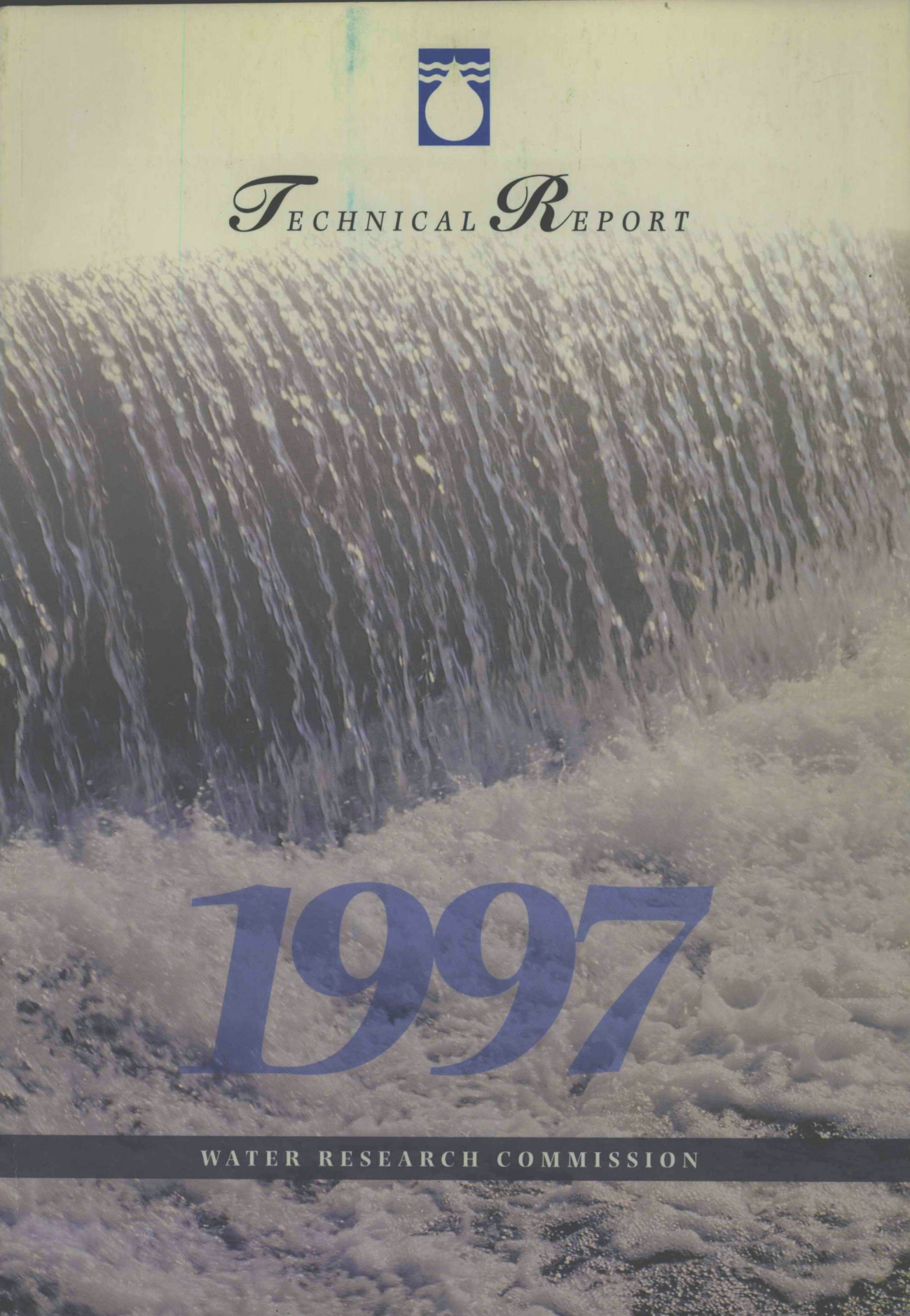
TECHNICAL REPORT



1997

WATER RESEARCH COMMISSION

1997

TECHNICAL REPORT

WATER RESEARCH COMMISSION

ADDRESS:

491 18th AVENUE
RIETFONTEIN
PRETORIA
0084

POSTAL ADDRESS:

PO BOX 824
PRETORIA
0001
SOUTH AFRICA

WEBSITE: http://www-wrc.ccwr.ac.za

☎ (012) 330-0340

F NATIONAL (012) 331-2565
INTERNATIONAL (2712) 331-2565

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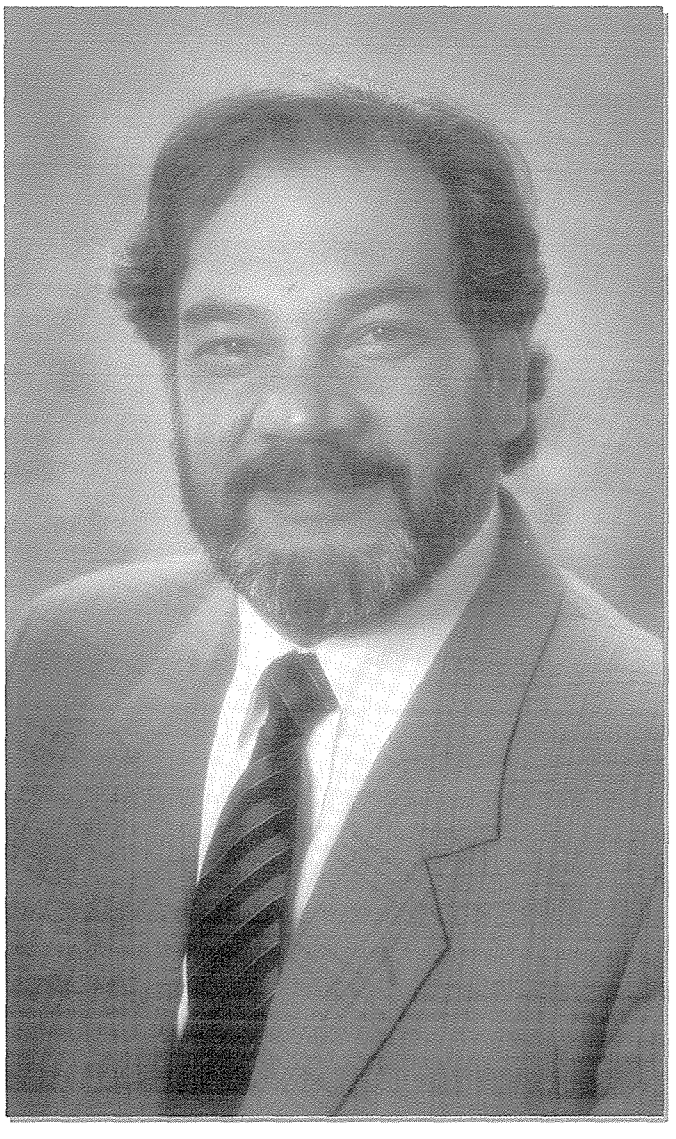

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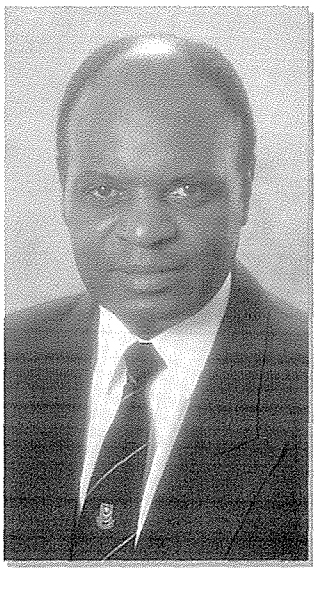

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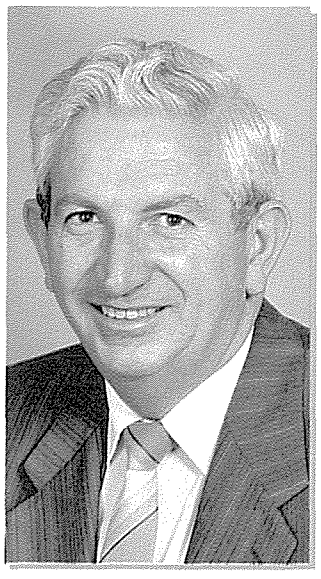

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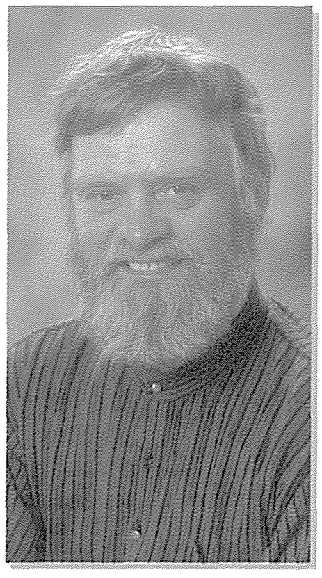

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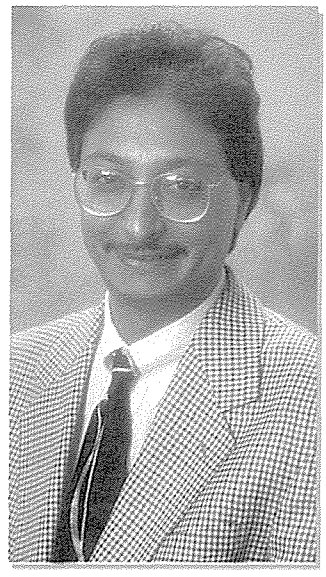

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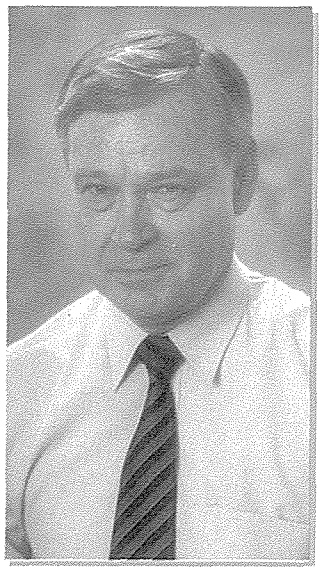

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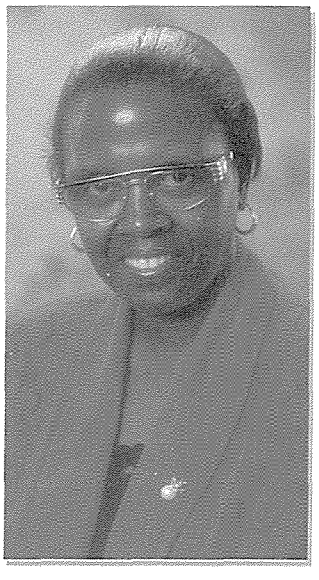

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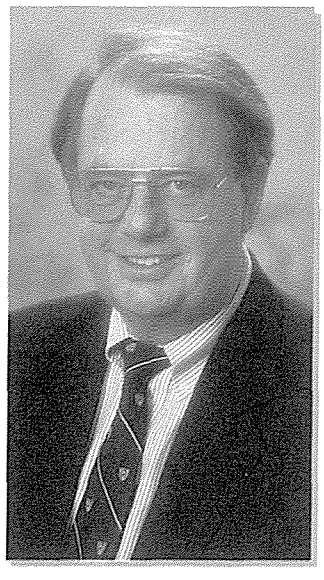

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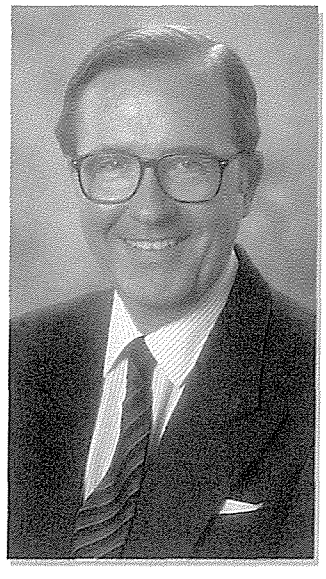

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Assistant research manager

Dr IM Msibi

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THE YEAR UNDER REVIEW

The diverse number of research fields supported by the Water Research Commission (WRC) bears testimony to its multidisciplinary approach to water research. The research fields and allocation of funds to the various fields for 1997 are indicated in Figure 1.

The WRC does not itself undertake research, but enters into agreements with other organisations to carry out the research. In Table 1 the research sectors which are responsible for the research, are listed, as well as the extent of their involvement:

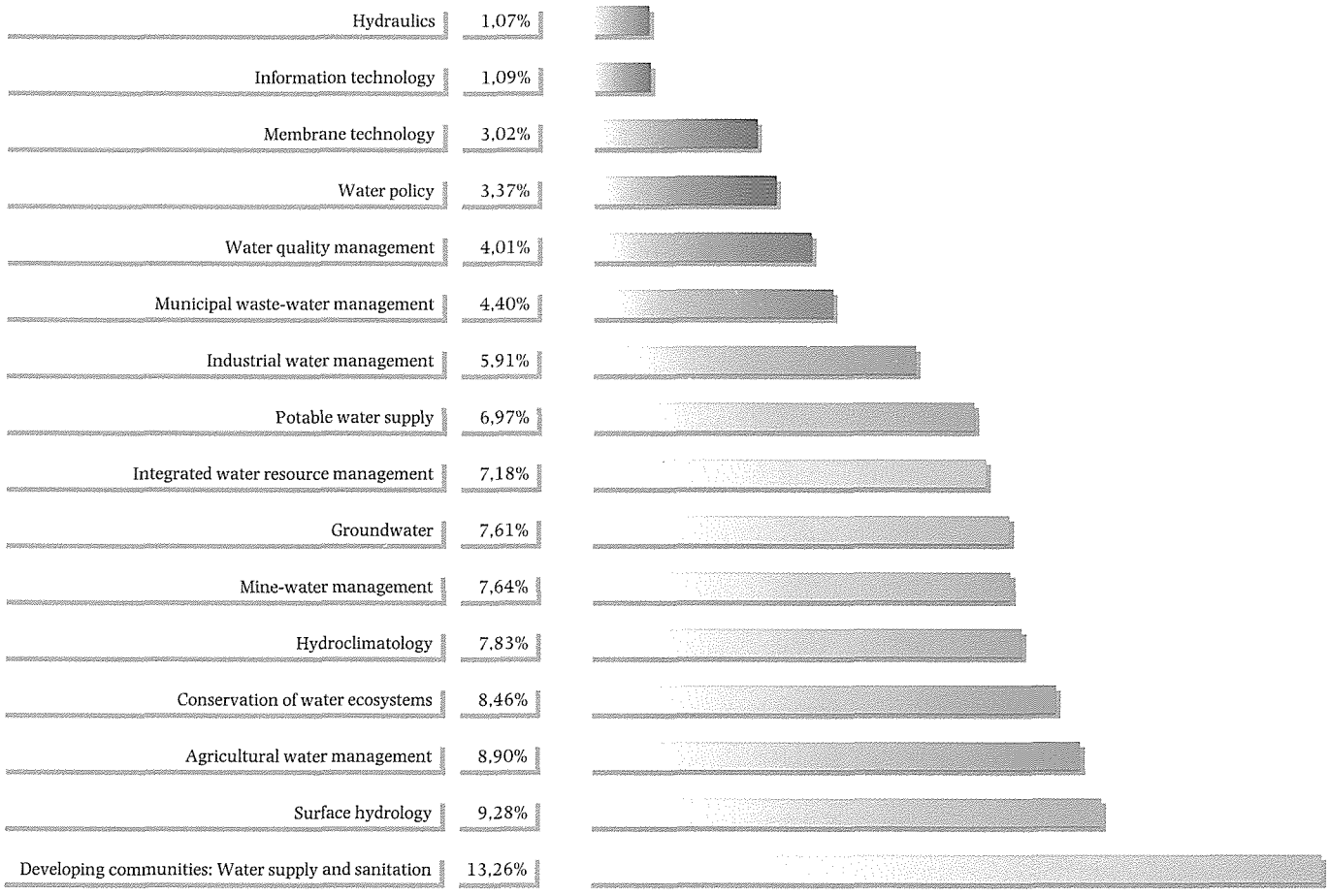
Table 1

Research sector	Number of times involved	%
Universities	124	52,99
Consultants	46	19,66
CSIR	38	16,24
Other	10	4,27
Water boards	9	3,85
Government departments	6	2,56
Local authorities	1	0,43
Total	**234**	**100**

From the figures it is evident that universities are involved in 52,99% of the total number of contracts. The number of times that organisations are involved, namely 234, 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 1997 the WRC financially supported 232 projects at a budgeted amount of R40 460 400.

In addition to the direct funding of contractual research projects, the WRC also finances the Computing Centre for Water Research (CCWR), a research support service, and the development of the WATERLIT database.

Figure 1. Allocation of funds (%) to the various fields during 1997



Community participation in integrated catchment management

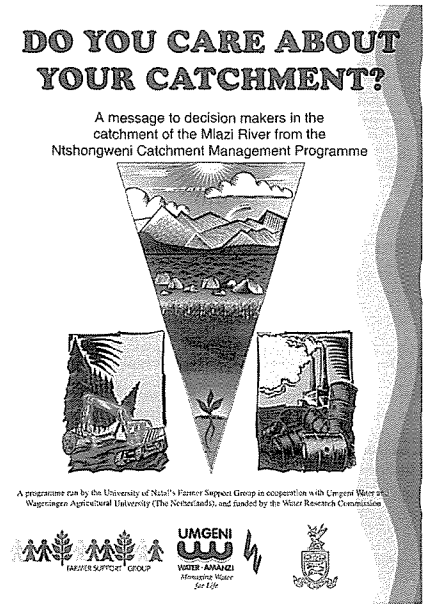
Two years ago the WRC initiated a pilot study with the Farmer Support Group, University of Natal, on the development of a framework for community participation in integrated catchment management. The catchment selected was the area above Ntshongweni Dam in Natal.

The project achieved a remarkable degree of success in mobilising a wide variety of stakeholders in the Mlazi catchment as a whole. The following groups have shown a willingness to co-operate: Umgeni Water, Mondi Forest, Commercial Farmers, Natal Parks Board, Umlazi Irrigation Board, Conservancies, Hammarsdale Textile Industry and many others.

A promising start has been made with the organisation of local communities. The Mpumalanga Environmental Forum was formed, the Ezakhiweni Field Committee is involved and, in general, great support is achieved through the schools in the area. With the new Water Act around the corner the relevance of this project cannot be over-emphasised. Based on the initial success and progress of the pilot study a new three-year project was started this year.

Co-ordinating Committee for Research on Water Supply and Sanitation for Developing Rural and Urban Communities (CCRUC)

With the co-operation and support of government departments, water boards, development consultants and researchers, the WRC published a Preliminary Strategic Plan that identifies priority research areas within the field of **Developing Communities: Water Supply and Sanitation**. This strategic plan was used by the CCRUC user group subcommittees as a guide for selection of project proposals for funding in 1998.



The development of a dynamic cross-flow sand filter for rural water treatment

A dynamic cross-flow sand filter for water clarification, was evaluated by Environmentek, CSIR. In this filter an adequate portion of raw water flows rapidly across the surface of the sand bed to re-entrain deposited turbidity particles into the cross-flow stream. This innovation avoids the frequent cleaning of the filter, which is a tiresome and time-consuming operation.

A pilot filter was erected, with financial assistance obtained from the Mvula Trust and the Thukela Joint Services Board, at Emmaus in KwaZulu-Natal. Field tests conducted revealed, *inter alia*, that the raw feed water's turbidity could be reduced by 76% and that the faecal coliform removal efficiencies were over 70%. Terminal disinfection is necessary in order to ensure safe drinking water and to maintain a residual disinfection capacity in the water in the distribution system.

The study has revealed that the dynamic cross-flow sand filter is sufficiently uncomplicated to enable rural communities not only to construct the system, but also to operate and maintain the filter to yield drinking water of acceptable quality.

Strategies for improving women's participation in water and sanitation projects

The principle of a gender-balanced approach to the management of water supply and sanitation services has been endorsed by international forums such as the Dublin Conference, the Earth Summit in Rio de Janeiro and the Women's Summit in Beijing. Women as primary users of water supply schemes have a major role to play in ensuring the sustainability of these schemes. It is therefore necessary to develop strategies for empowering them so that they can participate fully in the implementation, operation and maintenance of water supply schemes. This research project which is being executed by Environmentek, CSIR, will develop a programme for empowering women so that their level of participation in the management of water and sanitation projects can be enhanced.

UNESCO/UNDP/UNICEF regional workshop on women's participation and gender consideration in water supply and sanitation services

During 1997 the WRC collaborated with UNESCO, UNDP and UNICEF in organising a workshop on *Women's Participation and Gender Consideration in Water Supply and Sanitation Services*. The aim of the workshop was to enable delegates from 14 African countries to share their experiences and to develop operational lessons for the promotion of women's participation and gender considerations in water and sanitation services. The workshop was held in Pretoria between 24 and 26 November 1997.

Solid waste management in developing urban areas of South Africa

Palmer Development Group was contracted by the WRC to evaluate solid waste practice in developing urban areas of South Africa. This study showed that between 35% and 50% of black urban populations lack access to adequate waste collection services. This poor level of ser-

vice is due to a lack of institutional capacity to provide services in these areas. The study recommends that a national waste management board/department should be established to co-ordinate waste management at provincial and local government levels. There is also a need to promote community-based contractors in order to improve access to solid waste services for the developing urban areas.

Technology Transfer and Strategy Planning Sessions on Drinking-Water Research

The combined *Technology Transfer and Strategic Planning Sessions* held on 29 and 30 October 1997 were seen as a great success by the participants. These consisted of the WRC, researchers and stakeholders. The objective was to review science, technology, social and institutional issues affecting the water treatment industry and to develop strategies for investments in the drinking water supply research portfolio of the WRC over the next 2 to 5 years and also a strategic planning base for those seeking ongoing research involvement with the WRC through the submission of research proposals.

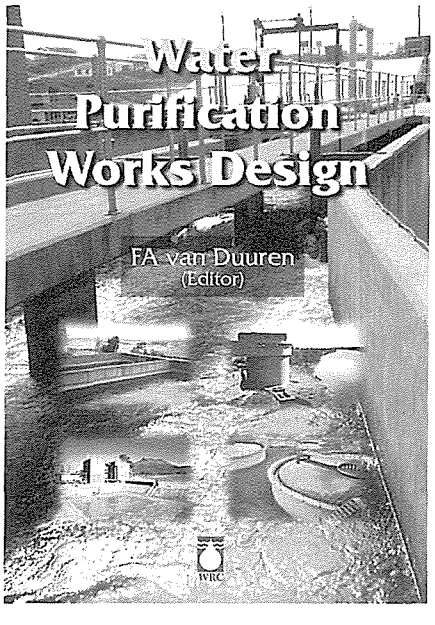
Research performance with respect to the 1992 Strategic Plan for Research on Drinking-Water Treatment was reviewed and updated. This will result in a revised version of the Strategic Plan to be released in 1998. A number of presentations were made including keynote presentations on "How sanitation is dealt with in the water services bill" and "water treatment technologies". Proceedings of this meeting and the Strategic Plan will be made available shortly.

