds finally dissipated. Despite an encouraging degree of statistical significance, further experimentation is needed to confirm and better quantify this result. Furthermore, to clarify the limits of applicability of the hygroscopic seeding technique and to ensure its ultimate universal acceptance, it will also be necessary to concentrate efforts on gaining a more adequate understanding of the physical mechanisms which link hygroscopic seeding to enhanced precipitation.

The good progress made has nevertheless provided grounds for optimism that an area-wide experiment to evaluate the success of a potential rainfall enhancement technology over a predetermined specific area may be feasible in the foreseeable future. Planning of such an experiment should commence soon. Desk-top studies are already under way to estimate the potential impacts of an operational cloud seeding programme on water resources and forestry as part of a broader economic and environmental impact assessment.



Display of cloud conditions and particle images on board the aircraft

Completed project

Generation of a spatially distributed daily rainfall data base for various weather modification scenarios (No 373)

Hydrological Research Institute, Department of Water Affairs and Forestry

As the foundation for rainfall modification impact studies we need a realistic, state of the art set of natural and modified areal rainfall series applicable in the Bethlehem-Nelspruit region. This project developed the necessary models and data sets to generate such series using available records of daily rainfall and data on the mean radar-estimated effects of seeding on individual convective cloud complexes.

When applying the models to cloud-seeding effects observed during the PAWS experiment (1984/85 to 1986/87), the increase in mean annual rainfall was estimated at 7,3% for daylight hours seeding only. The effect of weather modification on a particular day showed great variability, with a number of days where the seeding effect was in excess of 20%.

A major product of this research which has wider applicability is the development of a fast rainfall interpolation algorithm together with a data-base management system capable of managing 6 000 rain maps within a single base.

Cost: R92 998
Term: 1991

New project

Potential impacts of rainfall stimulation on water resources and forestry in the Nelspruit-Bethlehem target zone (No 439)

Ninham Shand (Cape) Inc.

After approximately a decade of WRC and Weather Bureau sponsored research into the feasibility of rainfall stimulation through cloud seeding, there is now strong evidence that clouds can be modified in a manner which is consistent with an increase in rainfall. However, the next major step will undoubtedly be a programme to demonstrate an ability to increase rainfall significantly over a large area during a specified period. Such a programme will, however, have to be preceded by a thorough assessment of the potential impacts and net benefits of rainfall stimulation for activities in the target area as a whole. Three studies are contemplated, one of which is the impact of rainfall stimulation on water resources and forestry, the subject of this project proposal. It is further envisaged that the results of these component studies will be drawn together in a final socio-economic cost-benefit study. This research proposal therefore represents a major and essential component of a larger programme to assess the potential benefits of rainfall stimulation for South Africa.

The project will be executed over a period of 18 months.

Research projects

Completed

- **373** Generation of a spatially distributed daily rainfall data base for various weather modification scenarios (Department of Water Affairs and Forestry - Hydrological Research Institute)

Current

- **H1/133** National precipitation research programme (NPRP) with a view to rainfall enhancement (Company for Research on Atmospheric Water Supply and Department of Environment Affairs -Weather Bureau, subcontracting CloudQuest (Pty) Ltd, UNISA and others)

New

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

4 Surface hydrology

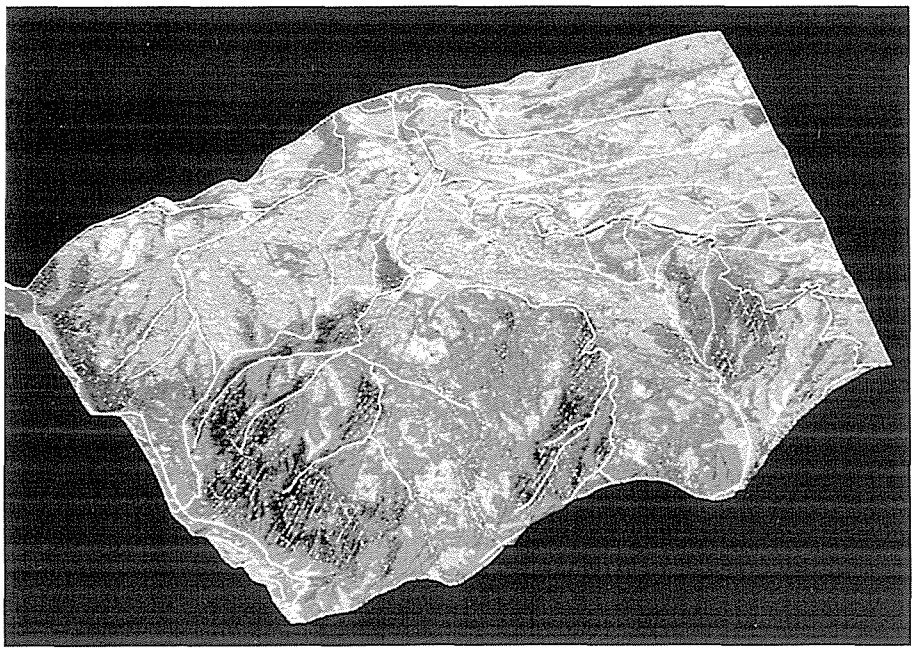
Integrated catchment management is a prerequisite for an equitable allocation of limited water resources

Research in the field of surface hydrology aims at supporting the optimum development and management of our scarce surface water resources. Research on several water management orientated projects this year has shown that some fundamental economic principles could possibly be applied on a wider basis in water management. The true value of water is determined by its alternative uses. Integrated catchment management (ICM) is, therefore, a prerequisite for an equitable allocation of South Africa's limited water resources. It is also a fundamental economic law that the scarcity of water relates to its price. As the price of water increases, augmentation of existing resources by means of technologies of which the costs are currently prohibitive may become real alternatives.

The complexity in water management is deepening. Complications so far have been identified on a relatively small scale at secondary catchment level. However, repercussions of errors in decision-making now stretch from the local scale to the global scale (effects of possible climate change). At national level a few examples illustrate this point. The Lesotho Highlands Project provides water to the PWV area, but the economic implications to the lower Orange River are still largely undetermined. Providing clean water and proper sanitation to developing communities is very costly, but the costs of not providing these services have not been comprehensively evaluated yet. A concerted effort is needed to internalise environmental costs to all forms of development.

Research now clearly indicates that ICM must become the pinnacle of the thinking about water. ICM means that all interests are considered as a whole and that *ad hoc* decision-making under conditions of rapid change is no longer acceptable. Modern technology such as geographic information systems (GIS) makes better decisions possible. However, it must also be realised that a holistic approach requires better integration of technical and non-technical(socio-economic) issues. In the Sabie catchment, for example, afforestation in the upper catchments is limited through the application of the afforestation permit system, but irrigation development in the lower catchment continues uncontrolled. At the same time river water supply to the Kruger National Park is under stress. Furthermore, population growth and settlement patterns of the developing communities in the bordering areas emphasise the point that the solution to these problems can only be found if they are treated as an integrated whole. It is in these kinds of situations that ICM requires a far more formal and institutionalised approach. Only then will sound scientific understanding of the hydrology achieve its full potential application.

Modern technology can assist integrated catchment management (Upper Umgeni catchment)



Development of a flood advisory service

The Department of Water Affairs and Forestry, supported by a consortium of senior advisers, is reconsidering key aspects around flood management at the moment. This investigation has identified the need for a feasibility study into the possibility of a flood advisory service as one of the facets of flood management deserving attention.

The main aim of a flood advisory service is to allow institutions responsible for flood management at local or regional level, timely and prompt access to that information which is of vital importance from a flood management viewpoint. To formulate a potential flood advisory service with regard to contents and extent, the WRC, in collaboration with the Department of Water Affairs and Forestry, signed a consultation agreement with the consortium in terms of which the Department of Civil Engineering of the University of Pretoria would undertake the development of the flood advisory service.

The latter organisation has succeeded in establishing the basis of an advisory service to collect, process and transfer weather forecasts, as well as warnings on the possibility of heavy rains, details on rainfall during the previous 24 h and other flood-related warnings and information. Further-

more, the feasibility of a near-real time flood advisory service has been demonstrated.

Facets that need further attention and are being investigated at the moment, are the implementation of the service (initially on a relatively limited scale) and additional research into the underlying principles.

Completed projects

Development of methods to assess the impact of agricultural practices on water resources in Southern Africa (No 198)

Department of Agricultural Engineering, University of Natal

This project has developed the agrohydrological component of the ACRU modelling system. The impact on water resources of alternative land management options can now realistically be simulated. Crops include maize, wheat, sugar cane and timber. The results are given in a comprehensive report with a complete review of the theory behind the ACRU modelling system and many examples of model verification and scenario testing.

The modelling system provides comprehensive default values for most of the important input variables and it is based on the South African 1:250 000 land type maps and the associated binomial soil classification.

Cost: R1 206 986
Term: 1987-1992

Development of a model to simulate flow in alluvial rivers (No 236) BKS Inc.

Although a generic computer model was originally aimed at, the research objectives had to be modified for practical reasons to a more realistic but theoretically sound aim in order to answer the following question: Given the design discharge and an accompanying known sediment size, what will nature choose for the width, depth and bed slope of the channel to convey both the water and sediment from one point to another if the channel is to flow between banks and on a bed, all made of its own sediment?

The developed empirical relationships based on Parker's theory proved to be a simple but reliable method in determining width and depth of a river for a given discharge and sediment size.

However, the main success of the research is the development and testing of a new theory based on basic hydraulic principles, applied stream power theory and critical flow conditions. It is recommended for future use in river behaviour forecasting.

Cost: R350 236
Term: 1988-1992

Preparation of a summary document on sediment transport in Southern Africa, including a revision of the sediment production map of Southern Africa

(No 297) Sigma Beta Consulting Civil Engineers

Information on sediment delivery in our rivers is required for dam design, ecological management, land-use planning etc.

The main results of the project are given in 2 reports and can be summarised as follows:

- A fundamental treatise on open channel flow and associated hydraulic sediment transport processes, based on the principle of conservation of stream power, is given.
- Observed sediment yield patterns in Southern African rivers are described, as well as methods to make meaningful estimates of average annual sediment loads, including an attempt to quantify the variability which is encountered.
- Maps of various physical and geographical features of Southern Africa which influence sediment yield were prepared and placed on GIS.

Cost: R414 733
Term: 1990-1992

New projects

Development of an urban component for the ACRU model (No 424) Department of Geography, University of Durban-Westville

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

Development of an integrated catchment management system for the Crocodile River catchment *(No 425) Division of Forest Science and Technology, CSIR*

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

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

Development of improved flow gauging structures for South African rivers

(No 442) Sigma Beta Consulting Civil Engineers

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

Against this background the 30-month project aims at:

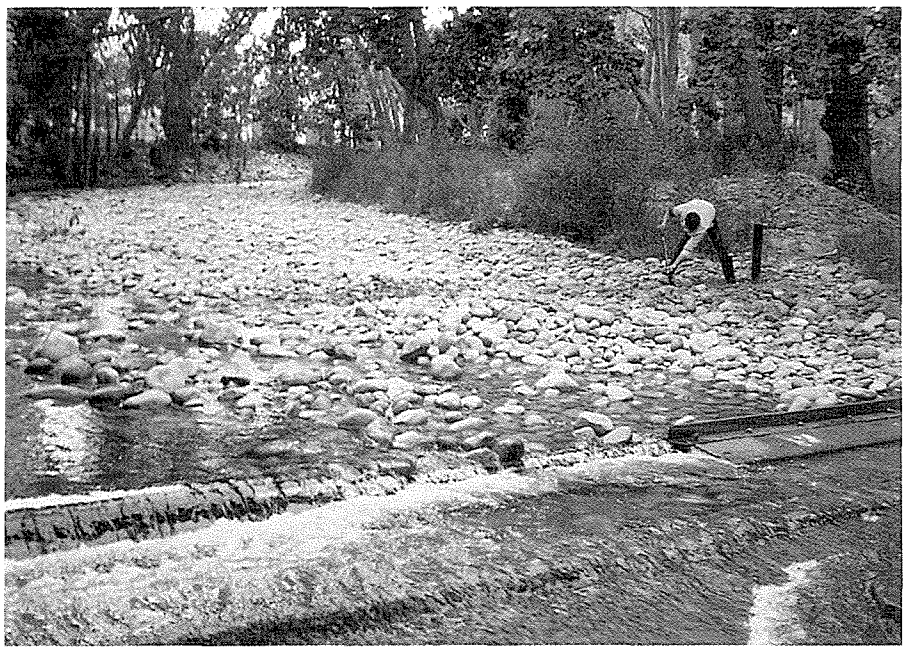
- Upgrading existing gauging stations and the standardisation thereof, as far as possible, to ensure more reliable flow gauging results
- Developing a gauging structure which requires minimum maintenance but ensures flow gauging of adequate accuracy.

Development of rigorous engineering methodology for designing vegetative erosion protection systems *(No 444) SRK Inc.*

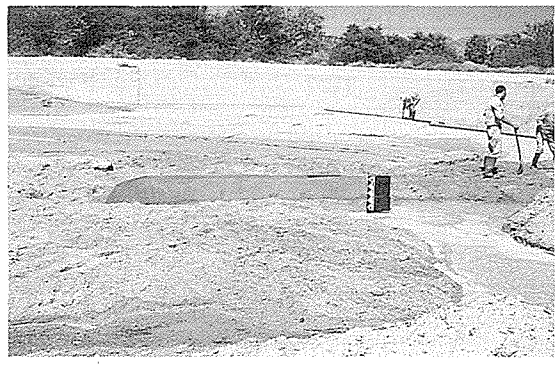
Well-established suitable plant growth remains the most cost-effective, pro-active, erosion control measure. Some instances where these measures can be applied could however, benefit from a design approach where for example, the selection of a suitable plant type could be made on sound scientific principles.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

- Mathematical formulation of the reinforcement of soils by means of root systems
- Laboratory determination of the strength properties of root-reinforced soils

Lourens River at Somerset West: Flow observations were ceased in the beginning of 1991 as a result of problems experienced with pebble stones



Olifants River at Barandas: These photos show the problems experienced at the gauging weir as a result of high sediment levels in the pool. The pool must be cleaned regularly to enable meaningful measurements to be made at the gauging weir



- Determination of the erodibility of root-reinforced soils
- Investigation of existing root morphologies suitable for specific areas
- Developing a design guideline for erosion control by means of root-reinforced soils.

Development of flood damage functions and a computer program to determine the advantages of flood and flood damage control measures (No 490)

Department of Agricultural Economics, University of the Orange Free State

Against the background of the regularity of floods causing major damage, the Department of Water Affairs and Forestry is revising the current flood management policy. It is expected that the new policy will include guidelines and regulations whereby the different flood-sensitive areas will have to formulate and apply their own flood management plans.

Optimal flood control and flood damage control measures need information on losses/damage which can be prevented if the measures are applied. Flood damage functions for different land uses are therefore needed. Against this background the 3-year project aims at the following:

- Development of flood damage functions for the different land uses in the flood plains of the test area
- Development of a computerised data base for the application of flood damage functions in the test area
- Establishment of a computer program to determine the advantages of different combinations of flood control and flood damage control measures by means of the flood damage functions in the data base.

Modelling the effect of the agricultural environment on water resources (No 492)

Department of Agricultural Engineering, University of Natal

As we approach the turn of the century the impacts of human modification of the natural environment are becoming a cause for increasing concern. Successful research funded during the past 5 years has provided certain useful modelling tools and information bases but has simultaneously left some existing and newly emerging questions unanswered.

This 4-year project through fieldwork, collaborative research, synthesis and model development aims at enhancing the ACRU agrohydrological modelling system, to help make it an objective planning tool to those questions and challenges of the water-related agricultural environment for which decision-makers currently, or in the near future, seek answers. These include questions on impacts related to afforestation practices, irrigation, agricultural management systems and global climate change on water resources as well as on agricultural water utilisation and production.

Development and testing of a water balance model for a grassland catchment in the summer rainfall area of South Africa (No 493) Division of Forest Science and Technology, CSIR

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

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

Research projects

Completed

- **198** Development of methods to assess the impact of agricultural practices on water resources in Southern Africa (University of Natal - Department of Agricultural Engineering)
- **236** Development of a model to simulate flow in alluvial rivers (BKS Inc.)
- **297** Preparation of a review document on sediment transport in Southern Africa, including revision of the sediment production map of Southern Africa (Sigma Beta Consulting Civil Engineers)

Current

- **183** Effects of urbanisation on catchment water balance (University of the Witwatersrand - Department of Civil Engineering, Water Systems Research Group)
- **235** Hydrological modelling studies in the Eastern Cape (Rhodes University - Department of Geography)
- **270** Hydrological systems model development (University of Natal - Department of Agricultural Engineering)
- **296** Quantitative structuring of national water planning objectives for use in decision support systems in South Africa (University of Cape Town - Department of Mathematical Statistics)
- **298** Surface water resources of South Africa 1990 (Consortium of consulting engineers)
- **299** Adaption and calibration of an urban runoff quality model (CSIR - Division of Water Technology)
- **300** Utilisation of geographic 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)
- **317** Urban catchment monitoring (Welkom City Council and SRK 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)
- **415** Application of resource economics to water management decision-making in South Africa (University of Natal - Institute of Natural Resources)

New

- **424** Development of an urban component for the ACRU model (University of Durban-Westville - Department of Geography)
- **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 Consulting Civil Engineers)
- **444** Development of rigorous engineering methodology for designing vegetative erosion protection systems (SRK Inc.)
- **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** Modelling the 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)

5 Ground water

Fractured rock environments are particularly vulnerable to contamination

It is estimated that more than 90% of South Africa's ground water is contained within secondary aquifers, comprising fractures, faults, dyke contacts and solution cavities. An understanding of the physical nature and behaviour of such aquifers is essential, not only in the correct siting of boreholes and judicious abstraction of ground water, but also in the protection of such aquifers from the ingress of pollutants. Fractured rock environments are particularly vulnerable to contamination due to their inherent lower attenuation capacity and higher ground-water flow rates compared to primary or porous-flow aquifers.

In order to review past research in the field of fractured rock aquifers, identify high priority research needs and develop a strategy to address these needs, a workshop was held on 10 April this year. Attended by 25 participants from the ground-water research and consulting community, the general consensus was that a fractured rock aquifer research programme should be initiated to guide research, ensure technology transfer and promote education in this field.

Considerable progress in terms of the hydrogeological mapping programme has been made during the past year. Preparation of a national-scale map legend, based on the international UNESCO legend and adapted for local conditions, has been completed. A project to compile a hydrogeological map of South Africa commenced in January 1992 and it is anticipated that the first national-scale map will be produced towards the end of 1993. This progress has provided momentum for the regional hydrogeological map series, which is being co-ordinated as part of the Department of Water Affairs and Forestry's regional ground-water characterisation programme.

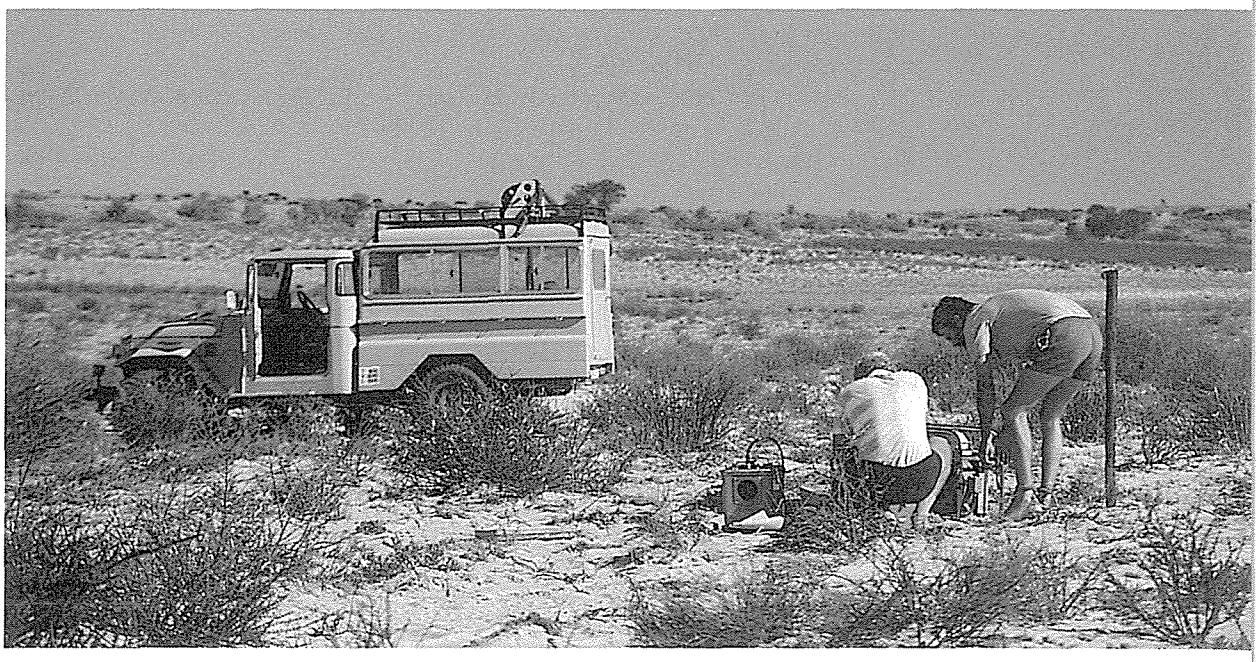
During 1992 the WRC supported 29 projects related to ground water of which 8 commenced during the year and 9 were completed.

Completed projects

Use of electromagnetic exploration techniques for the development of ground-water resources *(No 212) Department of Geology, University of Pretoria*

The use of geophysical techniques plays an important role in the development of ground-water resources. Geophysical techniques that are traditionally applied include magnetics, gravity and/or DC resistivity. There are, however, many areas in the country where geological conditions exclude the use of gravity and magnetics, or where DC resistivity techniques are either too cumbersome or unreliable to be of practical use. This project set out to evaluate the time-domain electromagnetic (TDEM) method and various frequency-domain electromagnetic (FDEM) techniques in such areas.

Employing TDEM, the applicability of both the sounding and profiling techniques was investigated at 3 localities in the Kalahari. It was found



Time domain electromagnetic soundings for ground-water resources development in the Kalahari

that the TDEM sounding technique can be used to map the thickness of the Kalahari sediments, but it was unable to resolve individual layers within this sequence.

To test the usefulness of FDEM, the MaxMin III, GENIE SE-88, Geonics EM34-3, Crone CEM and OMNI-PLUS VLF systems were evaluated in areas where steeply dipping fracture zones occurred beneath conductive and non-conductive overburdens of various thicknesses.

A physical modelling facility was developed at the University of Pretoria to facilitate the interpretation and understanding of the various TDEM and FDEM techniques, as well as shallow seismic techniques. The facility is versatile enough to address a wide variety of geophysical problems.

Cost: R216 000
Term: 1987-1991

Evaluation and development of techniques for the determination of geohydrological parameters by using geoelectrical methods *(No 216) Division of Earth, Marine and Atmospheric Science and Technology, CSIR*

The main aim of this research project was to study the relationship between the geo-electrical and geohydrological properties of selected primary and secondary aquifers in South Africa and to evaluate the applicability of the relationships. It was not expected that the development of suitable relationships for the various types of aquifer in South Africa would eliminate pump tests, but certainly that it would be possible to decrease the number of boreholes (and therefore the cost attached to them).

The results have indicated that primary unconsolidated aquifers are eminently suited to the drawing up of relationships between geoelectrical and geohydrological properties.

Correlation between electrical cross-resistance and transmissivity of hydraulic conductivity yields good results which can be usefully applied in practice for the siting of production boreholes. Alternatively electrical longitudinal conductance can also be used, although this is a less sensitive parameter.

In the case of multiple-layer aquifers, i.e. weathered and seamed granite, the different aquifers need to be investigated geoelectrically as well as according to their hydraulic properties. In practice this is often difficult and the drawing up of correlations has to be done with circumspection by taking into account the effect of every layer/aquifer separately and to correct for it.

Cost: R68 000
Term: 1987-1989

Development of techniques for the evaluation and effective management of surface and ground-water contamination in the Orange Free State goldfields
(No 224) Institute for Ground-water Studies, University of the Orange Free State

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

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

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

Cost: R917 234
Term: 1988-1990

Enhancement of the National Ground-water Data Base facilities *(No 225) Institute for Ground-water Studies, University of the Orange Free State*

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

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

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

Apart from the obvious benefits of providing the geohydrologist with a powerful tool to store, process and display ground-water data, HydroCom has become an important data capturing facility. Valuable sources of data outside of the Department of Water Affairs and Forestry can be stored on Hy-

droCom and at a convenient opportunity loaded onto the NGDB in Pretoria. This capability has provided, and will in the future provide the foundation for hydrogeological mapping efforts in South Africa.

Cost: R431 948
Term: 1988-1990

Preliminary survey of pesticide levels in ground water from a selected area of intensive agriculture in the Western Cape *(No 268) Division of Water Technology, CSIR*

World-wide, and especially in the USA, concern has been expressed and investigations have been undertaken to investigate the levels of contamination of pesticides in ground water.

In order to ascertain whether similar problems exist in South Africa, an area of intensive agriculture in the Hex River Valley of the Western Cape was selected as a case study for the detection of pesticides applied in the area.

Selected boreholes and drains intercepting irrigation drainage were sampled on three occasions to take into account seasonal variations in rainfall and irrigation application. As no pesticides were detected in the drainage water, attention was focused on the possible accumulation of pesticides in the soil profile. Further tests were carried out on soils, drainage water and deeper ground water in the Vaalharts area. Again the results revealed no accumulation of pesticides.

Although further studies in areas having different hydrogeologic and climatic conditions would be required before making general statements on the situation in South Africa, this study showed that the newer generation organophosphate pesticides tend to break down fairly rapidly in the soil horizon and that, in the areas investigated, pesticide application is in accordance with the manufacturer's specifications.

Cost: R140 913
Term: 1989-1991

Comparative study of two- and three-dimensional ground-water models *(No 271) Institute for Ground-water Studies, University of the Orange Free State*

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

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

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

Cost: R540 500
Term: 1989-1991

Investigation into the oscillation method for the determination of aquifer transmissivity *(No 272) Institute for Ground-water Studies, University of the Orange Free State*

During the early stages of the research project it became evident that the oscillation method would be of limited value under South African hydrogeological conditions. Consequently the research team directed their attention towards other variable head test methods, such as slug and bail tests.

The findings revealed that, for the areas tested, the results from different variable head tests compare favourably with one another and with those obtained from pumping tests. In general, the repeatability of the tests was high with deviations being less than 10%. It was also found that the results that emerged from the analysis of variable head tests can be used to differentiate between different types of aquifer. Since such tests are comparatively cheap and faster to conduct than pumping tests, more tests can be performed to obtain a better representation of areal distribution of aquifer permeabilities. Pumping tests cannot, however, be completely replaced by slug tests, since they are still needed for the determination of storativity. Variable head tests can therefore be efficiently used in identifying the nature of aquifers and their transmissivity or permeability under conditions prevailing in South Africa.

Cost: R84 948
Term: 1989-1990

Compilation of a comprehensive guide for ground-water sampling in South Africa *(No 339) Division of Water Technology, CSIR*

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

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

Cost: R76 400
Term: 1990-1991

Compilation of information on the magnitude, nature and importance of coastal aquifers in Southern Africa

(No 370) Institute for Coastal Research, University of Port Elizabeth

Coastal aquifers contain significant ground-water resources which can, and in many instances do yield relatively large volumes of water to coastal towns and holiday resorts.

The deleterious impacts of over-abstraction, often resulting in saline intrusion, are well understood in terms of the aquifer itself. However, the effect of over-abstraction on coastal ecosystems, such as surf zones, estuaries and dune vegetation, is poorly understood.

Prior to initiating a large-scale investigation into the relationship between ground water and coastal ecosystems, a decision was taken to compile a document on the magnitude, nature and importance of coastal aquifers in Southern Africa, based on available information.

The study found that from an ecological point of view, the most important water quality variables are nitrate and silicon. Nitrate in borehole water ranged from 0,1 to 1 000 mg/*l*; the west coast having high values. Silicon concentrations ranged from 0,1 to 33 mg/*l* with particularly high values in the aquifers along the west coast, south of the Olifants River. TDS ranged from 6 to 21 000 mg/*l*.

For dune and marsh vegetation as well as surf zone ecosystems, both the water quality and the water table depth appear to be important controls. However, in estuaries freshwater input appears to be the key factor. Whereas marsh vegetation has been studied extensively, the dependence of dune vegetation, estuarine vegetation and surf micro-algal communities on ground water has not.

The collection and collation of data, and preparation of data bases from which the data and information can be extracted in the form of maps, tables and reports, are of considerable significance for future research.

Cost: R60 000
Term: 1991-1992

New projects

Geochemistry and isotopes for resource evaluation in the fractured rock aquifers of the Table Mountain Group *(No 481)*

Division of Water Technology, CSIR

Reliable resource evaluation in fractured rock aquifers is a developing science not only in South Africa but world-wide. Useful and practical working tools to evaluate ground-water recharge and residence time in these aquifers are required.

This 3-year project aims to use the aquifers of the Table Mountain Group to assess the applicability and usefulness of hydrochemical and isotope time-series monitoring as a tool in fractured rock aquifer resource evaluation.

The research is expected to complement the work on the characterisation of the ground-water resources of the Table Mountain Group currently being undertaken by the Department of Water Affairs and Forestry.

Geochemistry and isotope time-series used to evaluate ground-water recharge in the fractured rock aquifers near Struisbaai on the Southern Cape coastline

Development of a strategy to monitor ground-water quality on a national scale

(No 482) Division of Water Technology, CSIR

The evaluation of ground-water quality in terms of spatial differences and quality associated with the various geological units published in the mid-1940s is still used today as a major reference by those requiring ground-water quality information on a national scale. The advent of the National Ground-water Data Base and associated water quality data base has, however, made it possible to update and refine this work to facilitate the preparation of a strategy to monitor ground-water quality on a national scale.