An expert system for water treatment plant design

The first version of a computerised, expert system for the selection of water treatment processes and the design of a water purification plant has been released. The program uses a powerful shell and incorporates the user option of a true, criteria-based, expert system in the process selection phase. After entering the raw water data and desired finished water quality, a full treatment plant may be designed, making use of the expert system. Alternatively, the user may choose the processes for the program to design. Under password protection, the user is allowed to modify a number of aspects of the program to his or her specific requirements. The expert system rules, criteria used, and design and costing formulae may readily be accessed and changed. The program has been designed to handle 15 water quality parameters and a number of unit processes, including pretreatment, rapid mixing, coagulation (mechanical and hydraulic), dissolved air flotation, sedimentation (rectangular, circular and plate), slow-sand and rapid-sand filtration, granular activated carbon, pH correction, disinfection and gravity sludge thickening.

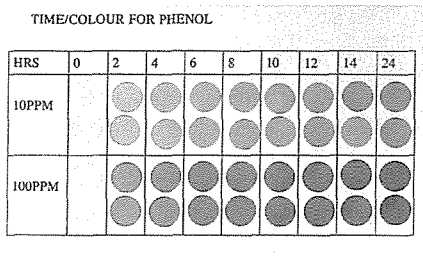
South African guide: *Water Purification Works Design*

A new South African textbook for the design of water purification and treatment works was released. The Guide is the culmination of the contributions of 9 authors and 29 reviewers, with Dr Frank A van Duuren as editor. The Guide was written with South African conditions in mind. It is aimed at the following users: Designers of waterworks; students and education; planning and controlling bodies; and operations and plant personnel. The 21 chapters cover the full spectrum of water needs determination, process selection, process design, mechanical and electrical, instrumentation and process control, costing and estimation, and operation, control and management of the completed plant. The Guide contains just over 430 pages and is bound in soft cover. It is meant to be updated at a later stage, therefore comments on any aspects of the Guide would be welcomed by the WRC.



A membrane "bioprobe" for the analysis of organics in water

A new method of analysing for phenols and other organic contaminants in water was developed by the Department of Microbiology and Biochemistry at Rhodes University as part of their bioreactor research programme. This method uses a "dipstick" consisting of the outer-skinless membrane developed at the Institute for Polymer Research, University of Stellenbosch, and an enzyme with a colour reagent immobilised on the membrane. The membrane may be used as a "dipstick"-type monitor to determine the concentration of phenols in water, at concentrations of 0 to 100 mg/l, by the intensity of the colour developed. The innovation has been patented.



Colour development using the "Bioprobe" in laboratory experiments.

A novel system to effect membrane defouling on demand of the operator

The Department of Biochemistry and Microbiology, Rhodes University, carried out an exploratory study on a new approach to membrane defouling, which has yielded some promising outcomes. This approach involves the immobilisation of an "activatable" enzyme (or combination of enzymes) onto the active layer of an ultrafiltration membrane.

During the process of ultrafiltration, a foulant layer would typically develop, which would eventually reduce the transmembrane flux to an unacceptably low level. Using this system, the flux decline caused by fouling can then be alleviated "on demand" by injecting an activator solution to the feed or during back-flushing. The activator triggers the enzyme – which has been lying dormant up to this stage – causing catalytic degradation of the foulant layer by the immobilised enzyme. The choice of "activatable" enzyme depends on the nature of the foulant layer.

This defouling strategy is a significant advancement of current enzyme-based and other cleaning-in-place systems for membrane defouling, given its simplicity, non-toxic and non-polluting nature and potential ease of automation. The technology is currently being applied to colour removal from highly coloured surface water using immobilised peroxidase enzymes. Hydrogen peroxide is employed as an activator. A provisional patent has been registered by the WRC on this process.

A novel method to render anion-exchange membranes non-fouling

A study of the fouling of polymer-based anion-exchange membranes, carried out by the Department of Chemistry, University of the Western Cape, and funded jointly by WRC and Eskom, resulted in the development of a new membrane treatment method. This method allows for more than a fivefold reduction in membrane fouling, and is suitable for most types of commercial ion-exchange membranes. The treatment affects membrane properties only to a very small extent, but prevents membrane poisoning during the electrodialysis of solutions containing macro-anions which may penetrate into the membrane matrix and deteriorate its transport characteristics. Treatment is effected by the formation of a layer of negatively charged functional groups on the membrane surface which provides electrostatic repulsion of large organic anions. The treatment operation requires only 10 min and allows stable membrane performance for at least 30 d. The technology has been proven at laboratory scale and will be evaluated for large-scale application at one of Eskom's main power stations.

Workshop on biofiltration and secondary clarification

In November 1997, the WRC, in conjunction with Wates, Meiring and Barnard (Pty) Ltd, held a *Technology Transfer Workshop on Biofiltration and Secondary Clarification*. The workshop followed a research project on high-rate biofiltration which the firm had undertaken on behalf of the WRC.

Biofiltration is a widely used technology in the treatment of sewage and industrial effluents. The technology can be applied to large sophisticated waste-water treatment plants as well as to small community-based systems. Local materials can be used to construct biofilters, such as natural stone, and labour-based construction techniques can be employed. Many existing biofilters are under-utilised and new technology can be applied to upgrade and to optimise these old facilities.

Secondary clarification is commonly used in biological treatment plants using biofiltration or activated sludge processes. The state of the art in this field was recently documented by an international project team under the auspices of the International Association of Water Quality (IAWQ). The workshop included a preview of the new IAWQ report on the theory, modelling, design and operation of secondary settling tanks.

The workshop was presented by a number of local and international specialists, some of whom co-authored the IAWQ report. The latter included Dr Denny Parker, a well-known specialist from the USA.

Municipal sewage sludge disposal: Development of guidelines and expert systems

Currently, most countries dispose of sewage sludge to land, as this route has significant positive economic and environmental consequences if planned and managed correctly.

This project, carried out by the CSIR, prompted the formulation of a common set of guidelines for South Africa: *The Permissible Utilisation and Disposal of Sewage Sludge*. The guidelines were the result of co-ordinated efforts by the WRC, the Department of Health, the Department of Agriculture, the Department of Water Affairs and Forestry (DWAF), and the Sludge Division of the Water Institute of Southern Africa (WISA). The guidelines are intended to promote the safe handling, disposal and utilisation of sewage sludge. It classifies sewage sludge by type and indicates the beneficial uses of sewage sludge as well as general requirements and precautionary measures according to type of sludge. It also indicates restrictions in the application of sludge with respect to metals, inorganics, nitrogen and organic chemicals present in sludge.

Complementary to, and in support of, these guidelines, an expert system was developed: *SLADS – Sludge Land Application Decision Support*. This software should further promote the effective management of sludge disposal in meeting environmental health objectives.

Full-scale demonstration of bulking control at the Mitchells Plain Waste-Water Treatment Plant

The Water Research Group at the University of Cape Town undertook research to develop methods of controlling the filamentous bulking in biological nutrient removal plants. The Mitchells Plain Waste-Water Treatment Plant will be used to verify, at full scale, the specific bulking control hypothesis developed by this research team from laboratory-scale research over the past six years. This demonstration study will provide an incentive for other municipalities with nutrient removal plants to implement similar strategies to control bulking.

A new technical division for WISA: Health-Related Water Aspects

The above-mentioned Technical Division was initiated by the WRC at the 1996 WISA Conference in Port Elizabeth. At the *Workshop on the Assessment Guide*, February 1997, (see following section) the new Division was introduced to the stakeholders and enrolment response was overwhelming. Two meetings of the new Division have already been held.

The objectives of the Division are to promote scientific knowledge and managerial skills regarding planning, education and research concerning health-related water aspects.

A Guide for Health-Related Aspects of Potable Water

A *Guide for the Health-Related Assessment of the Quality of Water Supplies* was compiled by the Interdepartmental Co-ordinating and Liaison Committee for Water Supply and Sanitation, consisting of representatives from the DWAF, the Department of Health and the WRC, who also funded the publication of 4 000 copies.

The Guide was widely distributed to Water Boards, Local Authorities, NGOs and other interested parties. In February 1997 a workshop was held to consult with a selected group of users on the applicability of the Guide. Representatives agreed that the novel approach used to present the information was highly successful. The workshop was also attended by a representative of the World Health Organisation (WHO), who believes that the Guide can be used in other parts of the world as well.

Two proposals for improvement were the preparation of an *Interpretation Guide* and a *Sampling Guide*, respectively. These supplementary guides are being funded by the WRC, and are due for completion, together with the amended *Assessment Guide*, by February 1998. The three documents will then be discussed at a workshop to ensure that they are user-friendly, before being distributed simultaneously. The intention is to obtain the endorsement of the WHO for the total package.

Contribution to the South African water law review process

As part of the South African water law review process, a number of task teams were established within the DWAF to address key policy issues. The WRC collaborated with some of these task teams, and in many instances, facets of ongoing or completed WRC projects were drawn upon to provide needed information for the review process. In several instances, the WRC funded special supportive investigations, while in some cases the direction of ongoing research projects was changed for the same purpose.

Effluent treatment clubs

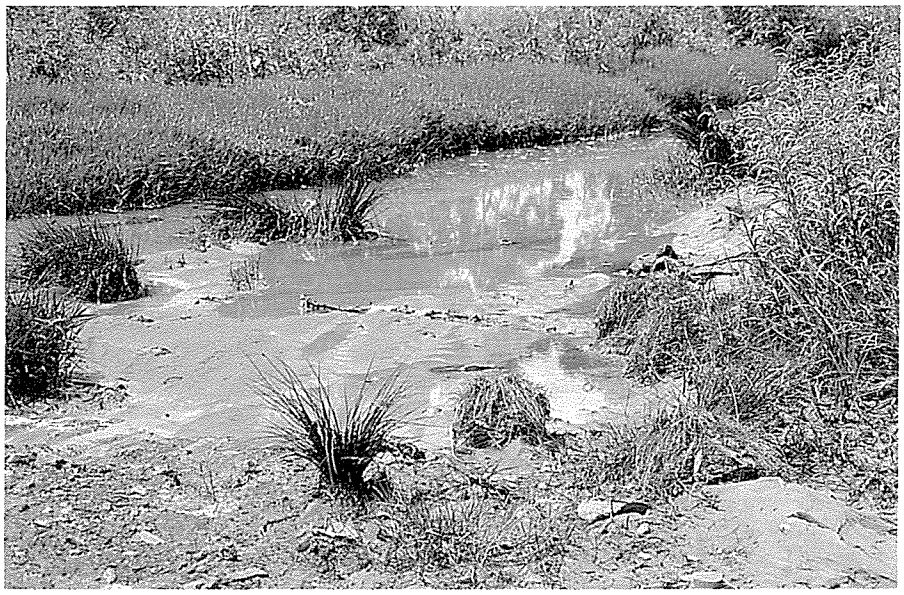
There is a national initiative to promote the establishment of industrial small-, medium- and micro-enterprises (ISMMEs). International experience indicates that cumulatively these organisations are significant sources of pollutants. Their diverse and intermittent discharges have a detrimental effect on the operation of sewage treatment works and impact negatively on downstream water users. Individually, members of this sector often do not have the resources to access conventional know-how to deal with these issues. Furthermore, conventional approaches usually overlook opportunities to make the ISMMEs more profitable through the implementation of waste minimisation and cleaner production options.

An alternative approach, which has been successfully applied internationally, is to incorporate ISMMEs into regional waste minimisation and effluent treatment clubs, in which cleaner production practices can be cost-effectively established. Experience indicates that once the culture of waste minimisation clubs has been established, large savings can be achieved.

A project will now be launched to demonstrate and evaluate the system in South Africa. The work will be undertaken by the Pollution Research Group, University of Natal, M L Sultan Technikon, Natal Technikon, University of Durban-Westville and the University of Cape Town.

Algal pond technology applied to acid drainage

Mine drainage waters and certain industrial effluents containing heavy metals and high sulphate levels, present serious environmental problems which have reached critical proportions



One of the point-source discharges of mining effluents entering the Vaal Barrage catchment.

on the East Rand ("the Grootvlei crisis"). Over 100 Ml/d of acid mine water are pumped to surface by Grootvlei Mine, threatening the ecologically sensitive Blesbokspruit RAMSAR site.

WRC-sponsored research on algal ponding technologies, undertaken in the Department of Biochemistry and Microbiology at Rhodes University over a number of years, has resulted in a novel algal integrated ponding system (AIPS) for the removal of heavy metals and sulphate from such waste waters. The system has been developed from fundamental and laboratory studies, through pilot-scale, to the construction of full-scale and demonstration plants, treating a range of waste waters at various sites. The development of a double-deck trench digester (WRC provisional patent), integrated with AIPS, further enhances the flexibility of the AIPS technology. Potential benefits include the cost-effective reduction of sulphates, the recovery of large volumes of treated water, low-cost co-disposal of large quantities of domestic sewage organics, the commercial recovery of elemental sulphur, and the production of significant quantities of high-value algal biomass on which small- and micro-enterprise aquaculture operations may be based.

This technology has been selected (amongst others) for evaluation in pilot-scale trials – requested by the DWAF – for addressing the Grootvlei problem.

Magnetic scale-prevention mechanism explained

A research team from the Rand Afrikaans University succeeded in explaining why some of the magnetic devices employed for the control of calcium carbonate scale in water systems seem to function – and why some do not. Using a fundamental approach, they discovered that the scaling control is effected by the release of micro-quantities of selected metals into the water from the metal bodies of these devices, and not by the magnetic field created by the device. The metal species should be introduced directly from the metal, i.e. as an ionic, unbound species. The effect of these species is twofold: Firstly, a delay in crystallisation time is accomplished. Secondly, the crystal type is modified. Instead of forming the normal, scaling, calcite form of crystal, the aragonite form of crystal results, thereby not forming a scaling layer on the surface of the pipe or heating surface. The invention was patented. Since this form of scaling control will be simple and inexpensive to implement in practice, the discovery could have significant benefits in alleviating this world-wide problem.

Mining-related water research and technology transfer needs

Mining-related water research activities are being co-ordinated by the Co-ordinating Committee for Mining-Related Water Research (CCMRWR), comprising representatives and individuals from Government, mining and the research communities. At a workshop held during April 1997, the CCMRWR reviewed research progress made during the past number of years and assessed the present water-related research and technology transfer needs of the industry. The following six problem areas were identified as those in which technology is either not available or inadequate:

- Water treatment options
- Water management options
- Tools and techniques for predicting environmental impacts at source level on a mine
- Quantification of the effect of mining operations on surface and groundwater resources
- Data acquisition systems, databases and information systems
- Policy with regard to the effect of mining on the water environment.

The workshop formulated and prioritised the relevant research and technology transfer needs. These were made available to interested and affected parties and are expected to guide research and technology transfer activities over the next three years.

Regional treatment options for gold-mine effluents entering the Vaal Barrage catchment

Indications are that four gold mines are contributing some 26% of the salt load to the Vaal Barrage by way of point-source discharges. The effluents from three of these mines are largely derived from mining operations undertaken during the last 100 years. These point-source effluents, therefore, constitute a regional problem which requires a co-ordinated management strategy, with inputs by the mining industry and the regulating authorities.

The costs associated with the salt load are felt by users supplied by Rand Water, Western Transvaal Regional Water Company, Goudveld Water and direct abstractors from the Vaal River system. A study was, therefore, initiated through Stewart Scott (CE) Inc. to identify cost-effective strategies to manage/treat point-source gold-mine effluents currently being discharged into the Vaal Barrage catchment. The ultimate decision on how to deal with these mine effluents should take into account the costs to downstream users of not treating these effluents.

The role of environmental chemistry in the management of pollution derived from urbanisation and industrialisation

On 22 July 1997 Vista University hosted a one-day *National Symposium on Environmental Science and Industry – Awareness, Edutraining and Research*. The seminar emanated from a WRC-funded project: **Impact of Urbanisation and Industrialisation on the Environment** (Project No 717).

The seminar specifically addressed the crucial importance of physical sciences in ensuring a sustainable environment. The emphasis was on the need to use physical sciences to assess, qualitatively and quantitatively, the contribution of pollutants derived from urbanisation and industrialisation, and to develop control strategies and technologies.

Consensus was reached that environmental chemistry had a role equal to that of ecological and biological sciences, in the management of the environment. The

seminar also spawned networking amongst participants and identification of key research areas in the field of environmental chemistry.

The management of urban impoundments in South Africa

A report was published which presents the *status quo* in South Africa regarding the management of water quality in urban impoundments. The document is an interim research report by Stewart Scott (CE) Inc. It has been published in the belief that the information collected to date by the project team will be of immediate value to urban impoundment managers. In the document, a register of South African urban impoundments and the results of a detailed analysis of environmental problems experienced in ten selected urban impoundments are presented.

The document is structured as a guide which allows users to identify other impoundments with similar characteristics to their own, and to evaluate specific management strategies which have been implemented in other urban impoundments for addressing water quality problems. A further report will follow which provides guidelines for the development of unique integrated management plans for specific urban impoundments. These guidelines will be published in early 1998, as a companion volume to the first report.

Phase III of the Kruger National Park Rivers Research Programme (KNPRRP) launched

In the 1996 *WRC Technical Report* mention was made of the planning activities regarding Phase III of the KNPRRP. During 1997 these planning activities culminated in launching Phase III (i.e. 1997 to 1999) during which the following objectives are to be addressed:

- To achieve a common understanding of the water quality and quantity requirements to sustain the natural environments of rivers which flow through the Kruger National Park.
- To develop, refine and implement methods for predicting and monitoring the responses of the natural environment of rivers flowing through the Kruger National Park to fluctuating flow and variable water quality.
- To achieve corrective action through enhancing individual and institutional capacity in the conceptualisation, implementation and management of transdisciplinary research on river systems.

An essential difference between Phase II and Phase III of the KNPRRP will be to focus on broadening the base of understanding to river forums and other stakeholders, and on the application of the knowledge and understanding to the management of rivers.

In order to meet these objectives, the Programme is again structured around subprogrammes:

- Information management and facilitation
- Integrated river management
- Research
- Monitoring
- Corrective action.

Ecological risk assessment

Ecological risk assessment is a recently developed methodology for assessing the impacts of man's activities, taking into account the inherent variability of natural systems. This gives decision-makers a more accurate assessment of the likely influence of their actions on the environment, and so presents the opportunity to make informed decisions.

The WRC, in conjunction with the CSIR, the DWAF and some leading industries, sponsored a visit by Dr Glenn Suter from the Oak Ridge National Laboratory, USA, to South Africa. Dr Suter is an internationally renowned expert in ecological risk assessment. In addition to spending time with various industries and research institutions in the country, he also addressed an open workshop on the methodology and its application. The workshop was well attended by practitioners as well as decision-makers and scientists.

Water quality requirements for riverine biota

A study on the water quality requirements of riverine biota, undertaken by the Freshwater Research Unit, University of Cape Town, has been ongoing for a number of years. One of the valuable outputs of the study has been the compilation of an extensive database, which includes taxonomic and physical/chemical data from virtually all the ecological studies that have been carried out on South African rivers. The database makes it possible to investigate both the geographic localities and the water quality conditions in which individual taxa occur. Data available on some rivers go back four decades, giving a valuable historical record for these rivers. The database will be available early in 1998.

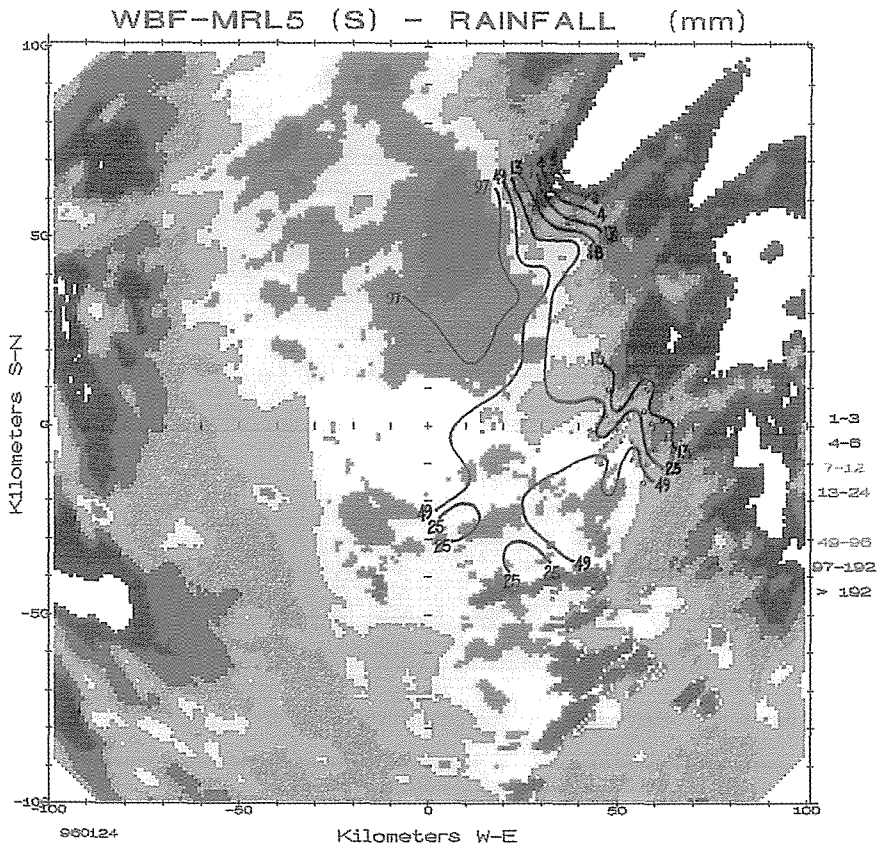
Acknowledgement for *Surface Water Resources of South Africa 1990*

After the WRC had made available the *Surface Water Resources of South Africa 1990* on a CD at nominal costs, the use of the data and methodologies was further enhanced by a nation-wide set of short courses. Two-day courses were held in Stellenbosch, Pretoria and Pietermaritzburg while one-day courses were held in Bloemfontein, Nelspruit, East London and Port Elizabeth. A total of 167 people attended these courses and especially the consulting fraternity has made use of the opportunity. As a trial the data have also been made available on the Internet through the Website of the Computing Centre for Water Research (CCWR).

During 1997 the project team responsible for the compilation of the document, received the Water Division of SAICE's Water Engineering Award for innovative contribution to water engineering.

Research on rainfall enhancement: The end of an era

Through its contribution of approximately R40 m. over a period of 14 years, the WRC has played a major role, together with the Weather Bureau,



Rainfall on 24 January 1996 around Bethlehem as measured by radar.

in researching the potential for rainfall enhancement in South Africa. The products of this research include not only a fundamental understanding of precipitation growth mechanisms in convective clouds in South Africa's summer rainfall areas, but a proven hygroscopic cloud-seeding technology for enhancing the efficiency of precipitation growth. A valuable by-product of this research has been the development of weather radar as a device for the quantitative measurement of areal rainfall.

The WRC will no longer be funding the further development of the rainfall enhancement technology, which now needs to be tested and applied within the operational context. The Weather Bureau, together with potential users of the technology, will henceforth assume responsibility for funding and testing the technology. A start has already been made via operations in the Northern Province. It is, however, possible that the WRC will assist in the co-ordination of investigations designed to ensure the optimal operational use of the rainfall enhancement technology.

International Workshop on Climate-Based Technologies in Water Management

In April 1997 some 110 delegates from 23 countries attended the *International Workshop on Weather- and Climate-Based Technologies to Benefit Water Resource Management*, held in Pretoria. The workshop focused on three technologies in particular, all of which have received a high priority within the WRC's overall hydroclimatological research thrust. The technologies in question were firstly rainfall enhancement, secondly the advanced monitoring of rainfall by incorporation of radars and satellite monitoring networks and finally, the forecasting of seasonal rainfall.

The workshop took place under the auspices of the RSA-USA Bilateral Commission, with the National Oceanographic and Atmospheric Administration (NOAA) being the lead agency from the USA. The WRC chaired the International Planning Committee. The purpose of the workshop was to bring together atmospheric scientists and water resource practitioners to jointly plan the further refinement of the technologies with a view to maximum applicability within the water resource context.

Handbook on the Hydrogeology of the Karoo Supergroup

The need to document the results of Karoo aquifer research projects, carried out over a period exceeding 20 years, was identified by the WRC's Fractured Rock Aquifer Task Group. Not only is this information of interest to those responsible for the provision of water supplies to the hundreds of villages dependent upon groundwater from Karoo aquifers, but it is essential in providing guidance on future research needs in Karoo aquifers.

Three workshops to facilitate the preparation of the Handbook were held. Experts from the geological (structural geology and sedimentology) and geohydrological fields were assembled to formulate the structure and content of the Handbook.

Workshop on exploration, monitoring and management of groundwater in Botswana, Namibia, South Africa and Zimbabwe

The WRC was invited to participate in a workshop hosted by the National University of Science and Technology in Bulawayo, Zimbabwe, from 2 to 4 June 1997. Representatives from a number of Southern African countries presented papers on the current status of groundwater within their countries.

General consensus was reached on the need to improve access to groundwater information through the publication of

hydrogeological maps at local, national and regional scales. Furthermore, the formulation of data standards for monitoring groundwater was deemed as vital for the SADC region. The need to maintain and expand national groundwater databases and share in building groundwater capacity in the region poses interesting challenges for the future.

Commodity studies as an input in the irrigation policy formation process

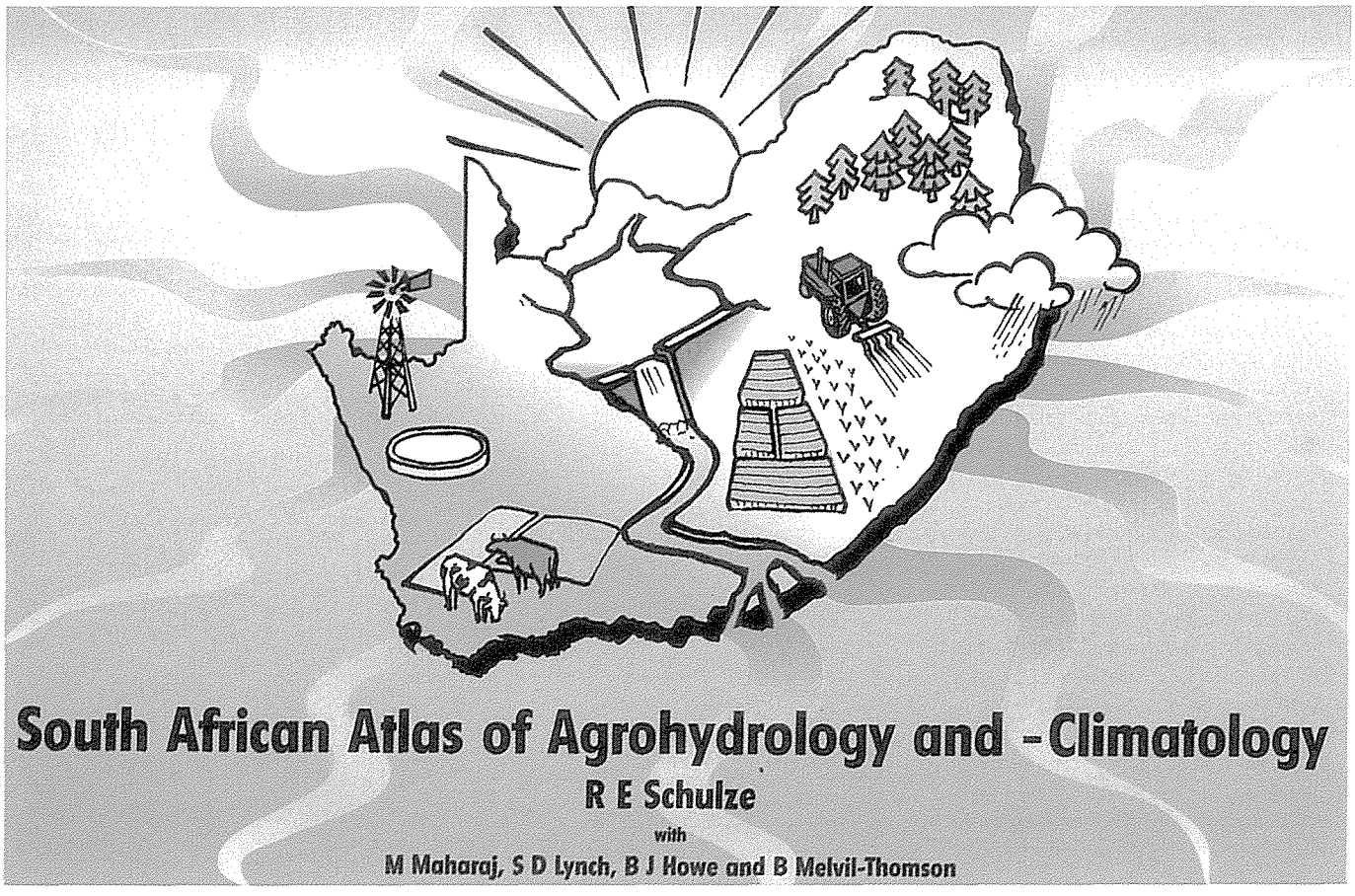
During 1996 the South African National Committee on Irrigation and Drainage (SANCID), managed by staff of the WRC, approached the Ministry of Water Affairs and Forestry, indicating a willingness to contribute towards the irrigation-policy consultation process. It was agreed that an appropriate contribution would be the initiation of commodity studies of all important crops grown under irrigation.

After consultation with representatives of the Agricultural Research Council, South African Agricultural Union and professional societies in crop and horticultural sciences, it was decided to arrange a number of discussions by all interested parties to explore ways and means of undertaking the task. Agreement was reached that affected commodity organisations take the responsibility of drawing up commodity reports, addressing issues such as the area cultivated, geographic location, water use, total production, value of production, total investment, employment, contribution to food security, links with input-supplying and product-processing industries, multiplier effects in rural economies and earning of foreign exchange.

The following commodity reports were received by SANCID and presented to the DWAF on behalf of the following respective organisations:

- **Citrus** – Outspan International Ltd.
- **Cotton** – Cotton Board and Agricultural Research Council
- **Forage crops** – Agricultural Research Council
- **Maize** – National Maize Producers Organisation
- **Oilseeds** – National Oil and Protein Seed Producers Organisation
- **Potatoes** – Potato Producers Organisation
- **Sugar** – South African Sugar Association
- **Tobacco** – Lowveld Co-operative
- **Vegetables** – Agricultural Research Council
- **Wheat** – Winter Grain Producers Organisation
- **Wine** – KWV

The information contained in these commodity reports will serve as a valuable reference on the factual and contextualised contribution of irrigated agriculture to the economy of South Africa.



South African Atlas of Agrohydrology and -Climatology

The WRC has supported the University of Natal's Department of Agricultural Engineering for a long time in their research on agrohydrology. With the new era of water management now firmly embedded in the new Water Act, the informative value of an Agrohydrological Atlas will be considerable. The initial print-run of 1 000 copies should reach users in a wide circle of water interests.

The Agrohydrological Atlas contains maps and explanatory notes that will enable people to place their local catchment environment into a wider South African context. The Atlas will have special value with regard to the hydrological impacts of land use.

Wide international recognition for ACRU model

The Department of Agricultural Engineering, University of Natal, developed the ACRU modelling system for synthesising typical South African hydrology, which aimed at practical application in water management and planning. The model was developed with WRC support over many years.

ACRU has now achieved extensive international recognition. This is illustrated by the following developments:

- ACRU has been selected by the International Geosphere-Biosphere Programme's GAIM (Global Analysis and Interpretation Models) as their hydrological model to assess climate-change impacts for the entire African continent. In this context, an ACRU course on modelling climate-change impacts will, in early 1998, be presented in Mombasa, Kenya.
- The third European course on ACRU was given in Germany during February 1997. Previous overseas courses have been given in France and Germany.
- ACRU has been selected by the Global Change and Terrestrial Ecosystems Programme as one of the models for estimating sediment yield in an international model inter-comparison in April 1997.
- ACRU has been applied as a hydrological decision model as far afield as Chile and the island of Crete. It is currently being tested in Ph.D. studies by students in Switzerland, Australia, Germany and Zimbabwe. Operationally, the model has been used in the USA, Botswana, Namibia, Mozambique, Lesotho and Swaziland.

Senior staff changes and achievements

- **Mr JN Bhagwan** was appointed Research Manager in January.
- **Dr TC Erasmus**, Research Manager, retired in December. He had been with the WRC since 1989.
- **Dr IM Msibi** was appointed Assistant Research Manager in July.
- **Mr ZT Ngcakani**, Research Manager, resigned at the beginning of January. He had been with the WRC since 1994.
- **Dr HM Saayman**, Research Manager, retired at the end of February. He had been with the WRC since 1989.
- **Mr GN Steenveld** was appointed Research Manager in April.
- **Mr DS van der Merwe**, Deputy Executive Director of the WRC, was elected Vice- President of the International Commission on Irrigation and Drainage (ICID).

Dr Gert J Stander (1911-1997)

Dr Gert J Stander.

Dr Gerrie Stander passed away in Pretoria on 3 December 1997. He played a leading role in the establishment of the Water Research Commission in 1971, and became its first Chief Executive Officer, a post he held until his retirement in 1979.

Dr Stander also pioneered the establishment of the CSIR's National Institute for Water Research (now Environmentek) in 1957, and became its first director. He was a founding member of the International Association on Water Quality (IAWQ) in 1965 (IAWPR at the time). He was elected president of this international association in 1969, and had the singular distinction of being re-elected as president for a further three two-year terms of office.

He received numerous international and South African awards.

The WRC recognises the tremendous contribution which Dr Stander made to the development of water research in South Africa.

2

DEVELOPING COMMUNITIES: WATER SUPPLY AND SANITATION

During 1997 the DWAF launched a White Paper on National Water Policy. According to this policy paper, water required to meet basic human needs and maintenance of healthy aquatic ecosystems, will be guaranteed as a right. It is therefore necessary to ensure that the pursuit of health goals does not conflict with environmental sustainability goals. Research is necessary to provide information on how a balance between delivery of basic services and environmental sustainability can be achieved.

A major challenge that is facing the delivery of basic services to the unserved is sustainability, i.e. the ability of the schemes to perform effectively and indefinitely after handover to the beneficiary communities. It is generally acknowledged that community management of rural water supply and sanitation schemes is critical to the sustainability of these schemes. Effective community management depends on empowered community leaders who have the necessary skills to participate fully in all phases of project planning, implementation and the post-implementation process, such as operation and maintenance. There is also a need for strong, functional institutional structures at all levels to ensure that community-based structures receive full support from both regional and national government. In order to achieve sustainable community management of water and sanitation schemes, there must be a clear definition of roles and responsibility before any project is implemented. Roles of government and local authority structures must be clearly defined as well as channels of communication between all the different stakeholders. Research has a role to play in providing information on the strategies for promoting community management, strengthening the institutional structures at all levels of government and appropriate communication channels between all the levels of government and rural communities.

During the year under review, the WRC published a preliminary Strategic Research Plan for the field of community water supply and sanitation which identified research priority areas within this field that must be addressed in order to support the national government in its mammoth task of providing water and sanitation services to the unserved communities in a sustainable manner. The user group subcommittees of the Co-ordinating Committee for Research into Water Supply and Sanitation for Rural and Urban Communities (CCRUC) played a very important role in guiding the WRC in the selection of new projects for funding. In future, the WRC will continue to rely on these user groups for guidance in the selection of research proposals that address research needs of the stakeholders.

Completed projects

Development of programmes to combat diffuse sources of water pollution in residential areas of developing communities

(No 519) Afrosearch CC

The development of programmes for combating diffuse sources of water pollution from developing communities is a priority in ensuring proper management of the limited water resources of South Africa. The main objective of the research was the development of an appropriate and sustainable preventive programme to combat diffuse sources of pollution in three prototype communities (Mpumalanga, North-West and Northern Provinces)

Diffuse sources of pollution in developing communities are generally due to a lack of adequate infrastructure for water supply and sanitation, poor waste management and bad land-use practices.

The study has shown that interventions aimed at containing diffuse sources of water pollution can be launched by focusing on the promotion of effective community-based water, sanitation and waste management schemes. An analysis of diffuse sources of water pollution in developing communities has shown that pollution is related to basic development needs and can only be addressed through the implementation of sustainable develop-

ment programmes that are aimed at meeting human basic needs in an ecologically sustainable manner. As part of this project, a field guide was developed and tested. This field guide embraces the principles of process-oriented research and development aimed at the promotion of participatory appraisal, training and participative development management.

Cost: *R272 000*
Term: *1993-1994*

Development of a dynamic cross-flow sand filter for rural water treatment

(No 539) Division of Water, Environment and Forestry Technology, CSIR

Water clarification is an important step in the production of drinking water. Clarification can be effected by the dynamic cross-flow sand filter which, being less complicated than conventional alternatives, is suitable for operation in rural communities.

By causing an adequate portion of raw water to flow rapidly across the surface of the sand bed, the deposited turbidity particles are re-entrained into the cross-flow stream. This innovation avoids the frequent cleaning of the filter, which is a tiresome and time-consuming operation.

The project aimed to produce a technical guide for the design and operation of the dynamic cross-flow filter under South African rural community conditions. The information needed for such a guide was gathered by:

- Constructing a pilot filter in a rural community
- Monitoring the filter scheme to identify any unforeseen practical problem.

The pilot filter was erected, with financial assistance obtained from the Mvula Trust and the Thukela Joint Services Board, at Emmaus in KwaZulu-Natal. The 100-day field tests revealed, *inter alia*, that the raw feed water's turbidity could be reduced by 76% and that the faecal coliform removal efficiencies were over 70%. Terminal disinfection is necessary in order to ensure safe drinking water and to maintain a residual disinfection capacity in the water in the distribution system.

The study has revealed that the dynamic cross-flow sand filter is sufficiently uncomplicated to enable rural communities not only to construct the system, but also to operate and maintain the filter to yield drinking water of acceptable quality.

The dynamic cross-flow sand filter is only suitable for rural communities located in mountainous areas. This is to avoid pumping of large volumes of filter-cleaning water.

Cost: *R119 000*
Term: *1993-1996*

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

(No 629) Palmer Development Group

Poor solid waste disposal contributes significantly to the diffuse pollution load on rivers and impoundments in urban areas of South Africa. Better solid waste removal will improve the diffuse pollution loads of urban runoff. The broad objective of this project was to carry out a strategy evaluation of the present status of domestic solid waste services in developing urban communities of South Africa.

The following conclusions were drawn from the study:

- Between 35% and 50% of the black urban populations lack access to adequate waste collection services.
- Lack of institutional responsibility and capability to provide service in black local authorities.
- It is proposed that a national waste management board/department should be established to co-ordinate waste management at the local government levels.
- There is a need to promote community-based contractors in order to address the employment problems. However, guidelines for contracting the service must be prepared.
- Low-cost technology which is affordable to the target communities must be used.
- Resource recovery and recycling should be promoted by using incentives and creating markets for the recycled goods.

Cost: *R221 000*
Term: *1994-1996*

New projects

Solar still batteries in arid rural sites without electricity supply to provide potable water from brack, salty water

(No 792) McCracken Solar Stills Co. (Pty) Ltd.

Solar still technology was imported from the USA, and in a trial study two units were put to the test with very successful results. The process involves desalination of brackish, salty raw water with 8 000 to 10 000 mg/*l* TDS, producing a minimum of 8 to 12 *l*/d of distilled water.

This technology provides some solution for 2 000 to 4 000 water-deficient communities in South Africa in drought-stricken or arid areas without electricity. The appropriateness of this technology is in the costs and local manufacture of the units.

Hence, this follow-up study aims to develop solar stills employing cheaper raw materials than those used in the imported units to make the stills more affordable to communities and farmers in arid, drought-prone areas with brack and salty water of high total dissolved solids contents and without an electricity supply. The aluminium-based body will be wholly or partially replaced by resin-impregnated corrugated cardboard made from recycled waste paper, and these will be field-tested for local conditions and compared with the performance of imported stills.

Results will be relevant to the promotion of this technology as affordable and appropriate and provide capacity for the local manufacture of the solar stills.

Estimated cost: *R 75 000*
Expected term: *1997-1998*

Development of strategies for empowerment of women in water supply and sanitation projects

(No 817) Division of Water, Environment and Forestry Technology, CSIR

There is an increasing awareness of the role of women as key stakeholders in water supply and sanitation projects. However, the progress in the improvement of women's participation in water management remains very slow. Special efforts are necessary to assist women in overcoming barriers that limit their full partic-

ipation in decision-making on water and sanitation programmes.

The government must make systematic efforts/interventions to promote involvement of women in decision-making. There is a need to strengthen the managerial capabilities of women in order to improve efficient and sustainable use of water at local and national levels. Women, as major users of water and sanitation services, should play a greater role in decision-making from the planning stages of a project to implementation and operation and maintenance of water projects.

The specific objectives of this project are to:

- Analyse the role and impact of women's involvement in water supply and sanitation projects in Mpumalanga, Eastern Cape and Northern Provinces
- Assist in the development of a strategy for the enhancement of the role of women in water supply and sanitation projects
- Initiate and design workshops to ensure women's involvement in water supply and sanitation projects
- Analyse the impact of women's involvement in development projects on the empowerment of women.

Estimated cost: R263 000
Expected term: 1997

Development and evaluation of sanitary surveillance methods for rural communities' water supply and sanitation system maintenance

(No 818) Division of Water, Environment and Forestry Technology, CSIR

Sanitary surveillance is the ongoing routine assessment of the conditions of water supplies, sanitation and other health-related facilities – e.g. refuse dumps, food shops, cattle kraals etc., and a methodology or process for dealing with problems encountered. Though being a community-driven process, support of district or regional authorities with district laboratory facilities for laboratory water analyses, is required for success and sustainability. This concept has been successfully applied for some years in South America (Argentina, Brazil) and is primarily carried out at community or village level. The WHO guidelines on water quality also specifically deal with this topic.

Sanitary surveillance at community or village levels results in significantly increased awareness of health-threatening situations in communities and places the responsibility for this in the hands of the community. While we have considerable experience and expertise in monitoring water and sewage treatment plants by provincial authorities in South Africa, this concept has not been considered or applied. Hence the research programmes aim to:

- Introduce sanitary surveillance of water supply, sanitation and other health-related facilities at community level
- Develop a methodology and information package on sanitary surveillance for regional and district authorities
- Assess, through a pilot application, the importance and effect of sanitary surveillance within a community.

If such a programme is well-implemented, it will result in significant benefits and devolve the responsibility and decision-making process down to community level, where health conditions can be effectively controlled with small actions and changes in attitudes.

Estimated cost: R364 025
Expected term: 1997-1998

Hygiene education to support water supply and sanitation interventions in developing communities

(No 819) Division of Water, Environment and Forestry Technology, CSIR

The National Sanitation Policy White Paper recognises the importance of health and hygiene education and awareness promotion in bringing about an improvement in the quality of life for all South Africans who lack adequate access to basic services. Lessons learned from the International Drinking Water and Sanitation Decade have shown that provision of infrastructure for water supply and sanitation in the absence of appropriate hygiene education results in unsustainable water and sanitation schemes.

The specific objectives of this project are to:

- Understand the knowledge, attitudes and practices (KAP) towards water and sanitation in developing communities, using key informant interviews, focus groups and participatory techniques.
- Based on these above KAP studies, to develop a hygiene education programme, which will be implemented in six to eight selected communities in different provinces.
- Evaluate the hygiene education programme to assess whether it has influenced a change in hygiene behaviour in the context of water supply and sanitation.
- Prepare a final hygiene education methodology, supported by manuals, training aids and intervention strategies which can be used in promoting sustainable water supply and sanitation development and environmental health.

Estimated cost: R370 000
Expected term: 1997-1998

Field evaluation of alternative disinfection systems for small water supply schemes

(No 828) Division of Water, Environment and Forestry Technology, CSIR

Previous studies have indicated a possibility for more reliable and cost-effective alternative disinfection systems for small water supply schemes (WRC project No. 449) whilst at the same time indicating that chlorine dosing systems and slow-sand filter treatment systems are less reliable and ineffective for these small treatment systems. The inadequate disinfection of water in the small water treatment systems is placing many small communities at risk of disease outbreaks during times of disease epidemics.

This project involves the installation of five different alternative disinfection systems in small water supply schemes which are operated and maintained by the community. The criteria for the use of each individual system would be considered in selecting the communities for which each system would appear to be most appropriate. Systems that are proposed for evalua-

tion include the MOGGOD (or MIOX) on-site disinfection system, UV disinfection system and on-site hypochlorine generation. A part of the study will be carried out in conjunction with EAWAG/SANDEC of Switzerland. Field evaluations of these technologies will facilitate adoption of appropriate disinfection technologies for rural South African communities.

Estimated cost: R336 000
Expected term: 1997-1998

Level of communication between communities and engineers in the provision of engineering services

(No 830) Philip Pybus CE

The provision of water supply and sanitation to developing communities needs to be a bottom-up process that will enhance the capacity of communities. The communities should be in a position to take decisions affecting the level of service and the final form of the scheme. They should accordingly be empowered to make these decisions. This is fundamental to the RDP.