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

Compilation of a hydrogeological map of South Africa *(No 483) JR Vegter Esq. and the Department of Water Affairs and Forestry*

The compilation of a hydrogeological map of South Africa has been prompted not only by the requirements of planning and development, but also because of a need to create public awareness of ground water as an ubiquitous but limited resource that needs to be protected and used judiciously. The objective of this 2-year project is to depict the occurrence of ground water on a regional basis; the relative magnitude of the resource taking into account storage and recharge; the contribution of ground water to perennial river flow; and ground-water potability.

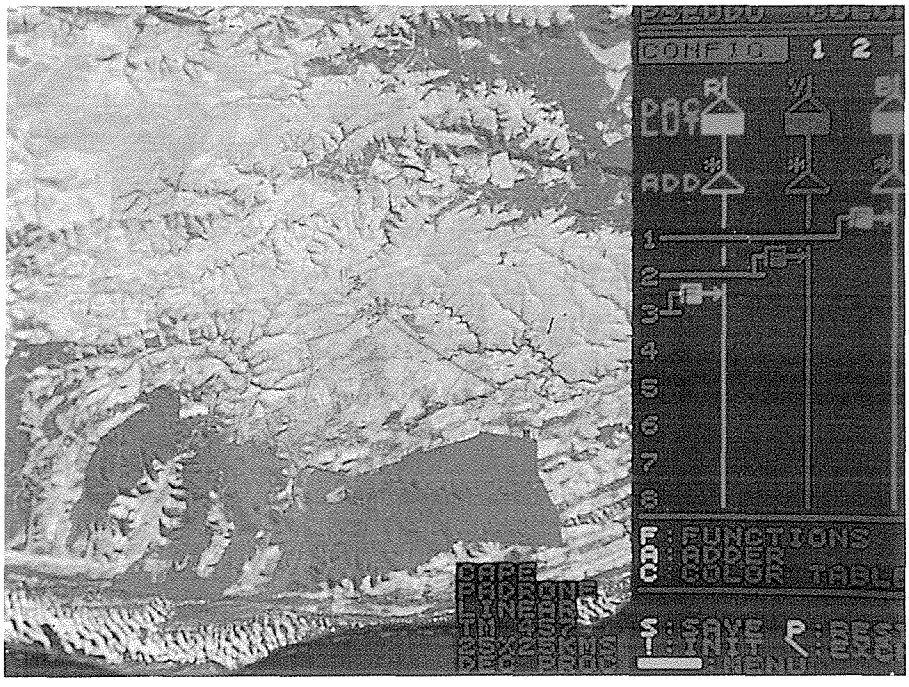
The map will be compiled mainly from data held by the Department of Water Affairs and Forestry in the form of reports on ground-water investigations amassed over the past 50 years and some 200 000 logs of state-drilled boreholes.

An integrated multidisciplinary geodynamic/geophysical approach to groundwater exploration around the South African coastline *(No 484) Atomic Energy Corporation of SA Ltd (AEC)*

Over the past 10 years the Department of Earth and Environmental Technology of the AEC has been involved in nuclear siting studies around the South African coastline. The most important aspect of these studies was the structural analysis of the region in order to date the last movement on the faults, as well as fault classification. In order to do this, a technology was developed which has the potential for application in ground-water exploration.

In this 3-year project the proposed research technique centres around the use of micro-seismic measurements and remote sensing to produce a geodynamic/structural interpretation of the Algoa Basin and its environs. This will be followed by a structural domain analysis to determine the stress field directions and ground geophysics to pinpoint the most favourable water-bearing structures.

The use of satellite imagery forms a key component of an investigation into ground-water exploration around the SA coastline



Development of a systematic method for evaluating site suitability for waste disposal based on geohydrological criteria *(No 485) Division of Water Technology, CSIR*

The protection of ground-water resources, especially of aquifers regarded as sole sources of drinking water, requires a proactive approach. Although ground-water quality is affected by virtually every activity of society, most controlled waste can be landfilled without any detrimental effect on the public or the environment if the sites are carefully selected.

The CSIR and the Department of Water Affairs and Forestry have embarked on a joint research project which aims to develop and field-validate a South African-based methodology for evaluating site suitability for waste disposal based on geohydrological criteria. The first phase of this 2-year project involves an evaluation of methods and systems applied in other countries for this purpose. From this knowledge, a formal method will be developed and field-tested at approximately 10 previously investigated waste disposal sites.

Catchment water quality deterioration as a result of water-level recovery in abandoned gold mines on the eastern and central Witwatersrand *(No 486) Institute for Ground-water Studies, University of the Orange Free State*

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

This 3-year project aims to investigate the rate of water-level recovery in the abandoned gold mines of the eastern and central Witwatersrand, investigate processes affecting the quality of water in these mines and quantify possible seepages upon full recovery of the ground-water level. In this way the overall impact on catchment water quality will be estimated and possible ameliorative measures recommended.

Analyses and interpretation of aquifer tests in secondary aquifers *(No 487) Institute for Ground-water Studies, University of the Orange Free State*

With a few exceptions earlier investigations of ground-water sources in South Africa were based on our understanding of flow in primary aquifers. Most of the ground-water sources in the country, however, occur in so-called secondary aquifers, in rock formations such as dolomite, sandstone, granite, shale, etc. Research conducted of late at the Institute for Ground-water Studies, has indicated that the structure of these rock formations in no way resembles the structure used as basis in the establishment of the porous model. This means that earlier determinations of the parameters for these formations are not reliable. As these parameters are of prime importance for the effective management and utilisation of ground-water sources, it is necessary for this uncertainty to be eliminated or at least mitigated.

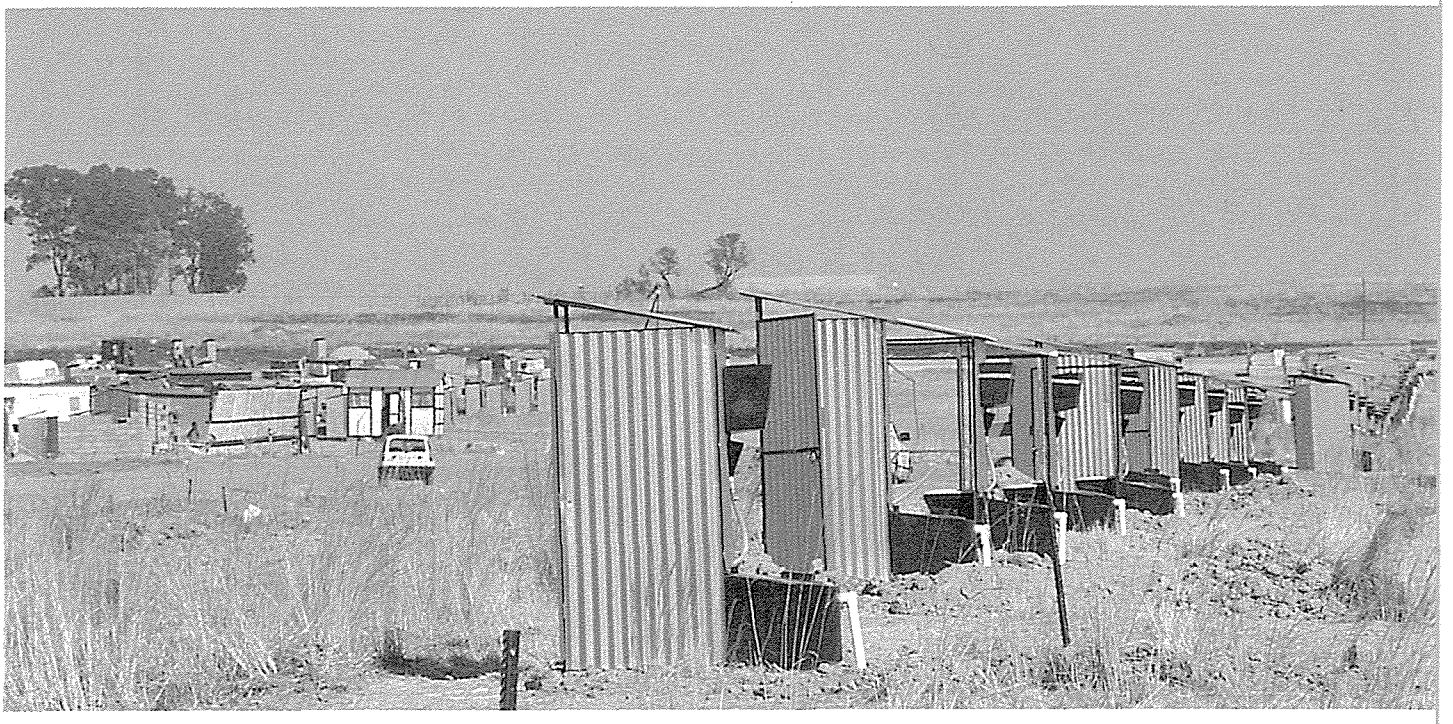
The objectives of this 3-year research project are therefore to investigate the nature and behaviour of secondary aquifers and to establish improved and/or new techniques for use in conducting aquifer tests in secondary aquifers.

Identification and verification of polluted areas in the dolomitic aquifer of the PWV area *(No 500) Atomic Energy Corporation of SA (AEC)*

The dolomitic aquifers of the PWV area are one of the most important sources of ground water in South Africa. They have been investigated and developed to provide emergency water supplies in times of drought. It is, therefore, imperative that this vulnerable resource be protected from pollution by mining, industrial and urban development, and agricultural activities.

Samples taken before 1987 by the Department of Water Affairs and Forestry indicate that elevated levels of pollutants are present at certain localities within the dolomites. The aim of the project is to resample the identified boreholes showing elevated levels of pollutants, such as sulphates and nitrates, in order to confirm the recorded values. Once this has been established, a further investigation limited to a specific area will be conducted to determine the type, extent and possible cause of the pollution. Where possible, suggestions for remedial plans of action to reduce or stop the pollution process will be put forward.

Possible impacts from e.g. mushrooming informal settlements have given rise to the need for a ground-water monitoring strategy



Research projects

Completed

- **212** Use of electromagnetic exploration techniques for the development of ground-water resources (University of Pretoria - Department of Geology)
- **216** Evaluation and development of techniques for the determination of geohydrological parameters by using geoelectrical methods (CSIR - Division of Earth, Marine and Atmospheric Science and Technology)
- **224** Development of techniques for the evaluation and effective management of surface and ground-water contamination in the Orange Free State goldfields (University of the Orange Free State - Institute for Ground-water Studies)
- **225** Enhancement of the National Ground-water Data Base facilities (University of the Orange Free State - Institute for Ground-water Studies)
- **268** Preliminary survey of pesticide levels in ground water from a selected area of intensive agriculture in the Western Cape (CSIR - Division of Water Technology)
- **271** Comparative study of two- and three-dimensional ground-water models (University of the Orange Free State - Institute for Ground-water Studies)
- **272** Investigation into the oscillation method for the determination of aquifer transmissivity (University of the Orange Free State - Institute for Ground-water Studies)
- **339** Compilation of a comprehensive guide for ground-water sampling in South Africa (CSIR - Division of Water Technology)
- **370** Compilation of information on the magnitude, nature and importance of coastal aquifers in Southern Africa (University of Port Elizabeth - Institute for Coastal Research)

Current

- **221** Geohydrological investigation and evaluation of the Zululand coastal aquifer (CSIR - Division of Earth, Marine and Atmospheric Science and Technology)
- **267** Evaluation and development of geophysical techniques for characterising the extent and degree of ground-water pollution (CSIR - Division of Earth, Marine and Atmospheric Science and Technology, and Division of Water Technology)
- **273** Investigation of the potential use of NOAA satellite remotely sensed data for identification of regional-scale fracture zones for ground-water supply purposes in Southern Africa (SRK Inc.)
- **291** Regional investigation into ground-water 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 Ground-water Studies)
- **310** Integration of remote sensing, digital image processing and geographical information systems technologies for regional-scale ground-water resources assessment in South Africa (SRK Inc.)
- **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)
- **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)
- **353** Preparation of a manual on quantitative estimation of ground-water recharge and aquifer storativity (Department of Water Affairs and Forestry)
- **368** A preliminary investigation of the nitrate content of ground water and limitation of the nitrate input (CSIR - Division of Water Technology)
- **371** Assessment of health aspects of the impact of domestic and industrial waste disposal activities on ground-water resources (CSIR - Division of Water Technology)
- **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 Ground-water Studies)
- **378** Development of techniques for risk analysis and ground-water management of Southern African aquifers (University of the Orange Free State - Institute for Ground-water Studies and CSIR - Division of Earth, Marine and Atmospheric Science and Technology)

New

- **481** Geochemistry and isotopes for resource evaluation in the fractured rock aquifers of the Table Mountain Group (CSIR - Division of Water Technology)
- **482** Development of a strategy to monitor ground-water quality on a national scale (CSIR - Division of Water Technology)
- **483** Compilation of a hydrogeological map of South Africa (JR Vegter Esq. and Department of Water Affairs and Forestry)
- **484** An integrated multidisciplinary geodynamic/ geophysical approach to ground-water exploration around the South African coastline (Atomic Energy Corporation of South Africa Ltd)
- **485** Development of a systematic method for evaluating site suitability for waste disposal based on geohydrological criteria (CSIR - Division of Water Technology)
- **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 Ground-water Studies)
- **487** Analysis and interpretation of aquifer tests in secondary aquifers (University of the Orange Free State - Institute for Ground-water Studies)
- **500** Identification and verification of polluted areas in the dolomitic aquifer of the PWV area (Atomic Energy Corporation of South Africa Ltd)

6 Agricultural water utilisation

A suitable irrigation practice for developing agriculture is that it should comply with the relevant economic criteria, humanitarian objectives and human capabilities

Water utilised for agricultural purposes is for the most part needed for irrigation activities. The total area presently irrigated in the RSA is generally accepted to be approximately 1,5 million ha. Inevitably a portion of this area will be occupied by conditions of developing agriculture. Moreover it is estimated that approximately 10% of the total irrigated area could be classified as developing agriculture.

In the more arid areas irrigation can contribute significantly to improving and stabilising crop yields. Irrigation production under developing agricultural conditions passes through various stages, from subsistence agriculture initially to commercial agricultural production eventually. It can therefore only in the long term make a significant contribution to the amelioration of food shortages.

A prerequisite for a suitable irrigation practice for subsistence and emergent farmers is that it should comply with the relevant economic criteria, humanitarian objectives and human capabilities. By its very nature irrigation development, however, often causes human problems. In addition the social and institutional impact of irrigation projects is more difficult to determine than, for example. the economic implications thereof.

Bearing in mind the above background it is clear that the type of irrigation system is one of the variables in developing irrigation agriculture which requires serious attention. Not only should it enable the irrigator to utilise the natural resources optimally, but, given the economic limits in force under the conditions concerned, it has to stimulate development. The recommended system therefore has to be in step with the development objective. Should the development objective therefore be the settlement of farmers on small units, centre-pivot irrigation cannot be considered. The physical characteristics of the chosen system therefore have to be within the means of the user, in addition to performing to a level acceptable from the point of view of water usage.

It was specifically with the latter aspect in mind that the WRC's Co-ordinating Committee for Irrigation Research identified irrigation in developing areas as a high-priority field of research. During 1992 the WRC took the first steps in this regard by developing research proposals directed specifically at developing irrigation agriculture. A workshop to determine additional research needs is being planned for early 1993.

The number of agriculture-related research projects financed by the WRC, in 1992 came to 29. Of these 3 were completed while 6 new research agreements were entered into.

Completed projects

Practical scheduling of irrigation in the Northern Transvaal (No 152) Department of Crop Production, University of the North

This research project was carried out over a period of 5 years in the Pietersburg area with the aim of investigating the applicability of irrigation scheduling methods under practical farming conditions; promoting the use of scientific scheduling methods by means of farmer study groups; and developing scheduling criteria for automated linear-move and centre-pivot systems.

Serious staff problems handicapped the second objective of the project. It nevertheless became clear that recommendations pertaining to practical irrigation scheduling have little or no value unless tested extensively under practical farming conditions. During this test phase farmer co-operation has to be established and maintained by means of regular contact with and feed-back to co-workers. The scheduling approach followed by farmers in general led to under-irrigation which in turn led to a progressive decline in the ground-water status of deeper-lying ground layers.

Further, although accurate comparisons with conventional soil cultivation were not possible, the project demonstrated the value of stubble mulching under irrigation. It is estimated that during the early growth stages water applications can be reduced by up to 30%. A dramatic improvement was also observed in infiltration rates under stubble mulching.

Two computer programs were developed in the course of the project:

- WATERCALC which is used for processing neutron hygrometer results. Ground-water abstraction and the ground-water balance are calculated and presented graphically
- IRRISCHED, a program representing the culmination of a great deal of research on scheduling methods, and which eliminates the majority of the practical problems under actual farming conditions.

It is especially the latter program which potentially holds the greatest benefits for irrigation in practice.

Cost: R354 201
Term: 1984-1991

Drip irrigation of tomatoes *(No 185) Department of Plant Production, University of Pretoria*

This project was carried out mainly on the experimental farm of the University of Pretoria in Hatfield. The indications are that high-frequency deficiency irrigation with a drip-irrigation system has the potential to lead to considerable savings in water usage with tomato yields and quality only being slightly affected. This practice stimulates the utilisation of water in deeper ground layers and a larger degree of drought tolerance is promoted. The results were, however, obtained on deeply disturbed sandy, clay and loam soils and have still to be confirmed on shallower and normally cultivated soils, preferably under practical farming conditions. First attempts at demonstration experiments on farms brought certain problems to light with regard to co-operation and these will receive attention during follow-up research.

Cost: R826 442
Term: 1986-1991

Development of criteria for sprinkler irrigation systems to combat surface sealing of soils *(No 208) Department of Pedology, Potchefstroom University for CHE and Department of Agricultural Engineering, University of Pretoria*

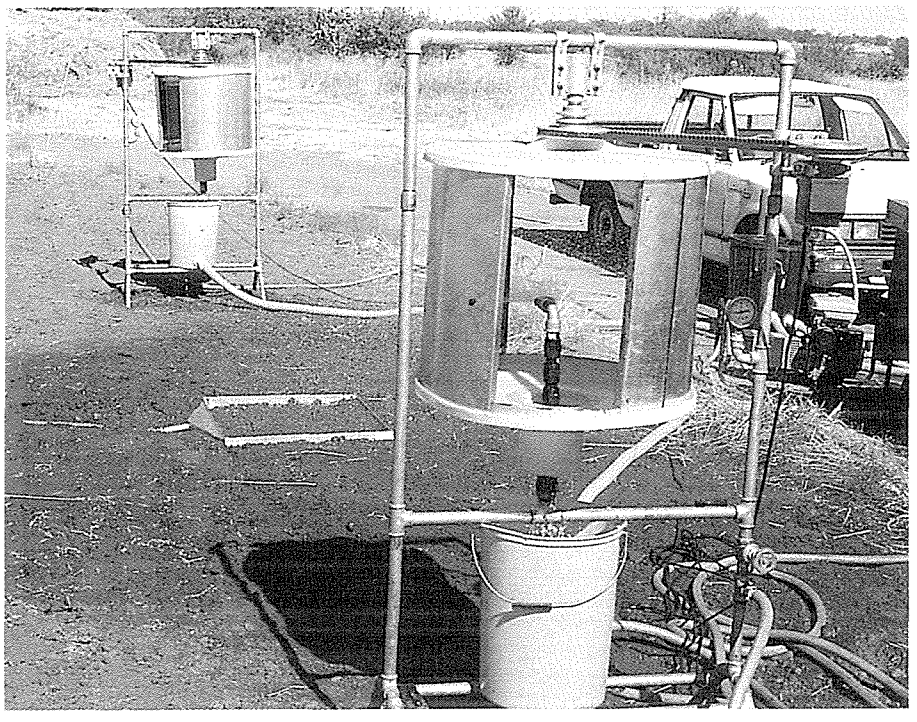
Against the background of the problems caused by crust formation or sealing under sprinkler irrigation the project aimed to quantify the factors influencing infiltration ability as well as soil-water dynamics; to establish an irrigation simulator and infiltrometer; and to make recommendations on the adaptation of sprinkler irrigation systems for more effective water utilisation under conditions of crust formation.

The second objective was successfully attained by the Department of Agricultural Engineering of the University of Pretoria which succeeded in developing an irrigation simulator which can produce a spectrum of drops of a uniform size (typical of standard sprinkler irrigation systems) at different energy levels. This apparatus, developed for laboratory purposes, eliminates a number of the shortcomings of other simulators. A "field irrigation simulator" was built for use in research and for the design of irrigation systems.

The Department of Pedology at the Potchefstroom University for CHE used the apparatus mentioned for research in connection with the other objectives. An index was compiled which included drop size, application rate, drop speed and infiltration ability, and which correlated well with erosion. The final infiltration ability of 67 South African soils was determined at 4 energy levels and correlated with the physical-chemical properties of the soils. With the aid of these results and multiple regressions, predictions can be made of the final infiltration ability and the maximum allowable irrigation energy flow of a soil based on its properties. Furthermore the relationship between maximum allowable energy flux, design application and soil properties was expressed in the form of mathematical equations.

Cost: R414 940
Term: 1987-1991

A field irrigation simulator to determine infiltration rates when designing irrigation systems



New projects

Optimal water utilisation by turf *(No 417) Department of Plant and Soil Sciences, Potchefstroom University for CHE*

Irrigated sports grounds can eventually comprise 5% of the total irrigated area of South Africa and, if the irrigation of grass-covered recreational areas is also taken into account, large quantities of water can clearly be involved in this. It is estimated that the net water consumption of sports grounds alone could increase to 1,2 million m^3 per day as the necessary developments take place. The aim of this 2-year project is threefold. Firstly the water consumption of 6 different grass species generally used on South African sports grounds will be determined. Secondly it is planned to determine the influence of various management practices on the water consumption, viz. cutting height and fertiliser application. Thirdly the information on water consumption will have to be made available in a

form able to contribute to the most effective irrigation of sports grounds under different climatic conditions.

Identification of irrigated land in an intensively cultivated agricultural area in the South-Western Cape by means of satellite remote sensing *(No 440) Institute for Cartographic Analysis, University of Stellenbosch*

Effective management of water resources depends on sound knowledge of the water usage and requirements of water users in various sectors. Large uncertainties regarding irrigation water usage could have serious negative impacts on the rational allocation of scarce water resources to various competing water users. In this 2-year project research will focus on the capabilities of the higher resolution satellites (Landsat TM, SPOT) to combine satellite remotely sensed data with existing information on soils and slope. It is hoped to provide an economical means of obtaining land-cover information which will be suitable for assessing water utilisation by irrigation in the South-Western Cape and other equally complex regions.

Determination of the relationship between transpiration rate and declining available water for **Eucalyptus grandis**
(No 441) Division of Forest Science and Technology, CSIR

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

In this 3-year project attention will be given to quantifying the total amount of soil water potentially available to trees; the soil water threshold below which transpiration begins to decline; relationships between transpiration and declining soil water content below this threshold; and the relative importance to transpiration of water in the soil profile and the subsoil. This information will then be applied in developing prediction models of transpiration of *Eucalyptus grandis* under conditions of limited soil water.

Transfer of research results on the irrigation of vegetable crops into practice
(No 476) Department of Plant Production, University of Pretoria

Research having been conducted for a number of years at the experimental farm of the University of Pretoria on the irrigation of vegetable crops, it became necessary to apply the knowledge acquired in order to solve water management problems in the vegetable industry. A 2-year project was consequently launched, aimed, in collaboration with producers and extension officers, at identifying specific problems experienced with the irrigation of vegetable crops, and afterwards to address such problems making use of existing knowledge, recent research results, the creation of management tools and appropriate experiments. The management tools to be created include strategically positioned automatic weather-stations and computer models which will provide irrigation scheduling information. Effective technology transfer is enhanced by the active involvement of both producers and extension officers.

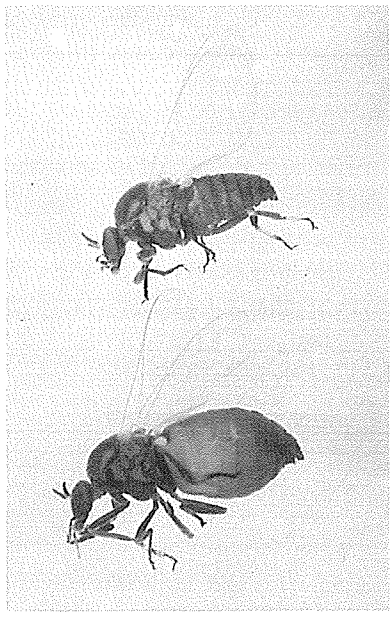
Molecular approach to drought tolerance *(No 479) Institute for Plant Biotechnology, Agricultural Research Council*

Conventional plant breeding programmes have had limited success in producing crop strains with greater drought tolerance and water-use efficiency than existing strains. Provided suitable techniques can be developed, the production of transgenic plants has great potential for enhancing drought tolerance. The approach used in this 6-year project will be to identify and characterise genes involved in producing desirable responses to water stress in potato, cotton, tobacco and maize plants. Attempts will be made to transfer such genes to drought-sensitive plants which will then be tested under greenhouse conditions for increased drought tolerance. While the project will be executed by the Institute for Plant Biotechnology, major contributions to the research will also be made by the Department of Botany at the University of Natal and the Department of Genetics at the University of the Witwatersrand.

The effect of exchangeable sodium percentage and clay mineralogy on the infiltration capacity of soils already sealed due to cyclic irrigation *(No 499)*

Department of Plant and Soil Sciences, Potchefstroom University for CHE

This 1-year project is undertaken as a follow-up to a previous project. In the previous project research was undertaken to develop criteria to combat the surface sealing associated with sprinkler irrigation. The current project is aimed at further investigating the change in the infiltration ability of soil exposed to cyclical irrigation. It will be determined to what extent the surface seal which forms under the impact of drops, remains stable or breaks up during subsequent irrigations. The extent to which research findings obtained with initially unsealed soils, can also be applied to initially sealed soils, will also be investigated further.



Left: Unfed and engorged blackfly females

Dr Rob Palmer at the Orange River examining a rock for immature blackflies

Research projects

Completed

- **152** Practical scheduling of irrigation in the Northern Transvaal (University of the North - Department of Crop Production)
- **185** Drip irrigation of tomatoes (University of Pretoria - Department of Plant Production)
- **208** Development of criteria for sprinkler irrigation systems to combat surface sealing of soils (Potchefstroom University for CHE - Department of Pedology and University of Pretoria - Department of Agricultural Engineering)

Current

- **226** Maximising irrigation project efficiency in different soil/climate/irrigation situations (University of the Orange Free State - Department of Agrometeorology)
- **227** Storage and utilisation of rain water in the soil for the stabilisation of plant production in semi-arid areas (University of the Orange Free State - 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 Orange Free State - Department of Agronomy and Hortology)
- **229** Estimation and evaluation of moisture stress in crops by means of remote control aerial surveillance (University of the North - Department of Soil Science)
- **257** Water-use efficiency of certain irrigated temperate pasture species (University of Pretoria - Department of Plant Production)
- **260** Relationship between climate and crop factors (University of the Orange Free State - Department of Agrometeorology)
- **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)
- **301** Investigation into the quality of water for animal production (University of Pretoria - Department of Animal Production)
- **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 (Department of Agricultural Development - Soil and Irrigation Research Institute)
- **343** Development of an effective and environmentally safe larviciding programme for the control of the blackfly, *Simulium chutteri*, along the Orange River (Department of Agricultural Development - Veterinary Research Institute)
- **347** Global farm approach to enhancing the economic efficiency of water and energy use for irrigation in the central RSA (University of the Orange Free State-Department of Agricultural Economics)
- **348** Root development and water usage of commercial timber species (University of Natal - Department of Agronomy)
- **367** Development of a consolidated computer software package for the management of an irrigation scheme (Rand Afrikaans University - Systems Laboratory)
- **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)
- **379** Decision-making procedures for the determination of crop water requirements (MBB Inc.)
- **382** Evaluation of the interdependent factors which determine the viability of irrigation farming (MBB Inc.)
- **389** Scheduling irrigation of tuber crops with specific reference to potatoes (Department of Agricultural Development - Vegetable and Ornamental Plant Research Institute)

New

- **417** Optimal water utilisation by turf (Potchefstroom University for CHE - Department of Plant and Soil Sciences)
- **440** Identification of irrigation 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)

7 Water pollution

Certain experts now regard the conservation of water quality as a bigger long-term problem than water supply as such

Due to South Africa having a relatively low and variable rainfall, the development of water sources was emphasised initially, the intention being to ensure adequate water for use during drier months and years. To supplement the water shortage the purification and reuse of effluents were therefore actively pursued. As water sources were more fully developed and the contribution of the natural dilution effect diminished, the water quality in certain areas starting deteriorating. The need to maintain water quality, in addition to the development of water sources, became increasingly obvious - to such a degree that certain experts now regard the conservation of water quality as a bigger long-term problem than water supply as such. The Department of Water Affairs and Forestry currently attempts protecting water quality by adopting an integrated approach to water quality management, aimed to keep our water sources suitable for all acknowledged water users. Due to the integrated nature of water quality management far more emphasis is placed *inter alia* on the control of diffuse pollution than in the past. These aspects, and others, are therefore reflected in modified research needs and new research projects.

Salinisation

Salinisation remains one of the most problematic consequences of water pollution in South Africa. It is the result of a variety of salts being added to the water environment caused almost inevitably by, among others, the escalating use and reuse of water as a result of development. As the salt content of water increases, the water becomes less suitable for most users, incurring additional costs.

In 1992 the WRC financed 11 salinisation projects of which 4 were new.

Eutrophication

Eutrophication is the enrichment of the water environment with plant nutrients which promote the excessive growth of algae and aquatic plants. It is still causing serious problems such as defacing the water environment and impeding water purification.

During the year the WRC financed 8 eutrophication projects of which 3 were new and 2 were completed.