The process, however, depends on the extent to which parties concerned can communicate effectively. This requires the community to be informed, in a manner that will enable them to understand the technical choices and the consequences of selecting any of the options. It appears that, although many consulting engineers working in the field of water supply and sanitation pay attention to the principles of community participation, the level of empowerment of communities is not as it ought to be, as most of the training and capacity-building tends to be directed towards the implementation stages of projects. Hence there is a need for facilitators and engineers to comprehend the needs and aspirations of the communities and to react accordingly.

This project aims to establish:

- Which procedures must be put in place to ensure that communities understand the proposals of engineers in regard to both the technical choices offered as well as financial implications.
- Which procedures must engineers follow to fully understand the needs and aspirations of the communities.
- To what extent do the engineers dictate the standards of service and which procedures need to be put in place to ensure that engineers communicate with the client community at an early stage of the feasibility report.
- Whether expectations of the community are being met and the end-product is satisfactory.
- How reports should be prepared to ensure proper transfer of information.

The output of this project will improve the communication and interaction between communities and engineers through the development of guidelines and methodology.

Estimated cost: R160 000
Expected term: 1997-1997

Guidelines for the development of rural water supply schemes – Further development of a decision support system

(No 837) Institute for Water Research, Rhodes University

In 1995 the Institute for Water Research at Rhodes University embarked on a WRC-funded project to develop guidelines for the evaluation of water resources for rural development with an emphasis on groundwater. The motivation for this study arose from the fact that at that time some 80% of South Africa's rural citizens did not have access to adequate water supplies and of those that did, a large number experienced failure of their water supplies.

While the recently completed project concentrated on aspects related to the evaluation of potential groundwater sources, it has also addressed all the other aspects that are relevant to small-scale water supplies.

The primary objective of the research programme is to incorporate the proposed guidelines for the development of rural water supply schemes into a decision support system (DSS) and to promote its use for planning and evaluating future rural water supply projects. Feedback from potential users such as DWAF, consulting engineers, NGOs, funding organisations and training establishments will result in further refinements and developments.

Estimated cost: R300 000
Expected term: 1997-1998

Reliability of small spring water supply systems for community water supply projects, and the enhancement of flows from springs

(No 859) Division of Water, Environment and Forestry Technology, CSIR

In the eastern parts of South Africa many small rural water supply schemes have been based on protected springs. However, in many cases these have not resulted in any significant improvement in the water supply to the communities, and in certain cases the original natural spring has been irreparably damaged when attempts were made to improve the water supply from the spring.

A lack of data on the sustainability of springs and the possible impact of land-use practices on their flow and quality have highlighted the need for a proper study on the nature of flow from small springs. This is of particular relevance at the present time when so much attention is being given to the implementation of rural water supply schemes.

Should the project succeed in unravelling some of the factors affecting spring flows, and developing ways of predicting flows, it will considerably improve the planning and design of rural water supply schemes in those areas where springs are a significant resource. In this way funds spent on springs which cannot sustain the required yield will be limited. Conversely, when springs are able to provide sufficient water for a community, this resource could be developed with increased assurance and usually considerable cost savings over alternative supplies. Even where springs cannot meet all requirements, they could be incorporated into conjunctive use schemes, or at least provide a bridging resource until other sources such as boreholes could be developed.

Estimated cost: R650 000
Expected term: 1997-1999

Development of guidelines for the management of rural groundwater resources

(No 861) Division of Water, Environment and Forestry Technology, CSIR

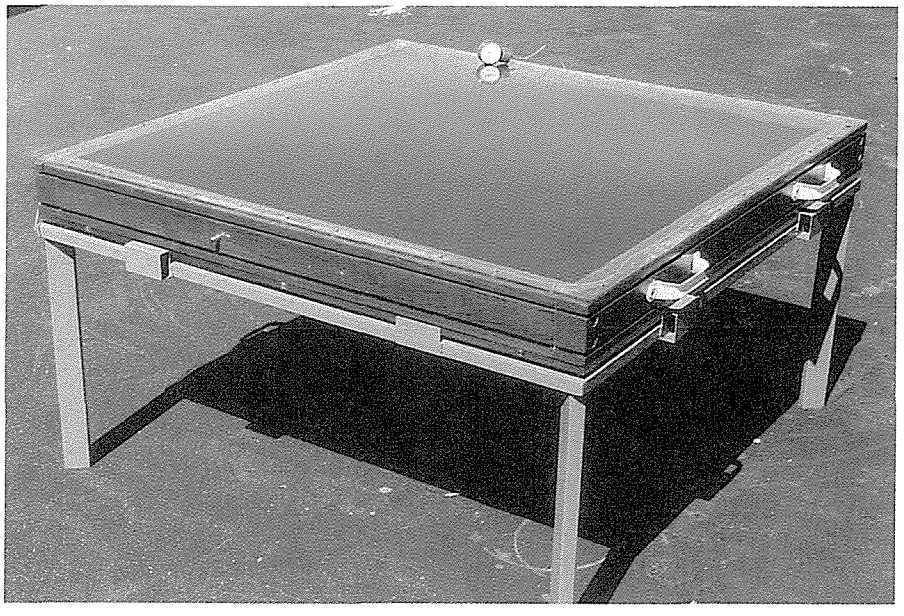
Groundwater has been recognised as a very important water resource in the more remote rural areas of South Africa, where the relatively low population density and high cost of implementing surface water schemes very often make such schemes uneconomical. However, some of these more remote areas also have a low groundwater potential, for example certain parts of the Northern Province, being underlain by low-yielding granitic and gneissic aquifers, and experiencing limited recharge because of low and variable rainfall.

As most or all water demands of the population in these areas have to be satisfied from groundwater, the likelihood of over-exploitation of these aquifers is high, which may eventually lead to the failure of boreholes. Furthermore, with an assured water supply, it is probable that water demand will in future increase in many of these areas. There is consequently a great need to manage these groundwater resources in a sustainable manner.

These increasing demands on groundwater have resulted in an urgent need to collect data and information which can be used in planning and management of groundwater resources in a manner that will be economically feasible and environmentally sustainable. Such water source performance information constitutes a fundamentally important and most urgent data source necessary for the proper exploitation of the nation's groundwater resources.

This research project proposes the design and implementation of an affordable, community-driven groundwater management scheme which will secure a water supply to the community over the long term and create a sense of ownership of the resource. The emphasis will be on self-management by the community by involving them in the process. The design of an appropriate groundwater monitoring system will be central to the success of the management scheme.

Estimated cost: R310 000
Expected term: 1997-1999



A solar-powered Stirling motor for water pumping is presently under development. The picture shows a test-chamber which is used to test different materials for their solar energy absorption behaviour.

Development of an appropriate, low-cost, solar-powered Stirling motor for water pumping

(No 875) Wagner Systems (Pty) Ltd.

In any rural water supply development, the power unit to drive the system is a very important component, not only from the point of view of the eventual reliability of the system, but also as far as installation and operational costs are concerned. In addition selection of a suitable power unit is complicated by the availability of a suitable energy source and the power unit's needs regarding its maintenance and repair.

In the case of conventional energy sources (electricity and liquid fuels) the selection process may be complicated if these fuels respectively require a grid extension or transport costs. Under these conditions alternative energy sources, e.g. solar energy may become a viable proposition.

This project intends to integrate a unique method of energy conversion with appropriate technology in order to develop a low-cost solar water pump. Although climatic conditions are good for the utilisation of solar power in much of the developing regions of Africa, the cost and complexity of existing systems have prevented their general implementation. Although the Stirling cycle is by no means a new invention, recent developments now allow the use of low-temperature heat sources, thereby justifying an investigation into the possibility of a solar-powered power unit operating on this cycle. Under these conditions of relatively low maximum cycle temperatures, the manufacturing process and the materials for these power units may be such that it may become suitable for production and maintenance by local communities.

The objectives of this project, therefore, are to investigate the development and construction of a low-cost and appropriate solar-powered power unit, operating on the Stirling cycle, and dr ving an integrated water pump. This investigation will include prototyping and design of the integrated unit, optimisation of its efficiency, and testing, evaluation and assessment in a rural setting. Furthermore, in order to ensure that conditions in rural areas do not inhibit this technology, opti-

misation of cost, appropriateness, sustainability and technical complexity form an important part of the investigation. To safeguard the optimal impact of the proposed unit on the availability of domestic and agricultural water in a rural setting, socio-technical evaluation and commercial viability will also be assessed.

Estimated cost: R425 000
Expected term: 1997-1998

Groundwater pump for use in informal settlements

(No 876) Stass Environmental

All groundwater sources require a pump to bring the water to within easy reach of the community or farmers using the water. Keeping the locality of many of these pumps in mind, it is essential that the principle of operation and the construction of the pump be such that the abstraction device is very robust and easily maintained by the user. Furthermore, the energy requirements of these pumps should not be excessive and of such a nature that they require too much physical effort on the part of the user.

Over the years pumps with various abstraction devices requiring various power units have been developed. Many of these pumps may be faulted regarding special equipment for maintenance, inaccessibility of moving parts, thereby complicating maintenance, and the need for high-speed power units. As far as rural water supply is concerned, therefore, there is still a need for what could be described as the ideal borehole pump.

In this research project a new pumping unit, with only one moving part and constructed entirely of plastic, thus eliminating corrosion, is to be investigated. This is to be combined with a power unit utilising compressed air as energy source. Various means to provide compressed air are to be investigated.

The objectives are to:

- Provide a design of an inexpensive groundwater abstraction system for use in informal settlements
- Further develop equipment for the conservation and storage of wind energy with the aim of driving the pumping unit
- Test the combination regarding its reliability, capacity and pumping efficiency.

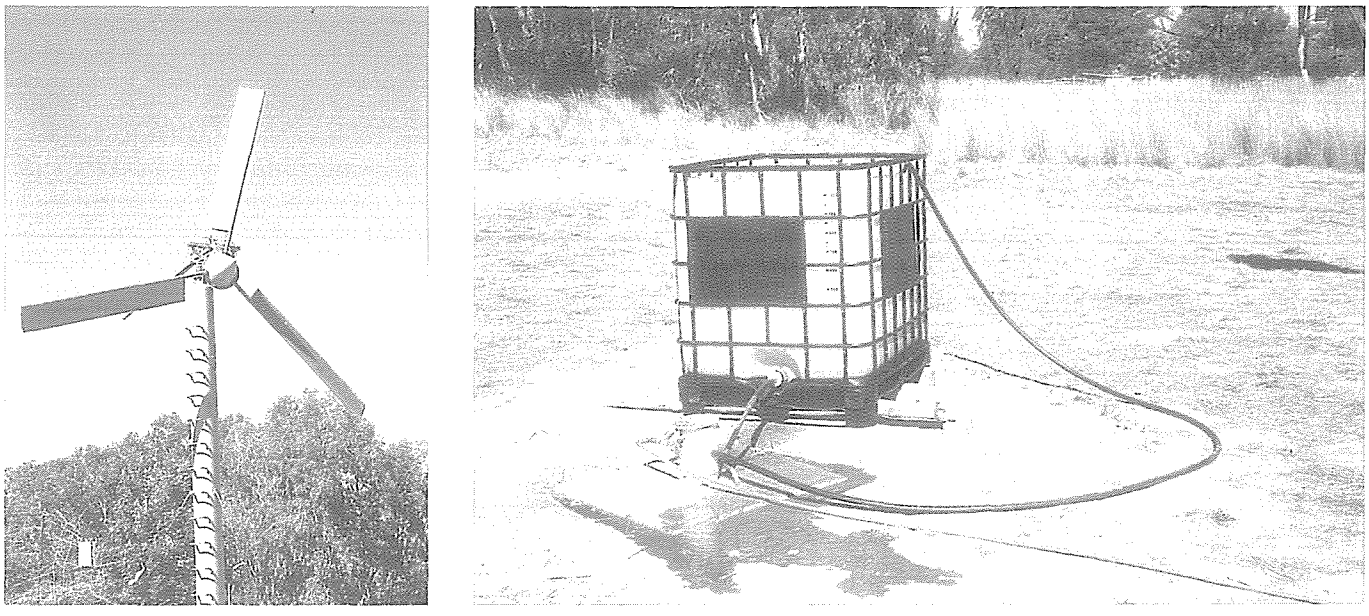
Estimated cost: R140 800
Expected term: 1997

Development of standards and mechanisms for quality management in the water and sanitation training sector

(No 880) National Community Water and Sanitation Training Institute, University of the North

In recognition of the fact that education provides the basis of security and social advancement, and in recognition of the fact that there are no clear goals or standards for training in the water and sanitation sector in South Africa, this project aims to provide a basis upon which a national education and training framework can be developed. The specific aims of the project include the establishment of training needs, the evaluation of existing material and facilities and the identification of shortcomings. It will also establish the needs of the target groups and the methodologies available to address those needs. Having established these, it will develop competency-based modular training in accordance with the community needs and the National Qualifications Framework, and evaluate the effectiveness of the material developed.

Estimated cost: R600 000
Expected term: 1997-1998



Project No 876 investigates the utilisation of wind energy to provide compressed air to activate a pumping unit situated in the borehole. Left: wind-pack assembly and right: borehole and water storage set-up.

Removal of nitrogen from ventilated improved pit latrines (VIP) systems by nitrification and denitrification processes

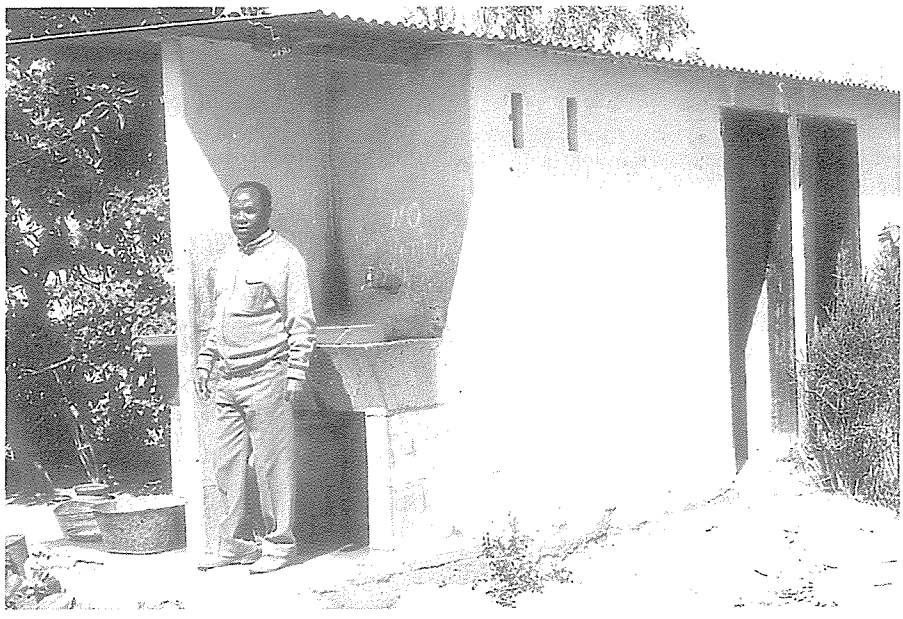
(No 885) Technikon Pretoria and FRD

In most developing countries, ventilated improved pit latrines (VIP) are considered to be the most appropriate and affordable form of technology for improved sanitation. Though having many advantages, such as improving health and controlling communicable diseases, a major disadvantage is its potential to contaminate groundwater sources with nitrate. This poses a health risk when the groundwater source is to be used for drinking water purposes, with recommendation that there should not be more than 6 mg NO_3–N/*l* in drinking water. The extensive use of VIP technology in South Africa could pose problems in certain areas.

Hence this project aims to develop a low-cost method of preventing groundwater contamination with nitrate by testing, in the laboratory, a system which will convert all the nitrogen which leaches out of a VIP system into nitrogen gas by a combination of nitrification/denitrification. The nitrogen gas will escape to the atmosphere, whereby nitrate pollution of the groundwater source will be prevented.

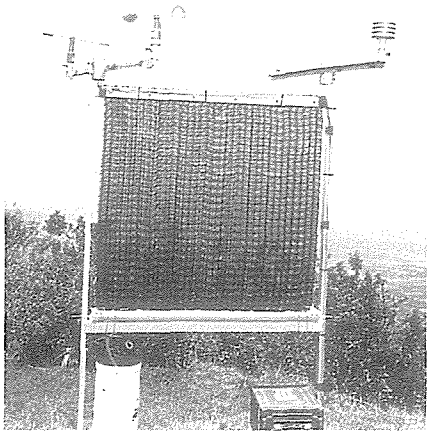
This project is jointly funded by the FRD and WRC.

Estimated cost: *R101 000*
Expected term: *15 months as from October 1997*



Typical four-unit aqua-privy block with wash troughs.

Example of water environments in an informal settlement with restricted sanitary services. The water consists predominantly of stormwater runoff. In at least some cases it includes seepage from pit latrines.



Left: A 1m² pilot fog collecting screen at Hanglip in the Soutpansberg. This screen collected an average of 6,5 *l* water /m².d during 1995.

Research projects

Completed

- **519** Development of programmes to combat diffuse sources of water pollution in residential areas of developing communities (Afrosearch CC)
- **539** Development of a dynamic cross-flow sand filter for rural water treatment (CSIR – Division of Water, Environment and Forestry Technology)
- **629** Evaluation of solid waste practice in developing urban areas in South Africa (Palmer Development Group)

Current

- **346** Study of the relationship between hydrological processes and water quality characteristics in the developing Zululand coastal region (University of Zululand – Department of Hydrology)
- **384** Water resources and sanitation systems sourcebook with special reference to KwaZulu-Natal (University of Natal – Department of Economics)
- **386** Development of a cross-flow microfilter for rural water supply (University of Natal – Department of Chemical Engineering, and Umgeni Water)
- **435** Development of a training programme on community water supply management for village water committees (CSIR – Division of Water, Environment and Forestry Technology, and Appropriate Technology Information)
- **514** Groundwater contamination as a result of Third-World type urbanisation (CSIR – Division of Water, Environment and Forestry Technology)
- **520** Guidelines on appropriate technologies for water supply and sanitation in developing communities (CSIR – Division of Water, Environment and Forestry Technology)
- **521** Water scheme cost recovery (Umgeni Water)
- **544** Determination of sludge build-up rates in septic tanks, biological digesters and pit latrines in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **586** Development of a decision support system for the selection of the most appropriate sanitation option for developing communities (Umgeni Water)
- **598** Appropriate management of urban runoff in South Africa (University of the Witwatersrand – Water Systems Research Group and CSIR – Division of Water, Environment and Forestry Technology)
- **599** Co-disposal and composting of septic tank and pit latrine sludges with municipal refuse (CSIR – Division of Water, Environment and Forestry Technology, and La Trobe Associates)
- **603** Development of effective community water supply systems using deep and shallow- well handpumps (CSIR – Division of Water, Environment and Forestry Technology)
- **622** Rapid quantitative evaluation of water quality using a modified biological test – Phase 1 (University of the Witwatersrand – Department of Microbiology)
- **631** Assignment of a financial cost to pollution from on-site sanitation, with particular reference to Gauteng (University of the Witwatersrand – Department of Civil Engineering)
- **649** Assessment of common problems associated with drinking water disinfection in the developing areas (CSIR – Division of Water, Environment and Forestry Technology)
- **651** Appropriate low-cost sewage treatment using the advanced algal high-rate oxidation pond (Rhodes University – Department of Biochemistry and Microbiology)
- **656** Appropriate low-cost treatment of sewage reticulated in saline water, using the algal high-rate oxidation ponding (AHROP) system (Rhodes University – Department of Biochemistry and Microbiology)
- **670** Graded standards for landfilling in South Africa: Establishing appropriate affordable standards for disadvantaged communities (University of the Witwatersrand – Department of Civil Engineering)
- **671** Fog collection as a supplementary water source for small rural communities (University of the North – Department of Geography)
- **677** Guidelines for the evaluation of water resources for rural development with an emphasis on groundwater (Rhodes University – Institute for Water Research)
- **684** Development of a community-based integrated catchment management programme with special reference to water supply and sanitation in the Ntshongweni catchment (University of Natal – Farmer Support Group)
- **685** Occurrence and survival of protozoan parasites in source water and drinking water used by unserved rural communities (CSIR – Division of Water, Environment and Forestry Technology)
- **698** Land-based effluent disposal and use: Development of guidelines and expert-systems-based decision support (CSIR – Division of Water, Environment and Forestry Technology)
- **708** Guidelines for the operation and maintenance of septic tank effluent drainage (STED) systems by communities in South Africa (CSIR – Division of Building Technology)
- **709** Preparation of standard engineering drawings, specifications and guidelines for ventilated improved pit latrines in South Africa (CSIR – Division of Building Technology)
- **710** Pilot study for the development of a GIS database on water and sanitation in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **712** Biological processes in on-site low-flush volume sanitation systems (CSIR – Division of Water, Environment and Forestry Technology)
- **714** Socio-biological study of the aquatic resources and their utilisation in an underdeveloped rural region, the Mutshindudi River catchment (University of Venda – Department of Zoology)

- **715** Quantitative determination and removal of nitrogenous pollutants from natural waters (University of the Northwest – Department of Chemistry)
- **724** Pollution of domestic water supply and health-related problems in the rural areas of the Molopo region of the Northwest Province (University of the Northwest – Department of Nursing Science, Chemistry and Agriculture)
- **727** Effect of water supplies, handling and usage on water quality and quantity in relation to health indices in the Eastern Cape Province (Prowater Health) (University of Fort Hare – Department of Development Studies)
- **734** Development of a strategy for disseminating information from the hydrogeological mapping programme to village water committees (Water Systems Management)
- **738** Guidelines for the upgrading of existing rural water treatment plants (CSIR – Division of Water, Environment and Forestry Technology)
- **743** Health impact of water-borne viruses and methods of control in high-risk communities (University of Pretoria – Department of Medical Virology)
- **764** Water supply to rural and peri-urban communities using membrane technology (University of Stellenbosch – Institute for Polymer Science)
- **765** Evaluation of on-site sanitation systems for applicability in low-cost housing from a socio-economic perspective (Bernhardt Dunstan and Associates)
- **767** Sustainability and affordability of community-based integrated waste and waste-water management for dense, informal urban settlements (SRK (CE) Inc.)
- **770** Handbook of water disinfection processes (CSIR – Division of Water, Environment and Forestry Technology)
- **771** Preparation of a booklet for new owners of sanitation systems that will contain the essential operation and maintenance requirements of sanitation systems (CSIR – Division of Building Technology)
- **772** Information booklet on drinking water for creating a greater awareness among the general public (CSIR – Division of Water, Environment and Forestry Technology)
- **786** Application of visual settlement planning (ViSP) computer software in South Africa: Building the capacity of local communities in urban development (University of Cape Town – Department of Civil Engineering)