Water quality studies

The gradual deterioration in water quality coupled with the greater awareness of water quality as a factor determining the utilisation potential of water, led to the identification of a number of research needs. The WRC currently finances 10 projects in connection with water quality studies of which 1 commenced during the year.

Marine disposal

Marine disposal of effluents is often more economical than treating them on land. At first this practice was condoned world-wide because it was assumed that the sea possessed a virtually unlimited capacity to absorb specific wastes. With the realisation that this capacity to assimilate waste is limited and because marine disposal is occasionally abused for the disposal of material detrimental to the marine environment, coupled with the unfavourable publicity associated with pipelines which are not well operated or are of poor design, increasing public resistance against marine disposal is being experienced world-wide. It is nevertheless a practice which is employed widely (also in South Africa) by coastal communities to dispose of their effluents. In order to enable the responsible consideration of marine disposal as an alternative to the land-based treatment of effluents, the WRC currently finances 3 projects of which 1 commenced during the year.

Completed projects

Effects of land use on runoff quality in selected catchments in Natal (No 237)

Division of Water Technology, CSIR

The aim of this project was to gather information on the water quality associated with various land uses for incorporation in a water-quality model planned for the Mgeni catchment area. Runoff quality from three pairs of small catchment areas was monitored for this purpose. The one pair comprised forestry and small farms, respectively, another natural bush and veld in contrast with subsistence agricultural units, and the third an unused feedlot in contrast with grassland. The processed

data gives a good indication of the water quality which can be associated with various types of land use.

Cost: R222 874
Term: 1988-1991

Harvesting of algal drift from Hartbeespoort Dam water for the reclamation of fine chemicals *(No 264) Division of Water Technology, CSIR*

This project investigated the potential for recovering valuable chemicals such as beta-carotene, vitamin E, cobalamin (vitamin B_{12}) and also lipids from the *Microcystis* algae species normally prevalent in Hartbeespoort Dam.

Although the algal materials have a great potential value it is concluded that economic exploitation would not be readily feasible at present due to the seasonal variation of algal species and biomass in the dam. Another aspect militating against the commercial exploitation is the variability recorded in the concentration of the desirable chemicals.

Cost: R73 000
Term: 1989-1990

Salt accumulation in a spruit in the Vaalharts Irrigation Scheme

New projects

Water quality and quantity assessments in catchments with changing land uses in the Umzinto coastal area *(No 419) SA Sugar Association Experiment Station*

This project will be conducted over a period of 3 years. As the demand for suitable land and the competition between forestry, sugar cultivation and other uses in parts of Natal increase, the need for information which can contribute to the conservation of natural resources increases concomitantly. Little information is available on soil and water losses which go hand in hand with the tilling of steep slopes, various cultivation practices and crop rotation. The intention of this project is among others to test in practice design principles for the control of runoff from steep slopes. In addition to this the differences in runoff, sediment load and other water quality variables for small catchment areas planted with trees or sugar-cane will be compared with those of a natural grassland.

Long-term salt balance of the Vaalharts irrigation scheme *(No 420) Stewart Scott Inc.*

In an investigation, conducted in 1987 for the Department of Water Affairs and Forestry, the conclusion was reached that only 20% of the salt which was part of the irrigation water supplied to Vaalharts between 1935 and 1984 leached from the area as irrigation return flow. This represents an accumulation of about 3 million ton of salt. As it is unlikely that such a quantity of salt can be retained indefinitely in a "salt-pit" and its release has far-reaching implications for users downstream from Vaalharts, it needs to be ascertained whether the 1987 findings were correct and what is to be expected in the future. The current 2-year investigation will make use of available information to ascertain whether a problem does, in fact, exist and the extent and urgency thereof.

Relationship between atmospheric deposition and water quality in a small upland catchment *(No 421) Division of Water Technology, CSIR*

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

Compilation of guidelines for the use of peroxone and other oxidants in the treatment of eutrophic water *(No 443) Division of Water Technology, CSIR*

The purpose of this 3-year project is to investigate the efficacy of peroxone (a mixture of ozone and hydrogen peroxide) as chemical oxidant in eutrophic waters. Comparative studies with other oxidants and combinations thereof will also be carried out. The results obtained, together with research previously carried out, will be summarised in the form of guidelines for the use and application of different oxidants in drinking-water treatment. The advantages of the guidelines will be the following:

- It will enable consulting engineers to choose suitable oxidants for specific waters
- Water boards and municipalities will become aware of the various options available
- Cost-effectiveness of water purification can be improved.

Optimising diffuser design for off-shore pipelines - Laboratory experiments

(No 447) Division of Earth, Marine and Atmospheric Science and Technology, CSIR

The high dilutions achievable render marine pipelines an effective means of discharging both industrial and domestic effluents to the marine environment. The total dilution attainable is the aggregate of initial and secondary dilutions and bacterial decay and of these the larger initial dilution is the only process that is design controlled. A more effective design, leading to higher initial dilutions, will not only diminish the environmental impact of marine discharges but will also reduce the length of the pipeline required.

Relatively little is known about the dilution-promoting effect of port spacings and diffuser orientations. It is anticipated, however, that a diffuser orientated parallel to the coast, instead of perpendicular to it as is generally the case, can result in higher on-shore dilutions. The 3-year project aims at studying these aspects under controlled laboratory conditions.

Occurrence of bacteria causing acid mine drainage in the outer layers of coal waste dumps *(No 454) Department of Microbiology, University of Stellenbosch*

Acid mine drainage is a serious problem in the coal mining areas of South Africa. It is a result of the oxidation of pyrite which is greatly facilitated by the action of certain bacteria. One method to control the oxidation of pyrite by bacteria is to create anaerobic conditions by means of appropriate coal dump construction. The purpose of this 3-year research project will be to study iron oxidising bacterial populations which could catalyse acid drainage production in the outer layers of coal waste of different constructed dumps. The ultimate aim is to make an assessment of the success of the present construction techniques for coal waste dumps in inhibiting or limiting the development of iron oxidising bacteria.

Detergent phosphorus in South Africa: Impact on eutrophication with specific reference to the Umgeni catchment

(No 465) Department of Chemical Engineering, University of Natal and Umgeni Water

The undesirable effects of eutrophication can be reversed by the elimination or reduction of the nutrient supply to an impoundment. Generally phosphorus is the limiting nutrient and could arise from various sources such as domestic and industrial waste waters, agricultural wastes and fertilisers. Research carried out in other countries has shown that the phosphorus contained in laundry detergents makes up a significant proportion of the domestic load which in turn constitutes a significant proportion of the total load.

A WRC study conducted in 1986 investigated the implications of banning or severely reducing the phosphorus content of detergents in South Africa. While detergent phosphorus was shown to be a significant phosphorus source, a cost-benefit assessment indicated that the costs associated with

limiting detergent phosphorus outweighed the benefits. The aim of this 1-year project is to re-examine and update the 1986 report in the light of the current situation.

Guidelines and procedures to assess and ameliorate the impact of gold mining operations on the water environment

(No 477) Chamber of Mines Research Organisation (COMRO)

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

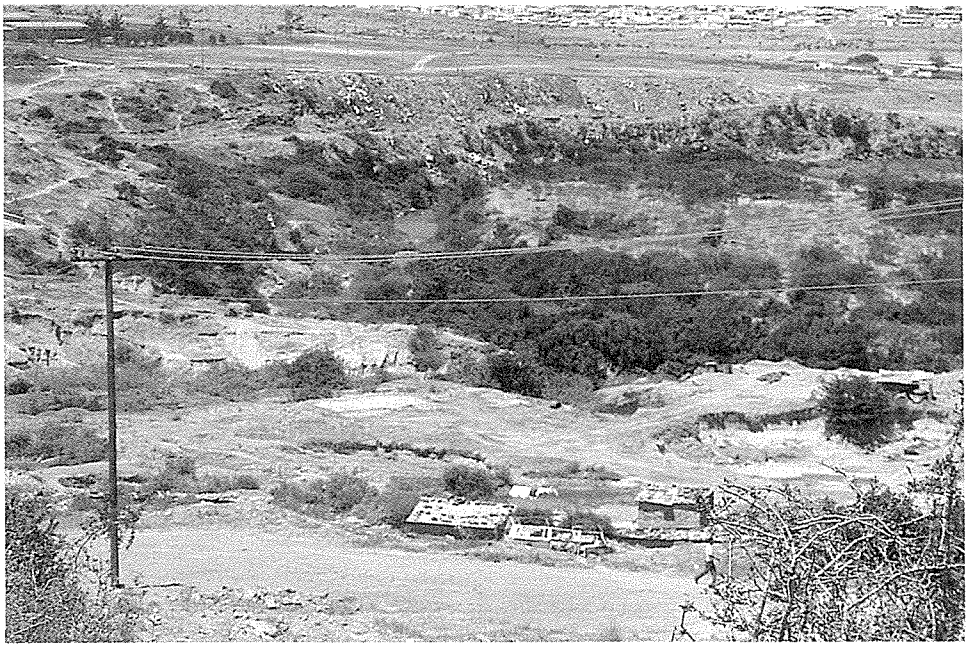
Collection and evaluation of runoff water quality data from a disused feedlot in Natal *(No 498) Division of Water Technology, CSIR*

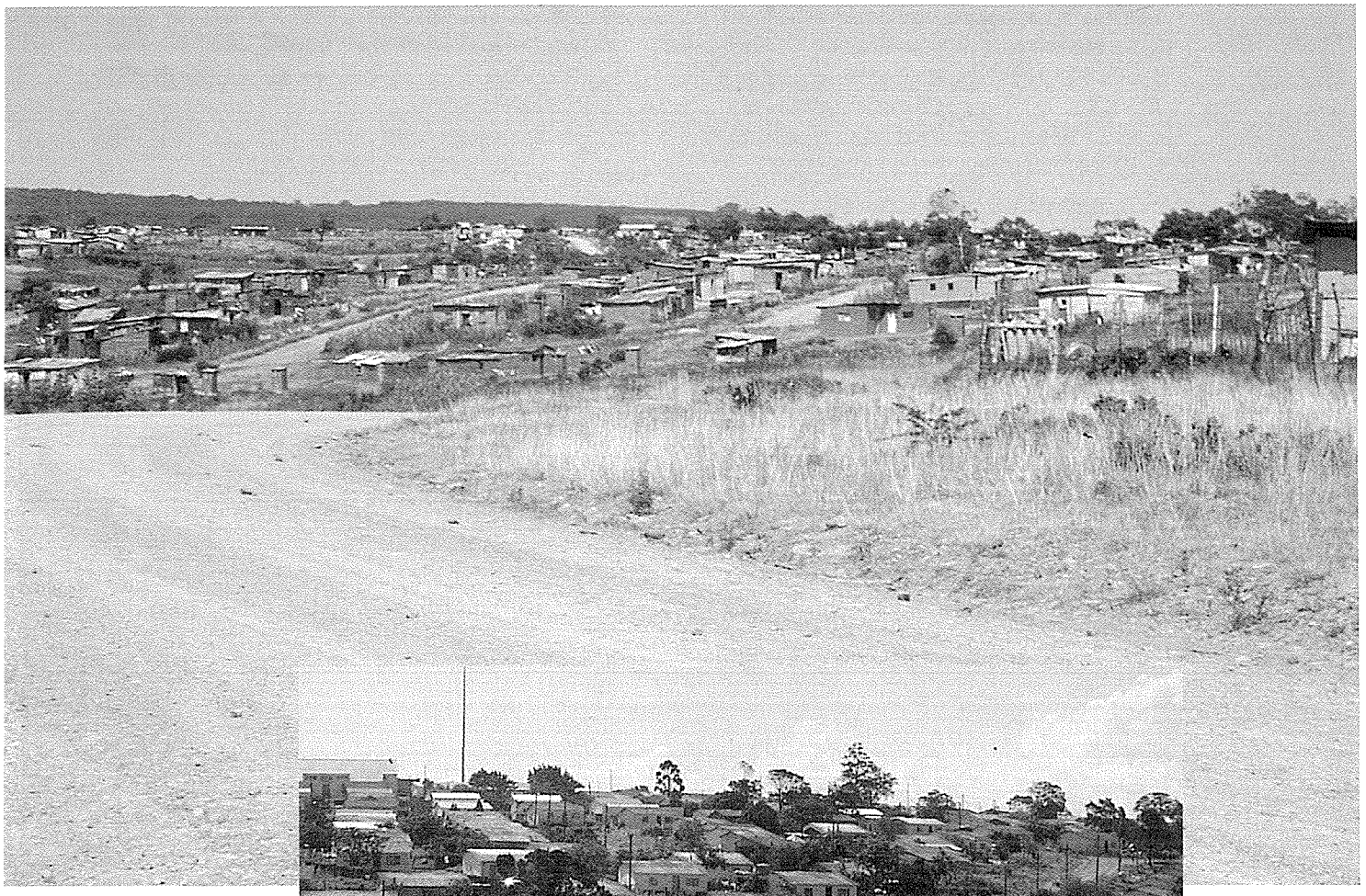
As part of an already completed project to quantify the effects of land use on the quality of runoff, the runoff from an unused feedlot was monitored for a short period. The indications so obtained were that storm-water runoff contains plant nutrient concentrations and organic pollution comparable with those in raw sewage, while pollution was largely absent from the base flow. Due to the restricted nature of the information gathered and its large potential impact, it was decided to conduct follow-up monitoring in order to obtain more reliable export coefficients and knowledge of the time-dependent tendencies which can be used in water quality models.

This follow-up project will extend over 1 year.

Coal waste dumps in the Eastern Transvaal. A project during which the occurrence of bacteria causing acid mine drainage in the outer layers of coal waste dumps is being investigated

A situation analysis of water quality in the Buffels River (Eastern Cape) with special emphasis on the impact of low cost, high density urban development on water quality





Research projects

Completed

- **237** Effects of land use on runoff quality in selected catchments in Natal (CSIR - Division of Water Technology)
- **264** Harvesting of algal drift from Hartbeespoort Dam water for the reclamation of fine chemicals (CSIR - Division of Water Technology)

Current

- **195** Hydrosalinity studies in the Eastern Cape (Rhodes University - Institute for Water Research)
- **196** Abilities of several solute and water transport models to predict the quantity and quality of water leaving the root zone (University of Stellenbosch - Department of Soil and Agricultural Water Science)
- **197** Phosphate export models for catchments (CSIR - Division of Water Technology)
- **256** Design and use of irrigation systems in the Breë River with a view to the control of potential drainage losses (MBB Inc.)
- **266** Extension of the management-orientated models for eutrophication control (CSIR - Division of Water Technology)
- **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)
- **304** Applicability of hydrodynamic reservoir models for water quality management in stratified water bodies in South Africa (Ninham Shand Inc. and the University of Cape Town - Department of Civil Engineering)
- **312** Occurrence and accumulation of selected heavy metals in freshwater ecosystems affected by mine and industrial polluted effluent (Rand Afrikaans University - Department of Zoology)
- **313** Concentration ratios of selected radionuclides in aquatic ecosystems affected by mine drainage effluents (Rand Afrikaans University - Department of Zoology)
- **326** Assessment of the feasibility and impact of alternative water pollution control options on TDS concentrations in the Vaal Barrage and Middle Vaal (SRK Inc.)
- **344** Contribution of ground water to the salt load of the Breë River using natural isotopes and chemical tracers (University of the Orange Free State - Institute for Ground-water Studies)
- **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 off-shore 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 Board)
- **401** Revised water quality criteria for the South African coastal zone (CSIR - Division of Earth, Marine and Atmospheric Science and Technology)
- **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 micro-organisms (University of Pretoria - Department of Medical Virology)
- **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)
- **414** Soil buffering of rain-water salinity in the Vaal Dam catchment (University of Natal - Department of Agronomy)

New

- **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 off-shore pipelines - Laboratory experiments (CSIR - Division of Earth, Marine and Atmospheric 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)
- **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)
- **477** Guidelines and procedures to assess and ameliorate the impact of gold mining operations on the water environment (Chamber of Mines Research Organisation (COMRO))
- **498** Collection and evaluation of runoff water quality data from a disused feedlot in Natal (CSIR - Division of Water Technology)

8 Municipal waste water

The maintenance of an adequately trained work-force to manage the water and waste-water treatment works in particular, has long been recognised as a problem by both the Water Institute of Southern Africa and the Department of Water Affairs and Forestry

South Africa's incipient water shortage has been accentuated by the drought this year, and this has underscored the necessity for good resource husbandry. The maintenance of an adequately trained work-force to manage the water and waste-water treatment works in particular, has long been recognised as a problem by both the Water Institute of Southern Africa and the Department of Water Affairs and Forestry. At the request of the latter the WRC has initiated an investigation into the training and education of water-care operators. People from the water industry and the educational institutions have been involved in work sessions, and this initiative is designed to obviate many of the existing problems.

Attention has once more been focused on waste-water sludge with the publication of draft guidelines on sludge quality by the Department of National Health and Population Development. Environmentally acceptable methods for the disposal of waste-water sludge remain a major problem and the WRC continues to support research on this subject.

In this field which encompasses **Sewage Treatment, Sewage Sludge Treatment and Disposal** and **Wetlands,** the WRC supported 21 projects during 1992, of which 8 commenced during the year, 9 are current and 4 were completed.

Completed projects

Evaluation and optimisation of the process of dual digestion of sewage sludge

(No 189) Division of Water Technology, CSIR and Town Council of Milnerton

A new sludge treatment system developed in the USA during the 1970s and known as dual digestion, combines 2 separate treatment processes, autothermal aerobic digestion and anaerobic digestion, in a two-step system. The WRC recognised the potential of this new process during its development but realised that some modifications to adapt the American system to local requirements would be needed. The necessary research was conducted in 2 stages:

As the first stage, the autothermal aerobic digestion of sewage sludge was investigated at pilot-plant level by the Johannesburg City Council to establish its effectiveness to pasteurise the sludge, to assess the effect of varied solids loadings and retention periods, the significance of operational problems, economic implications and the potential of the dual digestion system for application in South Africa.

As the second stage, a tripartite agreement between the WRC, the Division of Water Technology of the CSIR and Milnerton Town Council was entered into for further research at full scale into the application of dual digestion at the Milnerton Wastewater Treatment Works.

The final report consisting of 4 sets of documents is aimed at providing researchers, designers and decision-makers with sufficient information to assist them in assessing the suitability of the process for their specific applications.

Cost: R550 274
Term: 1986-1990

Phosphate crystallisation in activated sludge systems *(No 215) Division of Water Technology, CSIR*

Phosphates are key nutrients in the eutrophication of South African rivers and reservoirs, and their removal from effluents is mandatory in all the major catchment areas of the country.

The main aims of this project were to determine the kinetics of the crystallisation of calcium phosphate, to develop operating criteria for a phosphate crystallisation reactor and to establish its optimum process configuration.

Key parameters in the process proved to be pH level, the calcium and phosphate concentrations, the calcium to phosphate ratio and the most suitable seed material for the fluidised bed reactor.

A technology transfer document was drawn up to assist potential users in implementing this technology.

Cost: R118 097
Term: 1987-1989

Phosphate fixation in waste waters by means of controlled struvite formation

(No 250) Division of Water Technology, CSIR

Uncontrolled precipitation of struvite (magnesium ammonium phosphate) causes major scaling and clogging problems in waste-water treatment and piping systems.

The main objective of this study was to use the controlled formation of struvite to immobilise phosphates, particularly in anaerobic digester effluents. This included a study of the kinetics of

struvite formation and the development of operating criteria for a struvite crystalliser.

The results of this investigation included optimisation of the effluent pH to greater than 8, supplementation of the anaerobic digester effluents with $MgSO_4$ and K_2HPO_4 to achieve the optimum 1:1:1 molar Mg:N:P ratio and using quartzitic sand as suitable seed material for the crystallisation of struvite.

Cost: R180 537
Term: 1988-1991

Compilation of an operators guide on anaerobic digestion of sewage sludge

(No 390) Ross Consultancy CC

This guide was written for people involved with the anaerobic digestion of waste-water sludge. It follows the passage of the sludge from the head of works, through primary sedimentation, thickening, the anaerobic digestion process, dewatering to disposal. Throughout the guide, potential problems are highlighted and solutions given. The importance of proper monitoring is stressed.

The guide will be of value to all involved in the anaerobic digestion of waste-water sludge.

Cost: R15 000
Term: 1991

New projects

Application and performance of full-scale constructed wetlands for waste-water treatment in South Africa *(No 416)*

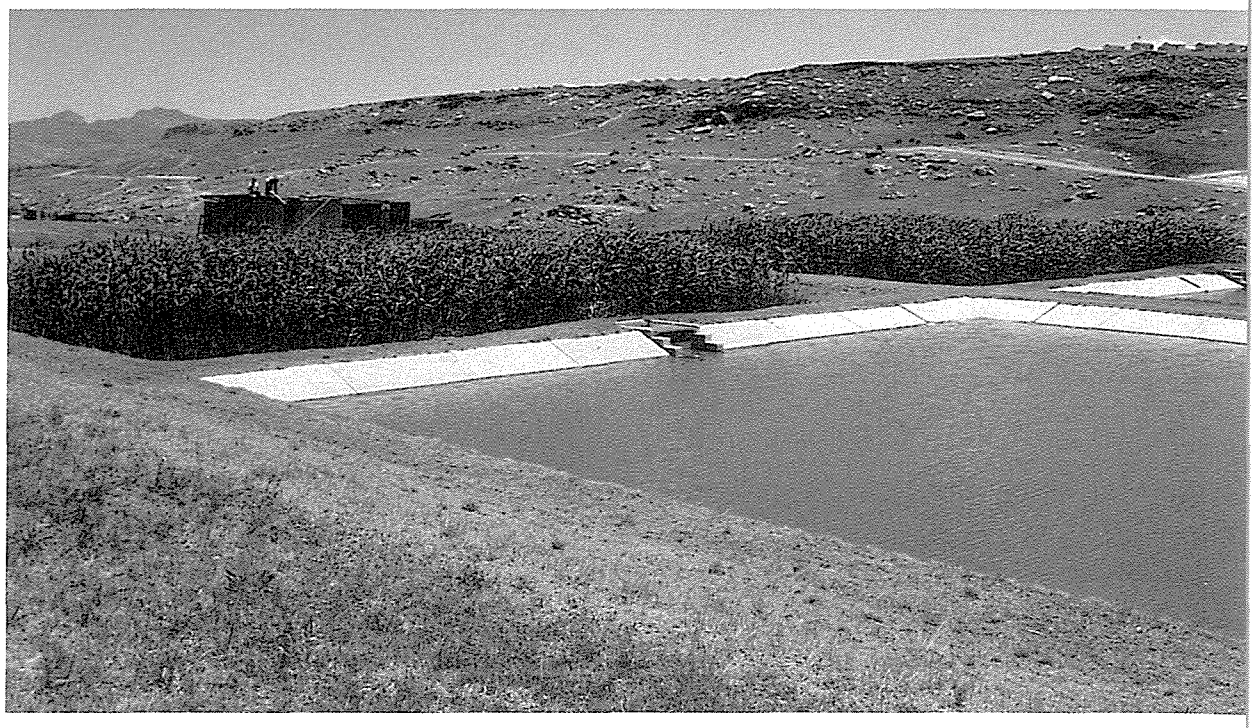
SRK Inc.

Natural wetlands function as natural water treatment systems through a number of complex interactions between the physical, chemical and biological components of the system. Based on the principles of natural wetlands, artificial wetlands can be constructed to enhance the processes of nature systematically.

Wherever land availability is not a limiting factor, the capacity of wetlands to treat water to acceptable standards makes them ideal for small communities, such as leisure resorts, rural schools and informal settlements which have no access to a municipal sewerage system.

They can be sited at the point of waste-water production as they are environmentally and aesthetically acceptable. Wetlands can provide a cost-effective and low-maintenance alternative to ensure water of reasonable quality.

This 4-year project will test pilot-study results on full-scale wetlands and test the possibility to manipulate the functions of the different elements of a wetland to enhance the performance of any of the component processes.



A full-scale constructed reedbed for waste-water treatment in Qua-Qua

Development of electro-osmotic sludge dewatering technology *(No 427) Division of Water Technology, CSIR*

The aim of this 2-year study is to optimise a South African patented technology for the electro-osmotic dewatering of sludge. Mechanical dewatering leaves interstitial water in the sludge floc, but the electro-osmotic technology displaces this water. Potentially this technology could yield a much drier sludge than that yielded by a mechanical belt press.

Bio-augmentation technology for wastewater treatment in South Africa *(No 429) Division of Water Technology, CSIR*

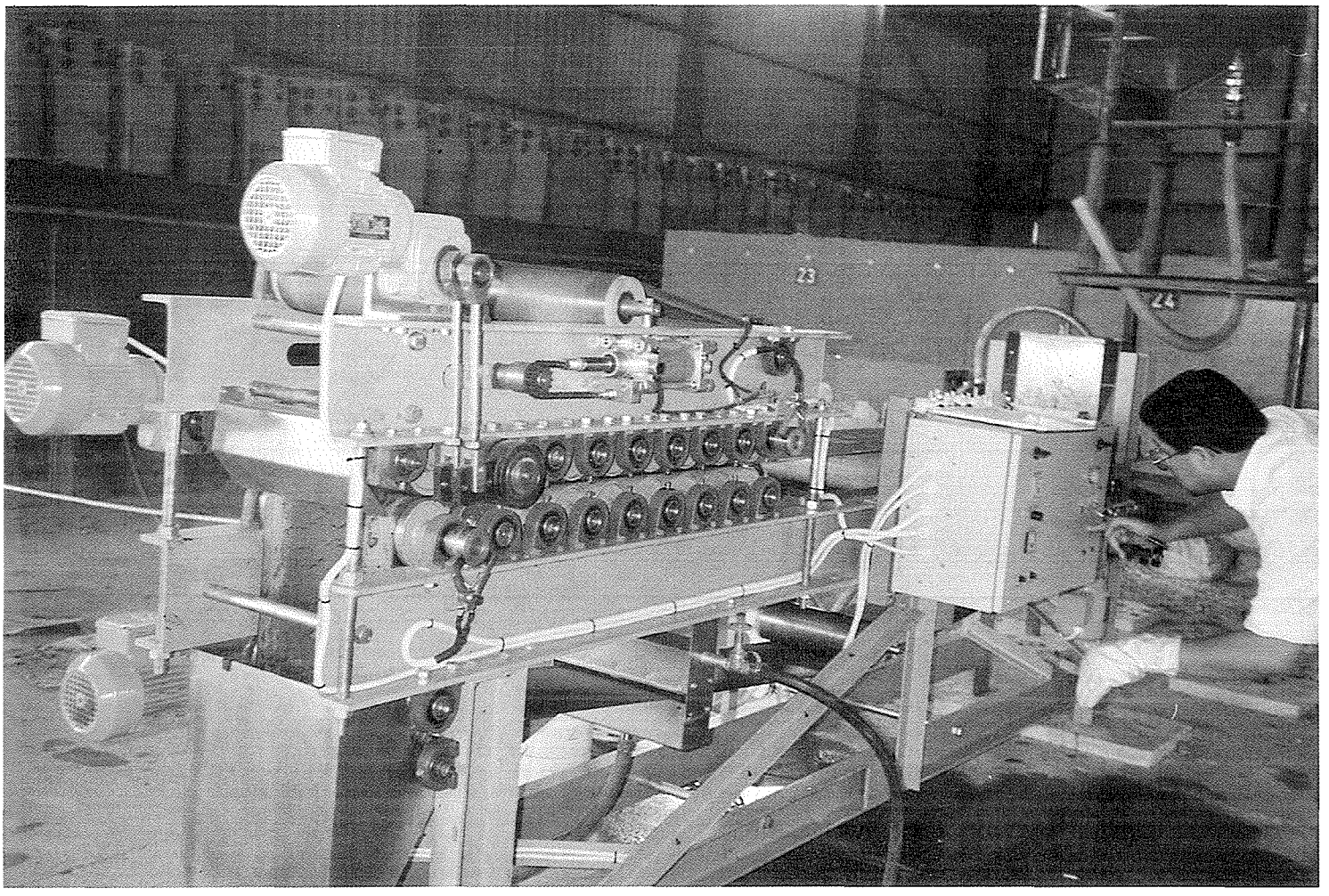
Bio-augmentation is a major industry in developed countries, and has been successfully employed in incidents such as the Exxon Valdez oil spill. However, the indication is that not all products perform as claimed. The primary aims of this 3-year project are to:

- Establish criteria for the evaluation of biosupplements to make sure that they meet specifications and are safe to use
- Establish micro-organism screening, isolation, culture and storage protocol for the successful implementation of bio-augmentation technology in South Africa
- Develop and/or improve biosupplements for local conditions.

Comprehensive study of an iron-phosphate removal system *(No 430) Division of Water Technology, CSIR*

Phosphates act as nutrients in the eutrophication of rivers and may be removed by either biological or chemical means. Conventional chemical treatment suffers from disadvantages, such as pH changes, additional use of flocculants, production of voluminous precipitates and increases in the total dissolved solids of the effluent. Contact with elemental iron, however, offers an alternative chemical treatment for the removal of phosphates from

Pilot plant for electro-osmotic dewatering of sludge



sewage effluents as insoluble iron phosphates are formed.