New

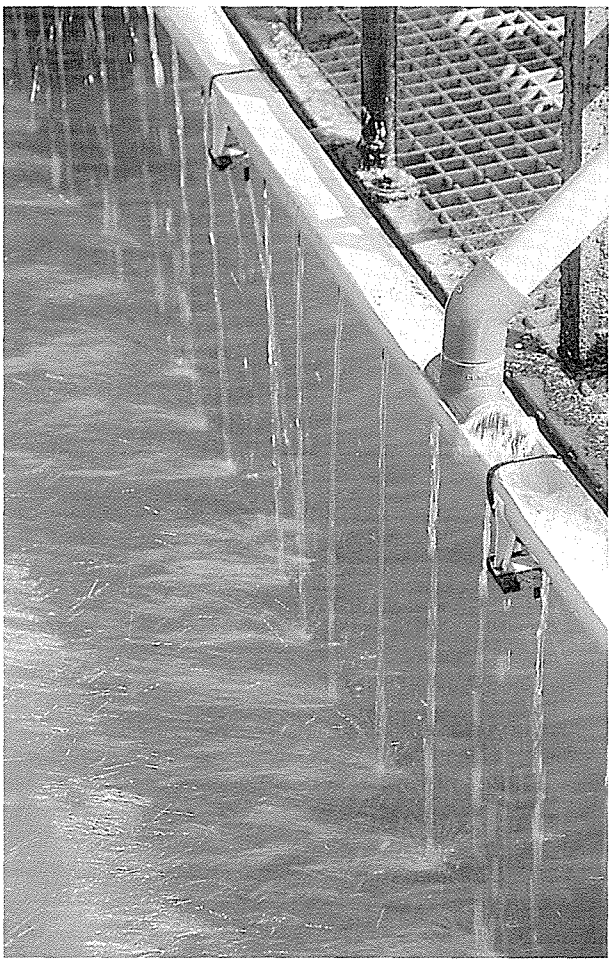
- **792** Sustainability and affordability of community-based integrated waste and waste- water management for dense, informal urban settlements (McCracken Solar Stills Company (Pty) Ltd.)
- **817** Development of strategies for empowerment of women in water supply and sanitation (CSIR – Division of Water, Environment and Forestry Technology)
- **818** Development and evaluation of sanitary surveillance methods for rural communities' water supply and sanitation system maintenance (CSIR – Division of Water, Environment and Forestry Technology)
- **819** Hygiene education to support water supply and sanitation interventions in developing communities (CSIR – Division of Water, Environment and Forestry Technology)
- **828** Field evaluation of alternative disinfection systems for small water supply schemes (CSIR – Division of Water, Environment and Forestry Technology)
- **830** Level of communication between communities and engineers in the provision of engineering services (Philip Pybus CE)
- **837** Guidelines for the development of rural water supply schemes – Further development of a decision support system (Rhodes University – Institute for Water Research)
- **859** Reliability of small spring water supply systems for community water supply projects, and the enhancement of flows from springs (CSIR – Division of Water, Environment and Forestry Technology and DWAF)
- **861** Development of guidelines for the management of rural groundwater resources (CSIR – Division of Water, Environment and Forestry Technology)
- **875** Development of an appropriate, low-cost, solar-powered Stirling motor for water pumping (Wagner Systems (Pty) Ltd.)
- **876** Groundwater pump for use in informal settlements (Strass Environmental)
- **880** Development of standards and mechanisms for quality management in the water and sanitation training sector (University of the North – National Community Water and Sanitation Training Institute)
- **885** Removal of nitrogen from ventilated improved pit latrines (VIP) systems by nitrification and denitrification processes (Technikon Pretoria and FRD)

CONTACT PERSONS

- **Dr NP Mjoli**
  (Sanitation and Microbiological Aspects)
  e-mail: nozi@wrc.ccwr.ac.za
- **Mr JN Bhagwan**
  (Provision of Services)
  e-mail: jbhagwan@wrc.ccwr.ac.za
- **Dr SA Mitchell**
  (Sanitation and Health Aspects)
  e-mail: steve@wrc.ccwr.ac.za
- **Mrs APM Oelofse**
  (Health Aspects)
  e-mail: annatjie@wrc.ccwr.ac.za
- **Dr IM Msibi**
  (Water Treatment)
  e-mail: msibi@wrc.ccwr.ac.za

☎ **(012) 330-0340**

3 POTABLE WATER SUPPLY



The gradual increase in water demand accompanied by a decrease in water quality and an increase in health risk, has made not only careful water management, but also the fundamental approach to drinking water treatment and distribution to consumer taps, a priority.

In order to ensure that all communities in the country obtain pollution-free, pathogen-free water under these increasingly demanding circumstances, water treatment industries and suppliers require the necessary knowledge and technology. This is acquired through the following approach:

- Carrying out continuous strategic and applied research
- Seeking to understand the factors which affect water quality and their significance
- Continuous development of new and optimised treatment technologies
- Investigating alternative disinfection technologies for health risk reduction
- Development of strategies which will provide for improved water quality at minimal cost both in urban and rural communities.

In the above regard, the WRC supports both technical and sociological research projects pertaining to drinking water in the following main research areas, i.e. **Water Treatment and Reclamation, Drinking-Water Quality and Health Aspects**, and **Urban and Rural Water Supply**.

Water treatment and reclamation

This area of research deals with the development, improvement and selection of cost-effective plants and processes for the supply of drinking water which complies fully with the Department of Health water quality guidelines. The research is guided by the Strategic Plan for Research on Potable Water Treatment in South Africa, which is currently under review.

Variation in raw water quality due to different sources and to pollution has placed a great emphasis on appropriate technology, and on improved and alternative treatment systems. Effects on microbiological quality of water, taste, colour and odour have necessitated a focus on research designed to deal with these problems. Investigations into the application of activated carbon and its regeneration in treatment plants, as well as other methods of removal of organics in water, are some of the research areas currently supported by the WRC. Water quality problems associated with algal growth in surface water and subsequent demands on water treatment technologies and quality of final water are being given adequate attention. Maintaining water quality through distribution systems is also becoming increasingly important owing to increased focus on the quality of water at the consumer end.

A review of the Strategic Plan for Research on Potable Water Treatment in South Africa (see **Year under Review**) based on assessing achievements of the past and identifying and evaluating new critical research needs has resulted in an updated research plan incorporating a total quality management approach.

Drinking-water quality and health aspects

Water quality and safety are issues that increasingly attract the attention of public health authorities. The logarithmic increase in waterborne disease outbreak, both in frequency and severity, has increased public awareness of the importance of water microbiology.

The safety of drinking water is declining throughout the world because of microbiological contamination. Waterborne microbes are now more of a concern than toxic chemicals and heavy metals. The decline in microbiological quality of drinking water affects both developing and developed countries. Population growth, decaying infrastructure, pollution and the increasing resistance of microbes to water treatment chemicals are threatening global drinking water supplies.

The subject of microbiological safety of water will very soon become an international priority as travel across national boundaries and the numbers of humans increase in the decade ahead, placing Promethean demands on water resources.

The challenge for the future is to renew efforts in catchment protection, official reporting of waterborne diseases, and public education. In addition, continued technology transfer as well as research and development on low-cost, low-technology water treatment systems are needed.

Worldwide funding for research in the areas of water microbiology and public health has been declining in this time of pressing need for information to underpin decision-making and response to emergency events. A plan of action to mitigate the problems associated with microbiologically unsafe drinking water needs to be developed, emphasising resource management, behavioural patterns, and related human factors contributing to waterborne infections. As for the African continent the Pretoria declaration (September 1997) on health may be the first step towards formulating a plan of action.

Rural and urban water supply

Steadily increasing demand for water in conjunction with limited supplies has made water use the driving force of the urban and rural water cycle. The main challenge now is to devise ways and means of convincing consumers and suppliers alike of the need to conserve water at all times. The application of 21st century technology to the problem could make significant improvements. Innovation in all forms of domestic water use (washing, personal hygiene and garden irrigation) could lead to more efficient services at lower cost. Reduction in *per capita* water use, especially in urban areas should be sought to reduce impacts of abstractions from rivers and of waste-water disposal.

Current studies on the management of potable water distribution systems have great potential to improve cost-effectiveness in providing water supply services. A combined manual for the reduction and control of unaccounted-for water (UAW) in distribution systems and code of practice (COP) for the management of potable water in distribution systems is now expected to be available during 1998 as a result of WRC-commissioned projects.

Completed projects

Effect of water quality and chemical composition on the corrosivity in mild steel pipelines

(No 259) Rand Water

Since the objectives of the project were to gain more knowledge regarding chemical stabilisation of potable water; and the determination of the extent to which water needs to be treated to ensure that its quality will remain constant between the purification plant and the consumer, laboratory-scale tests as well as scaled-down pilot-plant investigations were conducted. During the laboratory tests, the effects of different chemical species and compounds were determined, as well as the effects of temperature, pH and calcium carbonate precipitation potential (CCPP). Actual corrosion rates were measured on coupons and compared to the values predicted by different indices. Corrosion rates and variations in chemical and physical properties were monitored in continuous flow systems. From the results the following conclusions were drawn:

- There is a direct relationship between the corrosion rate of mild steel and the conductivity of the water and hence the total dissolved solids content of water. Temperature also plays an important role. Three equations were developed which allow prediction of the corrosivity of a specific water towards mild steel.
- The chemical composition of water with good protective properties, tested by comparing actual measured corrosion rates with calculated values of the indices, was determined. The composition of water which has the potential of being neither corrosive nor aggressive in contact with mild steel, is reflected in the following table:

Determinand	Range
Conductivity (mS/m)	14,5 – 17,0
pH	8,3 – 8,6
TDS (mg/*l*)	97,4 – 116
Alkalinity (as mg/*l* $CaCO_3$)	71 – 89
Hardness (as mg/*l* $CaCO_3$)	69 – 73
Calcium (mg/*l*)	19 – 25
Magnesium (mg/*l*)	2,6 – 3,4
Sodium (mg/*l*)	3,9 – 10,0
Iron (mg/*l*)	0,05 – 0,61
Activated SiO_2 (mg/*l*)	4,0 – 9,6
Total SiO_2 (mg/*l*)	9,0 – 10,0
Ammonia (mg/*l*)	<0,05
Nitrite-N (mg/*l*)	<0,30
Nitrate-N (mg/*l*)	0,11 – 0,69
Sulphate (mg/*l*)	<5
Chloride (mg/*l*)	<5

- The CCPP is the only "index" by means of which the exact amount of calcium carbonate that may precipitate or dissolve, as well as the equilibrium alkalinity and pH, can be determined. It is, therefore, a most useful operational criterium for use in water purification.
- The use of non-activated silicate resulted in a decrease in corrosion rate for silicate contents up to 10 mg/*l* as SiO_2, and an increase in corrosion rate for silica contents exceeding 10 mg/*l*. Activated silicate led to an increase in corrosion rate. At a concentration of 1 mg/*l*, monochloramine may act as a corrosion inhibitor.

Cost: *R99 000*
Term: *1990 – 1993*

Development of a combination of sedimentation, flotation and sand filtration processes for water treatment (SEDIDAFF)

(No 282) Division of Water, Environment and Forestry Technology, CSIR

The project investigated the use of a combination of settling, dissolved air flotation (DAF) and sand filtration in one process unit for the purification of surface waters containing both lighter and heavier solids, such as eutrophic water containing some turbidity.

It was shown that DAF alone was able to clarify raw waters with turbidities of up to approximately 75 NTU. The inclined-plate presettler performed reasonably well although inclined plates proved to be too few in number to provide repeatable results which could be scaled up. Nevertheless, the results did show that most of the suspended solids load could be removed before DAF, thereby enabling the combination of sedimentation and DAF to be used in the treatment of the more problematic raw waters containing both clay particles and lighter material, such as algae.

Cost: *R30 000*
Term: *1989*

Evaluation and development of deep-bed filtration for the treatment of South African surface waters

(No 354) Division of Water, Environment and Forestry Technology, CSIR

The aim of the project was to evaluate the suitability of the deep-bed, course-medium, series filtration process to serve as an appropriate and inexpensive water treatment process for the rural and smaller water supplier. The system consists of a 2,5 m deep up-flow, coarse-medium (2 to 3 mm dia.) coagulation/filtration sand bed, followed by a standard, down-flow sand filter.

It was shown that the process could produce potable water of less than 1 NTU from feed water turbidities of up to 400 NTU. However, at these high turbidities, run times between back-washes are drastically reduced. The use of cationic polymers increases run times significantly. Whereas high turbidity and eutrophic waters could be treated successfully, problems were experienced with the purification of highly coloured water. It seemed that the fragile nature of these flocs – even when dosing polymers – caused floc break-up, resulting in penetration of turbidity through the down-flow sand filter. Because of its low cost and simple, logic-controlled operation, the process shows good potential, as borne out by the latest, 5 Ml/d, full-scale plant operating in Mpumalanga.

Cost: *R136 000*
Term: *1991-1992*

Guidelines for the use of peroxone and other oxidants for the treatment of eutrophic and coloured waters in South Africa

(No 443) Division of Water, Environment and Forestry Technology, CSIR

The relative oxidative powers of peroxone in the treatment of water, when compared to those of a number of other oxidants have been systematically researched and collated for the South African water utilities and plant designers. Local research results, obtained from research performed both before and as part of the project, give a very good indication of what may be expected from peroxone and other oxidants applied to various local water types. Interesting differences between local and overseas peroxone oxidation results have been shown and confirmed in this study. Whereas overseas studies showed improved flocculation when using peroxone or ozone, this study confirmed other South African findings that these oxidants have little, or even a negative effect, on the flocculation process. The guidelines for the use of peroxone and various other oxidants in water treatment include both cost and technological suitability. As such, these guidelines, and the background work in the report from which these guidelines were derived, could provide invaluable assistance to water suppliers not yet employing oxidants other than chlorine in the treatment of their water to potable standards.

Cost: *R285 000*
Term: *1992-1994*

Performance criteria for package water treatment plants

(No 450) Division of Scientific Services, Umgeni Water

The supply of potable water to rural and peri-urban areas is a national development priority. Package and preconstructed plants have a major role to play in the rapid provision of water. There is an obvious need for package plants in the provision of water to communities that do not have immediate access to potable water. However, consultants are reluctant to recommend such equipment because of lack of long-term testing or authoritative evaluation of this type of equipment.

The main objectives of this project were to develop and carry out formal testing procedures in conjunction with all classes of users and taking into account the range of capacities and degree of sophistication required. Ten different package water treatment plants comprising a range of different turbidity removal and disinfection technologies were evaluated, with minor modifications where necessary to improve performance.

The results showed a variation in capability of these systems when tested against the following water treatment criteria: disinfection, turbidity and aesthetics, micropollutant removal, sludge and effluents, robustness and reliability, potential for

upgrading capacity, control systems and capital and operating costs. Guidelines and a protocol for the selection of package water plants in general are available as products of this project.

Cost: *R373 000*
Term: *1992-1994*

Optimisation of the Rand Water system

(No 488) Water Systems Research Group, University of the Witwatersrand

Two facets have been attended to in this project:

Water demand patterns in Gauteng

Flow patterns were monitored for 14 areas in Gauteng, including very low, low, medium and high-income residential, commercial and industrial areas. It was clear that water consumption patterns vary significantly from suburb to suburb. The fact that these suburbs draw different peaks at different times provides an opportunity which may be used to advantage when planning water reticulation systems. The project generated daily hydrographs which are useful for estimating balancing storage volumes, and *per capita* consumption for various income groups and for industrial/commercial areas.

The results indicate that densely populated, low-income areas have a lower *per capita* consumption than high income areas, which often have low population densities. This has the effect of levelling out the consumption per unit area to about 10 m^3/ha.d, with a maximum of about 20 m^3/ha.d in high-density, high-income areas such as cluster complexes.

Although the existing guidelines give an accurate consumption per stand, the data gathered in this project indicate that factors such as population density, supply type, housing type and others can have a significant effect on the overall consumption.

It is recommended that in the planning stages of new developments, the effect of combining water supply to industrial/commercial and residential areas should be investigated. Peak flows can thus be reduced by 10 to 20%, leading to lower distribution costs. Furthermore, a flexible approach to the unit consumption and peak factor figure recommended in the existing guidelines, is suggested. Particularly where cost-saving is important lower peak factors can be used. In addition, when calculating peak factors for very low income areas without yard taps or house connections, the number of supply points should be used as a guide rather than the number of stands.

Cost model for water supply in the Rand Water distribution area

Since many developing communities requiring potable water cannot afford it, some form of subsidisation will have to be developed. The true cost of water as supplied to Gauteng needed to be determined before alternative tariff structures could be evaluated.

Data from current Rand Water records, historical contract data and other data from other sources were entered into a spreadsheet model for analysis. The model calculates the cost of building and running each pipe and node in the distribution network, and divides that cost by the volume of flow through each of these components. Because of the difficulty in obtaining all the data, a number of estimation procedures were built into the model to ensure that the analysis could be carried out.

It was found that the cost of water in Gauteng varies from about 43c/k*l* near to the Vaal River, to 77c/k*l* at the extreme points on the network. This variation, not as significant as expected, indicates that there are probably no areas where the cost of water would make these areas significantly favourable for development.

Purification costs represent a quarter to a third of the total cost, and are likely to increase in the future. Consequently the difference in cost of supplying water to points close to the source and to points further afield will probably decrease in the future.

Cost: *R432 000*
Term: *1992-1995*

Guide for water purification and plant design: Phases 2 and 3

(No 504) Dr FA van Duuren

Even as far back as 1990, the capital invested in water purification works was estimated at R15 bn., whilst the expenditure on new water purification works and augmentation of existing works amounted to R1,23 bn./a. Additional distribution systems, service reservoirs and pipe networks added another R15 bn./a. Given these financial details and risk to the population, inefficient water purification systems are extremely costly.

The increase in the population to be served with purified and treated water, averages 1 m./a. Eutrophication of water sources and aquatic growth are on the increase. The increase in the algal content of raw water and the significance of the diverse raw water qualities in relation to the method of purification must be given proper attention when considering design criteria.

This project was aimed at facilitating the optimal, most economical water purification and treatment works by providing a design guide based on water quality considerations, processes and operations. This Guide indicates water quality requirements, control and management of procedures, and water demands in all sectors. It provides and formulates a system of processes and operations for given qualities and quantities of water, sufficient theoretical details of the unit operations and processes, and examples of waterworks design, estimation and costing. It also categorises water purification and treatment processes and operations.

The main result of this project is a 434-page Guide (*Water Purification Works Design*) on the treatment of water for potable purposes.

Cost: *R310 000*
Term: *1992-1994*

Guidelines to coagulation and flocculation for South African waters

(No 537) Pavel Polasek Ass.

The project aimed to compile and present a set of guidelines for the coagulation and flocculation of various types of South

African waters intended for use mainly by water treatment plant designers and plant personnel. In conjunction with a literature search, a number of water treatment plants throughout South Africa were studied and some on-plant tests performed in order to draw up these guidelines. However, due to unforeseen problems experienced with the project execution and compilation of the final report, the final report as completed by the project leader could not be released. The research material gathered during the project is, however, being utilised by a consultant commissioned by the WRC to produce the required guidelines.

Cost: *R440 000*
Term: *1993-1994*

Application of bacteriophages as indicators of water quality

(No 540) Department of Medical Virology, University of Pretoria

Microbiological analytical procedures for the identification and quantification of viruses are mostly tedious, time-consuming and expensive. The research team successfully investigated, developed, optimised and evaluated detection methods for phages as indicators of water quality. These techniques proved suitable for the quantitative enumeration of phages in waste water, river water, sea water and dam water, as well as the sensitive routine qualitative monitoring of treated drinking water. The DWAF has used the results of the study in the formulation of water quality guidelines.

The research was primarily focused on the following:

- Methods for the quantitative enumeration of somatic coliphages, male-specific coliphages, and *B. fragilis* HSP 40 phages.
- Quantitative recovery of phages using adsorption-elution methods.
- Direct-plate assays on large volumes of water using single agar layers in large petri dishes.
- Qualitative presence-absence (P-A) tests on large volumes of water.
- Statistical evaluation of results according to procedures established with the Division on Biostatistics of the Medical Research Council.

The project team worked in close collaboration with the International Organisation for Standardisation (ISO) as well as leaders in the field in a number of laboratories abroad. The techniques investigated have been standardised, with modifications, and recommended by ISO.

Cost: *R421 000*
Term: *1993-1996*

Algal toxins in drinking water supplies

(No 549) Umgeni Water and Division of Water, Environment and Forestry Technology, CSIR

Cyanobacterial (blue-green) blooms are common to many South African freshwater impoundments that supply bulk water to potable water treatment works. Certain genera are known to produce a range of toxins that are potentially harmful to humans and animals if consumed. The most prevalent group comprises the hepatoxic microcystin toxins and modularin, which have caused numerous animal deaths throughout the world, including South Africa.

Previous investigations conducted in South Africa have found that microcystin toxins can persist even after conventional water treatment processes. The project yielded a final report in two volumes.

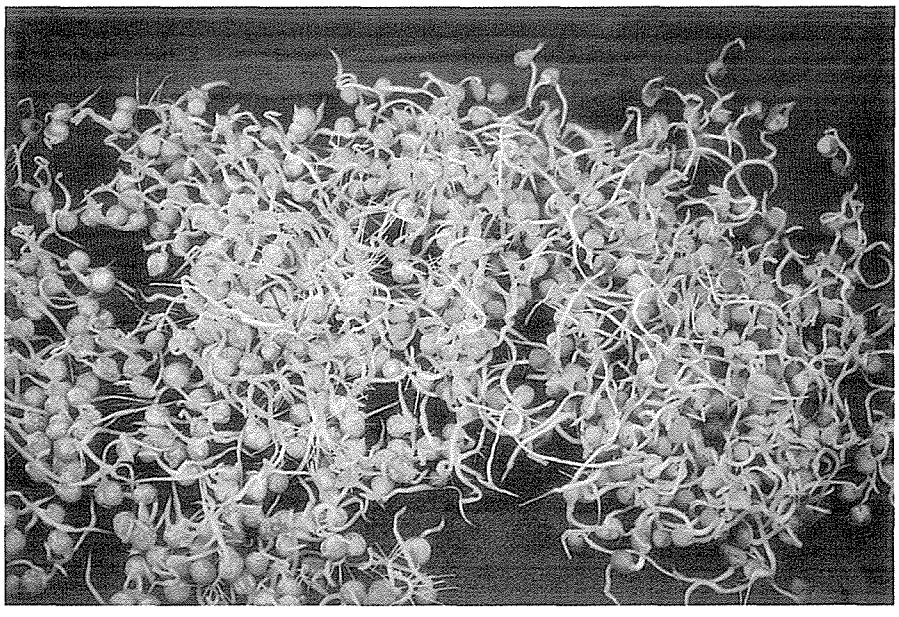
Volume I (Umgeni Water)

This report deals with the HPLC (high pressure liquid chromatographic) methods investigated for the determination of microcystin toxins in aqueous media, detailed monitoring of major impoundments in the Umgeni catchment, and the investigated treatment options for the removal of these toxins. Also included, are aspects concerning the isolation of microcystin toxins from algal material and the laboratory culture of toxic *Microcystis* to possibly serve as a source of the toxins that are not available commercially.