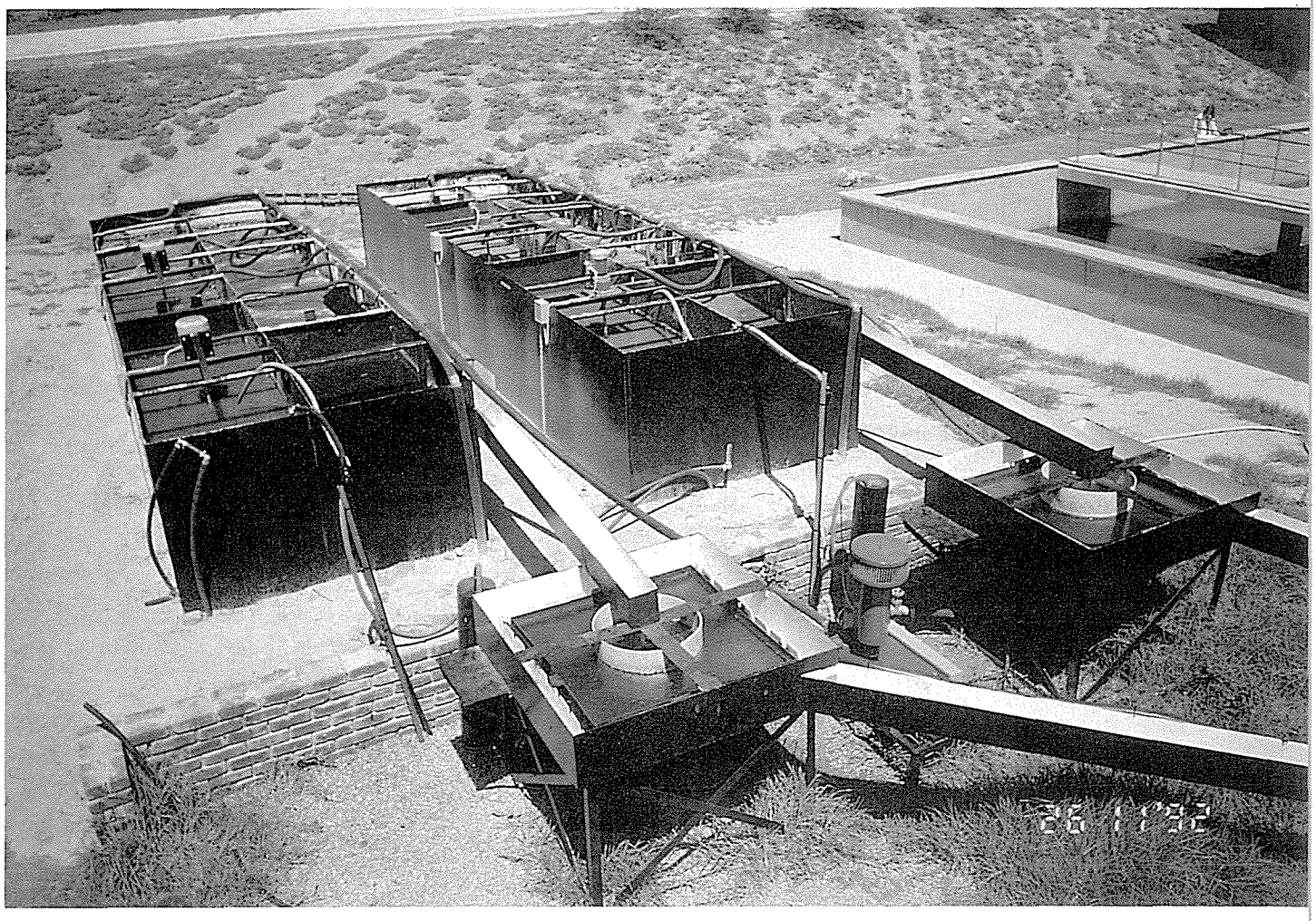
This 1-year study aims to establish suitable conditions for the optimal removal of phosphates from sewage effluents, using a modular rotating contactor containing iron filings. Accurate pH and influent feed control will be studied to achieve phosphate removal to a level of 1 mg P/*l*.

Activated fixed and suspended cultures for nitrification *(No 462) Department of Chemical Engineering, University of Pretoria*

An important factor limiting the capacity of activated sludge plants is the need for effective nitrification. As nitrifiers can only function in the aerobic basin, the aerobic sludge age limits nitrification. The hypothesis being tested over 1 year by this research is that the maintenance of active biomass in the aerobic basin, either on a fixed bed or on suspended material, will increase the effective nitrification rate. If this can be achieved the sludge age may be reduced, allowing for a larger volume of effluent to be treated by a works.

Pond enhanced trickling filter operation (PETRO) *(No 491) Wates, Meiring and Barnard Inc. and the Division of Water Technology, CSIR*

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



Pilot plant testing the potential of fixed media to enhance nitrification

Human viruses in diffuse effluents and related water environments *(No 496) Department of Medical Virology, University of Pretoria*

This project will study the impact of rapid third world urbanisation and squatting on the virological quality of water resources and supplies. Selected areas country-wide will be investigated. The investigation will also include the collection of information on related infections in the communities concerned so that health risks may be better assessed.

The results of this 3-year project will help the decision-makers meet the future challenges when formulating strategies for the protection and optimal utilisation of limited water resources.

Research projects

Completed

- **189** Evaluation and optimisation of the process of dual digestion of sewage sludge (CSIR - Division of Water Technology and Town Council of Milnerton)
- **215** Phosphate crystallisation in activated sludge systems (CSIR - Division of Water Technology)
- **250** Phosphate fixation in waste waters by means of controlled struvite formation (CSIR - Division of Water Technology)
- **390** Compilation of an operators guide on anaerobic digestion of sewage sludge (Ross Consultancy CC)

Current

- **232** Preparation of engineering design guidelines for artificial wetlands for waste-water treatment (CSIR - Division of Water Technology and Stewart Scott Inc.)
- **248** Chemical augmentation of biological phosphate removal (City Council of Johannesburg)
- **286** Development and evaluation of specific control methods for ameliorating low F/M bulking (University of Cape Town - Department of Civil Engineering)
- **314** Biological phosphate removal mechanisms in the activated sludge process (University of Pretoria - Department of Microbiology and Plant Pathology)
- **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)

New

- **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)
- **430** Comprehensive study of an iron-phosphate removal system (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)

9 Industrial effluents

A survey of industrial effluent discharges into public sewers conducted in 1973 for the WRC indicated the directions into which research on industrial effluents should be channelled

A survey of industrial effluent discharges into public sewers conducted in 1973 for the WRC indicated the directions into which research on industrial effluents should be channelled. It was divided into the following categories:

- Industrial waste management
- Solid and toxic wastes
- Special problems (such as nitrates, phosphates and problematic effluents from certain specific industries such as dyestuffs, pharmaceuticals, explosives and toxic substances)
- Water quality protection (including potentially toxic chemicals)
- Analytical techniques and instrumentation
- Technology transfer.

Research was extended to include the difficulties encountered by specific industries producing effluents which are difficult to manage and to purify in order to meet the quality requirements. These industries include mining, textiles, meat, hides and skins, fruit and vegetable canning and others.

Over the years a considerable amount of research aimed at the above categories has been promoted by the WRC. The work was aimed at finding methodology, technology and suitable management techniques to overcome problems associated with industrial effluents. However, it became evident that there were still a number of effluent problems in various parts of the country. It was considered that some of the problems arose from a lack of suitable technology, but also that management needed to be made more aware of the impact of industrial waste on the environment.

The first phase of a study to reassess the strategy with respect to industrial effluent discharge with special reference to advanced technology treatment methods involved the identification of these problems. This study was undertaken in consultation with the 6 regional representatives of the Department of Water Affairs and Forestry who have continued contact with industries and are therefore capable of identifying and assessing the main problems in their areas. The recommendations from this study will be used as guidelines for future research into the water and waste-water management of industries.

Water economy at power stations

Dry-cooling technology has considerable application potential in a semi-arid country like South Africa. This is particulary true for the power generating field where, in future, there will perforce be greater reliance on coal fields remote from water sources. Although South Africa leads the world in the field of dry-cooled power generation, economical considerations necessitate improved understanding of the technical and environmental factors that affect the cost of the system. It is to this end that research funding in the field is maintained.

In this field of **Industrial Effluents** and **Water Economy at Power Stations** 41 projects were supported, of which 9 were completed and 10 commenced during the year.

Completed projects

Thermal feedback caused by dry cooling at power generating stations *(No 158) Eskom and Division of Earth, Marine and Atmospheric Science and Technology, CSIR*

Matimba is one of the largest dry-cooled power stations in the world. Its siting in the rural area of Ellisras afforded a unique opportunity to study how a major waste heat emitting industry would impact on an otherwise almost virgin environment, and this constituted the essence of this project.

Five field stations, installed near and at approximately 10 km distances around the power station site, automatically recorded the necessary meteorological data. After 6 years of data collection, which had started before construction commenced, the station was still not yet fully operational as only 2 of the 6 generators were in simultaneous operation at any time. Statistical analysis of the available information revealed that no significant increase in the downwind temperatures was verifiable at the distant field stations. The project was, therefore, terminated despite the possibility that a detectable heat island effect may yet result when the station is eventually fully operational.

Cost: R288 168
Term: 1984-1990

Pelletisation in upflow anaerobic sludge bed (UASB) systems *(No 249) Department of Civil Engineering, University of Cape Town*

The following aspects of UASB were researched during this project:

- **The development of a hypothesis for pelletisation** - Extensive experimental investigation implicated an extracellular polypeptide polymer generated by one of the methanogenic bacteria
- **Kinetic model** - The hypothesis formed the basis for the development of a kinetic model simulating COD, SCFA (fatty acids with short chains), organic N and NH_3-N
- **H_2CO_3- alkalinity and pH control** - It was shown that with recycle the UASB can generate sufficient alkalinity
- **H_2CO_3- alkalinity measurement** - A 5-point titration method was developed for this and is available under separate cover.

Cost: R253 190
Term: 1988-1991

Effect of biocorrosion in water systems

(No 253) Division of Water Technology, CSIR

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

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

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

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

Cost: R150 000
Term: 1988-1991

Abattoir solid waste: Development and implementation of a treatment system

(No 277) South African Abattoir Corporation

The disposal of solid waste from abattoirs is experiencing ever-increasing resistance from environmentalists and environmental bodies. Alternative disposal methods are restricted to incineration, feed reclamation and composting for agricultural utilisation. The first 2 methods have the disadvantage of high cost and under-developed technology. Composting shows most promise, but efforts to compost solid abattoir waste have in the past failed, despite this type of waste having a high biological degradability coefficient.

The technology of mechanised composting applied over the past 15 years has indicated the importance of bulking material, carbon:nitrogen ratio, porosity and structural integrity, while the aerated static pile technique results in accelerated decomposition while eliminating the need for frequent turning of piles. The end-product thus obtained is dry, stable and disinfected, with valuable agricultural properties.

A number of experimental runs were conducted at the Kimberley abattoir to determine the compostability of paunch contents. By making use of bulking materials available on the premises (kraal manure, grass and wood shavings) mixtures could be prepared which complied with the chemical and physical requirements of composting by means of forced aeration. The results indicated that the process was relatively impervious to change in the composition of the runs. All the runs resulted in an acceptable end-product in terms of aesthetic appearance, pasteurisation, stabilisation, germination support and crop growth. Design criteria for full-scale operation are given in the report.

Cost: R33 000
Term: 1989-1990

Interaction between the atmospheric boundary layer and the natural-draught cooling towers at Kendal Power Station

(No 284) Eskom and Division of Earth, Marine and Atmospheric Science and Technology, CSIR

To promote effective design, the project aimed to establish:

- The degree of entrainment of the stable boundary layer into a natural-draught dry-cooling tower
- The region of influence of the cooling tower under stable conditions as an indication of optimum inter-tower spacing.

The entrainment of the stable boundary layer into

the cooling tower, adversely impinging on its performance, could not be quantified with accuracy and the entrainments measured varied between 50% and 78%.

Temperature measurements revealed the region of influence of Cooling Tower No. 1 to extend to at least 270 m downwind of the tower. This suggests that under certain weather conditions the inter-tower spacings might not be sufficient to prevent plume entrainment from neighbouring cooling towers and tower efficiency could thus be detrimentally affected.

Due to the unfavourable meteorological conditions that prevailed during the test, a recommendation to repeat the experiment was made and accepted.

Cost: R126 000
Term: 1989-1991

Use of yeast biomass and yeast products to accumulate toxic and valuable heavy metals from waste water *(No 392) Department of Biochemistry and Microbiology, Rhodes University*

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

The accumulation was adversely affected by high hydrogen ion concentrations, but not by moderate levels of alkaline-earth metal ions. Metal-laden biomass could be harvested from solution by ultrafiltration.

During further investigations yeast biomass was chemically modified to yield a dry, stable material that was found to be capable of accumulating a wide range of heavy metal ions, such as Cd^{2+}, Co^{2+}, Cu^{2+}, Hg^{2+}, Ag^{2+}, Fe^{3+}, Cr^{3+} and Pb^{+}. This granular biomass could be stored indefinitely in a dehydrated form and could be rehydrated again, when required.

Cost: R17 000
Term: 1991

Reassessment of the strategy with respect to industrial effluent discharge with special reference to advanced technology treatment methods: Phase I *(No 407) Pollution Research Group, University of Natal*

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

- **Mine waters from coal-mining areas** in the Witbank and Northern Natal areas (i.e. Transvaal and Natal Regions) and from gold-mining operations in the Highveld and Orange Free State Regions
- **Agricultural activities** - Effluents arising from agricultural activities and from industries related to these activities
- **Freshwater aquaculture** (Western and Eastern Cape regions)
- **Storm-water runoff** from e.g. feedlots and in urban areas from e.g. fertiliser plants etc.
- **Coloured effluents** - Colour in discharge waters from e.g. textile dyehouse operations (Natal Region)
- **Tanning industry**, including possible problems with new chemicals replacing salt in some areas.

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

Cost: R89 000
Term: 1991

Application of the anaerobic digestion/ ultrafiltration (ADUF) process to fruit processing effluent *(No 460) Membratek (Pty) Ltd*

A laboratory-scale study was undertaken to determine:

- The biodegradability of fruit processing effluent by means of mesophylic anaerobic digestion
- The ability of the ADUF system to cope with fruit processing effluents.

The flux values of the ultrafiltration unit could be maintained at 20 to 25 $l/m^2 \cdot h$ and fouling was never serious enough to cause decreased throughput.

At space load rates not exceeding 1,5 kg $COD/m^3 \cdot d$, COD reductions of more than 95% could be obtained to yield final treated effluent COD values as low as 50 mg/*l*. Operation at higher space load rates proved to be problematic. It was, nevertheless, concluded that the effluent is readily biodegradable, although high load rates could not be obtained. Further studies to obtain more economical space load rates were recommended.

Cost: R35 500
Term: 1992

New projects

Interaction between the boundary layer and Kendal Power Station natural-draught dry-cooling tower *(No 452) Division of Earth, Marine and Atmospheric Science and Technology, CSIR and Eskom*

This 1-year project is a repeat of an earlier project (No 284) which, due to unfavourable weather conditions, allowed but limited observations to be made and thus yielded somewhat inconclusive results. The project aim, as before, is:

- To obtain an indication of optimum inter-tower spacing by determining the region of influence of the cooling tower under stable conditions
- In aid of effective tower design, to establish the degree of entrainment of the stable boundary layer into a natural-draught dry-cooling tower.

Development of procedures to assess whole effluent toxicity *(No 453) Division of Water Technology, CSIR*

This 2-year project addresses an aspect of toxicity assessment necessary for the successful application of the receiving water quality objectives approach to water quality management of the Department of Water Affairs and Forestry. It aims to:

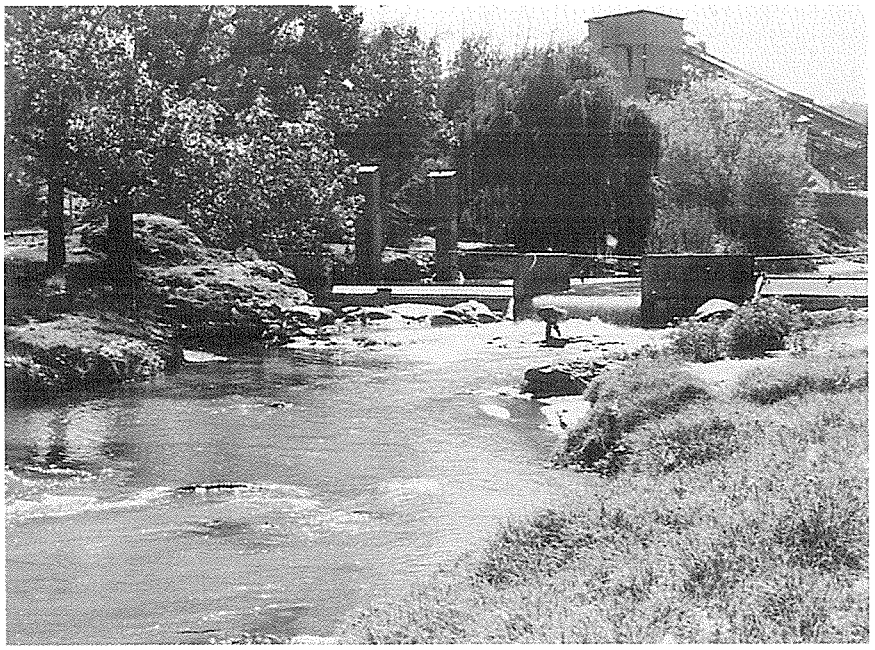
- Establish a set of toxicity testing procedures to quantify whole effluent toxicity
- Develop procedures to evaluate and interpret results
- Establish guidelines for determining acceptable dilution values.

Anaerobic digestion of dairy factory effluents *(No 455) Irene Animal Production Institute, Agricultural Research Council*

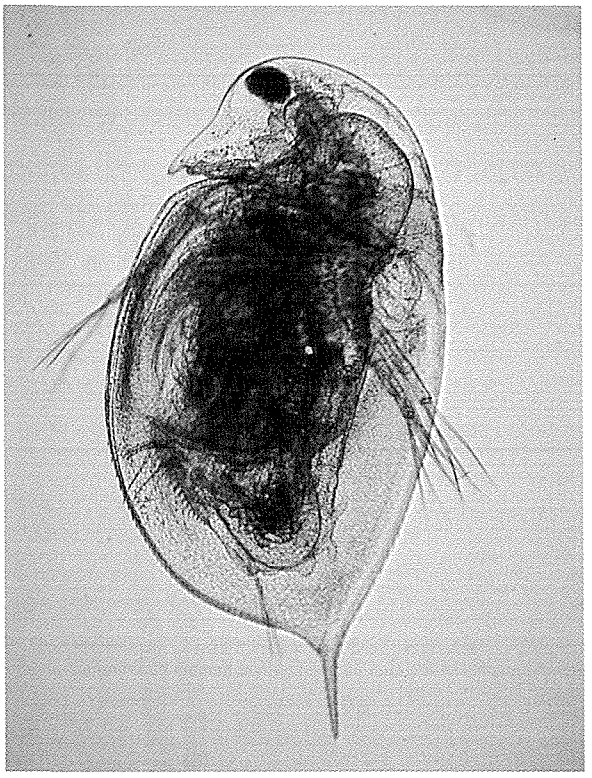
The aims of the study are to:

- Survey the South African dairy industry to determine the present situation, requirements and need for effluent treatment
- Investigate the use of anaerobic digestion of dairy waste water
- Investigate the use of the anaerobic digestion/ultrafiltration (ADUF) system for the treatment of dairy waste water
- Investigate the possible development of the ADUF system into an efficient process for the treatment of dairy waste water.

One of the river water samples evaluated for toxicity was collected at this spot



Right: The Daphnia pulex *used for lethality tests*



Regional treatment of textile and industrial effluents *(No 456) Department of Chemical Engineering, University of Natal*

The objectives of the 3-year project are to:

- Determine the fate of textile and specific industrial effluents through sewage treatment processes
- Determine the effect of specific textile and industrial effluents on sewage treatment processes
- Investigate the addition of polymers, flocculants or adsorbents at a sewage works to improve the removal of specific classes of pollutants
- Investigate the addition of processes within a sewage works to improve the removal of specific pollutants
- Investigate the treatment of specific concentrates which have been segregated at source and transported to the sewage works.

Monitoring and optimisation study of high-rate biofiltration (HRBF), aerobic biological treatment processes for tannery and fellmongery waste water *(No 457) LIRI Technologies*

Initially the aim of this 2-year programme is to monitor and optimise the HRBF as an alternative treatment process for tannery effluents. Investigations into the effects of nutrient supplementation and flow control are to be undertaken.

The ultimate aim is to develop a closed waste/waste-water biological treatment system to manage tannery wastes with minimal liquid, gaseous and solid wastes for disposal. Possible treatment processes include algal treatment, anaerobic digestion and microfiltration techniques and these would complement work already being undertaken by the Department of Biotechnology and Microbiology at Rhodes University.

Development of an expert systems approach to water management in the fruit and vegetable processing industry *(No 458) SRK Inc.*

The processing of fruits and vegetables for freezing and canning is a water-intensive operation generating heavy hydraulic and organic effluent loadings. It has been amply demonstrated that a great deal of scope exists within the industry in South Africa for improving conservation of water and reducing effluent loads, but the wide variety of commodities processed, together with other factors, make these measures difficult to implement consistently.

The aims of the 2-year project are to develop and implement a proactive and interactive water management system as a practicable and effective tool within the industry.

Laboratory-scale treatment of acetic acid effluent by the anaerobic digestion/ultrafiltration (ADUF) process *(No 459) Membratek (Pty) Ltd*

A sugar producer in Durban is considering biodegradation as an alternative to the currently used marine disposal of the 2,9 $Ml \cdot d^{-1}$ of acetic acid effluent emanating from their plant. Although acetic acid is easily digested, the presence of furfural and bagasse could prove to be inhibitive to anaerobic digestion. Furfural is known to have biocidal properties, whereas bagasse does not decompose readily. The effect of these substances on the activity of the anaerobic microbes needs investigation.

The 6-month project aims to determine the applicability of the ADUF process for the treatment of acetic acid effluent by performing laboratory studies to determine the process parameters and limits, process economics and data required for scale-up to process plant level.

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*

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

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

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

- Identify cellular components responsible for metal accumulation by yeasts
- Determine the efficiency and kinetics of heavy metal accumulation by yeast cells at varying metal-ion concentrations
- Use yeast biomass systems for the removal of metals from selected industrial waste waters.

Saving of water with air-cooled heat exchangers *(No 478) Department of Mechanical Engineering, University of Stellenbosch and Eskom*

Because they require little or no cooling water, air-cooled heat exchangers are finding increasing application in South African power plants, petrochemical and process industries and mines. A previous study to develop performance evaluating computer programs for such heat exchangers revealed certain system characteristics to have a major influence on the performance of these systems, particularly under adverse meteorological conditions.

Accordingly, the current multi-faceted 3-year project aims at an in-depth study of:

- Ineffective dephlegmator operation and maldistribution of steam flow which may cause non-condensables to collect in critical zones in the heat exchanger
- The interaction between wind and atmospheric inversion which in turn affects cooling tower performance
- Maldistribution of air flow through heat exchangers and plume air recirculation which reduces heat transfer performance
- Factors affecting fan performance and fan blade durability.

Biotechnological approach to the removal of organics from saline effluents

(No 495) Department of Biochemistry and Microbiology, Rhodes University

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

- For the treatment of saline effluents to remove organics and dissolved nutrients (NPK)
- For the co-disposal of organic solids such as secondary treatment sludges and other refractory organics
- To evaluate the production of algal products of economic value by the selective culture of halophilic micro-algae such as *Dunaliella salina* in high-salinity brines and *Spirulina* sp. in alkaline brine wastes
- To establish a utility for brine wastes based on saline algal biotechnology.

Harvesting of the alga Spirulina *from Western Tanning's saline effluent pond*

Research projects

Completed

- **158** Thermal feedback caused by dry cooling at power generating stations (Eskom and CSIR - Division of Earth, Marine and Atmospheric Science and Technology)
- **249** Pelletisation in upflow anaerobic sludge bed (UASB) systems (University of Cape Town-Department of Civil Engineering)
- **253** Effect of biocorrosion in water systems (CSIR - Division of Water Technology)
- **276** Biological techniques for the treatment of pulp bleaching effluents (Sappi Management Services) (Confidential - no report)
- **277** Abattoir solid waste: Development and implementation of a treatment system (South African Abattoir Corporation)
- **284** Interaction between the atmospheric boundary layer and the natural-draught cooling towers at Kendal Power Station (Eskom and CSIR - Division of Earth, Marine and Atmospheric Science and Technology)
- **392** Use of yeast biomass and yeast products to accumulate toxic and valuable heavy metals from waste water (Rhodes University - Department of Biochemistry and Microbiology)
- **407** Reassessment of the strategy with respect to industrial effluent discharge with special reference to advanced technology treatment methods: Phase I (University of Natal - Department of Chemical Engineering, Pollution Research Group)
- **460** Application of the anaerobic digestion/ ultrafiltration (ADUF) process to fruit processing effluent (Membratek (Pty) Ltd)

Current

- **161** Treatment of wool scouring effluents (University of Natal - Department of Chemical Engineering, SRK Inc. and Gubb and Inggs (Pty) Ltd)
- **239** Transfer of waste-water management technology to the meat processing industry (SRK Inc. and South African Abattoir Corporation)
- **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)
- **285** Evaluation of various factors affecting dry-wet cooling (Eskom and University of Stellenbosch - Bureau of Mechanical Engineering)
- **308** Recovery of water and chemicals from ion exchange regeneration effluents (University of Natal - Department of Chemical Engineering)
- **309** Phase diagrams of complex precipitants (University of Natal - Department of Chemical Engineering)
- **315** Utilisation of the fungus *Geotrichum* in waste water (University of Pretoria - Department of Chemical Engineering)
- **318** Optimisation of biofouling control programmes (University of Pretoria - Department of Microbiology)
- **322** Study on a mine water reclamation test plant (Chamber of Mines Research Organisation)
- **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)
- **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)
- **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)
- **398** Degradation of mortar linings and concrete by micro-organisms in industrial water systems (Eskom - Engineering Investigations Division)
- **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)

Research projects

New

- **452** Interaction between the boundary layer and Kendal Power Station natural-draught dry-cooling tower (CSIR - Division of Earth, Marine and Atmospheric Science and Technology and Eskom)
- **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 Unit)
- **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 Inc.)
- **459** Laboratory-scale treatment of acetic acid effluent by the anaerobic digestion/ultrafiltration (ADUF) process (Membratek (Pty) Ltd)
- **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)
- **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)

10 Drinking water

The user is entitled to water containing no harmful substances or pathogenic organisms, and which is aesthetically acceptable

There is a noticeable tendency world-wide, mainly under pressure from the authorities, to supply an increasingly higher quality water to an already critical water consumer.

The surface water sources in South Africa are to an ever-increasing degree being subjected to pollution and this makes great demands on the water supplier to provide water which complies with prescribed quality criteria, in a cost-effective manner.

It is for this reason that the WRC undertakes several research activities relating to drinking water. The global aim of the research is to gather information on all aspects of drinking-water quality and to support the development of the necessary technology for water treatment in order that water which does not constitute a health risk and meets the required quality criteria, can be sold to the user at a reasonable price.

In the light of the above, the WRC supports several research programmes and 39 projects (of which 2 were completed and 15 are new) in the following fields of research:

Water treatment and reclamation

In order to place future research in the field of water treatment and reclamation on a sure footing and to manage it more purposefully, the Co-ordinating Committee for Research on Potable Water Treatment completed and released a Strategic Research Plan (See full description under **Chapter 1**). As the aims of this plan are directed at the short- and medium-term future, they provide an early indication for research organisations of what are regarded as the national priorities in this field.

Drinking-water quality and health aspects

As drinking water is essential for man the quality thereof has to be such that it does not in any way pose a health risk. The user is entitled to a high-quality water which can, in general, be described as water containing no harmful substances or pathogenic organisms, and which is aesthetically acceptable. It has to be clear and colourless and possess an acceptable odour and taste. Drinking water therefore has to come up to certain standards which is the reason why drinking-water quality guidelines or standards exist world-wide and in South Africa.

Urban and rural water supply

The wasteful use of potable water is, under a policy, aggressively discouraged at all levels of supply and one of the most visible facets of this policy is the common domestic water meter. Rather less visible but just as important, is the continuing activity in underground leak detection whereby vast amounts of leaking water can be detected before any signs of leakage appear on the surface.

Although metering of water is not a new concept, some innovations are being applied in this direction. The first innovation concerns the development of a water-meter body made of plastics material, instead of the more usual brass which has an attractive scrap value. Examples of plastics bodies in the past have not proven a great success because previously no real and urgent need had been identified to act as a motivator or driving force. Vandalism in South Africa has caused this situation to change, and instead of waiting for overseas developments to be adopted, the South African industry is now pursuing this avenue in-house, with nominal financial assistance from the WRC.

To enable households to budget more accurately for their water service various options for the prepayment of water are being investigated. Concerning a second innovation Eskom is looking at the possibility of incorporating a second channel into their energy dispenser so that water consumption can also be recorded by the same instrument.

The use of plastics materials to pipe potable water has shown a marked increase in recent years, yet very little is actually known about the long-term performance of these materials, especially when the situation is complicated by the use of these materials for hot water supplies.

Completed projects

Comparative study on chlorine dioxide and other oxidants in potable water treatment *(No 247) Western Transvaal Regional Water Company; Division of Water Technology, CSIR and Floccotan (Pty) Ltd*

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

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

Cost: R182 335
Term: 1988-1990

Taste and odour forming micro-organisms occurring in South African surface waters *(No 320) Division of Water Technology, CSIR*

Fifty-four dams and pans were inspected and the presence of taste and odour problems was determined in 32% of the cases. All affected water bodies displayed algal blooms, 90% of which was dominated by *Microcystis*. The substances imparting odour to the water, generally described as earthy or decaying vegetation, were geosmin, sulphur compounds, and pyrazine and anisole derivatives. Methylisoborneol, commonly associated with odours in water overseas, was not found during this survey.

Options scanned for taste and odour removal included coagulation/sedimentation, coagulation/flotation, activated carbon adsorption and oxidation (chlorine, chlorine dioxide, hydrogen peroxide, ozone, peroxone). Carbon adsorption, ozone and peroxone were selected as the most appropriate methods for the successful removal of taste and odour from water. The minimum dosages necessary for complete removal of different concentrations of selected nuisance substances were experimentally estimated.

Cost: R265 000
Term: 1990-1992

Mrs A Wnorowski of the DWT, CSIR shown sampling surface waters for the detection of micro-organisms causing tastes and odours

New projects

Microbial corrosion of common piping materials in the PWV area (No 432) Division of Materials Science and Technology, CSIR

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

The aim of this 2-year project would be to gain a better understanding of the failure mechanisms of potable water pipes using a multidisciplinary approach involving microbiological, metallurgical and chemical studies. This will provide guidelines for materials selection and recommending remedial and/or preventative measures if microbially induced corrosion proves to be a widespread problem. Information gained from the project would ultimately be of benefit to all users and suppliers of water.

The inside of a potable water pipe which is heavily biofouled. Bacterial tubercles are evident

Evaluating the long-term use of polypropylene for hot- and cold-water piping (No 434) Division of Materials Science and Technology, CSIR

The recent global swing to the use of plastics materials has not only established plastic pipes as a serious contender but has also highlighted certain weaknesses, mostly pertaining to the need for care when storing, handling, installing and manufacturing the pipes.

Despite widespread use of polypropylene pipes, little is known about their long-term behaviour and ageing tendencies, especially in hot water applications. Because of these uncertainties, many authorities have expressed reservations regarding the use of polypropylene pipes. This implies a need for a sound scientific investigation of the long-term performance properties of polypropylene to provide the relevant performance data on which criteria for a standard specification could be based and to develop appropriate test procedures for quality control that will guarantee satisfactory performance over the required service life.

The project will be executed over 18 months.

Removal of colour from Cape waters using ozonation and ultrafiltration (No 445) Stewart Scott Inc.

Cape South Coast raw water supplies are frequently discoloured by humic substances. Colour removal is, therefore, a major consideration in the selection of the water treatment system used.

Treatment usually consists of alum flocculation at a pH of 5 to 6, where colour adsorption is most effective. In higher colour ranges alum dosages tend to be higher than necessary for turbidity removal and operating problems may arise. Hence there is a need for alternative methods to remove colour.

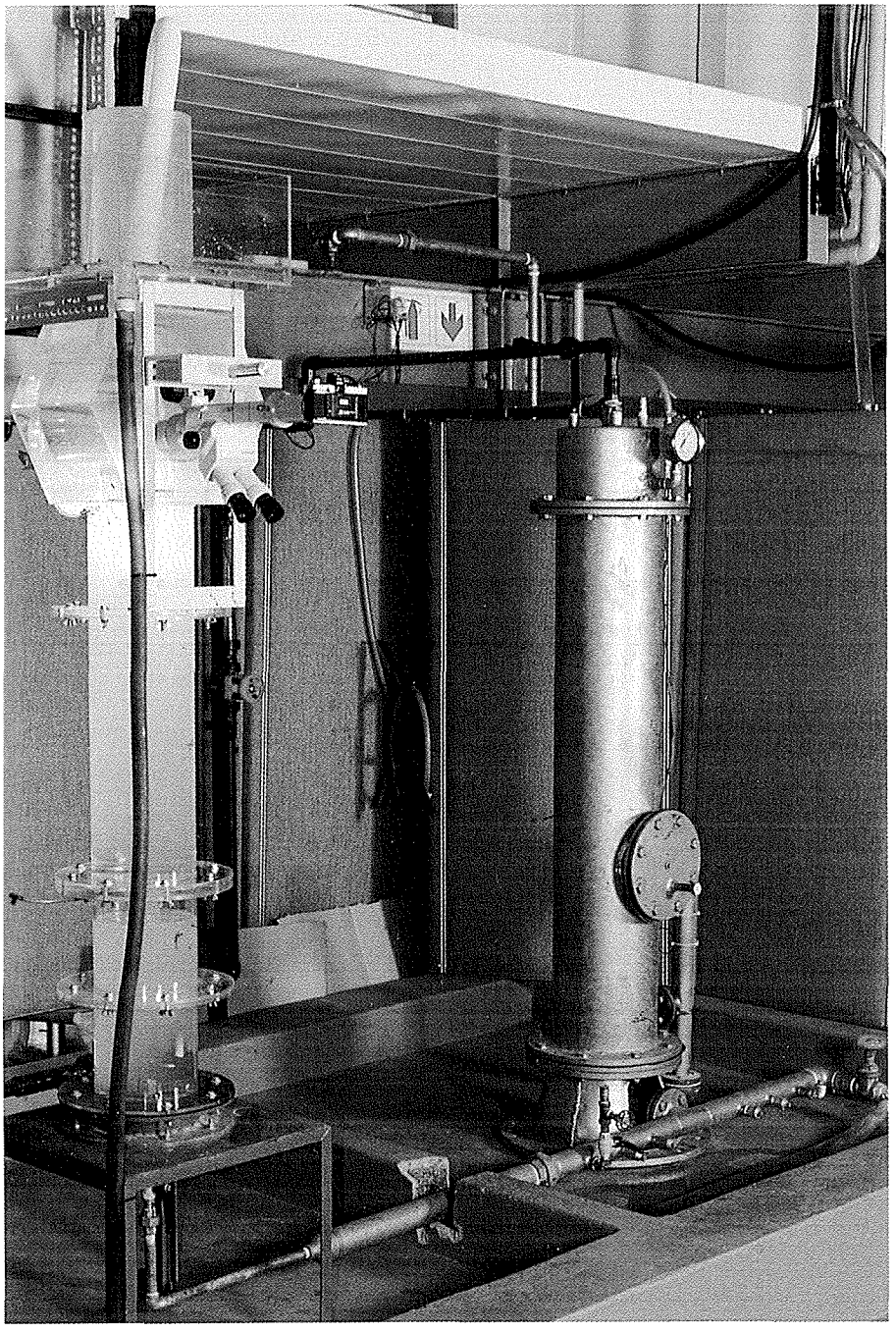
The aim of the present 2-year study is a comparative evaluation of ozonation and ultrafiltration unit processes for the removal of natural colour from selected Southern Cape waters.

Improvement of injection nozzles for dissolved air flotation (No 448) Department of Civil Engineering, Rand Afrikaans University

The key to successful flotation for water and effluent purification is to be found, among others, in the size of the bubbles produced. Too large bubbles rise too rapidly without entrainment of small particles, while too small bubbles rise too slowly to effect phase separation within a reasonable

time. The purpose of this 2-year study is to identify the factors which determine bubble size distribution. The following factors which are believed to play a role, will be systematically tested: temperature, pressure loss over the nozzle, diameter and length of the nozzle channel, outflow speed, presence of solid shields in front of the nozzle and the presence of substances influencing the development of the foam layer.

Apparatus for testing injection nozzles for dissolved air flotation



Evaluation of non-conventional disinfection technologies for small water systems

(No 449) Division of Water Technology, CSIR

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

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

Performance criteria for package water treatment plants *(No 450) Umgeni Water and Pollution Research Group, University of Natal*

The supply of potable water to rural and peri-urban areas is a national development priority. Package or preconstructed plants have a major role to play in the rapid and decentralised provision of water.

At present there is a reluctance for consultants to recommend, and water supply authorities to install, such equipment because of the lack of authoritative evaluation and long-term testing of this type of water treatment plant.

The objectives of this 3-year project are therefore to:

- Establish a set of performance criteria for package water treatment plants by consulting various sources of expertise
- Develop a standard testing methodology from these criteria for the impartial evaluation of package plants
- Evaluate a number of package plant technologies against the performance criteria using the standard test procedure.

Occurrence of protozoan parasites in South African drinking water (No 451)

Division of Water Technology, CSIR

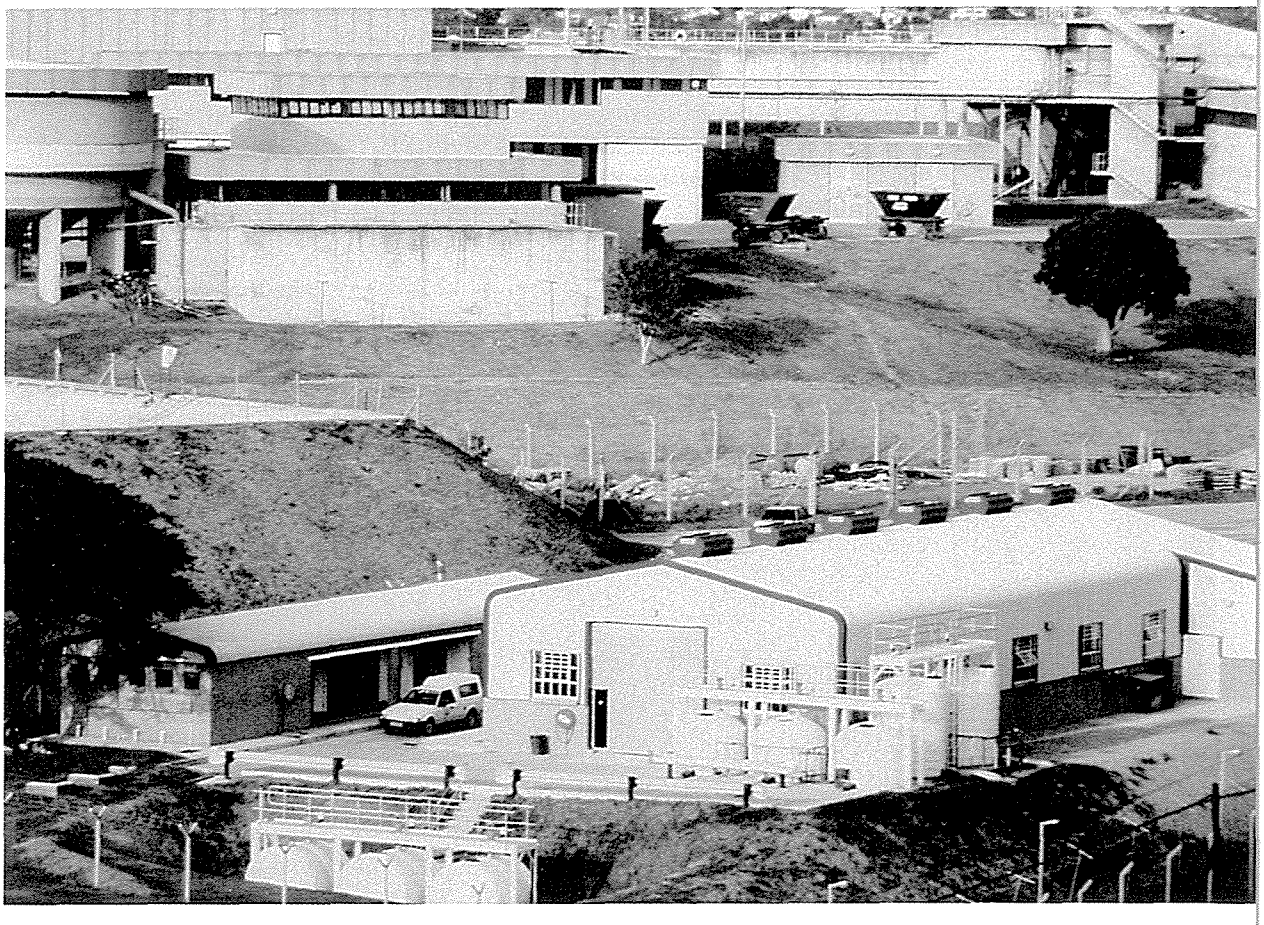
The parasites *Giardia* and *Cryptosporidium* are recognised causes of diarrhoeal illness in man. *Cryptosporidium* has been found to be the responsible agent for up to 23% of diarrhoeal cases world-wide, while *Giardia* prevalence in the population has been indicated to be as high as 24%. Contaminated water has been implicated in many parasitic diarrhoeal epidemics.

The major aims of this 3-year study are to:

- Develop, evaluate and apply concentration and detection methods for the water-borne protozoan parasites
- Study the occurrence of protozoan parasites in South African source and drinking waters
- Evaluate various treatment processes to determine their efficacy in the removal of protozoan cysts
- Evaluate commonly used indicator organisms for their ability to indicate possible contamination by protozoan parasites.

Studies on microbiological drinking-water quality guidelines (No 469) Division of Water Technology, CSIR

Rapid national and international changes in the approach to water quality, new technological advances and socio-economic conditions create the need to re-evaluate and, if necessary, revise microbiological guidelines for drinking-water quality. This 1-year study will conduct an in-depth investigation of available data on guidelines and standards which are utilised in different parts of the world, including both first and third-world situations. Upon accumulation of this information, the present situation in South Africa and the applicability of various guideline scenarios will be investigated. A working group, representing various authorities, universities and other concerned bodies will be established to use the research report as a base for brainstorming and decision-making in connection with microbiological drinking-water quality guidelines.



Outside view of the Wiggins process evaluation facility with Wiggins Waterworks in the background

Application of health risk assessment techniques to microbial monitoring data

(No 470) Division of Water Technology, CSIR

The task of formulating water quality criteria and guidelines for the protection of public health has always been complicated by the difficulties of relating levels of micro-organisms in water to health effects in the exposed population. Risk assessment aims to provide a quantitative estimate of the probability of illness associated with environmental exposure to hazardous substances, including infectious agents. The primary aim of this 1-year project is to investigate the usefulness of microbial risk assessment techniques in the South African context. Secondary aims are to assess the usefulness of data collected by current microbial monitoring programmes; to estimate the minimum levels of risk detectable using the volumes of water currently analysed; and to evaluate the usefulness and implications of health risk assessment for the formulation of microbiological guidelines for water quality.

Optimisation of mine service water disinfection *(No 471) Division of Water Utilisation, Department of Chemical and Environmental Engineering, University of Pretoria*

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

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

Various filter media are being investigated in order to determine standards

Characterisation of South African media for sand filtration *(No 472) Department of Civil Engineering, Rand Afrikaans University*

No uniform, generally accepted method of media specification exists for rapid gravity filtration in South Africa. This 2-year study characterises local, commercial filter sand and anthracite with regard to durability, particle size distribution, sphericity, solubility under acid and alkaline conditions and density. The media are rated according to international specifications in order to make recommendations for a possible local specification for filter media.

Magnetite as flocculant in water purification processes *(No 473) Division of Water Utilisation, Department of Chemical and Environmental Engineering, University of Pretoria*

Magnetite is a mineral which in a powdered form can be utilised as a relatively inert reusable flocculant in water purification processes. Due to the magnetisability/demagnitisability of magnetite it can be suspended in a demagnetised form until destabilisation and flocculation of impurities are completed. The magnetite is magnetised thereafter so that individual particles adhere to one another magnetically and form heavy flocs which settle more that tenfold faster than flocs formed by conventional coagulation and flocculation. The advantages are that fewer coagulants and a smaller settling tank are needed. In the literature it is reported that magnetite is successfully applied to remove colour, turbidity, phosphates, heavy metals, bacteria, viruses and COD from water.

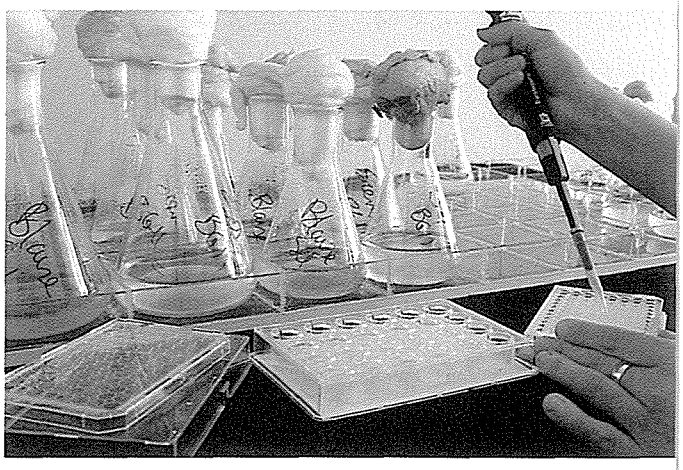
The purpose of this 1-year research project is to investigate the application of the large quantities of magnetite available in South Africa in water purification processes.

Optimisation of the Rand Water Board system *(No 488) Water Systems Research Group, University of the Witwatersrand*

The Rand Water Board operates the largest bulk water supply works to urban areas in Africa. The reliability and cost of water to the consumer are strongly influenced by the source and quality of water, the storage in reservoirs and the demand pattern. Guidelines have been developed over the years for minimising costs and achieving their objectives in the most efficient manner. These need to be reviewed in the light of changes which are currently occurring in the country.

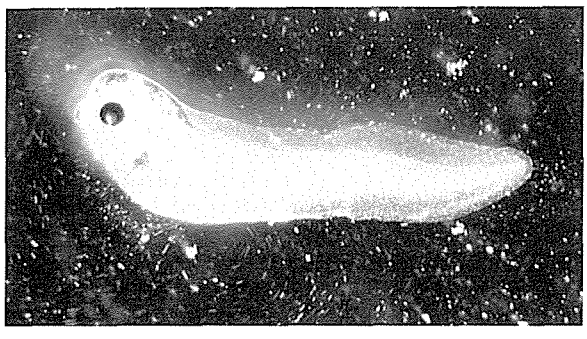
The improvement of the provision of services in townships is currently a high priority, although consultations have indicated that the availability of current demand patterns, particularly for low-income areas, is limited.

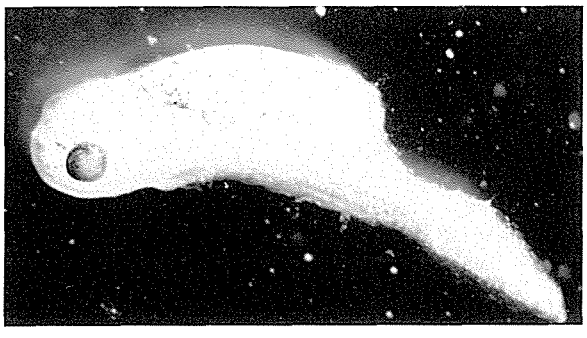
The results of this 2-year research project will be equally applicable to other water boards and local authorities in South Africa.

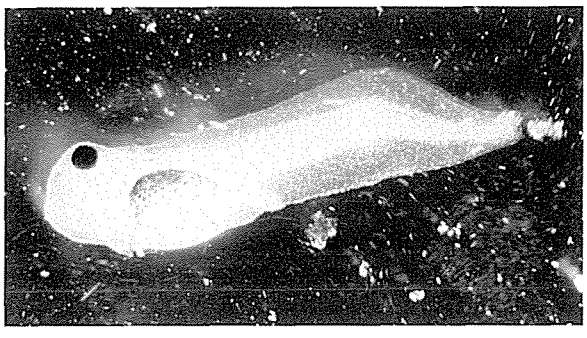


Setting up the algal test to bioassay a water sample for low toxicity levels

Xenopus *tadpoles showing spinal deformities resulting from low toxin levels in the water*







Development of procedures for the control of unaccounted-for water in water distribution systems and for the reduction of water loss *(No 489) De Leuw Cather Inc.*

Previously it has been stated that in the longer term, the availability of water could be the most serious factor threatening the growth of South Africa.

Unaccounted-for water (UAW) for the Republic is estimated conservatively at 20%, equivalent to 800 million m^3 annually. This exceeds the total demand of Johannesburg, Cape Town and Durban together. This water is also the highest quality, purified water delivered to the point of consumption and is therefore also the most expensive water. Unfortunately there is little evidence of co-ordination of effort to identify and quantify the problem and to seek solutions. This 4-year project therefore aims to establish the status quo of UAW in the Republic and to determine the approaches currently employed to identify and reduce the magnitude of the various components of UAW.

Guide for water purification and plant design: Phases 2 and 3 *(No 504) FA van Duuren*

The objective of this 3-year project is to facilitate the optimal, most economical water treatment works by providing a design manual based on water quality considerations, processes and operations for predominantly South African application. Such a manual would be used by design engineers, post-graduate students, planners, and by authorities involved in the control, management and operation of water purification works.

Research projects

Completed

- **247** Comparative study on chlorine dioxide and other oxidants in potable water treatment (Western Transvaal Regional Water Company; CSIR - Division of Water Technology and Floccotan (Pty) Ltd)
- **320** Taste and odour forming micro-organisms occurring in South African surface waters (CSIR - Division of Water Technology)

Current

- **254** Effects of varying water quality on the corrosion of different pipe materials in the PWV/Klerksdorp areas (CSIR - Division of Materials Science and Technology)
- **259** Effect of water quality and chemical composition on corrosivity in mild steel pipelines (Rand Water Board)
- **280** Evaluation of full-scale flotation-filtration and chlorine dioxide plants (OFS Gold Fields Water Board)
- **281** Effect of water quality on the effectiveness of chlorine dioxide in drinking-water treatment (Rand Water Board)
- **282** Development of a combination of sedimentation, flotation and sand filtration processes for water treatment (SEDIDAFF) (CSIR - Division of Water Technology)
- **321** Bacteriophages as water quality indicators (University of Pretoria - Department of Medical Virology)
- **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 bio-assaying of drinking and environmental waters in South Africa (CSIR - Division of Water Technology)
- **360** Mutagenicity of drinking water produced with conventional treatment methods of surface water sources (Rand Water Board)
- **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)
- **399** Determination of exposure to chemical residues in South African food and water intake (University of Cape Town - Department of Community Health)
- **400** Research into domestic meter replacement policy and testing of water meters (CSIR - Division of Building Technology)

New

- **432** Microbiological corrosion of common piping materials in the PWV 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** Removal of colour from Cape waters using ozonation and ultrafiltration (Stewart Scott Inc.)
- **448** Improvement of injection nozzels for dissolved air flotation (Rand Afrikaans University - Department of Civil Engineering)
- **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 - Pollution Research Group, Department of Chemical Engineering)
- **451** Occurrence of protozoan parasites in South African drinking water (CSIR - Division of Water Technology)
- **469** Studies on microbiological drinking-water quality guidelines (CSIR - Division of Water Technology)
- **470** Application of health risk assessment techniques to microbial monitoring data (CSIR - Division of Water Technology)
- **471** Optimisation of mine service water disinfection (University of Pretoria - Division of Water Utilisation, Department of Chemical and Environmental Engineering)
- **472** Characterisation of South African media for sand filtration (Rand Afrikaans University - Department of Civil Engineering)
- **473** Magnetite as flocculant in water purification processes (University of Pretoria - Division of Water Utilisation, Department of Chemical and Environmental Engineering)
- **488** Optimisation of the Rand Water Board 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)

11 Membrane technology

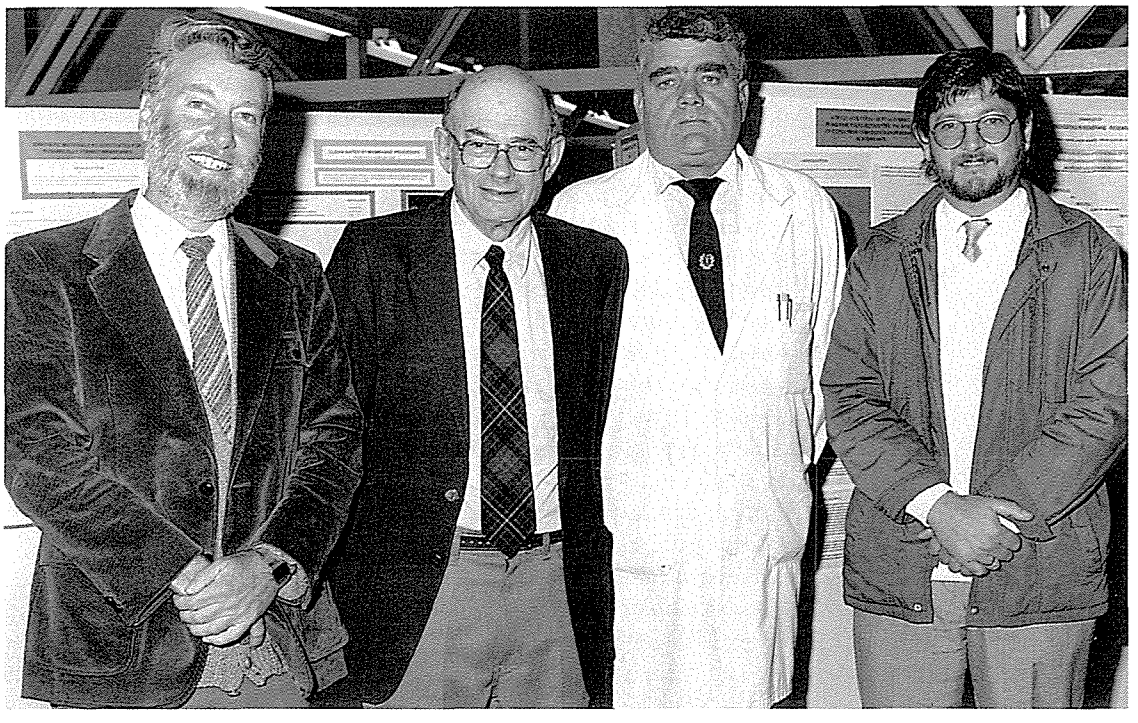
Membrane processes are being used to an increasing extent in the RSA to provide purified water from brackish or sea water, to fractionate and concentrate proteins and foodstuffs and to clarify fruit juice, wine and beer. Toxic and hazardous heavy metals are also removed from effluents originating from mining and industrial activities.

Several years ago a local membrane manufacturing industry was established by Membratek (Pty) Ltd and WRC-funded research has resulted in the development and application of a number of novel membranes and membrane systems. During June 1992 Membratek formed a joint venture company with Debex (Pty) Ltd (a subsidiary of the De Beers group), called Debex Desalination (Pty) Ltd with the main objective of strengthening existing local desalination technology in respect of the availability of a range of products as well as technical support. Debex Desalination's broader resource base enables it to offer improved technical and commercial assistance and security on large turn-key desalination projects. All projects not directly related to desalination will still be the responsibility of Membratek.

A specialised international conference on "Membrane Technology in Waste-water Management" was held in Cape Town during March 1992. The conference was organised by the Membrane Technology Division (MTD) of the Water Institute of Southern Africa (WISA) under the auspices of

Historic occasion

Prof Sidney Loeb paid a courtesy visit to the Institute for Polymer Science (IPS) in 1992. He was a student of Prof S Sourirajan (formerly of the National Research Council of Canada in Ottawa) with whom he developed the first synthetic reverse osmosis membranes in the late 1950s. Dr Derik Pienaar was the first person to do research on cellulose acetate membranes in South Africa and Dr Ed Jacobs developed the first tubular cellulose acetate membranes at IPS.



Left to right: Dr Ron Sanderson (Institute for Polymer Science, University of Stellenbosch), Prof Sidney Loeb (Professor Emeritus, Department of Chemical Engineering, Ben Gurion University, Beer Sheva, Israel), Dr Derik Pienaar (Department of Chemistry, University of Stellenbosch) and Dr Ed Jacobs (Institute for Polymer Science, University of Stellenbosch)

the International Association on Water Pollution Research and Control (IAWPRC), now the International Association on Water Quality (IAWQ). The presidential address was delivered by Prof Peter Grau, President of the IAWPRC, and 3 keynote addresses were given by eminent overseas membrane experts. In total 34 papers, covering all aspects of membrane technology, were delivered by local and overseas research workers and a number of posters were displayed.

During 1992 the WRC supported 23 research projects in the field of membrane technology, of which 5 were completed and 5 commenced. Funds for these projects were made available to the Universities of Stellenbosch, Natal, and Potchefstroom, the CSIR's Division of Water Technology, the Chamber of Mines Research Organisation (COMRO) and Membratek (Pty) Ltd.

Completed projects

Development of polymers for the formation of dynamic membranes and the evaluation thereof for the treatment of industrial effluents *(No 187) Department of Chemical Engineering, University of Natal, Institute for Polymer Science, University of Stellenbosch and Division of Water Technology, CSIR*

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

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

Cost: R524 851
Term: 1986-1988

Feasibility of reverse osmosis for water reclamation on large scale *(No 192) Municipality of Port Elizabeth, Division of Water Technology, CSIR and Membratek (Pty) Ltd*

A previous pilot-scale investigation revealed the reverse osmosis process capable of producing potable water from a sewage works tertiary effluent. This motivated the installation of a 400 m^3/d tubular reverse osmosis (RO) plant at the Fishwater Flats Water Reclamation Works in Port Elizabeth.

Operation of the plant for 11 621 h, at a product recovery rate of 67,5% and an average salt rejection of 88,3%, revealed:

- Total cost of the RO product to be R1,86/k*l* (50% of which is due to maintenance and replacement of equipment)
- Membrane fouling to be adequately controllable even though the feed received no pretreatment other than rapid sand filtration
- Chemical quality of the RO product to be good, with the possible exception of the levels of ammoniacal nitrogen and phenols and organic pollution indicators.

The bacteriological quality of the RO product was not always entirely satisfactory, but could easily be rectified by adequate post-disinfection.

Cost: R639 778
Term: 1986-1991

Concentration of industrial effluents with sealed-cell electrodialysis *(No 246) Division of Water Technology, CSIR*

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

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

Cost: R134 500
Term: 1988-1990

Pilot-scale desalination of sea water by means of reverse osmosis *(No 345) Membratek (Pty) Ltd*

The desalination of sea water by reverse osmosis (RO) was investigated on a pilot-plant scale. Emphasis was placed on the selection of an efficient pretreatment regime. It was found that the use of a low-cost tubular ultrafiltration system, in combination with dual media and cartridge filtration, produced RO feedwater of excellent quality, irrespective of the raw sea-water quality.

Although fouling of the UF membranes was experienced, flux restoration could be effected with the aid of sponge balls. The quality of the product water from the single-stage RO unit was well within the recommended SABS limits for domestic supplies. No RO membrane fouling was observed.

Cost: R50 000
Term: 1990-1991

Investigation into the organic fouling of ion-exchange membranes *(No 396) Division of Water Technology, CSIR*

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

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

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

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

Cost: R50 000
Term: 1991

New projects

Feasibility study of membrane characterisation by electrochemical measurements and membrane optimisation with computational fluid mechanics *(No 431) Faculty of Engineering, Potchefstroom University for CHE*

Corrosion of metals may be characterised by the measurement of certain electrolyte properties on the surface of the metal and in peripheral border zones.

Similarly, sophisticated electrochemical impedance techniques may be used to characterise the electrolytic border zones on both sides of a membrane.