Volume II (CSIR)

Part I deals with a novel attempt to use protein electrophoresis as a means of monitoring enzyme-mediated substrate-product concentration changes in assay mixtures, thereby avoiding the use of radioactive phosphorus isotopes in the assay. **Part II** deals with the use of a radio- labelled method developed by Codd and co-workers.

The overall conclusion is that for routine screening of water samples, the radiolabelled substrate and enzyme inhibition assay is the best available means for such tests. Positive or suspect samples could then be studied further by other methods,



Algal toxins: *Microcystis* (blue-green algae).

including HPLC, for confirmatory evidence, as well as for the resolution and identification of the specific toxins present.

Cost: *R331 000*
Term: *1992-1996*

Optimal operation of combined flotation/filtration of eutrophic surface water

(No 557) Water Research Group, Rand Afrikaans University

Though recently there have been some major advances in the refinement of practical design guidelines for the flotation of eutrophic water, uncertain areas remained, especially with regard to the choice of coagulant and requirements for a good flocculation. In the treatment of eutrophic water, metal complexes formed during flocculation may break through more easily than the sediment formed during flocculation of non-eutrophic water. This raises questions concerning the adjustments of the height loss and effective recovery of filter backwash water. At the same time the accumulation of organisms such as *Cryptosporidium* should be monitored and managed very carefully.

The objectives of this project were to optimise the following conditions and parameters of bench-scale as well as full-scale plant tests for the combined flotation/filtration of a typical eutrophic surface water:

- Optimum flocculation conditions
- Filtrate quality in terms of residual coagulant
- Optimal chemical dosing of filter backwash water.

This project established the protocol for the prediction of full-scale coagulation and flocculation, using an improved bench-scale flocculator for eutrophic waters. The advantages of a dual filter medium and chemical dosing of filter backwash water have also been established.

Cost: *R72 000*
Term: *1993-1994*

Provision of point-source water by air-gap membrane distillation

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

There is a need for a small, simple, device which can provide potable water in an emergency or that can supply small quantities of pure water in remote, rural areas. The objective of the project was to develop such a membrane-distillation-based bag which would, preferably, use solar energy.

By employing specialised membrane materials from various manufacturers, a solar-powered air-gap membrane still was developed that produced potable water, even at ambient temperatures. Fluxes varied between 0,1 and 0,9 $l/m^2.h$ depending on the temperature and brine salt content. A salt rejection in excess of 99% was achieved. The air-gap membrane distillation still has been patented.

Cost: *R98 000*
Term: *1994-1995*

Expert system for water treatment plant design and analysis

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

The first version of a computerised, expert system for the selection of water treatment processes and the design of a water purification plant has been released. The program uses a powerful shell and incorporates the user-friendly option of a true, criteria-based, expert system in the process selection phase. After entering the raw water data and desired finished water quality, a full treatment plant may be designed, making use of the expert system. Alternatively, the user may choose the processes for the program to design. Under password protection, the user is allowed to modify a number of aspects of the program to his or her specific requirements. The expert system rules, criteria used, and design and costing formulae may readily be accessed and changed. The program has been designed to handle 15 water quality parameters and a number of unit processes, including pretreatment, rapid mixing, coagulation (mechanical and hydraulic), dissolved air flotation, sedimentation (rectangular, circular and plate), slow-sand and rapid-sand filtration, granular activated carbon, pH correction, disinfection and gravity sludge thickening.

Cost: *R321 000*
Term: *1994-1995*

Balancing tank control application

(No 621) Watson Edwards Inc.

The aim of the project was to develop a controller which under the cyclic inputs of flow and load, could determine the appropriate outflow rate at any time so that the flow and/or load would be optimally equalised. The following conclusions can be drawn from the research:

- "Fuzzy logic" cannot be used to develop a balancing tank controller which is easy to set up and configure and which provides stable control. The main problem associated with the fuzzy logic controller which was developed, was the fact that it was not self-adapting; in other words it would not be self-correcting.
- It is possible to develop a controller based on iterative mathematical calculations, using historical data as a reference. The modified controller was developed to run as a Pascal subroutine, and was interfaced with a standard SCADA package which provided a user-friendly operator interface. The modified controller has been successfully installed at four waste-water treatment works operated by the Greater Johannesburg Metropolitan Council.
- Future research work may focus on developing a controller based on neural networks which have proved to have excellent pattern recognition characteristics. Early work in this regard showed promising results, but the complexities associated with "training" the neural networks proved to be a limiting factor. Recent developments in neural network training software may, however, have paved the way for further work in this field.

Cost: *R15 789*
Term: *1994-1996*

Prediction of chlorine decay from potable water in pipeline systems

(No 704) Scientific Services, Rand Water

Knowing the rate of chlorine level in a potable water distribution system is important for correct chlorine dosage. The research results from this project made a significant contribution to the improved design and management of local potable water disinfection technologies – especially in the case of long distribution lines typically found in South Africa. Overseas models could not be applied with confidence locally because of the:

- Higher level of treatment generally practised overseas
- Generally colder temperatures en countered there
- Higher levels of organic materials normally found in South African raw waters.

Overseas models generally use a first-order chlorine decay rate. However, the research team showed convincingly that the use of an n^{th} order model improves the accuracy of such a decay model. This reaction model, developed for both the decay of chlorine and chloramines, may now be used for almost all distribution systems found in South Africa. Other water utilities will be able to determine their own reaction rate constants for the model by using the test protocol described in the report.

Cost: R99 000
Term: 1995-1996

Re-evaluation of the existing guidelines for urban and industrial water supply, based on measured water uses. Phase 1: Pretoria supply area

(No 705) Department of Civil Engineering, University of Pretoria

Indications are that the use of the 1982 *Guidelines for the Provision of Engineering Services in Residential Areas* leads to costly overdesign. Pretoria City Council consumption data, dating back to 1982, were used to establish whether this is true or not. The electronically logged data were extracted and analysed to:

- Establish, *inter alia*, the effect of water restrictions, micro-climate and seasons on water consumption in Pretoria.
- Use the aforementioned analyses to assess the possibility of improving the 1982 Guidelines.

For the analysis, property tax was used to subdivide water users into high-, medium- or low-income groups. The income groups reacted differently to the imposition of water restrictions. For instance, the high-income group took the longest to reduce consumption and was the quickest to return to the pre-restriction consumption when restrictions were abolished.

Seasonal variation of various periodic peak consumption rates was established and the peak values were found to be lower than those indicated in the guidelines.

The general conclusions are that the existing guidelines are conservative and that additional analyses of water consumption data, under environmental conditions different to those of Pretoria, are needed before the Guidelines can be adjusted to facilitate optimisation of the components of water supply systems.

Cost: R72 000
Term: 1995-1997

New projects

Development of a standardised approach to evaluate burst and background losses in water distribution systems in South Africa

(No 803) Water Resources Department, BKS Inc.

The whole question of leakage management is rapidly gaining importance in South Africa as the new Water Act becomes a reality. The various water service providers will soon be required to demonstrate that they are taking water loss and leakage seriously and they will be required to demonstrate some form of "active leakage control policy".

The main aim of this project is to develop a pragmatic and easy-to-use computer-aided methodology to enable water service providers to reduce their water losses through the use of proper leakage management practices.

The products of the proposed research will provide uniform and simple methodology for estimating the likely number of bursts in any particular metered area. The software will be developed to complement other leakage management initiatives such as the water audit software and also link in with other national initiatives.

Estimated cost: R121 000
Expected term: 1997

Preparation and testing of kits for the detection and quantification by developing countries of *Cryptosporidium* oocysts and *Giardia* cysts in water supplies

(No 825) Scientific Services, Umgeni Water and Department of Microbiology and Plant Pathology, University of Natal

Cryptosporidium and *Giardia* (protozoan parasites) are among the most common causes of gastroenteritis in humans which may be fatal to immuno-compromised patients e.g. those with AIDS, cancer and older people and children. Oocysts and cysts are the environmentally resistant forms of *Cryptosporidium* and *Giardia*, respectively, which are found in raw and treated drinking water where they pose a public health risk in both developed and under-developed countries. For this reason much research has been directed towards developing sensitive and reliable methods for their detection so that high-risk areas may be identified.

Well-trained and experienced technicians are required to conduct presently available, and also expensive, test methods to detect these pathogens. A sensitive, cheap and simple method that can be applied to turbid as well as clear waters is needed to accurately analyse water supplies for the presence of these pathogens.

The project aims to develop a multiple solid phase kit with slide immunoenzymatic assay (SIA) technology that will be suitable for the detection of *Cryptosporidium* oocysts and *Giardia* cysts or their antigens.

Estimated cost: R308 000
Expected term: 1997-1999

Systems for the abstraction of surface water through river sand beds

(No 829) Chunnett, Fourie and Partners (CE)

A number of areas in South Africa have river waters with high sediment load or turbidity. Numerous problems are associated with the storage, abstraction and treatment of such waters, including:

- Accumulation of sediments in instream reservoirs, offtake structures and raw water pump sumps
- Rapid wear of raw water pumps and higher cost of chemicals for flocculation
- Lower capacity of water treatment plants due to more time required for flocculation, sedimentation and filtration
- More regular cleaning of sedimentation tanks, filters and higher water loss.

If water is abstracted through a river sand bed as opposed to being abstracted directly from the river, the sand can act as a natural filter and raw water with low turbidity can be supplied to water treatment plants. Many of the above-mentioned problems associated with high sediment-load waters could be drastically reduced.

An earlier study demonstrated that the use of such alternative systems could result in savings of up to R8.5 m. over a period of 20 years.

The aims of this new project are to:

- Establish a directory of systems in South Africa that were designed and constructed for the purpose of abstracting surface water from sand beds.
- Determine whether there is a correlation between low yield of abstraction system and factors such as design, method of construction, geology, surface water quality and total bacterial count.
- Establish guidelines for the design, construction and operation of river sand-bed abstraction systems, based on information obtained from the survey of the abstraction systems and from an in-depth case study.

Estimated cost: R449 000
Expected term: 1997-1999

Development and implementation of gas and liquid chromatographic organic water profiles as a management tool

(No 831) Scientific Services, Rand Water

Tastes and odours and organic micropollutants are major concerns in organic drinking water quality. The analysis of individual organic compounds is time-consuming, labour-intensive and generally very expensive – there are too many compounds. Numerous separation, concentration and extraction techniques have been developed and the resin-based techniques seem to have the largest and the most flexible band width. To identify the components of a complex mixture, the GC and HPLC are the most versatile and general.

Current methods such as those by Van Rensburg, who developed an Organic Pollution Index, have certain drawbacks such as lengthy extraction procedures which are prone to errors.

Development of this technique will therefore involve improvements in three areas:

- Preconcentration technique
- Chromatography to encompass a GC analysis phase and an HPLC analysis phase
- Analysis to use neural networks to establish the definition of the profiles.

Hence the research aims are to:

- Enlarge and develop GC and HPLC methods to determine the organic profiles and fingerprints of the volatile fractions in both source and drinking water
- Monitor differences in the sample profiles and group major troublesome compounds
- Formulate guidelines, removal efficiencies and cost of the different treatment processes.

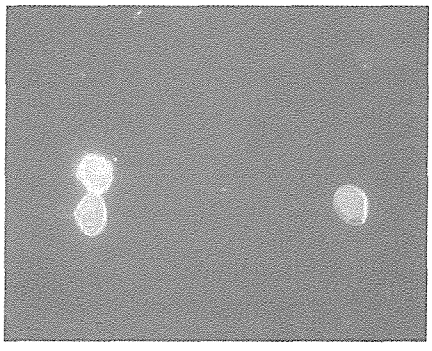
On distribution of the technology of the completed project, other water suppliers can obtain profiles of their particular water supply which can, in time, be networked/analysed to give an overall picture.

Estimated cost: R551 000
Expected term: 1997-1999

Application and efficiency of "mixed oxidants" for the treatment of drinking water

(No 832) Scientific Services, Rand Water

Chlorination in various forms is regarded as a reliable cost-effective method for disinfecting water for drinking purposes. This is used in both small remote plants and large sophisticated plants. However, the application of chlorine presents problems, especially in remote areas far from the point of manufacture of chlorine,



Above: Cysts of *Giardia* stained with fluorescein isothiocyanate (FITC) labelled antibodies and viewed by epifluorescent illumination on a Zeiss Axiophot using oil immersion.
Left: Cysts of *Giardia* viewed by differential interference contrast (DIC) on a Zeiss microscope using oil immersion.

where transport and deliveries are unreliable, expertise on dosing of chlorine is inadequate, electrical supply is unreliable or lacking and/or the quality of gaseous chlorine gas causes problems at the point of dosing. Further, the presence of chlorinated disinfection by-products (total trihalomethanes, total organic halogen, mutagenic substances) is still a cause for concern. One way in which the formation of the potentially dangerous compounds can be reduced is to prevent the formation of the precursors of these compounds or to use alternative disinfectants. Mixtures containing oxidants such as hydroxyl radicals, ozone, chlorine dioxide, hydrogen peroxide and chlorine have a number of potential advantages such as improved efficiency, residual concentration, on-site production, ease of control over concentration and combination. Research is therefore required into the evaluation of the application of "mixed oxidants" technology for the treatment of drinking water, and particularly for disinfection of water supplied to small and rural communities. An outcome of the research will be a set of recommendations to authorities on the application of "mixed oxidants" and the possible benefits or disadvantages of such a system.

Estimated cost: R130 000
Expected term: 1997

Measurement of COD (organics) in drinking waters and tertiary effluents

(No 833) Water Quality Group, Department of Civil Engineering, University of Cape Town

There has been a progressive decrease in river water quality with time in many regions of South Africa, especially in the Gauteng and Umgeni regions. In part, this deterioration is reflected by an increase in dissolved organic content. Removal of such organics (usually with activated carbon) requires continual monitoring of dissolved organics entering and leaving the treatment plants. Using such methods as total organic analysis requires expensive instrumentation and long time-scales between sampling, analysis and feedback.

Measurement of COD (chemical oxygen demand) using potentiometric titration appears to be a cheap practical alternative to total organic carbon measurement. Current methods for measuring COD use colorimetric (end-point) techniques – these are adequate for high COD waters (e.g. sewage waters down to about COD 50 mg/*l*).

The potentiometric method that is proposed does not depend on an end-point identification in the titration but uses a modified Gran method allowing more accurate and precise measurements.

Hence the aims of this research are to:

- Develop the methodology for measuring COD in waters containing low concentrations of dissolved organics (i.e. treated and pretreated drinking water)
- Apply this methodology to quantifying dissolved humics (colour) in waters
- Disseminate the methodology on a national basis addressing all laboratory personnel.

A manual of practice will be produced for implementing the technology. Also a user-friendly computer program will be developed for the use by personnel not acquainted with extended redox Gran function analyses.

Estimated cost: R163 000
Expected term: 1997-1998

Photocatalytic purification of drinking water

(No 834) Chemistry Department, University of Stellenbosch

Humic acids are a group of polyphenolic compounds ubiquitous in ground- and surface waters, and are associated with clay colloids. Conventional flocculation treatment removes only about 50% of the humic acids, while those of small molecular mass are retained. When water containing humic acids is disinfected by chlorination, toxic disinfection products are formed. Experimental work done in the Department of Physical Chemistry at the University of Stellenbosch on laboratory-scale reactors has indicated that humic acids can be degraded by the photocatalytic process. It is proposed that reactor designs which have a potential for commercial application be investigated in order to effectively remove these humic acids and microcystin toxins.

The main aims of the proposed research are therefore to:

- Develop and establish the optimum performance characteristics of a novel design of photocatalytic reactor for purification of raw drinking water containing humic acids, clay colloids and other organic pollutants.
- Evaluate and establish the optimum performance characteristics of photocatalytic reactor designs for the decomposition of microcystins in various potable water samples.

The key research products will be specifications for the building of photocatalytic reactors, performance data for photocatalytic reactors and authentic microcystin toxin analytical standards.

Estimated cost: R263 000
Expected term: 1997- 999

Evaluation and development of physical water treatment processes for the reduction of scale in heating and cooling circuits

(No 836) Departments of Chemistry and Mechanical Engineering, Rand Afrikaans University

The build-up of scale is an expensive problem for many industries and domestic users of heating and cooling installations involving water. Traditional chemical scale-control methods, requiring sophisticated dosing equipment, are expensive.

In physical water treatment (PWT), water with scale-forming potential is exposed to an electric field in a simple flow-through system. It is claimed that this treatment will reduce or prevent scale, remove existing scale, and produce a softer scale which can be removed easily without the use of chemicals. Although PWT therefore presents a promising alternative, it was up to now only substantiated by anecdotal evidence. Local industry would welcome an independent assessment of PWT and access to standardised testing facilities.

The objectives of the study are to:

- Test the effect of PWT devices on a number of common domestic and industrial heating and cooling appliances.

- Concurrently, test the effect of physical fields (used in commercial PWT devices) on colloidal particles and particle-producing chemical reactions such as scale-forming processes.
- Develop theoretical models to explain the mechanism of such effects.
- Develop a practical Zn electrode on the basis of the patent application registered by the WRC and compile guidelines for its industrial application.
- Develop a testing facility which can be used as an independent evaluation centre for PWT devices in South Africa.

Estimated cost: R399 000
Expected term: 1997-1999

In situ calibration of large water meters

(No 871) Stewart Scott (CE) Inc.

The new Water Act will make it a requirement that all water service providers conduct an annual water audit. It also influences the need for water conservation measures and for active leakage management programmes. The initial and most important step in the audit process is the evaluation of the accuracy of the water meters.

The accuracy of water meters deteriorates with age and leads to errors in the measurement of water use. A water meter that has been calibrated in the laboratory or test facility under ideal conditions can have reduced accuracy after installation on-site because of local conditions. Resulting errors contribute towards unaccounted-for-water (UAW) that most water service providers experience and a distorted picture of water consumption emerges. Inaccurate meter performance and readings might also impact heavily on the income or revenue of water service providers. Regular *in situ* checking is the most cost-effective method of determining the accuracy of these generally large water meters. Thus, this project aims to:

- Establish a flow reference standard for the cost-effective *in situ* calibration of large water meters required for water audits and other test purposes which will be acceptable to Director of Trade Metrology (DTM). This flow reference standard would mean that the accuracy of permanently installed water meters could be compared against this standard periodically to ensure that meters remain within the prescribed limits of accuracy.
- Consolidate local and overseas research results with a view to establishing the combined accuracy of flow determination by inserting flow-meter measurements, a velocity-area estimation method and a velocity profile function.
- Develop practical guidelines and a calibrated mathematical model.

Estimated cost: R100 000
Expected term: 1997

Design and analysis package for air saturation systems used in dissolved air flotation

(No 872) Department of Civil Engineering, Rand Afrikaans University

Dissolved air flotation (DAF) emerged into the drinking water treatment arena some 30 years ago with emphasis on empirical development of the process. South Africa played a leading role in the development of the process during this period and in recent years there has been renewed interest directed towards the development of a solid, theoretical, rational basis.

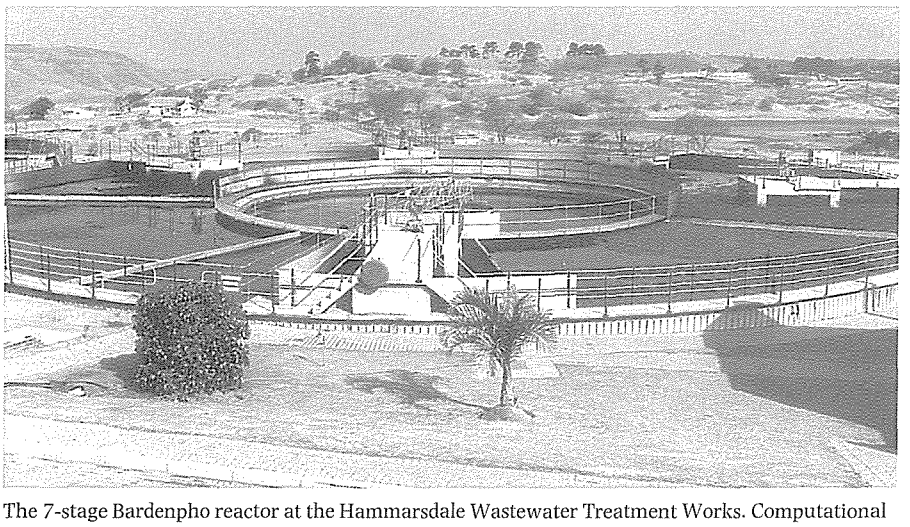
The WRC has been supporting developments in this area for the past five years. Much of this has entailed fundamental research into the nature of air suspensions and effects of the geometry of injection nozzles. Other local initiatives focused on modelling of air saturators and developing standardised test and calculation procedures.

Much of this information is available, but in a very fragmented form. This project aims to:

- Integrate and consolidate the latest research results into a comprehensive design methodology for air saturation systems used in DAF.
- Make this methodology available in user-friendly electronic format to the international consulting and academic community.

The intended output will be the development of multi-step design process software and an electronic hypertext document integrated into the software, for the benefit of design engineers, operators and academics.

Estimated cost: R75 000
Expected term: 1997



The 7-stage Bardenpho reactor at the Hammarsdale Wastewater Treatment Works. Computational fluid dynamic modelling of the anaerobic zone is part of an investigation which aims to improve the degradation of dyes in textile effluent.

Chemical and microbiological evaluation of the performance of commercially available home treatment devices

(No 873) Scientific Services, Rand Water

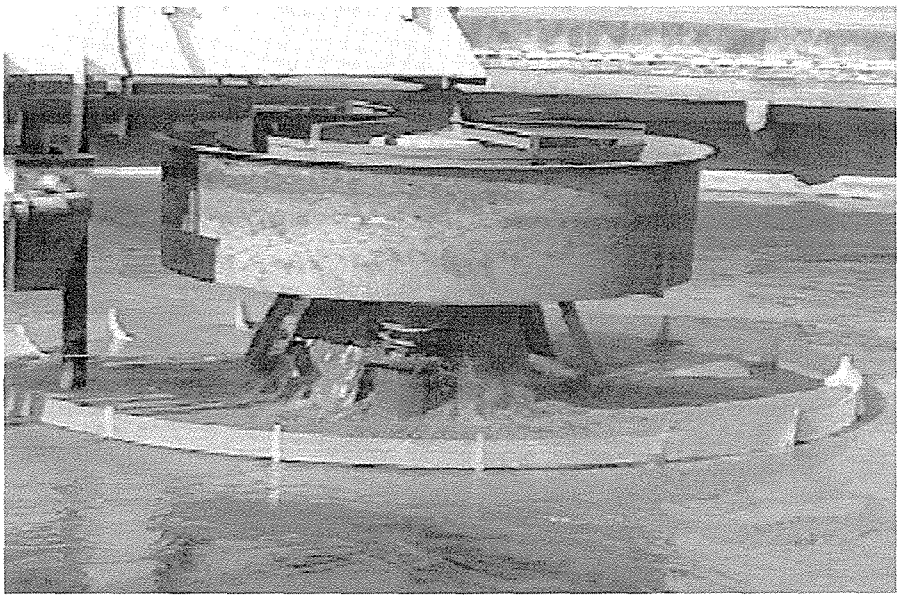
Most household treatment devices are oriented toward improving chemical and aesthetic aspects, and ignore microbiological contamination. In most of these cases the water may be subject to re-contamination when stored for drinking later. Given that Rand Water meets all accepted criteria for water for domestic consumption, and that the small amount of activated charcoal used in most of the home treatment devices is subject to de-activation and saturation, the half-life of these devices could render them little more useful than placebos for the unduly concerned. People might also use these devices on non-accredited water in the hope of purifying it. Hence claims made with respect to the performance of these devices and the quality of water produced need to be evaluated.