Aspects such as impedance, electrical resistance, capacitance and inductance will be measured and evaluated in relation to the values found in membrane flow situations. The fluid dynamics of membranes will be optimised with the aid of computational fluid mechanics.

The project will be executed over 1 year.

Reaction kinetics in a slurry precipitation and recycle reverse osmosis (SPARRO) seed reactor *(No 461) Chamber of Mines Research Organisation*

An earlier study revealed a constant flux for the membrane lifetime test (MLT) plant, as opposed to a declining flux for the slurry precipitation and recycle reverse osmosis (SPARRO) plant. This is ascribed to the difference in contact time of the mine water with slurry crystals in the seed reactor, prior to entering the respective reverse osmosis modules. Contact time for the MLT plant was 3 to 4 h and less than 1 min for the SPARRO plant.

To save capital costs on a full-scale plant it is necessary to minimise the seed reactor volume by optimising the contact time. This 1-year study will address the types and kinetics of the reactions occurring in the seed reactor.

Fluoro-carbon coating of ion-exchange membrane surfaces to overcome fouling and general scaling *(No 466) Eskom*

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

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

Development of an ultrafiltration pretreatment system for sea-water desalination by reverse osmosis *(No 467) Membratek (Pty) Ltd*

Desalination of sea water to produce potable water is becoming attractive for remote, coastal locations where water is scarce.

Extensive pretreatment of the raw sea water is required for the successful operation of reverse osmosis plants. Earlier studies have shown that problems of poor water quality, experienced with conventional pretreatment methods, may be resolved through ultrafiltration of the raw water.

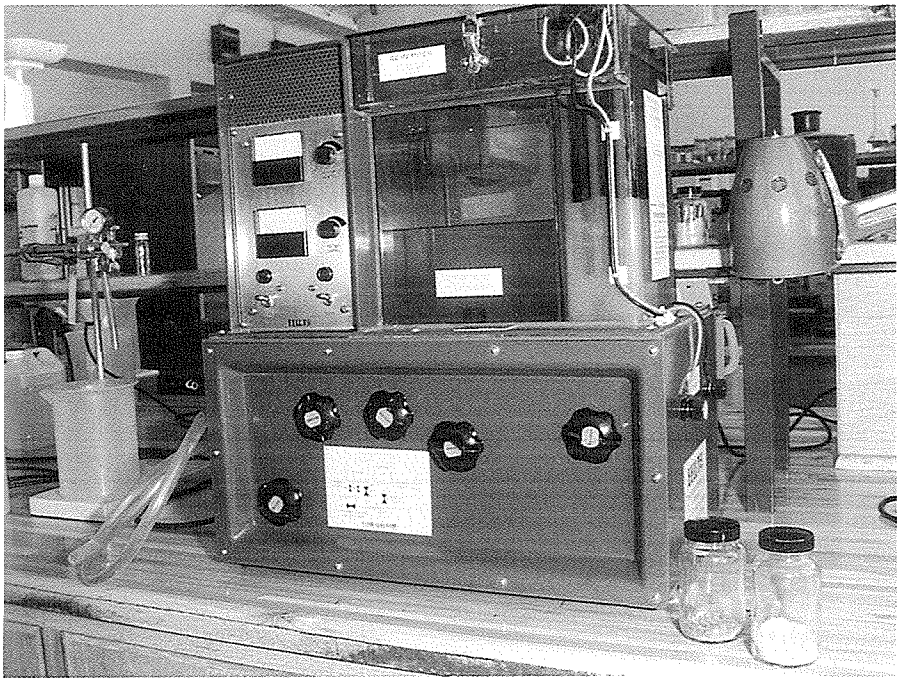
The aim of this 1-year project is to develop a suitable pilot-scale ultrafiltration system for the pretreatment of sea water before desalination by reverse osmosis. A cost-effective ultrafiltration pretreatment system will be developed which will optimise flow configurations and maximise flux values of locally-built sea-water desalination units.

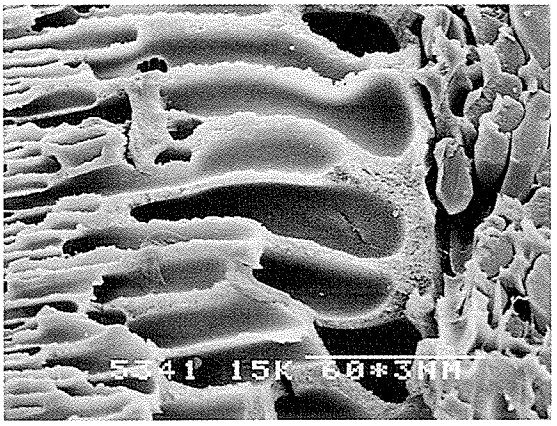
Feasibility study for the provision of point-source water by enhanced solar distillation *(No 468) Institute for Polymer Science, University of Stellenbosch*

In many arid, rural areas of the RSA there is a need for the large-scale production of potable water for human consumption and for stock watering. Solar-aided distillation of brackish water appears to offer the best possibility of achieving this. Hence research is being conducted into the use of novel fluorocarbon-coated membranes for the production of solar stills to provide desalted, decontaminated drinking water.

The primary aim of this 1-year project is to provide water to farmers with a water-production unit requiring minimal maintenance and negligible operating skills. Fluorocarbon-coated fabrics will not allow water to permeate, but will allow water vapour to pass through to create a novel solar still. Preheating the feed water and evaporative cooling of the distilled water will improve the operation of the still.

Electrolytic cell for the reclamation of metals from industrial effluents





Scanning electron micrograph of a section of a new tubular ultrafiltration membrane

Research projects

Completed

- **187** Development of polymers for the formation of dynamic membranes and the evaluation thereof for the treatment of industrial effluents (University of Natal - Department of Chemical Engineering, University of Stellenbosch - Institute for Polymer Science and CSIR - Division of Water Technology)
- **192** Feasibility of reverse osmosis for water reclamation on large scale (Municipality of Port Elizabeth, CSIR - Division of Water Technology and Membratek (Pty) Ltd)
- **246** Concentration of industrial effluents with sealed-cell electrodialysis (CSIR - Division of Water Technology)
- **345** Pilot-scale desalination of sea water by means of reverse osmosis (Membratek (Pty) Ltd)
- **396** Investigation into the organic fouling of ion-exchange membranes (CSIR - Division of Water Technology)

Current

- **172** Membrane development and fabrication for reverse osmosis and ultrafiltration (University of Stellenbosch - Institute for Polymer Science)
- **201** Treatment of inorganic brines and concentrates (University of Natal - Pollution Research Group)
- **219** Development of fixed and dynamic membrane systems for the treatment of brackish water and effluents (University of Stellenbosch - Institute for Polymer Science)
- **238** Design criteria for crossflow microfiltration (University of Natal - Pollution Research Group)
- **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 electro-plating 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)
- **362** Industrial application of membranes (University of Stellenbosch - Institute for Polymer Science)
- **387** Development and production of membrane systems (University of Stellenbosch - Institute for Polymer Science)
- **395** Development of a South African electrodialysis membrane system (CSIR - Division of Water Technology)
- **397** Evaluation of prototype capillary micro- and ultrafiltration membranes for industrial application (Membratek (Pty) Ltd)
- **402** Modelling of flow through porous membranes (University of Stellenbosch - Department of Applied Mathematics)

New

- **431** Feasibility study of membrane characterisation by electrochemical measurements and membrane optimisation with computational fluid mechanics (Potchefstroom University for CHE - Faculty of Engineering)
- **461** Reaction kinetics in a slurry precipitation and recycle reverse osmosis (SPARRO) seed reactor (Chamber of Mines Research Organisation)
- **466** Research into fluoro-carbon coating of ion-exchange membrane surfaces to overcome fouling and general scaling (Eskom)
- **467** Development of an ultrafiltration pretreatment system for sea-water desalination by reverse osmosis (Membratek (Pty) Ltd)
- **468** Feasibility study for the provision of point-source water by enhanced solar distillation (University of Stellenbosch - Institute for Polymer Science)

12 Conservation of aquatic ecosystems

Aquatic ecosystems can lay claim to its fair share of the dwindling water resources

The ever-increasing utilisation of the country's water resources necessitates that all user sectors be able to strongly motivate their own particular requirements as regards quantity and quality of water. Studies of aquatic ecosystems enable this sector to lay claim to its fair share of the dwindling water resources, based on scientific evidence.

This year saw the further consolidation of research in this field with another 9 projects commencing. This brings the number of projects to 18, with a total budget of over R2 million per year. It is probable that growth in this field has stabilised, with future projects replacing those that have been completed. As was the case in 1991, the new projects seek to eliminate gaps and weaknesses in existing knowledge and, by so doing, contributing to the establishment of water resource management guidelines for aquatic ecosystems.

The Co-ordinating Committee for Water Ecosystems Research met twice during the year. During the second meeting, which took the form of a two-day workshop, the masterplan/ guideline for research in aquatic ecosystems was finalised and accepted. The guidelines will be submitted to the WRC for formal acceptance in 1993.

Research within the multidisciplinary Kruger National Park Rivers Research Programme progressed well during the year. An annual meeting, followed by an intensive workshop that focused on the Sabie River, overviewed progress and identified various issues that require further attention such as, for instance, more detailed studies of invertebrate species sensitive to water quality changes.

The unusually low flows in the Sabie River provided an ideal opportunity to monitor, in real time, the effect of these flows on river fauna and flora. This *ad hoc* study was also funded by the WRC.

Completed project

Relationship between low flows and river fauna in the Letaba River *(No 293) Division of Water Technology, CSIR*

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

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

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

Cost: R322 000
Term: 1990-1992

New projects

Effects of catchment parameters and land use on runoff quality and estuary ecology *(No 418) Department of Zoology, University of Fort Hare*

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

This 4-year study will address this by looking at small catchments in the Eastern Cape area, and

comparing the effects of different land cover and land use on the quality of the water running off these catchments. In particular, the study will concentrate on the meiofauna, the interstitial fauna of the water course sediments. This fauna may be a very useful indicator of water quality, especially in seasonally flowing streams where moisture may only persist quite far below the surface during dry periods.

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

Rapid biological assessment of water quality impacts on streams and rivers

(No 422) Division of Water Technology, CSIR

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

Preliminary investigation of algal weeds in South African inland waters *(No 426)*

Department of Botany, University of Cape Town

Macro-algae cause considerable problems in the canals of many of South Africa's irrigation schemes. Dense growth of these algae can, for instance, reduce the flow of water in canals to less than 50% of the design flow. Much information has been documented about the nuisance value of these algae but very little is known about their ecological requirements. The aim of this 2-year project is to begin to develop management techniques for these algae via a detailed study of their habitats and other environmental factors which favour their growth.

Overview of the pesticide and heavy metal levels present in populations of the larger indigenous fish species of selected South African rivers *(No 428) Division of Water Technology, CSIR*

This 3-year project aims at integrating relevant scientific and management data with regard to the environmental impacts of heavy metals and pesticides in aquatic systems by:

- Integration of information from researchers studying 1 Western Cape and 5 Eastern Transvaal rivers
- Determination, as far as possible, of the sources of pesticide and heavy metal contamination
- Investigating contamination levels in selected tissues of selected fish from contaminated areas
- Establishing current levels of contamination
- Establishing a river surveillance protocol for pesticides and metals in rivers in collaboration with the Department of Water Affairs and Forestry and other researchers.

Diversity and productivity of biotic communities in relation to fresh-water inputs in Eastern Cape estuaries *(No 463) Department of Zoology, University of Port Elizabeth*

The main objective of this 2-year project is to develop a conceptual model for the assessment of the freshwater requirements of estuaries. Subsidiary objectives are to provide information on the quantity of freshwater necessary to create or maintain salinity gradient and to test the hypothesis that estuaries with homogeneous salinity have a lower biotic diversity than those with a distinct salinity gradient.

Developing an integrated approach to predicting the water use of riparian vegetation *(No 474) Department of Botany, University of the Witwatersrand*

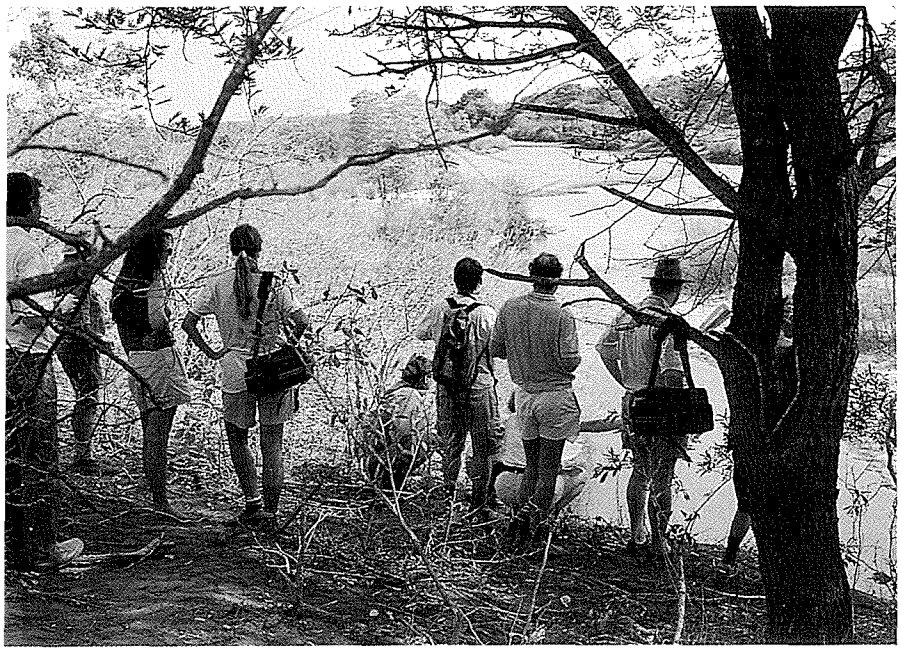
The natural riverine biota have, in recent years, come to be recognised as a legitimate demand sector in water resources allocation and management. One of the largest requirements for water within this sector is for the maintenance of the riparian vegetation. The aim of this 4-year project is to model the consumptive water use by vegetation under different river flow and meteorological conditions, and by so doing providing a means of predicting water use by this riverine community.

Development of a recirculating experimental stream system *(No 475) Institute for Water Research, Rhodes University*

One of the priority environmental issues in river ecosystem research and management is water quality effects on river biota. Little research has been done to establish the tolerances to water quality changes of, for instance, macro-invertebrates. This 4-year project aims to establish an experimental stream system which will provide

controlled conditions under which the tolerances of selected invertebrates to a variety of water quality conditions can be tested. This stream system will also provide a link between small-scale, intensive, laboratory studies and field surveys.

A study group under the leadership of Dr Bob Milhous (US Fish and Wildlife Services, second from right in bottom photograph), an acknowledged expert in the field of ecological water requirements, studied the rivers of the Kruger National Park inter alia *during October 1992, while the Park was still in the grip of a drought*



Geomorphological classification system for South African river systems *(No 497)*

Department of Geography, Rhodes University

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

Continuing research into the wetlands of Natal/KwaZulu *(No 501) Institute of Natural Resources, University of Natal*

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

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

The effect of land use on Gamtoos Estuary water quality *(503) Department of Oceanography, University of Port Elizabeth*

Estuaries are complex ecosystems with major water quality variations between the inflow and outflow points as a common feature, but which can otherwise also differ greatly. The Gamtoos River estuary differs from most of the others in that it is situated below an irrigation area and possibly also receives inflow from underground water sources. During this 2-year project the hydrology of the ground water in the flood plain of the Gamtoos River will be investigated, as well as the possible consequences of land use (among others the use of fertiliser, pesticides and weed-killers) on the quality of water in the estuary and on estuary processes.

Research projects

Completed

- **293** Relationship between low flows and the river fauna in the Letaba River (CSIR - Division of Water Technology)

Current

- **292** Freshwater requirements of estuarine plants (University of Port Elizabeth - Department of Botany)
- **294** Pre-impoundment study of the Sabie-Sand River system, E. Tvl., 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)
- **295** Assessment of the instream flow requirements of rivers (University of Cape Town - Freshwater Research Unit)
- **350** Effect of pollution on the physiology of fishes in the Olifants River (E. Tvl) (Rand Afrikaans University - Department of Zoology)
- **351** Effect of water quality variables on riverine biota (University of Cape Town - Department of Zoology)
- **376** Geomorphological response to changing flow regimes of the Sabie and Letaba River systems (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)
- **412** Contribution to the estuaries research programme (University of Natal - Institute for Natural Resources)

New

- **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 on streams and rivers (CSIR - Division of Water Technology)
- **426** Preliminary investigation of algal weeds in South African inland waters (University of Cape Town - Department of Botany)
- **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 freshwater 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)
- **501** Continuing research into the wetlands of Natal/KwaZulu (University of Natal - Institute of Natural Resources)
- **503** Effect of land use on Gamtoos Estuary water quality (University of Port Elizabeth - Department of Oceanography)

13 Developing communities

It has been estimated that some 11 million people are likely to migrate to the cities in the next decade

It has been estimated that some 11 million people are likely to migrate to the cities in the next decade. The capital cost of providing fully sewered sanitation to such a large number of people has been estimated at R3,9 billion. Experience has also shown that water-borne sanitation is often an inappropriate technology for developing communities, as the system is sensitive to the use of unapproved cleansing materials and the introduction of sundry foreign matter. Often manholes are used as depositories for all kinds of discard resulting in the complete failure of the system.

It is therefore essential to look at more robust technologies for sanitation which are also less costly than water-borne sewerage, yet able to provide the same health benefits and at the same time are socially and environmentally acceptable to the users. Although the various technologies *per se* might require little additional research, little is known of the social acceptance and economic affordability aspects when selecting suitable and appropriate sanitation systems. Another aspect is that the availability of water also influences the choice of sanitation system. If a "fetch and carry" water supply system is replaced with on-site water supply, the sanitation system may also have to be upgraded to cope with the additional household water (sullage).

In view of the urgency of providing adequate water supply and sanitation, as well as the pollution problems attached to current situations, research projects in this workfield have been awarded a high priority by the WRC. It has also become clear that in addition to the existing co-ordination of research regarding water supply and sanitation, formalised co-ordination of research in connection with the socio-economic aspects is urgently required. In this regard the WRC intends to take the necessary steps in 1993.

A voluntary Standing Committee for Water and Sanitation was established in January of this year. The committee has an advisory function and has representation from government departments, statutory bodies, extraparliamentary political organisations and non-governmental organisations. The WRC is represented on this committee and draws on the advise and views from this source in planning its research in this field.

During 1992 the WRC supported 9 projects directly related to developing communities of which 2 commenced during the year.

New projects

Development of a training programme on community water supply management for village water committees (No 435)

Division of Water Technology, CSIR

Considerable amounts of time and funds are being invested in the installation of community water supply schemes in Southern Africa. From lessons learnt in the past, more emphasis is now being placed on community involvement and management of such schemes to improve their cost-effectiveness and sustainability. However, although most community management members are very willing, they lack the basic knowledge and foundation to manage community projects effectively. Usually support is offered during the planning, design, and implementation phases of a community water supply project, but communities are expected to manage their own systems once they are in place. Management committees are usually ill-equipped to undertake the long-term operation and maintenance of a scheme.

Acceptance is normally greater if the community itself is involved in the management and decision-making processes from the outset. Hence it is desirable for the elected committee to undergo some management training even before the project is initiated, so that they can make decisions based on a clear understanding of the short- and long-term consequences of these decisions. A need has been recognised world-wide for courses which are specific for community water supply management and which are directed at the level of the village management committees.

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

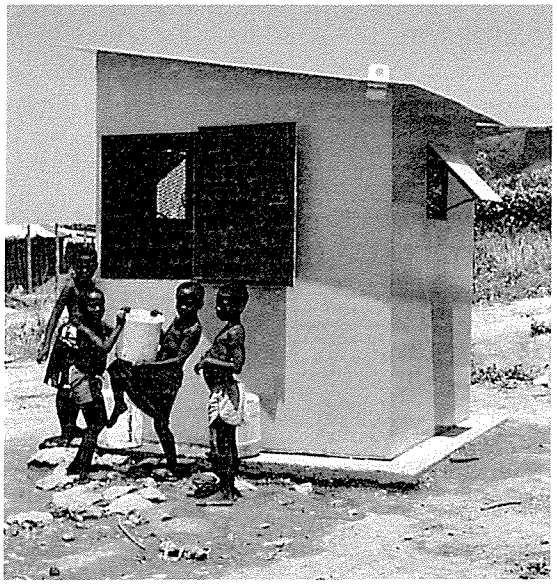
Per capita *water demand in developing communities* *(No 480) Water Systems Management*

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

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

The above pressures arise because available resources, particularly water and funds, are scarce. Estimates of water demand are usually arrived at by extrapolation and are complicated by deviations in the trend line while historical water use information is often not available.

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



Different methods currently used to supply water to developing communities

Research projects

Current

- **323** Hydrological investigation of stormwater runoff from the Khayelitsha urban catchment in the False Bay area, South-Western Cape (CSIR - Division of Water Technology)
- **341** Forced aeration composting of sewage sludge for rural communities (City Council of Grahamstown)
- **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 Natal/KwaZulu (University of Natal - Department of Economics)
- **385** Technical, socio-economic and environmental evaluation of sanitation systems for developing urban areas in South Africa (University of Cape Town - Department of Civil Engineering and the Palmer Development Group)
- **386** Development of a crossflow microfilter for rural water supply (Umgeni Water and the University of Natal - Department of Chemical Engineering)
- **403** Nitrate removal from potable water (University of Pretoria - Department of Chemical Engineering)

New

- **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)

14 General

Studies have been undertaken with a view to managing the extent and degree of water restrictions in future drought situations

Socio-economic effects of water restrictions

The drought which occurred in large parts of South Africa from March 1983 until September 1987 lies at the root of the WRC's involvement in this research. When water resources are limited, water restrictions are one of the first measures to be implemented by the Department of Water Affairs and Forestry. Attempts are then made to manage the extent and degree of the restrictions in such a manner as not to have an unacceptable socio-economic and financial effect on any of the sectors of the South African economy.

Since 1987 three research organisations:

- Bureau for Market Research, University of South Africa
- Centre for Applied Social Studies, University of Natal
- Department of Agricultural Economics, University of the Orange Free State

have reported extensively on various facets of the study. This consisted of qualified expositions of the total nature and scope of the tangible and intangible implications of the water restrictions over the entire period of drought (i.e. 1983 to 1987). The reports dealing with this section of the investigation are obtainable from the WRC on request.

Completed project

Determination of the socio-economical and financial implications of the water restrictions in force from 1983 up to its annulment in 1987 *(No 288) Department of Agricultural Economics, University of the Orange Free State*

In addition to the objective of determining the total financial impact of water restrictions, the project also aimed at determining the relationships between the nature and extent of the restrictions and the effects thereof. In this part of the project the emphasis was placed on the agricultural sector, in particular the Vaalharts State Water Scheme, the other sectors in the Vaal River System as a whole having received general attention.

Two approaches were adopted: Construction of loss functions for the Vaalharts irrigation area by means of simulation; and the determination of the mean unit value of water for different economic sectors in the Vaal River supply area by utilising the empirical results of that part of the project dealing with the total financial implications.

A loss function gives the relationship between varying levels of water supply and the resulting financial consequences. These functions were compiled for various typical farms (in one-, two- and three-plot situations), as well as for the Vaalharts area as a whole. The results of the loss function analysis can be summarised as follows:

- The ability of typical three- and more- plot farms to survive the effects of water restrictions, is considerably greater than that of typical one- and two-plot irrigation units
- The ability of typical farms to deal with sequential years of water restrictions, is greater at the end of a ten-year cycle than at the start. A typical one- and two-plot farmer is, for example completely unable to survive financially if a 50% water restriction is imposed consecutively in years 3 to 5, but can if it is imposed in years 8 to 10
- If movable capital items need replacing, and there is a movement from replacement at market value to replacement at replacement value, farming in the Vaalharts area ceases to be profitable as soon as water shortages occur (as a result of the large number of one- and two-plot farms).

The extent of the indirect effects for the different water application levels was relatively negligible and amounted on average to only about 2,5% of the direct effects.

With regard to the water restrictions from 1983 until 1987 in the Vaal River water supply area, a comparison between the agricultural, mining and industrial sectors indicates that the mean unit value (direct and total) of water was the lowest for agriculture, followed by mining, with the highest for industries. Although the mean unit values have some value for the management of water during shortage situations, the figures should be interpreted with great circumspection as water is a primary input in irrigation farming, which is largely dependent on biological production processes, this not being the case in other sectors.

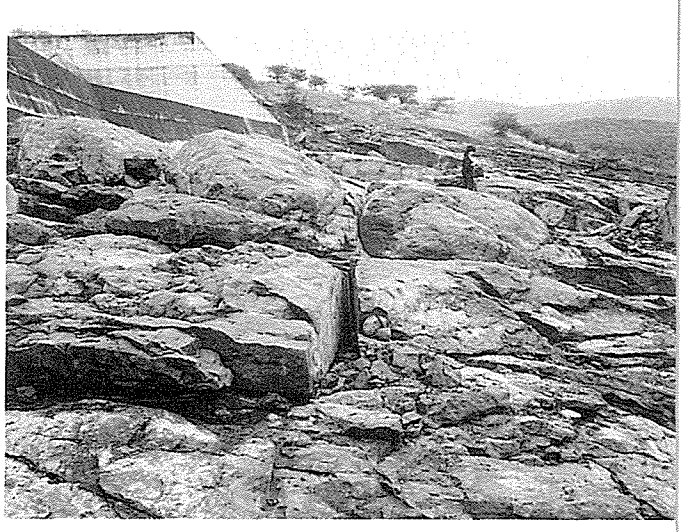
Cost: R103 000
Term: 1989-1991

Geological aspects (with reference to dam structures)

In terms of the Water Research Act (Act No 34 of 1971, as amended) the WRC is charged with promoting research with respect to among others the storage of water. The interpretation of this facet of the broad directive is that research of which the results will contribute to water being made available to the user at reduced prices, as a result of reduced construction costs of storage structures, therefore also forms part of the WRC's responsibilities. Furthermore this stipulation is also interpreted as authorising research concerning dam safety aspects.

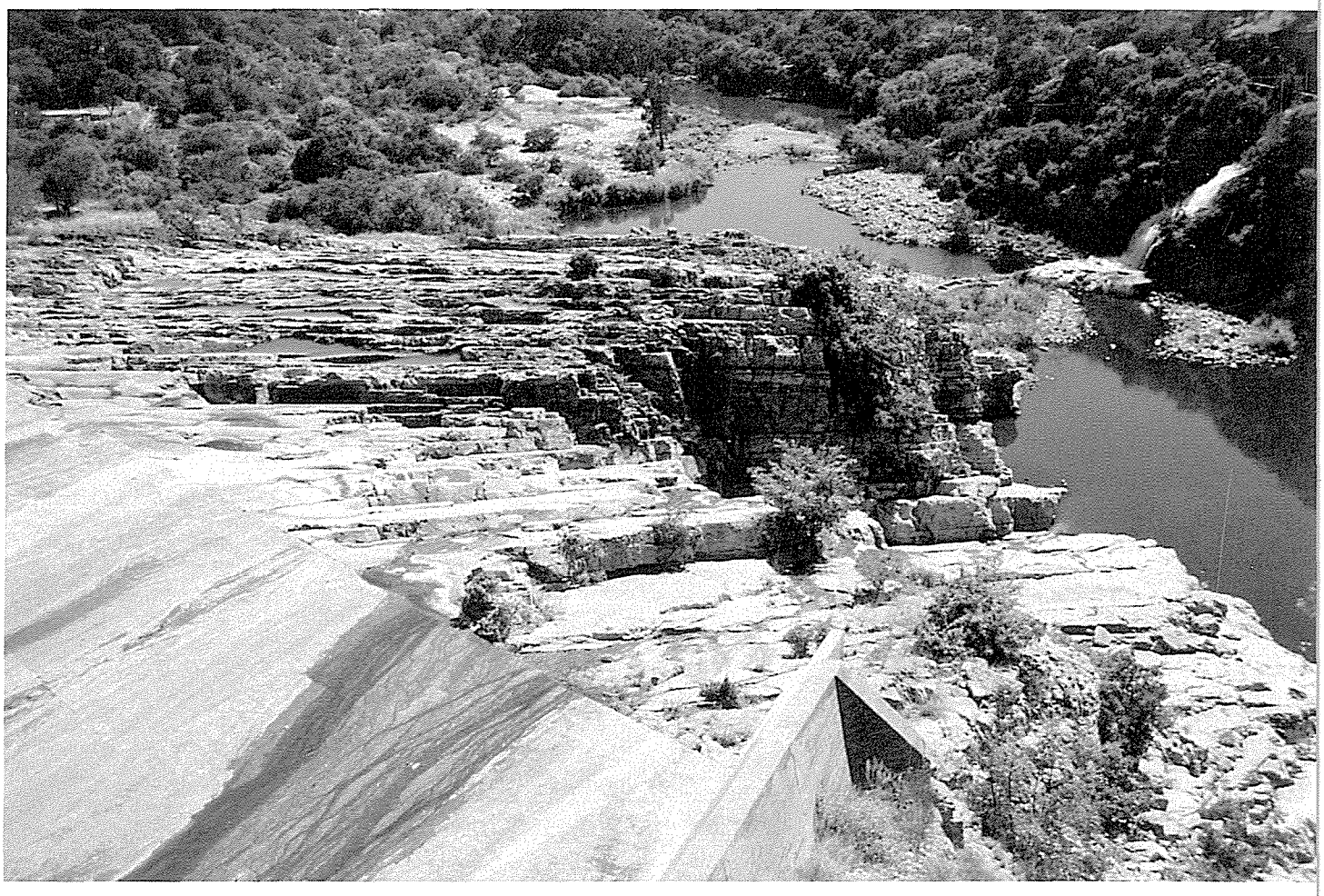
The WRC's involvement in research projects of the above nature was initially restricted to *ad hoc* studies of a relatively narrow scope. Upon the establishment in 1983 of the Subdirectorate for Dam Safety within the Department of Water Affairs and Forestry, the passing in 1986 of dam safety legislation and a comprehensive dam safety programme in 1989, a number of problems were identified indicating clear research needs. This led to the WRC's involvement since 1990 in the funding of specific research projects in this field of study. As could be expected geological aspects make up the core of these projects.

During the past year the WRC financed 3 projects of this nature of which 2 commenced.



Erosion downstream of the concrete structure at the Goedertrouw Dam

Area downstream of the concrete canal at the Hartbeespoort Dam



New projects

Engineering properties of important Southern African rock types with special reference to the shearing strength of concrete dam wall foundations (No 433)

School for Civil Engineering, Technicon Pretoria

The cost and safety of a storage dam depend on the design of the structure, the materials used in its construction and very importantly, the foundation on which it stands. Rock material parameters and especially the shear strength of joints play a very important role with regard to the slope and excavations for civil structures.

In the case of soil foundation materials, it is relatively easy to obtain representative samples, and to test these in the laboratory with the aid of reliable and standardised tests. Sampling rock is far more difficult and expensive and the material obtained by drilling for the most part does not represent the weakest zone along which failure could occur.

It is therefore regarded as vital that a special attempt should be made to obtain and test samples of different rock types from the weaker zones in order to establish a data bank of reliable shear strength parameters. Such a data bank can be used to evaluate the existing structures where it is not possible to conduct tests, as well as for new structures where sophisticated testing is not economically justified.

The project will be carried out over a period of 4 years.

Plunge pool scour reproduction in hydraulic models (No 502) Division for Earth, Marine and Atmospheric Science and Technology, CSIR

The provision for passing excess flood water over or through dam walls has long been recognised as a problem by design engineers. The problem lies in being able to pass the flood water in such a way that catastrophic scour does not occur downstream of the structure.

In recent years free trajectory jets have often been used as a means of dissipating the energy of the discharge. When the jet impacts on the river bed downstream of the dam, its energy is partly dissipated by excavating a scour hole. The accurate prediction of the depth and extent of scour holes is essential to ensure the stability of the dam wall, as well as the side slopes of the downstream channel. The development of a scour hole is a complex problem due to the influence of hydraulic, hydrological and geological factors which are difficult to assess theoretically.

As a result of the problems attached to the theoretical approach, designers very often have to rely on model tests to provide additional information on scour hole formation. Making a model representative of the actual situation is, however, a major problem especially as far as the material used in the scale model to represent the rock in the plunge pool is concerned. This 3-year project is aimed at an intensive investigation of the use of semi-cohesive materials in model studies.

It is anticipated that the results will contribute significantly to more economic dam designs (and consequently lower cost of water) by identifying more reliably those conditions which require expensive concrete-lined stilling basins.

Research projects

Completed

- **288** Determination of the socio-economical and financial implications of the water restrictions in force from 1983 up to its annulment in 1987 (University of the Orange Free State - Department of Agricultural Economics)

Current

- **302** Erodibility of different rock formations under varying flow conditions (University of Pretoria - Department of Geology)

New

- **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 of Earth, Marine and Atmospheric Science and Technology)

15 Research support services

South African Water Information Centre

The South African Water Information Centre (SAWIC) is a comprehensive source of information about water, waste water and sanitation. While concentrating mainly on bibliographic information from books, reports, theses, conference proceedings and more than 650 local and international journals, staff of the centre are also available to assist with a range of services.

Most of the more than 700 regular users of SAWIC will be familiar with WATERLIT, the comprehensive bibliographic data base which was established in 1975. This internationally recognised data base, containing almost 200 000 references, is now being marketed internationally on CD-ROM, by Cambridge Scientific Abstracts in the USA. It forms part of the aquatic Sciences Library, together with data bases such as Aqualine, Selected Water Resources Abstracts and Aquatic Sciences and Fisheries Abstracts. Reaction from users has been very positive.

WATERLIT is also available to users through qualified data-base searchers at the SAWIC offices at the CSIR in Pretoria, at the CSIR in Stellenbosch and at the Department of Water Affairs and Forestry's library in Pretoria (for staff of this department). In addition, users who have a modem connected to their PC may now subscribe to the CSIR's Info Access service and carry out their own data-base searches on WATERLIT and a range of other data bases. A system of user-friendly "menus" makes it a simple matter for even the most inexperienced user to carry out an effective search. A similar menu system is used with the CD-ROM version of WATERLIT.

During the past year approximately 500 literature searches were requested and 210 users subscribed to the customised monthly current awareness service. This service provides a monthly set of the latest references on a specified topic from the more than 1 000 new references added to the data base each month.

Copies of the original documents indexed for the data base are available through inter-library loan or on order from the CSIR's DocDel service.

The growing awareness of environmental issues has resulted in increasing numbers of queries on topics such as pollution, environmental aspects of water and waste-water treatment in industry, which are covered comprehensively by WATERLIT. This information is of great importance for problem-solving, planning and decision support.

Staff of the centre are continually monitoring new technology in the field of information sciences, and the changing requirements of users.

Computing Centre for Water Research

During the mid-1980s the WRC took the strategic initiative to enhance communication and hence co-operation between researchers in South Africa by founding the Computing Centre for Water Research (CCWR). UNINET is a world-wide network which links universities and other research organisations throughout South Africa and which has effective links to international computer networks. Both the CCWR and UNINET experienced significant advances in computer hardware and software in 1992. Water researchers country-wide have capitalised on these developments. This is reflected by the marked increase in co-operation, sharing, technology transfer and synergy which has been achieved by water researchers through use of the CCWR during the year under review.

The CCWR now plays host to 136 water researchers from 56 departments at 34 institutions countrywide. Some of the key areas of co-operation through the CCWR are:

- Agrohydrological modelling for use *inter alia* in the Kruger National Park rivers research programme and in water quality and quantity modelling in the Mgeni catchment
- Modelling for drought monitoring and management
- Estimating the impact of global climatic change on water resources in Southern Africa
- Modelling the impact of atmospheric deposition on water quality of the Vaal River.

The CCWR initiative is thus enabling the WRC to move closer to its goal of creating a culture of multidisciplinary team approaches to complex challenges facing water research in Southern Africa.

16 Transfer of information and technology

The promotion of information and technology transfer is one of the most important objectives of the Commission. 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 Commission 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 Commission's publications cater for three levels, viz. pure scientific, popular scientific and practical scientific.

Water SA

Water SA is the Commission'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; and
- 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 Commission publications

The **Annexure** to this annual report contains a list of publications (articles, papers and published reports) which appeared during 1992 and which emanated from research supported wholly or in part by the Commission.

Conferences, seminars, workshops and demonstrations

From time to time the Commission, 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 Commission has developed various methods to achieve this. Overseas specialists, for example, are engaged as consultants and the Commission 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 Statement of Income and Expenditure and the Balance Sheet have been drawn up in terms of Section 14(2) of the Water Research Act, 1971 (Act No. 34 of 1971), as amended and certified by the Auditor-General and cover the period 1 January 1991 to 31 December 1991.

The Commission derives its income from rates and charges on water usage and on scheduled irrigation land. The tariffs for the 1992 financial year were 1,43c/m^3 for water supplied for urban, industrial or domestic use, and 155c/ha of land scheduled for irrigation.

Statement 1

Balance sheet as at 31 December 1991

Capital employed	**1991 R**	1990 R
Accumulated fund	**58 409 817**	47 476 329
Reserve fund	**47 389 765**	30 177 429
Income over expenditure	**10 980 412**	17 212 336
Sundry creditors	**39 640**	86 564
	R58 409 817	**R47 476 329**
Employment of capital		
Fixed assets	**644 763**	551 729
Investments	**18 767 442**	13 229 500
Loans	**24 287 491**	21 371 767
Current assets	**14 710 121**	12 323 333
	R58 409 817	**R47 476 329**

Pretoria, 27/5/1992

(Signed) MJ PIETERSE
Acting Executive Director

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, subject to the effect of such corrections as might be necessary as a result of the matter referred to in paragraph 2 of this Report, are a fair representation of the financial position of the Commission as at 31 December 1991 and the results of its operations for the year then ended.

Pretoria, 6/1/1993

(Signed) HE KLUEVER
Auditor-General

Statement 2

Income and expenditure account for the year ended 31 December 1991

	Notes	1991 R	1990 R
Income		**38 286 642**	38 614 866
Water research levies	7	**35 379 447**	36 186 733
Interest on investments		**2 077 942**	1 562 744
Interest on loan		**655 709**	676 420
Sundry income	8	**173 544**	188 969
Expenditure		**27 306 230**	21 402 530
Salaries and allowances	9	**3 771 069**	3 274 893
Subsistence and transport	10	**546 447**	435 008
Postal, telegraph and telephone services	11	**94 150**	78 097
Printing, stationery, advertisements and publications	12	**707 884**	542 400
General expenses	13	**1 479 374**	1 267 484
Audit fees		**36 383**	34 378
Professional		**20 670 923**	15 770 270
Research projects and research support services	14	**20 070 334**	15 281 360
Specialist and consultation services		**593 494**	479 910
Research and other grants		**7 095**	9 000
Income over expenditure		**R10 980 412**	**R17 212 336**

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.

1.1 Fixed assets and depreciation

Land is shown at cost.

Office furniture, office equipment and motor vehicles are shown at cost price, less accrued depreciation. Depreciation on office furniture and office equipment has been calculated on the reducing balance at a rate of 5%. Depreciation on motor vehicles is written off on a pro rata basis calculated on annual kilometers travelled and the life expectancy in kilometers of the vehicles.

1.2 Investments

Investments are shown at cost.

	1991 R	1990 R
2. Sundry creditors		
General suspense account	**38 447**	105
Revenue paid in advance:		
Rates	**1 133**	3 859
Charges	**60**	82 600
	39 640	**86 564**
3. Fixed assets		
At cost		
Land	**5 000**	5 000
At book value		
Motor vehicles	**56 003**	87 099
Office equipment	**434 066**	305 067
Office furniture	**149 694**	154 563
	644 763*	**551 729***
4. Investments		
Corporation for Public Deposits	**18 011 503**	12 473 561
Unlisted shares in Erf Sewe-Nul-Ses Rietfontein (Pty) Ltd	**755 939**	755 939
	18 767 442	**13 229 500**
5. Loans		
Company for Research on Atmospheric Water Supply	**19 683 265**	16 552 502
Erf Sewe-Nul-Ses Rietfontein (Pty) Ltd	**4 604 226**	4 819 265
	24 287 491	**21 371 767**

* Capital assets purchased by organisations with research grants are not included.

		1991 R	1990 R
6.	**Current assets**		
	Cash in bank	**478 323**	421 293
	Cash on hand	**150**	150
	Deposits	**1 100**	600
	Sundry debtors:		
	Net project advances	**1 839 168**	2 315 900
	Motor financing	**181 658**	253 386
	Subsistence and transport advances	**10 072**	550
	Hydrological Information System	**57 977**	-
	Value-added tax	**207 242**	-
	Outstanding revenue:		
	Water research levies accrued but not yet payable	**11 934 431**	9 331 454
		14 710 121	**12 323 333**
7.	**Water research levies**		
	Rates		
	Government irrigation schemes with canal systems	**285 811**	236 021
	Irrigation board schemes	**338 171**	325 586
	Charges		
	Metered water from Government Schemes	**28 464 662**	29 259 122
	Municipalities	**6 276 193**	6 329 255
	Interest on charges in arrear	**14 610**	36 749
		35 379 447	**36 186 733**
8.	**Sundry income**		
	Interest on motor financing	**31 217**	18 174
	Collection fee on insurance premies (2,5%)	**774**	632
	Collection fee in respect of services rendered (1%)	**13 118**	-
	Registration fees for courses	**-**	95 210
	Publications	**55 823**	40 761
	Royalties	**13 801**	-
	Insurance claims	**58 811**	34 192
		173 544	**188 969**
9.	**Salaries and allowances**		
	Professional	**1 439 944**	1 255 297
	Administrative	**1 194 908**	1 098 877
	Commission members	**15 031**	11 525
	Service bonus	**209 277**	175 791
	Pension fund contributions, UIF, medical aid scheme and others	**911 909**	733 403
		3 771 069	**3 274 893**

		1991 R	1990 R
10.	**Subsistence and transport**		
	General transport and overseas travel expenses	**308 109**	302 432
	Transport and travel expenses of own staff and committee members	**220 495**	115 953
	Own transport (fuel and maintenance)	**17 843**	16 623
		546 447	**435 008**
11.	**Postal, telegraph and telephone services**		
	Postal and telegraph expenses	**21 900**	19 402
	Telephone calls	**72 250**	58 695
		94 150	**78 097**
12.	**Printing, stationery, advertisements and publications**		
	Publications	**463 191**	374 570
	Technology and information transfer	**176 065**	86 193
	Printing and advertisements	**68 628**	81 637
		707 884	**542 400**
13.	**General expenses**		
	Office rental and maintenance	**653 662**	565 073
	Collection fees	**315 518**	286 556
	Legal costs	**102 925**	85 013
	Depreciation	**63 398**	54 187
	Lease and maintenance of office equipment	**83 872**	90 169
	Computer software	**65 587**	13 679
	Other	**194 412**	172 807
		1 479 374	**1 267 484**
14.	**Research projects and research support services**		
	Research projects		
	Water Information Centre	**18 122 808**	12 616 911
	Computing Centre for Water	**866 010**	637 000
	Hydrologcal Information System	**582 659**	259 753
		498 857	1 767 696
		20 070 334*	**15 281 360***

* Only includes expenditure for which audited statements are received.

Statement 3

Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1991

Project	Expenditure		Total advances outstanding as at 31/12/91
	1991	Total to 31/12/91	
1. RESEARCH PROJECTS	**R**	**R**	**R**
Research on detailed geohydrological investigations in the Poesjenels River catchment in the Breede River valley, with special reference to mineralisation	6 062,59	239 997,96	-
A national industrial water and waste-water survey (NATSURV)	8 087,02	3 185 900,00	-
Research on the practical scheduling of irrigation in the Northern Transvaal	20 028,33	354 200,63	-
Research on the quantification and limitation of water losses associated with centre pivot irrigation systems	377,06	299 886,01	-
Research into the treatment of wool scouring effluents	186 391,90	1 386 299,53	-
Research on the socio-economic effects of water restrictions on industries and local governments	4 223,03	102 457,66	-
The development of a computer program to simulate water flow in distribution canals	1 741,34	144 999,59	-
Research on the effects of urbanisation on catchment water balance	376 792,89	1 110 398,69	23 207,11
Research on drip irrigation of tomatoes	171 180,10	826 441,70	*(1 180,10)
Research on epidemiological surveillance of potential changes in drinking-water quality	-	369 283,77	7 084,35
Research on the feasibility of reverse osmosis for water reclamation on large scale	-	639 777,60	*(7 393,60)
Hydrosalinity studies in the Eastern Cape	220 867,77	1 200 771,93	*(24 867,77)
Development of phosphate export models for catchments	66 052,58	266 035,88	*(11 051,88)
The development of methods to assess the impact of agricultural practices on water resources in Southern Africa	284 690,00	1 041 485,10	54 714,90
Research on the development of a stochastic daily climate model for South African conditions	5 008,50	158 393,26	12 461,31
Development of water quality monitoring strategies and procedures for water quality data interpretation	139 000,00	428 442,63	10 557,00
Research on the isolation and identification of mutagens in drinking water	-	139 402,68	*(8 229,68)
Research on the development of criteria for sprinkler irrigation systems to combat surface sealing of soils	132 755,08	414 939,02	3 344,92
Research on ground-water abstraction in residential areas	-	185 289,64	15 710,36
Research on the use of electromagnetic exploration techniques for the development of ground-water resources	11 834,15	216 000,00	15 251,95
Research on economic evaluation of alternative irrigation scheduling strategies for wheat in the irrigated area of the Orange Free State	-	274 983,42	25 800,00
The development of fixed and dynamic membrane systems for the treatment of brackish water and effluents	16,69	1 751 276,80	40 583,31
Research on geohydrological investigation and evaluation of the Zululand coastal aquifer	160 796,00	518 741,30	124 679,00
Research on the reconstruction of the climatic history of the last 2 000 years in the summer rainfall regions of Southern Africa	55 050,11	184 893,11	949,89
Research on maximising irrigation project efficiency in different soil-climate-irrigation situations	426 291,99	679 942,53	31 448,98
Research on the storage and utilisation of rain water in soil for the stabilisation of plant production in semi-arid regions	222 500,00	743 260,53	*(17 700,00)
Research on the factors affecting the water-use efficiency of irrigated crops, with special reference to the physiological responses of these crops	296 010,00	1 008 722,83	*(10,00)
Research on the estimation and evaluation of moisture stress in crops by means of remote control aerial surveillance	138 772,73	78 952,01	*(35 377,00)

Statement 3

Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1991 (continued)

Project	Expenditure		Total advances outstanding as at 31/12/91
	1991	Total to 31/12/91	
	R	R	R
Research on the preparation of guidelines on cost-effectiveness of rural water supply and sanitation projects	34 157,98	265 000,00	-
An investigation of the hydrological response to third-world settlements in peri-urban areas of Natal/KwaZulu	13 981,00	57 126,00	-
The development of a systems model for the Mgeni catchment	105 206,00	274 894,11	17 105,89
Hydrological modelling studies in the Eastern Cape	313 697,23	958 016,89	*(2 097,23)
The development of a model to simulate flow in alluvial rivers	110 502,74	322 235,84	*(30 191,28)
Research on the quantification of the effects of land-use runoff quality in selected catchments in Natal	14 527,00	222 873,71	27 926,29
Research on the design criteria for crossflow microfiltration	224 252,93	786 874,33	747,07
Transfer of waste-water treatment management technology to the meat processing industry	118 903,09	137 000,00	-
Research on the filtration of compressible cakes	20 500,00	83 985,18	*(19 732,50)
Research on solids-liquid separation in biological systems	1 109,99	41 966,70	-
Research on the concentration of industrial effluents with sealed-cell electrodialysis	19 889,00	135 072,58	-
A comparative study on chlorine dioxide and other oxidants in potable water treatment	-	182 334,73	*(3 686,73)
Research on chemical augmentation of biological phosphate removal	20 218,18	29 611,59	64 388,41
Research on pelletisation in upflow anaerobic sludge bed (UASB) systems	78 904,67	253 189,59	*(6 504,67)
Research on phosphate fixation in waste waters by means of controlled struvite formation	2 837,28	180 536,68	363,32
Consolidation of activated sludge and water chemistry research	-	191 407,15	8 271,09
Research on the assessment of water quality problems due to microbial growth in drinking-water distribution systems	10 033,73	306 000,00	*(0,73)
Research on the effect of biocorrosion in water systems	22 219,44	149 999,28	-
Research on the effects of varying water quality on the corrosion of different pipe materials in the PWV/Klerksdorp areas	122 623,62	346 319,29	33 750,00
Research on the development and testing of data logging equipment for the monitoring of water consumption patterns	-	86 120,77	12 379,23
Research on the evaluation of the design and use of irrigation systems in the Breë River with a view to the control of potential drainage losses	133 022,11	543 346,82	15 653,18
Research on the water-use efficiency of certain irrigated temperate pasture species	62 869,63	30 448,02	9 130,37
Research on the effect of water quality and chemical composition on the corrosivity in mild steel pipelines	23 000,00	29 799,38	-
Research on the relationship between climate and crop factors	81 874,31	135 441,82	20 125,69
Research on soil-plant-water relations in the upper reaches of plant available soil water	93 587,54	325 590,79	*(1 587,54)
Research on moisture sensors to facilitate water management	151 970,31	375 068,81	*(9 222,49)
Research on the biological treatment of industrial water with the simultaneous production of single cell protein	43 027,75	67 027,75	21 572,25
Research on human viruses in water	111 439,87	225 557,66	17 560,13
Research on the extension of the management orientated models for eutrophication control	51 296,03	175 293,40	45 703,97
Research on the evaluation and development of geophysical techniques for characterising the extent and degree of ground-water pollution	134 356,00	437 258,00	25 942,00
Research on a preliminary survey of pesticide levels in ground water from a selected area of intensive agriculture in the Western Cape	55 461,00	140 912,39	14 087,00
Research on the evaluation of the four-electrode electrical conductivity and electromagnetic induction techniques of soil salinity measurement for use under South African conditions	63 718,00	153 305,00	*(18,00)

Statement 3

Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1991 (continued)

Project	Expenditure		Total advances outstanding as at 31/12/91
	1991	Total to 31/12/91	
	R	R	R
Research on hydrological systems model development	491 497,00	1 139 906,00	47 494,00
A comparative study of two- and three-dimensional ground-water models	209 041,00	540 499,12	-
An investigation of the potential use of NOAA satellite remotely sensed data for identification of regional scale fracture zones for ground-water supply purposes in Southern Africa	-	67 953,15	2 046,85
Technical support for the application of dynamic membrane plants for the treatment of industrial effluents	51 073,24	401 159,42	*(25 204,15)
The investigation into the evaluation of membrane technology for electroplating effluent treatment	20 000,00	103 916,11	13 083,89
Research on abattoir solid waste: Development and implementation of a treatment system	33 000,00	33 000,00	-
Research on the prediction of South African summer rainfall variability from ocean surface temperatures	120 813,27	263 683,25	9 186,73
Research on relationships between lightning and precipitation	94 000,00	244 941,00	-
The evaluation of full-scale flotation-filtration and chlorine dioxide plants	49 279,00	120 308,00	*(92 808,00)
Research on the effect of water quality on the effectiveness of chlorine dioxide in drinking-water treatment	29 192,00	59 999,70	-
The development of a combination of sedimentation, flotation and sand filtration processes for water treatment (SEDIDAFF)	4 404,57	26 608,97	3 391,03
Research on and evaluation of various factors affecting dry-wet cooling	261 406,20	796 705,44	38 293,80
Research on development and evaluation of specific control methods for ameliorating low F/M bulking	159 345,77	300 972,06	41 054,23
Determination of the socio-economic and financial implications of the water restrictions in force from 1983 up to its annulment in 1987	19 935,84	99 943,71	2 556,29
Research on the management of phosphate concentrations and algae in Hartbeespoort Dam	5 738,00	149 420,07	4 262,00
Research on flood and furrow irrigation: A critical evaluation of design procedures and the computerisation of the most suitable approaches	39 952,21	108 710,80	*(2 952,21)
A regional investigation into ground-water quality deterioration in the Olifants River catchment above the Loskop Dam, with specialised investigations in the Witbank Dam sub-catchment	668 126,41	668 126,41	76 873,59
Research on the freshwater requirements of estuarine plants	-	55 551,22	66 660,00
Research on the relationship between low flows and the river fauna in the Letaba River	143 287,97	289 885,30	12 111,70
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	193 279,49	396 218,31	*(38 422,40)
Research on assessment of the instream flow requirements of rivers	125 118,87	249 045,58	11 181,13
Research on the quantitative structuring of national water planning objectives for use in decision support systems in South Africa	107 258,09	161 894,97	22 541,91
Research on the preparation of a review document on sediment transport in Southern Africa including revision of the sediment production map of Southern Africa	248 033,38	248 033,38	*(16 548,72)
Research on the surface water resources of South Africa 1990	890 000,00	1 190 000,00	*(193 049,80)
Research on the adaption and calibration of an urban runoff quality model	157 189,15	228 039,55	11 610,85
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	124 649,87	304 649,87	93 350,13
An investigation into the quality of water for animal production	69 596,61	143 776,20	70 403,39

Statement 3

Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1991 (continued)

Project	Expenditure		Total advances outstanding as at 31/12/91
	1991	Total to 31/12/91	
	R	R	R
Research on the erodibility of different rock formations under varying flow conditions	64 111,65	120 265,24	7 888,35
Research on the use of saline water for irrigation purposes and an assessment of salt tolerance criteria of crops	295 800,00	453 555,59	-
Research on the applicability of hydrodynamic reservoir models for water quality management in stratified water bodies in South Africa	164 366,33	246 197,33	1 965,67
Research on interpolation and mapping of daily rainfall model parameters for South Africa	86 601,90	104 834,18	13 398,10
Research on techniques for seasonal and long-term rainfall forecasting in South Africa	67 194,63	125 194,63	70 805,37
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	212 482,85	321 954,27	-
Research into the recovery of water and chemicals from ion exchange regeneration effluents	66 198,10	118 198,10	16 301,90
Research on phase diagrams of complex precipitants	69 190,64	116 251,56	*(14 190,64)
Research on the integration of remote sensing, digital image processing and geographical information systems technologies for regional scale ground-water resources assessment in South Africa	100 984,46	138 267,49	*(1 600,00)
Research on the development and evaluation of geohydrological and isotope hydrological methodologies for the identification of areas potentially suitable for waste disposal	164 997,54	164 997,54	2,46
Research on the occurrence and accumulation of selected heavy metals in freshwater ecosystems affected by mine and industrial polluted effluent	43 362,61	58 604,38	*(5 029,38)
Research on the concentration ratios of selected radionuclides in aquatic ecosystems affected by mine drainage effluents	45 003,14	51 479,76	*(479,76)
Research on biological phosphate removal mechanisms in the activated sludge process	39 938,98	90 938,98	11 061,02
Research on the utilisation of the fungus *Geotrichum* in waste water	63 946,62	88 163,22	6 053,38
Research on aspects of sewage sludge treatment and disposal	14 126,50	14 126,50	23 130,00
Research on urban catchment monitoring	2 542,80	84 551,14	21 448,86
Research on the optimisation of biofouling control programmes	78 729,02	168 229,02	11 070,98
Research on monitoring the effect of catchment development of urban runoff and water balance	269 040,72	269 040,72	100 959,28
Research on taste and odour forming micro-organisms occurring in South African surface water	90 395,76	150 859,71	14 140,24
Research on bacteriophages as water quality indicators	51 449,07	116 373,55	12 650,93
A study on a mine water reclamation test plant	400 000,00	400 000,00	-
Research on a hydrological investigation of stormwater runoff from the Khayelitsha urban catchment in the False Bay area, Southern Cape	155 378,11	312 302,81	17 621,89
Research on pollution loads, dispersion and effects of urban runoff from the Motherwell township into the Swartkops River, Eastern Cape	-	57 005,54	9 644,46
Research on modelling of tubular reverse osmosis systems	167 743,39	305 157,71	*(4 657,71)
Research on assessment of the feasibility and impact of alternative water pollution control options on TDS concentrations in the Vaal Barrage and Middle Vaal	298 409,56	598 409,56	*(14 454,55)
Evaluation of the active sewage pasteurisation (ASP) process for sewage sludge treatment	25 000,00	25 000,00	-
Full-scale study of chemical sludge bulking control	25 873,64	29 794,32	9 205,68
Research on improved oxygen transfer for high biosludge concentrations	16 473,16	16 473,16	58 526,84
The development of guidelines for the design and application of dissolved air flotation/filtration processes	37 500,00	75 000,00	*(21 479,27)

Statement 3

Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1991 (continued)

Project	Expenditure		Total advances outstanding as at 31/12/91
	1991	Total to 31/12/91	
	R	R	R
Research on the removal of suspended solids from pulp and paper effluents by employing a combined sedimentation, flotation and sand filtration process	7 030,21	17 230,21	10 269,79
The compilation of a comprehensive guide for ground-water sampling in South Africa	29 900,00	76 400,00	-
Research on forced aeration composting of sewage sludge for rural communities	24 320,00	44 320,00	-
Research on improvement in water usage control and waste-water treatment in the sorghum beer industry	23 752,41	46 793,17	22 006,83
Research on the development of an effective and environmentally safe larviciding programme for the control of the blackfly, *Simulium chutteri*, along the Orange River	51 900,64	52 682,24	-
An investigation into the contribution of ground water to the salt load of the Breede River using natural and chemical tracers	-	49 500,00	129 500,00
A study of the relationship between hydrological processes and water quality characteristics in the developing Zululand coastal region	61 331,84	61 331,84	28 968,16
A global farm approach to enhancing the economic efficiency of water and energy use for irrigation in the central RSA	126 677,77	126 677,77	42 322,23
Root development and water usage of commercial timber species	124 289,00	124 289,00	5 711,00
Evaporation measurements above vegetated surfaces using micro-meteorological techniques	138 625,00	138 625,00	*(625,00)
The effect of pollution on the physiology of fishes in the Olifants River (Eastern Transvaal)	52 028,73	52 028,73	*(3 028,73)
The effect of water quality variables on riverine biotas	80 344,82	80 344,82	73 655,18
Development of a method for the selection of suitable landfill sites, and of guidelines for sanitary landfill in municipal areas	55 932,85	55 932,85	10 367,15
Preparation of a manual on quantitative estimation of ground-water recharge and aquifer storativity	18 958,62	18 958,62	-
Research on the evaluation and development of deep-bed filtration for the treatment of South African surface waters	32 475,78	32 475,78	32 524,22
Research on the neutralisation of water containing high concentrations of sulphuric acid with calcium carbonate	71 460,46	71 460,46	3 539,54
The consolidation of activated sludge research	133 199,25	133 199,25	*(41 199,25)
Research on the microbiological transformation of metal contaminated effluents	192 615,15	192 615,15	32 384,85
The development of guidelines for toxicity bio-essaying of drinking and environmental waters in South Africa	104 000,00	104 000,00	-
An investigation into phytoplankton blooms in the Vaal River and the environmental variables responsible for their development and decline	82 470,11	82 470,11	2 529,89
Research on the mutagenicity of drinking water produced with conventional treatment methods of surface water sources	-	-	75 000,00
Research on the development of tolerant membranes	127 355,21	127 355,21	*(13 355,21)
Research on industrial application of membranes	72 180,19	72 180,19	19 319,81
The development and evaluation of small-scale potable water treatment equipment	80 664,33	80 664,33	1 835,67
Research on field dilution studies on large offshore pipelines	57 100,73	57 100,73	*(0,32)
Research on the evaluation and improvement of the anaerobic digestion/ultrafiltration (ADUF) effluent treatment process	80 661,99	80 661,99	13 838,01
Research on full-scale pilot plant studies on phosphate crystallisation in biological systems	43 038,85	43 038,85	12 461,15
The development of a consolidated computer software package for the management of an irrigation scheme	24 000,00	24 000,00	-