The objectives of this project are to:

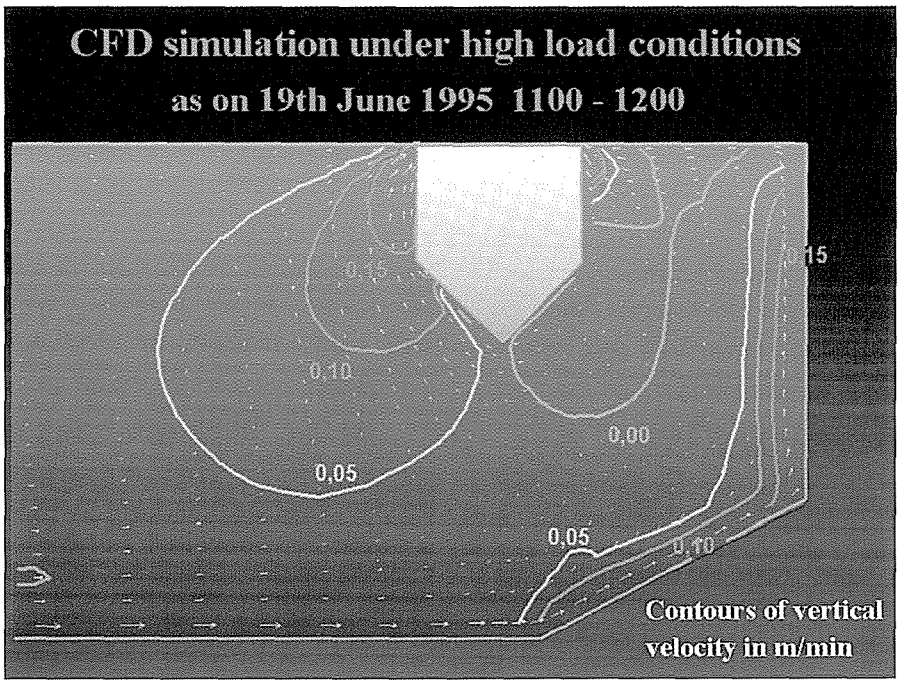
- Evaluate and compare the efficiency and effectiveness of commercially available home treatment devices with respect to microbiological and chemical performance.
- Examine the cost/benefit of the various devices.
- Compile a technical pamphlet with guidelines for consumers who wish to purchase these devices.

Further, the results can be used to compile a standard (such as SABS 1657:1996 specification for bottled natural water) to which suppliers of these devices must conform.

Estimated cost: R99 000
Expected term: 1997



The picture above shows a baffle design using CFD which has been installed in a secondary clarifier at Durban's Northern Wastewater Treatment Works, and the drawing below illustrates one of the simulations that was involved in its design.



Research projects

Completed

- **259** Effect of water quality and chemical composition on the corrosivity in mild steel pipelines (Rand Water)
- **282** Development of a combination of sedimentation, flotation and sand filtration processes for water treatment (SEDIDAFF) (CSIR – Division of Water, Environment and Forestry Technology)
- **354** Evaluation and development of deep-bed filtration for the treatment of South African surface waters (CSIR – Division of Water, Environment and Forestry Technology and Local Government Affairs Council)
- **443** Compilation of guidelines for the use of peroxone and other oxidants in the treatment of eutrophic water (CSIR – Division of Water, Environment and Forestry Technology)
- **488** Optimisation of the Rand Water system (University of the Witwatersrand – Water Systems Research Group)
- **450** Performance criteria for package water treatment plants (Umgeni Water and University of Natal – Department of Chemical Engineering, Pollution Research Group)
- **504** Guide for water purification and plant design: Phases 2 and 3 (Dr FA van Duuren)
- **537** Guidelines to coagulation and flocculation for South African waters (Pavel Polasek Association)
- **540** Evaluation of the use of bacteriophages as indicators for water quality (University of Pretoria – Department of Medical Virology)
- **549** Algal toxins in drinking-water supplies (CSIR – Division of Water, Environment and Forestry Technology and Umgeni Water)
- **557** Optimal operation of combined flotation/filtration of eutrophic surface water (Rand Afrikaans University – Laboratory for Energy)
- **591** Study for the provision of point-source water by air-gap membrane distillation (University of Stellenbosch – Institute for Polymer Science)
- **614** Expert system for water treatment plant design and analysis (Wates, Meiring and Barnard Inc. and Sutherland and Ass.)
- **621** Balancing tank control application (Watson Edwards Inc.)
- **704** Prediction of chlorine loss from potable water in pipeline systems (Rand Afrikaans University – Department of Civil Engineering)
- **705** Re-evaluation of the existing guidelines for urban and industrial water supply, based on measured water uses Phase 1: Pretoria supply area (University of Pretoria – Department of Civil Engineering)

Current

- **280** Evaluation of full-scale flotation-filtration and chlorine dioxide plants (Orange Free State Gold Fields Water Board)
- **358** Development of guidelines for toxicity bioassaying of drinking and environmental waters in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **363** Development and evaluation of small-scale potable water treatment equipment (University of Natal – Department of Chemical Engineering and Umgeni Water)
- **381** Corrosion performance of various non-metallic piping materials and coatings in potable water (CSIR – Division of Materials, Sciences and Technology)
- **383** Holistic approach to affordable planning and maintenance of water and sewer systems (Water Management Services)
- **446** Ozonation in the production of potable water from polluted surface water (University of Pretoria – Department of Chemical Engineering, Division of Water Utilisation Engineering and Rand Water)
- **470** Application of health risk assessment techniques to microbial monitoring data (CSIR – Division of Water, Environment and Forestry Technology)
- **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.)
- **534** Guidelines for the treatment of Eastern and Southern Cape coloured water (CSIR – Division of Water, Environment and Forestry Technology)
- **541** Bio-degradable organic compounds and microbial regrowth in drinking water (Rand Water)
- **567** Occurrence and distribution of algal species and related substances in a full-scale water purification plant (University of the Orange Free State – Department of Botany and Genetics)
- **568** Development of an Exxpress unit for the production of potable water and the dewatering of waterworks sludges (Umgeni Water)
- **587** Evaluation of water pipe leaks in the Johannesburg municipal area (CSIR – Division of Materials, Sciences and Technology)
- **611** Development of procedures for bio-degradability testing of organic chemical compounds (CSIR – Division of Water, Environment and Forestry Technology)
- **613** Stabilisation of aggressive and corrosive waters (CSIR – Division of Water, Environment and Forestry Technology)
- **615** Modelling the causes of algal blooms in impoundments of the Umgeni catchment and the consequences for potable water treatment (Umgeni Water)
- **628** Leak detection from municipal mains water systems in the PWV area using environmental isotopes (University of the Witwatersrand – Schonland Research Centre for Nuclear Sciences)
- **648** Application of computational fluid dynamics to improving the design and operation of water and waste-water treatment plants (University of Natal – Department of Chemical Engineering)

- **662** Evaluation and optimisation of a cross-flow microfilter for the production of potable water (University of Natal – Pollution Research Group)
- **679** Compilation of a computerised, diagnostic system for algal-related water purification problems (Rand Water – Scientific Services)
- **694** Treatment of eutrophic waters using pre- and intermediate ozonation, peroxone and Pica carbon (Umgeni Water)
- **737** Additional treatment requirements of water abstracted from the Vaal River system following the importation of Lesotho Highland water (Rand Water – Scientific Services)
- **741** Enteropathogens in water; rapid detection techniques, occurrence in South African waters and the evaluation of epidemic risks (health related) (CSIR – Division of Water, Environment and Forestry Technology)
- **742** Qualitative and quantitative evaluation of oestrogen and oestrogen-mimicking substances in the water environment (Rand Water – Scientific Services)
- **757** Development of a model for the optimisation of the pumping and design policies of reservoir systems (University of the Witwatersrand – Water Systems Research Group)
- **773** Enhanced coagulation for the removal of disinfection by-product precursors (Umgeni Water – Scientific Services)
- **779** Use of chloramination and sodium silicates to inhibit corrosion in mild steel pipelines (Rand Water – Scientific Services)
- **787** Production of a corrosion brochure for local authorities (CSIR – Division of Materials, Sciences and Technology)

New

- **803** Development of a standardised approach to evaluate burst and background losses in water distribution systems in South Africa (BKS Inc. – Water Resources Department)
- **825** Preparation and testing of kits for the detection and quantification by developing countries of *Cryptosporidium* oocysts and *Giardia* cysts in water supplies (Umgeni Water – Scientific Services, and University of Natal – Department of Microbiology and Plant Pathology)
- **829** Systems for the abstraction of surface water through river sand bed (Chunnett, Fourie and Partners (CE))
- **831** Development and implementation of gas and liquid chromatographic organic water profiles as a management tool (Rand Water – Scientific Services)
- **832** Application and efficiency of "mixed oxidants" for the treatment of drinking water (Rand Water – Scientific Services)
- **833** Measurement of COD (organics) in drinking waters and tertiary effluents (University of Cape Town – Department of Civil Engineering, Water Quality Group)
- **834** Photocatalytic purification of drinking water (University of Stellenbosch – Chemistry Department)
- **836** Evaluation and development of physical water treatment processes for the reduction of scale in heating and cooling circuits (Rand Afrikaans University – Departments of Chemistry and Mechanical Engineering)
- **871** *In situ* calibration of large water meters (Stewart Scott (CE) Inc.)
- **872** Design and analysis package for air saturation systems used in dissolved air flotation (Rand Afrikaans University – Department of Civil Engineering)
- **873** Chemical and microbiological evaluation of the performance of commercially available home treatment devices (Rand Water – Scientific Services)

CONTACT PERSONS

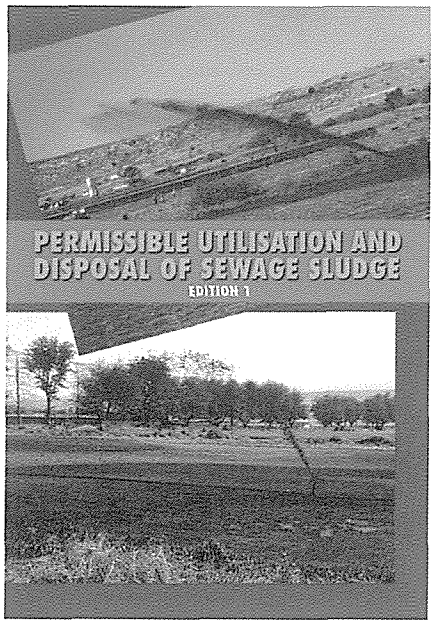
- **Dr IM Msibi**
  (Water Treatment and Reclamation)
  e-mail: msibi@wrc.ccwr.ac.za
- **Dr G Offringa**
  (Membrane Applications)
  e-mail: offringa@wrc.ccwr.ac.za
- **Mrs APM Oelofse**
  (Drinking-water Quality and Health Aspects)
  e-mail: annatjie@wrc.ccwr.ac.za
- **Mr JN Bhagwan**
  (Water Supply, Water Loss Control and Corrosion)
  e-mail: jbhagwan@wrc.ccwr.ac.za
- **Dr SA Mitchell**
  (Bioassaying)
  e-mail: steve@wrc.ccwr.ac.za

☎ **(012) 330-0340**

4

MUNICIPAL WASTE-WATER MANAGEMENT

Projected increases in water demand allowing for both the projected population increase, and the projected *per capita* increase with increasing sophistication of consumer economy, indicate that the importance of effective effluent treatment will increase. However, adding to this demand is the need to move towards demand management, conservation and protection of the environment. Hence the challenges are vast in moving from a hierarchy of waste-water management in South Africa which still relies heavily on waste-water treatment and disposal, towards using technology that produces fewer harmful pollutants and incorporates recycling as far as possible. This forward-looking approach will assist the country to begin to develop its own novel technologies, taking into account the needs and constraints of emerging communities, the economy and the environment.



Completed projects

Develop curricula for the operation of disinfection processes and operation of sludge handling processes

(K8/169) MTI Manpower Consultancy Services

The next step in the series on Watercare Operators Education and Training, was the development of curricula around the competencies identified. The areas addressed by this project were disinfection of water and sludge handling. On disinfection the following aspects were covered:

- All aspects of chlorine handling and treatment
- The use of ozone and ultraviolet
- The management of maturation ponds.

The curricula developed for sludge handling covered thickening (potable and waste water), digestion (waste water), dewatering (potable and waste water) and disposal of sludges from both potable and waste-water treatment plants. What still remains to be done on this level is to develop curricula for the other identified competencies, and then to develop courseware from the curricula.

WRC funding has provided a sound base for the development of an effective education and training system, and outcome-based curricula have been developed. Following this development the need is, firstly, for the enabling mechanisms to be put in place at national level so that the courseware may be used and, secondly, for course writers to be trained and educational institutions to move from classroom and semester-based education to the competency-and-outcome-based model.

Costs: *R35 244*
Term: *1994-1995*

Full-scale study of chemical sludge bulking control

(No 328) Department of Chemical Engineering, University of Pretoria

Chlorination of activated sludge is the most economical non-specific method of controlling bulking sludge in a nutrient removal activated sludge plant. With the necessary precaution such as a daily trend plot of sludge volume index values to follow the effect of chlorination and dosing at the minimum effect dose, bulking can be controlled by chlorination with only a marginal effect on phosphate removal. Hydrogen peroxide controls bulking during the initial stage of treatment. However, regrowth of the low F/M filaments occurs even while H_2O_2 is being dosed.

An important aspect which became clear during the course of this project, is that up-scaling from bench scale to full scale can easily give results which can lead to discarding serviceable technologies. Bench-scale experiments should only be used to establish a principle. To verify under what conditions the technology is applicable, and to gather data for up-scaling, it should be tested on an industrial pilot scale in which the actual conditions in the full-scale plant can be simulated. Furthermore, in non-specific bulking control in nutrient removal activated sludge systems using oxidants, dosages of the oxidants can only be optimised in a full-scale plant. Operators of full-scale plants should be encouraged to report their experiences in applying technologies.

If it is necessary to control bulking by non-specific methods, then the methods reported by this study may be effectively used. From the information available at this stage it is clear that it is not possible to design and operate a nutrient removal activated sludge system that will not bulk with low F/M organisms at some stage or another. The search for a more "nutrient-removal friendly" system of non-specific bulking control than chlorine must continue. To narrow the gap between bench scale and full scale and to keep the cost down, this research should be conducted on at least pilot scale.

Since the project was initiated, the understanding of sludge bulking has improved to a point where non-bulking plants may be predictably designed. Thus, the need for this technology will be largely limited to older plants. With this in mind, there are plants in the country where these results can usefully be applied.

Cost: *R52 000*
Term: *1990-1994*

Consolidation of activated sludge research

(No 356) Department of Civil Engineering, University of Cape Town

This project was primarily aimed at the transfer of information to the various user communities concerned with the treatment of sewage by the activated sludge process. Over the last 10 years the understanding of the phenomena of nitrification-denitrification and biological excess phosphorus removal from activated sludge systems has reached a point where it may now be applied at full scale. It is essential that the knowledge and experience gained during the course of the research into the activated sludge process be made available to the various user bodies.

The study resulted in the following:

Simulation model – The model was distributed and a considerable number of comments were received which were incorporated into it. This model is being distributed by the WRC.

Nitrification denitrification biological excess phosphate removal (NDBEPR) kinetic simulation model – This model includes 25 processes and 19 compounds and is very complex. Development of the model has consolidated information from this and previous WRC contracts on NDBEPR and has identified areas which require further investigation. However, it is concluded that the complexity of the process makes it very difficult to achieve a final product.

Characterisation of municipal waste water – The study indicates that batch tests may successfully be used to determine the parameters of municipal waste water.

Dynamic simulation of secondary settling tanks and evaluation of secondary settling tank design procedures – This work established relationships between the flux theory and the two empirical design procedures as used in Germany and Britain. There is substantial overlap between the procedures, and a one-dimensional model based on the flux theory gave very good predictions.

Treatability of stabilised landfill leachate in a nitrogen removal activated sludge system – This study indicated that there is merit in co-treating landfill leachate and sewage in an activated sludge unit. It was shown that the leachate was about 90% biodegradable and that the high readily biodegradable COD content of the leachate was sufficient not only to denitrify its own total Kjeldahl nitrogen but contributed to the denitrification of the sewage as well.

The effect of alternate detergent builders on NDBEPR systems – The effect of two alternative detergent builders (Zeolite 4A and high surface area (HSA) calcite) to polyphosphate was investigated on the activated sludge process. Neither of the two alternative builders had any detectable negative effect on N or P removal, although a very slight increase in total sludge production was possible.

The effect of thermophilic heat treatment on the anaerobic digestibility of sewage sludge – Due to the structural failure of the dual digestion reactor, one of the claimed advantages of dual digestion, that the time of the anaerobic digestion can be reduced compared to a conventional system when the sludge is pretreated in this way, could not be confirmed. At laboratory scale the biological auto-thermal heat generation was insufficient to heat the sludge, so external heat was applied. No difference in anaerobic digestibility of sludge treated this way was detectable from untreated sludge. This was not considered conclusive, as the micro-organisms in the sludge may not have been the same as those at full scale.

Costs: *R438 000*
Term: *1991-1994*

Investigation into the application and performance of constructed wetlands for waste-water treatment in South Africa

(No 416) SRK (CE) Inc.

In view of the fact that many constructed wetlands (CWs) fail to meet design objectives, this project was launched to investigate the application and performance of these systems in South Africa. A number of CWs were identified for detailed investigation in order to provide an overview of how they perform relative to their design objectives, and to identify factors affecting the performance of alternative configurations and operational approaches. Furthermore, opportunities for improving the relative performance of the different treatment approaches were assessed.

The investigation has confirmed that there have been flaws in the design and operation of CWs for waste-water treatment in South Africa. This was largely due to a general lack of understanding of the mechanisms and processes of waste-water treatment through a CW system. Despite the vegetation being perceived to be a primary treatment mechanism, its contribution is generally low, whereas the configuration and operation of the wetland are of significantly greater importance. The primary performance limitation is flow control through the system. Low permeability of the bed media tends to encourage surface flow rather than filtration through the bed for systems designed for subsurface flow, and similarly, surface flow systems demonstrate significant short-circuiting. These factors minimise available residence times and contact opportunity for optimal treatment.

Despite less-than-optimal flow conditions and limited plant contributions to pollutant removal, South African systems do demonstrate significant potential for waste-water treatment. Surface flow systems receiving secondary sewage can achieve removals of COD and SS up to 20 $g/m^2.d$, NH_3 and NO_3 removal of up to 1,5 and 6,0 $g/m^2.d$ respectively, but limited pathogen removal of 99%, and low phosphate removal. Subsurface flow soil systems are severely limited by permeability, but where flow is maintainable for secondary waste waters, COD, SS, NO_3 and PO_4 removal can be in excess of 85%, and pathogen removal of 10^5-fold, but NH_3 removal is low, <30%, due to poor oxygen transfer to the root zone. Subsurface flow gravel beds can achieve high COD removal rates at loadings up to 100 g $COD/m^2.d$ with settled sewage, acting as anaerobic filters. Secondary units are then required to polish residual organics, nutrients and pathogens.

Engineering design to account for hydraulic limitations can provide a new generation of CW better able to meet their treatment objectives. Surface flow systems, whether open-bed or channel configuration, may be improved by provision of alternate shallow and deep water areas, and intermediate berms to assist flow and velocity buffering. Multiple species planting in defined areas through which the waste water must flow assists contact opportunities for treatment by physical filtration, adsorption and absorption and biological treatment by attached micro-organisms. Subsurface flow systems are limited by the permeability of the selected media. For horizontal flow systems these require low width-to-length ratios and effective hydraulic gradients, or in a vertical mode, capacity to effectively distribute the water over the bed surface, and to collect the treated waste water from subsurface drains over the full bed area. In each system configuration, performance may be improved by alternate feeding and draining to balance flow distribution and enhance aeration conditions within the beds, particularly for N removal.

In general there is a move to multiple-unit systems which may include subsurface flow reedbeds, surface flow marshes, ponds, grasslands and forest or shrub areas as required to meet the treatment and environmental conservation objectives. Mechanical units, such as biological trickling filters for ammonia removal, or recirculating sand filters for pathogen removal, may be required where land is restricted or treatment performance needs to be efficiently controlled.

It is concluded that CWs can provide a viable and effective form of waste-water treatment. A primary consideration is the need to control the hydraulics to optimise retention times and contact opportunities for effective treatment. Multiple units, and integrated systems, provide an opportunity to tailor the system to many treatment and ecological objectives.

Cost: *R331 000*
Term: *1992-1995*

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

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

Precipitation of struvite and calcite is a common phenomenon in waste waters containing higher than usual concentrations of dissolved orthophosphates, free and saline ammonia, and magnesium and calcium ions.

Struvite/calcite precipitation occurs within the pipe network transporting the treated effluent, particularly at bends and inlets to pumps. The mass of precipitant formed can be so extensive that it may lead to operational failure.

Based on equilibrium chemistry of the ammonia, phosphate, carbonate and acetate weak acid systems in the water, a computer program was developed to:

- Estimate the struvite and calcite ($CaCO_3$) precipitation potentials in waste-water effluents with known TDS and temperature
- Assess the effects of varying parameters such as pressure, and alkalinity/acidity on pH and the struvite/calcite stability in effluents
- Estimate the desired effluent quality and the associated chemical treatment requirements (dosages) to adjust the effluent to a desired state.

The accuracy of the computer program was demonstrated by comparing the predicted values with actual measurements made in the laboratory. For the aqueous/gaseous phase equilibrium situation the predicted and observed pH values are within 0,05 pH units. For the aqueous/gaseous/solid phase equilibrium situation, the predicted and observed struvite precipitated is within 1%.