Statement 3

Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1991 (continued)

Project	Expenditure		Total advances outstanding as at 31/12/91
	1991	Total to 31/12/91	
	R	R	R
A preliminary investigation of the nitrate content of ground water and limitation of the nitrate input	62 318,83	62 318,83	*(2 318,83)
The completion of research relating to the Disa model - a daily irrigation and salinity analysis system model	85 434,76	85 434,76	*(37 088,81)
A compilation of information on the magnitude, nature and importance of coastal aquifers in South Africa	-	-	52 250,00
An assessment of health aspects of the impact of domestic and industrial waste disposal activities on ground-water resources	19 380,49	19 380,49	2 619,51
Assessing the impacts of varying rainfall conditions on vegetation dynamics, production and certain hydrological properties of natural grassland, using a system modelling approach	41 440,63	41 440,63	21 159,37
The generation of a spatially distributed daily rainfall data base for various weather modification scenarios	92 997,45	92 997,45	-
The development of a distributed hydrological modelling system to assist with water quantity and quality management in the Mgeni catchment: Phase II	46 644,00	46 644,00	*(944,00)
The geomorphological response to changing flow regimes of the Sabie and Letaba River systems	-	-	193 000,00
The use of geographic information systems and other computer-aided drafting facilities for the production of geohydrological maps	222 000,00	222 000,00	-
The development of techniques for risk analysis and ground-water management of Southern African aquifers	227 718,00	227 718,00	16 782,00
Decision-making procedures for determination of crop water requirements	-	-	137 000,00
Techniques for microbial aspects of water quality investigation of South African rivers	95 041,09	95 041,09	154 358,91
The corrosion performance of various non-metallic piping materials and coatings in potable water	216 657,42	216 657,42	*(116 657,42)
The evaluation of the interdependent factors which determine the viability of irrigation farming	-	-	107 756,62
An holistic approach to affordable planning and maintenance of water and sewer systems	75 200,00	75 200,00	*(12 884,00)
A water resources and sanitation systems source-book with special reference to Natal/KwaZulu	88 321,00	88 321,00	*(23 484,97)
Technical, socio-economic and environmental evaluation of sanitation systems for developing urban areas in South Africa	89 286,50	89 286,50	10 513,50
Research on development of a cross-flow micro-filter for rural water supply	273 553,41	273 553,41	*(11 553,41)
Research on the development and production of membrane systems	435 687,72	435 687,72	*(140 187,72)
Evaluation of various methods for the forming of free radicals for the oxidation of molecules in industrial effluents and potable water	105 415,89	105 415,89	117 584,11
Scheduling irrigation of tuberous crops with specific reference to potatoes	81 681,49	81 681,49	-
Compilation of an operators guide on anaerobic digestion of sewage sludge	15 000,00	15 000,00	-
Co-disposal of sewage sludge and refuse	20 000,00	20 000,00	-
The use of yeast biomass and yeast products to accumulate toxic and valuable heavy metals from waste water	17 000,00	17 000,00	*(6 000,00)
The use of algae to bioassay for toxic substances in water	39 527,89	39 527,89	2 472,11
The development of information strategies for rainfall stimulation	79 000,00	79 000,00	-
The development of a South African electro-dialysis membrane system	89 142,44	89 142,44	5 857,56
An investigation into the organic fouling of ion exchange membranes	50 000,00	50 000,00	-
The determination of exposure to chemical residues in South African food and water intake	27 271,73	27 271,73	6 728,27

Statement 3

Statement of expenditure and advances outstanding in respect of research projects and research support services as at 31 December 1991 (continued)

Project	Expenditure		Total advances outstanding as at 31/12/91
	1991	Total to 31/12/91	
	R	R	R
Research into domestic meter replacement policy and testing of water meters	30 645,56	30 645,56	*(10 645,56)
Establishing revised water quality criteria for the South African coastal zone	33 400,00	33 400,00	*(17 150,00)
Research on the modelling of flow through porous membranes	38 083,34	38 083,34	*(83,34)
Research on nitrate removal from potable water	27 591,53	27 591,53	16 408,47
The preparation of a manual for waste load allocation in South Africa	81 641,36	81 641,36	*(81 641,36)
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	164 772,48	164 772,48	28 827,52
A structural analysis of the water apportionment mechanisms in the Water Act 54/1956, in view of the requirements of competing user sectors	130 000,00	130 000,00	-
Reassessment of the strategy with respect to industrial effluent discharge with special reference to advanced technology treatment methods: Phase I	82 180,50	82 180,50	*(10 980,50)
Fats and oils in effluents	3 232,66	3 232,66	9 767,34
Phenols in the steel industry waste water: Origin, prevention and removal	6 114,89	6 114,89	32 885,11
A biological approach to the removal of organics from saline effluents	76 494,25	76 494,25	*(15 294,25)
Marine pollution: Pathogenic micro-organisms	52 500,00	52 500,00	*(52 500,00)
Contribution to the estuaries research programme	50 000,00	50 000,00	-
The use of vegetation in the amelioration of the impacts of mining on water quality - An assessment of species and water use	99 654,89	99 654,89	32 745,11
Soil buffering of rain-water salinity in the Vaal Dam catchment	31 584,00	31 584,00	*(31 584,00)
The application of resource economics to water management decision-making in South Africa	117 103,00	117 103,00	45 097,00
TOTAL	**18 122 808,55**	**45 238 181,39**	**1 903 587,42**
2. RESEARCH SUPPORT SERVICES			
South African Water Information Centre	866 010,16	866 010,16	40 239,84
The establishment of a National Hydrological Information System	498 856,35	6 019 561,51	-
The establishment of a Computing Centre for Water Research	582 659,00	1 777 483,51	*(104 659,00)
TOTAL	**1 947 525,51**	**8 663 055,18**	***(64 419,16)**
GRAND TOTAL	**20 070 334,06**	**53 901 236,57**	**1 839 168,26**

* Excess expenditure over advances for projects

Statement 4
Budget 1993

	R
ESTIMATED INCOME	**46 392 000**
Rates and charges in terms of Section 11 of the Water Research Act	43 000 000
Interest on investments	2 800 000
Erf Sewe-Nul-Ses Rietfontein (Pty) Ltd	592 000
APPROPRIATION FROM ACCUMULATED FUNDS	**4 821 990**
TOTAL ESTIMATED INCOME	**51 213 990**
ESTIMATED EXPENDITURE	
Administrative expenses	**8 289 500**
Salaries and allowances	5 054 000
Subsistence and transport	852 000
Postal, telegraph and telephone services	123 000
Printing, stationery and advertisements	110 000
General expenses	2 150 500
Approved research projects:	**22 637 590**
Research on the storage and utilisation of rain water in soil for the stabilisation of plant production in semi arid regions	207 000
Research on the factors affecting the water use efficiency of irrigated crops, with special reference to the physiological responses of these crops	180 000
Hydrological modelling studies in the Eastern Cape	298 500
Research on the effects of varying water quality on the corrosion of different pipe materials in the PWV/Klerksdorp areas	5 047
Research on the water-use efficiency of certain irrigated temperate pasture species	95 600
Research on soil-plant-water relations in the upper reaches of plant available soil water	133 000
Research on the evaluation of the four-electrode electrical conductivity and electromagnetic induction techniques of soil salinity measurement for use under South African conditions	21 595
Research on hydrological systems model development	632 000
Research on a flood and furrow irrigation: A critical evaluation of design procedures and the computerising of the most suitable procedures	75 000
A regional investigation into ground-water quality deterioration in the Olifants River catchment above the Loskop Dam, with specialised investigations in the Witbank Dam sub-catchment	406 873
Research on the freshwater requirements of estuarine plants	70 500
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	89 300
Research on the surface water resources of South Africa 1990	690 000
Research on the adaption and calibration of an urban runoff quality model	234 600
Research on the utilisation of geographical information system (GIS) and integrated environmental management (IEM) in the planning and management of water resources within river catchments	101 000
An investigation into the quality of water for animal production	96 000
Research on the erodibility of different rock formations under varying flow conditions	18 000
Research on the use of saline water for irrigation purposes and an assessment of salt tolerance criteria of crops	254 300
Research on the applicability of hydrodynamic reservoir models for water quality management in stratified water bodies in South Africa	159 000
Research on interpolation and mapping of daily rainfall model parameters for South Africa	70 000
Research on techniques for seasonal and long-term rainfall forecasting in South Africa	106 300
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	138 000
Research on the development and evaluation of geohydrological and isotope hydrological methodologies for the identification of areas potentially suitable for waste disposal	150 000

	R
Research on the occurrence and accumulation of selected heavy metals in freshwater ecosystems affected by mine and industrial effluent	80 200
Research on urban catchment monitoring	2 000
Research on the optimisation of biofouling control programmes	100 000
Research on monitoring the effect of catchment development on urban runoff and water balance	300 000
Research on modelling of tubular reverse osmosis systems	230 000
Research on the development of an effective and environmentally safe larviciding programme for the control of the black fly, *Simulium chutteri*, along the Orange River	133 800
A study of the relationship between hydrological processes and water quality characteristics in the developing Zululand coastal region	193 400
A global farm approach to enhancing the economic efficiency of water and energy use for irrigation in the central RSA	193 800
Root development and water usage of commercial timber species	73 200
Evaporation measurements above vegetated surfaces using micro-meteorological techniques	70 775
The effect of pollution on the physiology of fishes in the Olifants River (Eastern Transvaal)	84 000
The effect of water quality variables on riverine biotas	178 000
Development of a method for the selection of suitable landfill sites, and of guidelines for sanitary landfill in municipal areas	90 000
Preparation of a manual on quantitative estimation of ground-water recharge and aquifer storativity	8 000
The consolidation of activated sludge research	165 000
Research on the microbiological transformations of metal contaminated effluents	147 000
The development of guidelines for toxicity bio-assaying of drinking and environmental waters in South Africa	130 000
An investigation into phytoplankton blooms in the Vaal River and the environmental variables responsible for their development and decline	102 000
Research on the development of tolerant membranes	207 000
Research on industrial application of membranes	158 300
The development and evaluation of small-scale potable water treatment equipment	226 000
Research on field dilution studies on large offshore pipelines	6 500
Research on full-scale pilot plant studies on phosphate crystallisation in biological systems	111 200
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
The Southern Agulhas current and its influence on the weather and climate of Southern Africa	200 000
The development of a distributed hydrological modelling system to assist with water quantity and quality management in the Mgeni catchment, Phase II	569 300
The geomorphological response to changing flow regimes of the Sabie and Letaba River systems	247 000
The use of geographic information systems and other computer-aided drafting facilities for the production of geohydrological maps	233 000
The development of techniques for risk analysis and ground-water management of Southern African aquifers	307 000
Techniques for microbial aspects of water quality investigation of South African rivers	425 000
The corrosion performance of various non-metallic piping materials and coatings in potable water	157 900
A water resources and sanitation systems sourcebook with special reference to Natal/KwaZulu	110 700
Technical, socio-economic and environmental evaluation of sanitation systems for developing urban areas in South Africa	40 000
Research on development of a crossflow microfilter for rural water supply	292 000
Research on the development and production of membrane systems	414 300
The evaluation of various methods for the forming of free radicals for the oxidation of molecules in industrial effluents and potable water	269 000
Scheduling irrigation of tuberous crops with specific reference to potatoes	29 200
The degradation of mortar linings and concrete by micro-organisms in industrial water systems	20 000
The preparation of a manual for waste load allocation in South Africa	401 700
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	115 900
A structural analysis of the water apportionment mechanisms in the Water Act 54/1956, in view of the requirements of competing user sectors	60 000
Marine pollution: Pathogenic micro-organisms	87 700
Contribution to the estuaries research programme	50 000

Statement 4
Budget 1993 (continued)

	R
The use of vegetation in the amelioration of the impacts of mining on water quality - An assessment of species and water use	257 300
The application of resource economics to water management decision-making in South Africa	78 000
The application and performance of full-scale artificial wetlands for waste-water treatment in South Africa	153 200
Optimal water utilisation by turf	27 800
Catchment and land use: Effects on water quality and estuaries	14 000
Water quality and quantity assessments in catchments with changing land uses in the Umzinto coastal area	52 900
The long-term salt balance of the Vaalharts irrigation scheme	100 000
The relationship between atmospheric deposition and water quality in a small upland catchment	245 900
The rapid biological assessment of water quality impacts in streams and rivers	175 000
The effect of pre-programmed deficit irrigation on crop reaction	197 000
The development of an urban component for the ACRU model	73 900
The development of an integrated catchment management system for the Crocodile River catchment	247 900
Preliminary investigation of algal weeds in South African inland waters	72 200
The development of electro-osmotic sludge dewatering technology	164 500
An overview of the pesticide and heavy metal levels present in populations of the larger indigenous fish species of selected South African riviers	158 000
Research on bio-augmentation technology for waste-water treatment in South Africa	96 000
Microbiological corrosion of common piping materials in the PWV area	135 500
Engineering properties of important Southern African rock types with special reference to the shearing strength of concrete dam wall foundations	125 900
Evaluating the long-term use of polypropylene for hot and cold water piping	46 400
Development of a training programme on community water supply management for village water committees	55 000
Mechanisms of short-term rainfall variability	125 000
An assessment of the potential for using stable carbon isotope ratios of wood charcoal as a climate indicator	117 000
The development of a real-time, non-conventional rainfall mapping system	127 000
Potential impacts of rainfall stimulation on water resources and forestry in the Nelspruit-Bethlehem target zone	145 000
Identification of irrigation land in an intensively cultivated agricultural area in the South Western Cape by means of satellite remote sensing	35 900
Determination of the relationship between transpiration rate and declining available water for *Eucalyptus grandis*	124 800
Development of improved flow gauging structures for South African rivers	190 000
The compilation of guidelines for the use of peroxone and other oxidants in the treatment of eutrophic water	93 000
Development of rigorous engineering methodology for designing vegatative erosion protection systems	151 600
The removal of colour from Cape waters using ozonation and ultrafiltration	71 000
Ozonation in the production of potable water from polluted surface water	75 000
Research to optimise diffuser design for offshore pipelines - laboratory experiments	32 500
The improvement of injection nozzels for dissolved air flotation	26 000
Evaluation of non-conventional disinfection technologies for small water systems	31 000
Research on performance criteria for package water treatment plants	160 000
The occurrence of protozoan parasites in South African drinking water	120 500
Development of procedures to assess whole effluent toxicity	199 700
An investigation of the occurrence of bacteria causing acid mine drainage in the outer layers of coal waste dumps	48 500
Research on the anaerobic digestion of dairy factory effluents	45 100
The regional treatment of textile and industrial effluents	170 000
Monitoring and optimization study of high-rate biofiltration, aerobic biological treatment processes for tannery and fellmongery wastewater	106 700
Research on the development of an expert systems approach to water management in the fruit and vegetable processing industry	60 000
Diversity and productivity of biotic communities in relation to freshwater inputs in Eastern Cape estuaries	17 000
The use of yeast biomass and yeast products to accumulate toxic and valuable heavy metals from waste water	34 400
The characterisation of South African media for sand filtration	23 000
Developing an integrated approach to predicting the water use of riparian vegetation	289 300
The development of a recirculating experimental stream system	294 100
The transfer of research results on the irrigation of vegetable crops into practice	312 000
Guidelines and procedures to assess and ameliorate the impact of gold mining operations on the water environment	340 000
Research on the saving of water with air-cooled heat exchangers	216 500
Research on a molecular approach to drought tolerance	156 100

Statement 4
Budget 1993 (continued)

	R
Per capita water demand in developing communities	262 400
Research on geochemistry and isotopes for resource evaluation in the fractured rock aquifers of the Table Mountain Group	125 000
The development of a strategy to monitor ground-water quality on a national scale	20 000
The compilation of a hydrogeological map of South Africa	255 300
An integrated multidisciplinary geodynamic/geophysical approach to ground-water exploration around the South African coastline	254 000
Development of a systematic method for evaluating site suitability for waste disposal based on geohydrological criteria	200 100
Catchment water quality deterioration as a result of water-level recovery in abandoned gold mines on the eastern and central Witwatersrand	300 000
Analysis and interpretation of aquifer tests in secondary aquifers	329 300
Optimisation of the Rand Water Board System	202 000
The development of procedures for the control of unaccounted-for water in water distribution systems and for the reduction of water loss	475 000
The development of flood damage functions and a computer program to determine the advantages of flood and flood damage control measures	182 500
Research on pond enhanced trickling filter operation (PETRO)	208 000
Research on the effect of the agricultural environment on water resources	372 000
The development and testing of a water balance model for a grassland catchment in the summer rainfall area of South Africa	329 000
Classification and hydrological modelling of low flows in Southern Africa	317 500
Biotechnological approach to the removal of organics from saline effluents	135 000
Research on human viruses in diffuse effluents and related water environments	225 500
Research on a geomorphological classification system for South African River Systems	168 100
Continuing research into the wetlands of Natal/KwaZulu	43 100
Plunge pool scour reproduction in hydraulic models	245 100
The effect of land use on Gamtoos Estuary quality	25 700
A manual on water purification and plant design. Phases 2 and 3: A design guide for water purification	101 500
Expected projects	**15 353 900**
Other grants	**4 933 000**
Technology and information transfer	1 020 000
Research and other grants	145 000
Specialist and consultation services	1 400 000
Research support services	2 368 000
TOTAL ESTIMATED EXPENDITURE	**51 213 990**

Statement 5

Statement of receipts and payments for the year ended 31 December 1992

RECEIPTS	1992 R
Balance on 1 January 1992	**18 069 837**
Investment at Corporation for Public Deposits	**17 591 364**
Cash on hand	**150**
Cash in bank	**478 323**
Rates	**722 093**
Government irrigation schemes with canal systems	**383 086**
Irrigation Board schemes	**339 007**
Charges	**36 830 670**
Metered water from Government schemes	**30 371 261**
Municipalities	**6 449 455**
Interest on charges in arrear	**9 954**
Interest on investments	**1 955 775**
Loan: Erf Sewe-Nul-Ses Rietfontein (Pty) Ltd	**1 004 176**
Sundry income	**172 099**
Subsistence and transport advances recovered	**162 647**
	R58 917 297

PAYMENTS	1992 R
Administrative expenditure	**7 344 089**
Salaries and allowances	**4 254 661**
Motor transport	**20 184**
Subsistence and transport expenses	**273 677**
Subsistence and transport advances	**96 324**
Own transport: Purchases	**NIL**
General transport	**403 386**
Commission members' allowances	**16 170**
Postal and telegraph services	**26 790**
Telephone services	**76 647**
Printing and stationery	**95 294**
Advertisements	**11 712**
Office equipment: Purchases	**291 639**
Computer software	**20 393**
Lease and maintenance of office equipment	**90 232**
Entertainment	**35 503**
Office rental	**730 606**
Alterations to office complex	**6 984**
Electricity	**60 327**
Office furniture: Purchases	**10 752**
Maintenance and lease of furniture	**1 474**
Typing, translation and services rendered	**24 975**
Insurance and licences	**39 208**
Collection fees	**401 951**
Audit fees	**41 480**
Legal costs	**192 420**
Registration and subscriptions	**73 873**
Miscellaneous petty expenses	**27 433**
Loan: Erf Sewe-Nul-Ses Rietfontein (Pty) Ltd	**19 994**
Research expenses	**32 793 740**
Project advances	**27 380 958**
Research projects	**3 912 241**
Technology and information transfer	**659 403**
Research and other grants	**52 538**
Specialist and consultation services	**929 610**
Research support services	**(141 010)**
Balance as at 31 December 1992	**18 779 468**
Investment at Corporation for Public Deposits	**18 787 140**
Cash on hand	**150**
Bank overdraft	**(7 822)**
	R58 917 297

WATER RESEARCH COMMISSION PRETORIA, 2/3/1993

(Signed) PE ODENDAAL **EXECUTIVE DIRECTOR**

Annexure

PUBLICATIONS EMANATING FROM RESEARCH FINANCED WHOLLY OR PARTIALLY BY THE COMMISSION

This Appendix contains a list of publications released in 1992.
Requests for publications should be directed, as far as possible, to the authors.

Articles and papers (1992)

- Adam, BF and Hiscutt, FO (1992) Two-dimensional laser imaging of cloud particles. Poster presentation at the 9th Annu. Conf. of the S. Afr. Soc. for Atmos. Sci., Pretoria. 14-15 October.
- Adams, JB (1992) The role of freshwater in the maintenance of estuarine plant communities. Paper presented at the Inst. for Coastal Res. Symp., Univ. of Port Elizabeth, April; also in *The Naturalist* **36** (2).
- Adams, JB and Bate, GC (1992) An expert system to aid in the management of the freshwater requirements of estuarine plants. Paper presented at the Aquat. Ecosyst. Conf., Univ. of Cape Town. July.
- Adams, JB, Knoop, WT and Bate, GC (1992) The distribution of estuarine macrophytes in relation to freshwater. *Bot. Mar.* **35** 215-226.
- Adams, JB and Talbot, MMB (1992) The influence of river impoundment on the estuarine seagrass *Zostera capensis* Setchell. *Bot. Mar.* **35** 69-75.
- Arthington, AH, King, JM, O'Keeffe, JH, Bunn, SE, Day, JA, Pusey, BJ, Bluhdorn, DR and Tharme, R (1992) Development of an holistic approach for assessing environmental flow requirements of riverine ecosystems. *Proc. of an Int. Semin. and Workshop on Water Allocation for the Environ.*, Centre for Water Policy Research, Armidale, Australia. 69-77.
- Ashton, PJ (1992) The approach used in conducting a water quality situation analysis and evaluating the impacts of low-cost, high-density urban developments on water resources. Paper presented to the S. Afr. Inst. of Civil Eng., East London Branch, 3 March; and at Mini Symp. of Water Users in the Buffalo River Catchment, East London, 4 March.
- Baird, D and Heymans, JJ (1992) Preliminary network analysis of the Krom River estuary. Paper presented at Conf. on Aquat. Ecosyst., Cape Town. 7-10 July.
- Barnett, JL, Carliell, CM, Buckley, CA, Chetty, R and Senior, E (1992) Residence time methods for modelling and assessing the performance of anaerobic digesters. Paper presented at Anaerobic Digestion Conf., Pietermaritzburg. 10-13 July.
- Bate, GC, Campbell, EE and Parker-Nance, T (1992) Coastal aquifers in Southern Africa: Their ecological importance. Paper presented at 1st Int. Groundwater Ecol. Conf., Tampa, Florida.
- Bath, AJ (1992) Application of CE-QUAL-W2: A two-dimensional water quality and hydrodynamic simulation model. Paper presented at the Conf. of the S. Afr. Soc. of Aquat. Sci., Cape Town. 7-10 July.
- Bezuidenhout, D (1992) Tolerant poly(vinyl alcohol) membranes for wastewater treatment. Paper presented at Sasol Technol. Symp., Johannesburg. 1 July.
- Birkhead, AL and James, CS (1992 Developing an integrated approach to predicting the water use of riparian vegetation. Paper presented at 2nd Annu. Conf., KNP Rivers Res. Programme, Pretoria. March.
- Birkhead, AL and Van Coller, AL (1992) Is riparian vegetation structure related to groundwater movement? Paper presented jointly to the Centre for Afr. Ecol. and Centre for Water in the Environ., Univ. of the Witwatersrand. August.
- Bloem, AA en Laker, MC (1992) Ontwerp- en bestuurskriteria vir oorhoofse besproeiingstelsels om gronderosie te bekamp. Referaat gelewer by die 17e Nas. Kongr. van die Grondkundever. van S-Afr., Stellenbosch. 28-30 Januarie.
- Bosch, M and Cloete, TE (1992) Phosphate accumulation by *Acinetobacter* strains in activated sludge. Paper presented at 7th Bienn. Congr. of the S. Afr. Soc. for Microbiol., Bloemfontein. 30 March - 1 April.
- Bosch, M and Cloete, TE (1992) Protein profiles of *Acinetobacter* strains exhibiting variations in phosphate accumulation. Poster presentation at 16th Bienn. IAWPRC Int. Conf., Water Quality '92. Washington DC, USA. 24-30 May.
- Botes, JHF en Oosthuizen, LK (1992) Prosedures en probleme by die gebruik van 'n gewasgroeisimulasiemodel. *SA Tydskr. vir Plant en Grond* **9** (2) 87-93.
- Botha, A and Pieterse, AJH (1992) A comparative study of vegetative cells and aplanospores of *Haematococcus pluvialis*. Paper presented at Joint Conf. of the SA Soc. of Aquat. Sci. and the Phycol. Soc. of SA, Cape Town.
- Botha, GR, Sanderson, RD and Buckley, CA (1992) Brief historical review of membrane desalination, wastewater application and membrane development in Southern Africa. Paper presented at IAWPRC Spec. Conf. on Membrane Technol. in Wastewater Manage., Cape Town. 2-5 March.
- Botma, KL en Grabow, WOK (1992) Verhoging van die vatbaarheid van selkulture vir enteriese virusse. Plakkaataanbieding, Fakulteitsdag, Fakulteit Geneeskunde, Univ. van Pretoria. 22 Julie.
- Brouckaert, CJ (1992) The use of computer simulation of tubular reverse osmosis in conjunction with pilot-plant studies. Paper presented at IAWPRC Spec. Conf. on Membrane Technol. in Wastewater Manage., Cape Town. 2-5 March.
- Brouckaert, CJ and Buckley, CA (1992) Simulation of tubular reverse osmosis. *Water SA* **18** (3) 215-224.
- Brözel, VS and Cloete, TE (1992) Adaptation of *Pseudomonas aeruginosa, P. stutzeri* and *Bacillus cereus* to bactericides. Paper presented at 7th Bienn. Congr. of the SASM. March.
- Brözel, VS and Cloete, TE (1992) Evaluation of nutrient agars for the enumeration of viable aerobic heterotrophs in cooling water. *Water Res.* **26** 1111-1117.
- Brözel, VS and Cloete, TE (1992) Resistance of *Pseudomonas aeruginosa* to 2,2'methylenebis-(4-chlorophenol) is not alginate-mediated. Poster presentation at the 7th Bienn. Congr. of the SASM. March.
- Brözel, VS and Cloete, TE (1992) The adaptation mechanism of *Pseudomonas aeruginosa* to growth in the presence of 2,2'-methylenebis-(4-chlorophenol). Poster presentation at Water Quality International '92: 16th Congr. of IAWPRC, Washington, USA, May; and ISME-6, Barcelona, Spain, September.
- Bruyere, CL (1992) A one-dimensional time dependent cloud model. Paper presented at the 9th Annu. Conf. of the S. Afr. Soc. for Atmos. Sci., Pretoria. 14- 15 October.
- Buckley, CA (1992) Membrane technology for the treatment of dyehouse effluents. Paper presented at IAWPRC Spec. Conf. on Membrane Technol. in Wastewater Manage., Cape Town. 2-5 March.
- Buckley, CA, Brouckaert, CJ and Kerr, CA (1992) RO application in brackish water desalination and in the treatment of industrial effluents. In: Amjad, Z (ed.) *Reverse Osmosis: Membrane Technology, Water Chemistry and Industrial Applications.* Van Norstrand Reinhold Publishing Company, New York. 275-300.
- Buckley, CA, Kerr, CA and Simpson, AE (1992) Small-scale tests to determine the feasibility of reverse osmosis and ultrafiltration for the treatment of industrial effluents. *Water SA* **18** (1) 63-67.
- Casey, TG, Ekama, GA, Wentzel, MC and Marais, GvR (1992) Causes and control of low F/M filamentous bulking in nutrient removal activated sludge systems. Paper presented at Two-day Workshop on Prevention and Control of Bulking Activated Sludge, Perugia, Italy. June.
- Casey, NH, Meyer, JA and Van Niekerk, WA (1992) Water quality for livestock: Establishing quality criteria. Dep. of Animal Husbandry, Univ. of Pretoria.
- Casey, TG, Wentzel, MC, Loewenthal, RE, Ekama, GA and Marais, GvR (1992) A hypothesis for the cause of low F/M filament bulking in nutrient removal activated sludge systems. *Water Res.* **26** (6) 867-869.

- Chapman, GC and Ekama, GA (1992) The effect of sewage sludge co-disposal and leachate recycling on refuse stabilization. *Proc. Wastecon 92 - Waste Manage. in a Changing Soc.*, Johannesburg. November.
- Chetty, S and Buckley, CA (1992) Evaluation of cavitation for the oxidation of organic pollutants' international ozone association. Paper presented at 2nd S. Afr. Ozone Conf., Warm Baths. 27-28 October.
- Chikawaga, J, Jacobs, EP and Sanderson, RD (1992) Gas separation membranes from polysulphone and Lewis acid: Base complex solvent system. Paper presented at 5th Int. Conf. on Chem. in Africa, Gabarone, Botswana. 27-31 July.
- Chutter, FM and Pieterse, AJH (1992) Ecological status of the Vaal River System. *Proc. of the 1992 Water Week Conf.*, Water Research Commission, Pretoria. 17-19 September. 117-127.
- Cloete, TE, Bosch, M and Mienie, NJJ (1992) Organisms other than *Acinetobacter* capable of phosphorus removal from activated sludge mixed liquor. *Proc. European Conf. on Nutrient Removal from Wastewaters*, Leeds, UK Technomic Publishing Co., Lancaster, UK.
- Cloete, TE, Brözel, VS and Von Holy, A (1992) Practical aspects of biofouling control in industrial water systems. *Int. Biodet. and Biodegr.* **29** 299-341.
- Cloete, TE and De Bruyn, EE (1992) Culture media for the detection and enumeration of sulphate-reducing bacteria in industrial water systems. Poster presentation at Water Quality International '92: 16th Congr. of IAWPRC, Washington, USA. May.
- Cloete, TE and De Bruyn, EE (1992) Culture media for the detection and enumeration of sulphate-reducing bacteria in industrial water systems. Paper presented at ISME-6, Barcelona, Spain. September.
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