The computer program will have application in the treatment of both municipal and industrial effluents and will be beneficial to a number of fields of waste-water

treatment. It will enable controllers of waste-water treatment plants to easily predict the potential for mineral fouling, and to investigate chemical dosing strategies to prevent such fouling.

Cost: *R108 200*
Term: *1994-1996*

Municipal sewage sludge disposal: Development of guidelines and expert systems

(No 605) Division of Water, Environment and Forestry Technology, CSIR

Currently, most countries dispose of a large proportion of sewage sludge primarily to landfill. This is believed to be because municipal waste treatment and disposal facilities are located relatively close to each other, because alternative options are more costly and because the negative aspects of sludge for land treatment are seen to greatly outweigh the positive. Sludge disposal to land has significant positive economic and environmental consequences if planned and managed correctly.

The land application of sludge can be used to:

- Improve the physical properties of soil
- Supply plant nutrients
- Increase and buffer soil pH
- Increase the soil cation exchange capacity
- Reduce sludge disposal costs to municipalities.

The positive effects of sludge on soil are considered very relevant in South Africa. The effects of deterioration and loss of agricultural topsoils is generally considered to represent a major negative economic impact to this country. Further, soils with a high organic content and cation exchange capacity are better able to capture and retain water and nutrients, making them available to plants.

The major drawbacks relating to sludge disposal to land are sludges containing certain types and concentrations of constituents which are potentially harmful to humans, animals and/or plants. The risk associated depends mainly on sludge type, chemical characteristics, land-use and sludge management, and also soil, topographic and hydrological parameters at the site.

The report provides information on current guidelines, regulations and applicable research results locally and overseas. This has been used to develop applicable guidelines and methodologies for decision-support purposes regarding:

- Permit applications, permit assessments and the attachment of applicable conditions to permits for the application/disposal of sewage sludge to land
- The establishment of design and planning constraints for impact assessment purposes relating to the disposal of sewage sludge to land.

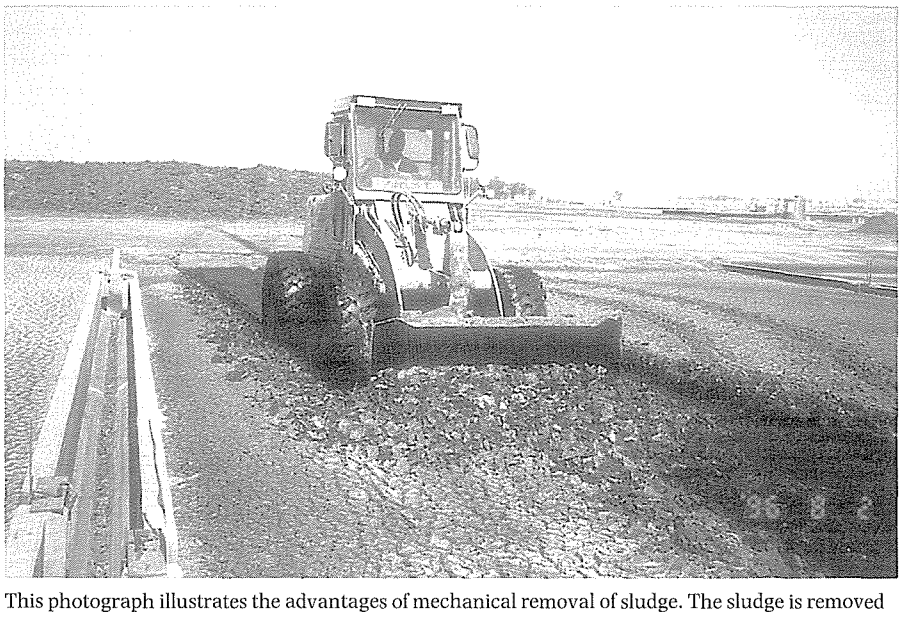
The expert system provides for:

- Identifying loopholes and indicating possible improvements or changes
- Regulatory authorities and/or consultants with user-friendly decision-support software for regulatory compliance and impact-control purposes
- Advising and aiding permitting authorities, consultants, sludge producers and landowners regarding the disposal of sewage sludge to land.

This project has prompted the development of a common set of guidelines for the country which has materialised with the co-operation of government departments and the WISA Sludge Division. The software or expert system complements these guidelines, hence making its use more relevant. The most important of all the results is that SA now has new guidelines, which have the support of the government departments involved. These guidelines being common, they can now be used by all different departments and users. The management of sludge utilisation will become much easier and co-ordinated.

In general, the results of this study produced improved or more easily applicable guidelines supported by an expert system.

Costs: *R193 600*
Term: *1994-1995*



This photograph illustrates the advantages of mechanical removal of sludge. The sludge is removed at higher moisture contents than compared with manual methods and is clearly more efficient than the latter.

Bioremediation of a river system using the Alpha Biocatalyst

(No 623) Alpha Biotech CC

The presence of informal settlements on water courses leads to a decrease in water quality to a point where it is not safe for use as a water source by those who rely on it. At the same time the cost and manpower requirements of upgrading these areas is such that it will take time. This project sought to find a cost-effective interim measure for this type of situation.

Bioremediation of a heavily impacted river, the Sipingo River, was undertaken to see if it would be possible to improve water quality to a point where it would be usable to those who depend on it as a water source.

The Alpha Biocatalyst technology has been used successfully to upgrade various waste-water handling facilities. This project was designed to test the ability of the Alpha Biocatalyst to improve the quality of a stream polluted with organic waste of domestic and industrial origin, and so maintain fitness-for-use of the river.

Results indicate that by the end of the treatment, the dissolved oxygen concentration downstream of the biocatalyst addition point tended to move upwards relative to the upstream concentration. The change took place over an extended period e.g. 4 to 7 months. This indicates a substantial improvement in the quality of this stretch of the Sipingo River.

The rate of disappearance of colony-forming units of *E. coli* appears to be quite high given that the residence time from the first sample point to the lagoon is in the region of only two days. The residence time from the sample point, where the highest concentration of *E. coli* was found, is much lower. Main sources of faecal contamination are from upstream of the sewage works and a large inflow somewhere in the canalised section of the industrial area. Both ammonia and nitrate concentrations trended downwards the further away downstream from the point of introduction of the biocatylist at the river and the discharge of the sewage works.

Although the results were not as dramatic as those obtained from using the product on overloaded waste-water treatment works, there was a trend which ultimately showed significant improvement in certain of the water quality parameters, particularly dissolved oxygen. Faecal coliform counts were also reduced. This technology increases the capacity of a water body to cope with organic enrichment, and so provides a cost-effective way of handling a situation. It would appear that this technology is suitable for the rehabilitation of rivers, but would probably perform better with a longer retention time in the river, as this is where most of the impact of pollution is felt.

Cost: *R88 800*
Term: *1994-1995*

New projects

Development and monitoring of integrated algal high-rate oxidation pond (AHROP) technology for low-cost treatment of sewage and industrial effluents

(No 799) Department of Biochemistry and Microbiology, Rhodes University

The WRC has made substantial financial investments into research and development of the AHROP process for treating high organic load effluents. In addition to its water treatment capability, the potential of the process to recover value-added algal biomass has been demonstrated which could be of particular significance for developing and disadvantaged communities. During the course of the preceding 3-project study, full-scale AHROP demonstration plants were constructed at Wellington, Grahamstown and Cato Ridge. The three projects all terminated at the end of 1996, before research associated with the optimisation of these systems and the identification of their full potential could be completed. To promote the application of the AHROP system, which is aimed at developing communities and small- and medium-sized industries requiring low-cost treatment, reliable performance data must be obtained for design and operating purposes.

The objectives of the research programme are to:

- Undertake a comprehensive monitoring programme of the integrated AHROP plants constructed for demonstrating the treatment of tannery, sewage and abattoir effluents, to establish confidence limits for these systems
- Evaluate parameters leading to the optimised operation of the demonstration plants and produce recommended parameters
- Report on the value-added potential of algal biomass produced in the AHROP plants
- Determine constraints and future research needs relating to the wide-scale application of the AHROP technology developed.

Estimated cost: *R510 000*
Expected term: *1997-1999*

Production and biodegradation of organic carbon from sewage and biological sludge for denitrification

(No 820) Pollution Research Group, University of Natal

This project will address the reduction of eutrophication through better removal of nitrogen compounds at sewage treatment works by improving biological denitrification. Improvement in denitrification will result in the following:

- Protection of the environment and reduction in the cost of producing potable water
- Reduction in the oxygen requirements of the activated sludge process by supplying oxygen in the form of nitrate.

The main objectives of this project are to:

- Develop a standardised technique that can be used by sewage works personnel to determine the kinetic parameters of their denitrification process
- Develop techniques to fractionate real sewage works streams to accurately simulate the characteristics of streams after the process modification
- Apply the basic understanding of the denitrification process to the improved operation of existing sewage works.

Estimated cost: *R208 000*
Expected term: *1997-1998*

Investigation and comparison of microbial contribution to nutrient removal in activated sludge and trickling filter waste-water treatment processes

(No 822) Department of Biotechnology, Technikon Natal

Waste water entering a treatment plant is composed of different and constantly changing substrates which can only be degraded by a mixed population of micro-organisms. The microbial communities in waste-water treatment plants contribute to the purification process, but their metabolic processes are influenced by the different environmental conditions that prevail in the different zones of the waste-water treatment plant. It is necessary to use a holistic approach to develop a better understanding of the association between microbes and nutrients in these plants.

The objectives of the research project are to:

- Undertake a microbiological survey of different sites of waste-water treatment at Danville/Umbilo Waste-Water Treatment Plants
- Monitor plant parameters such as COD, BOD, nitrogen and phosphorus removal
- Establish the extent of correlation between microbial predominance and nutrient removal
- Compare treatment technologies (i.e. trickling filter and activated sludge) with respect to microbial population and nutrient removal
- Construct a database of above correlations for future use in design and optimisation of respective treatment processes.

Estimated cost: R487 000
Expected term: 1997-1999

Full-scale demonstration of specific filamentous bulking control in a biological nutrient removal activated sludge plant at Mitchells Plain Waste-Water Treatment Plant

(No 823) Department of Civil Engineering, University of Cape Town

Specific control of filamentous bulking in biological N and N & P removal plants has been undertaken at laboratory scale by the Water Research Group at the University of Cape Town under contract to the WRC. The Mitchells Plain Waste-Water Treatment Plant will be used to verify the specific bulking control hypothesis developed by this research team from laboratory-scale research over the past 6 years at full scale. This project will also demonstrate and evaluate, at full scale, specific bulking control measures in N & P removal systems.

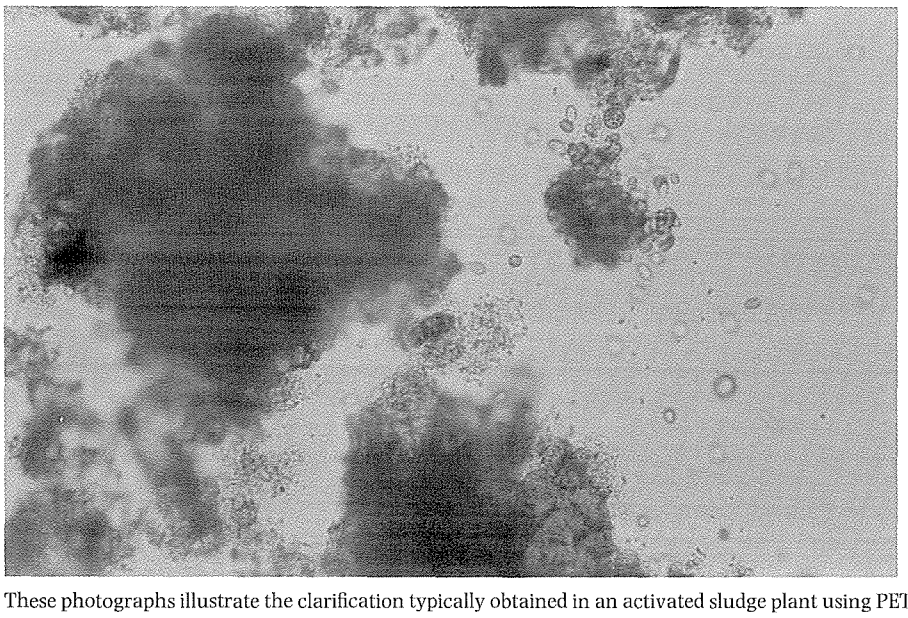
This demonstration study will provide an incentive for other municipalities with N & P removal plants to implement similar strategies for bulking control leading to improved sludge settleability and increased treatment plant capacity.

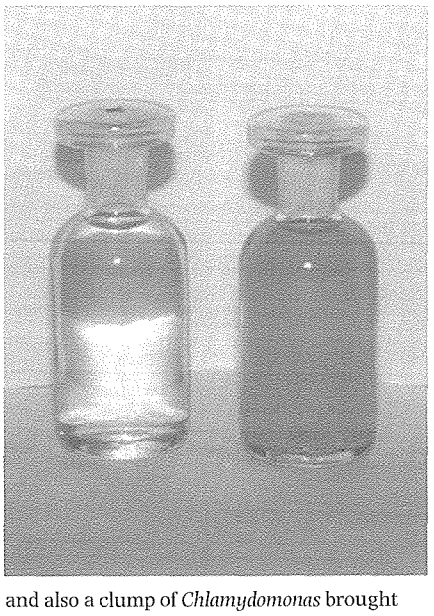
Estimated cost: R454 000
Expected term: 1997-1999

Hydrodynamic modelling of secondary settling tanks

(No 835) Department of Civil Engineering, University of Cape Town

The secondary settling tanks (SST) of activated sludge plants are the bottleneck limiting treatment capacity. This is influenced by two factors, namely the settleability of the sludge, and the hydraulics within the SST itself.





These photographs illustrate the clarification typically obtained in an activated sludge plant using PETRO and also a clump of *Chlamydomonas* brought about by natural flocculation of algae by exopolysaccharides. EPS are exuded by algae under stress having switched from autotrophic to heterotrophic metabolism.

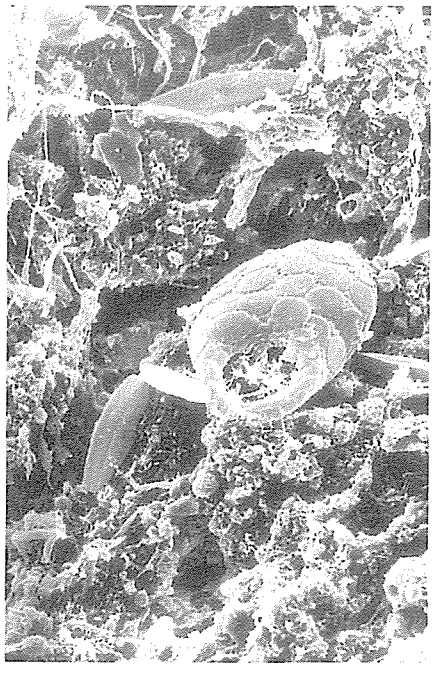
The reasons for the poor hydraulics are:

- Turbulence and density currents
- Poor effluent weir and baffle placement
- Effects of sludge collection mechanisms and inlet arrangement
- Absence of flocculating centre and settling wells
- Wind and temperature effects.

SSTs are usually designed by empirical rules and current design procedures give very little guidance on the design of these SST internal features, being very subjective and its effectiveness depending mainly on the experience of the design engineer.

The project aims to:

- Develop a publicly owned hydrodynamic SST model in South Africa which is available for use by competent engineers
- Develop an SST modelling algorithm – application to this area of computational modelling techniques which have been developed in contingent areas to improve efficiency and numerical stability of current SST modelling algorithms.



Hydrodynamic (or glass box) models, allow design and optimisation of the SSTs internal features. Although application is limited at this stage, these models are being used successfully in research programmes for 2D and 3D simulation of full-scale SSTs. Modifications in the design of the internal features based on the simulation results have shown significant improvement in SST capacity with a reduction in effluent suspended solids concentration.

Estimated cost: R 456 000
Expected term: 1997-1999

Water Institute of Southern Africa *Operators Handbook*

(No 848) Philip Pybus CE

Since 1984, when the *Operators Handbook* (Water Institute of Southern Africa) was last revised, technology has advanced considerably, particularly in the field of biological and chemical nutrient removal. There is a strong need to bring the *Operators Handbook* in line with modern advances in waste-water treatment and in accordance with the recent publications on anaerobic digestion and biological nutrient removal (e.g. WRC projects No 455, 457 and 460). The *Operators Handbook* is used widely in Technikons, Technical Colleges and most operators of waste-water treatment works.

A modern and updated edition is long overdue, hence the objectives of the project are to update and modernise the *Operators Handbook*. This will involve the revision and rewriting of each of the chapters of the 1984 edition of the *Operators Handbook* according to the need. This project will also make use of collaborating assistants with specialised knowledge of the chapter subjects. The handbook will be published in four volumes, just like the current one.

Estimated cost: R170 000
Expected term: 1997

Left: A scanning electron micrograph of biological slime obtained from a trickling filter showing a variety of micro-organisms including diatoms, algae that have been immobilised and a large protozoa surrounded by different algal and diatom species.

Research projects

Completed

- **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)
- **416** The application and performance of full-scale constructed wetlands for waste- water treatment in South Africa (SRK (CE) Inc.)
- **602** Application of chemical equilibrium to the control of struvite and calcite precipitation in waste-water treatment (University of Cape Town – Department of Civil Engineering)
- **605** Municipal sewage sludge disposal: Development of guidelines and expert systems (CSIR – Division of Water, Environment and Forestry Technology)
- **623** Bioremediation of a river system using the Alpha Biocatalyst (Alpha Biotech CC)
- **K8/169** Develop training curricula for the operation of disinfection processes and operation of sludge handling processes (MTI Manpower Consultancy Services)

Current

- **248** Chemical augmentation of biological phosphate removal (City Council of Johannesburg)
- **316** Aspects of sewage sludge treatment and disposal (City Council of Johannesburg)
- **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 (CE) Inc. and CSIR – Division of Water, Environment and Forestry Technology)
- **542** Causes and control of low A/A filament bulking in nutrient removal activated sludge systems (University of Cape Town – Department of Civil Engineering)
- **554** Study of activated sludge microbial population dynamics for the optimisation of biological phosphorus removal (University of Pretoria – Department of Microbiology and Plant Pathology)
- **555** Limitation of convection currents in clarifiers (University of Pretoria – Department of Chemical Engineering)
- **556** Refinement of design parameters for sludge thickening by dissolved air flotation (Rand Afrikaans University – Energy Laboratory)
- **560** Development of a cross-flow micro-filtration unit to improve the performance of anaerobic digesters at waste-water treatment works (University of Natal – Department of Chemical Engineering, Pollution Research Group)
- **569** High-rate recirculation and solids contact optimisation of biological filtration plants (Wates, Meiring and Barnard (CE) Inc.)
- **597** Technology adaption for successful application of septic tank systems in the coastal zone (CSIR – Division of Water, Environment and Forestry Technology)
- **604** Compilation of guidelines for the design and operation of sewage sludge drying beds (GFJ (CE) Inc.)
- **606** Practical application of special waste co-disposal with municipal refuse at the Coastal Park landfill bioreactor (Cape Town City Council – City Engineer's Department)
- **620** Modelling, design and operation of secondary settling tanks (University of Cape Town – Department of Civil Engineering)
- **668** Determination of dissolved organic loads in raw and other sewage and the termination of the COD and DOC ratios (East Rand Water Care Company)
- **688** Laboratory and pilot-plant bioreactor development for remediation of metal-contaminated waste water using activated sludge as biosorbent (Technikon Natal – Department of Biotechnology)
- **692** Treatment of waste waters with high nutrients (N and P) but low organic (COD) contents (University of Cape Town – Department of Civil Engineering)
- **707** Calibration of open channel flow measuring systems using laboratory calibrated velocity-head electronic measuring instruments, and by applying the continuity principle (East Rand Water Care Company, through Sigma Beta (CE))
- **713** Removal of algal and other biomass from treated waste waters employing the PETRO process (Wates, Meiring and Barnard (CE) Inc.)
- **739** Disinfection of purified effluent (University of Pretoria – Division of Water Utilisation Engineering, Department of Chemical Engineering)
- **775** Development of strategies for amelioration of bulking by anoxic-aerobic filamentous organisms in nutrient removal activated sludge systems (Stewart Scott (CE) Inc.)
- **776** Fingerprinting of activated sludge systems using PAGE analysis of total protein extractions for the optimisation of biological phosphorus removal (University of Pretoria – Department of Microbiology and Plant Pathology)

New

- **799** Development and monitoring of integrated algal high rate oxidation pond technology for low-cost treatment of sewage and industrial effluent (Rhodes University – Department of Biochemistry and Microbiology)
- **820** Production and biodegradation of organic carbon from sewage and biological sludge for denitrification (University of Natal – Pollution Research Group)
- **822** Investigation and comparison of microbial contribution to nutrient removal in activated sludge and trickling filter waste-water treatment processes (Technikon Natal – Department of Biotechnology)
- **823** Full-scale demonstration of specific filamentous bulking control in a biological nutrient removal activated sludge plant at Mitchells Plain Waste-Water Treatment Plant (University of Cape Town – Department of Civil Engineering)
- **835** Hydrodynamic modelling of secondary settling tanks (University of Cape Town – Department of Civil Engineering)
- **848** Water Institute of Southern Africa *Operators Handbook* (Philip Pybus (CE))

CONTACT PERSONS

- **Dr SA Mitchell**
  (Nutrient Removal and Sludge Treatment)
  e-mail: steve@wrc.ccwr.ac.za
- **Mr JN Bhagwan**
  (Low-cost Sanitation)
  e-mail:
  jbhagwan@wrc.ccwr.ac.za
- **Mr GN Steenveld**
  (Nutrient Removal and Algal Ponding Systems)
  e-mail: greg@wrc.ccwr.ac.za

☎ **(012) 330-0340**

5

WATER QUALITY MANAGEMENT

Water is only of use when it is of a suitable quality for its intended purpose. A deteriorating water quality, to which a water-scarce country like South Africa is particularly susceptible, therefore poses a threat to sustainable development. Because of the fairly high requirements for potable use, a deterioration in water quality would also threaten our national goal of providing for the basic water needs of our people.

South Africa, furthermore, does not have the luxury of most water-rich countries, of solving water quality problems by making use of the dilution capacity of surplus water supplies. It therefore comes as no surprise when experts warn that it may prove to be more difficult to provide users with water of an acceptable quality on a sustainable basis, than merely providing an adequate supply. Because of dissimilar conditions, South Africa thus cannot rely on overseas experience to solve our water quality management issues, but has to adapt such experience and even develop alternative water management strategies to suit local conditions.

Recognition of the problems we share with other countries and the need to develop solutions that are often uniquely suited to our particular situation have over the years been the guiding principle of the WRC's research activities in support of water quality management. This approach has empowered the water research community to make their much-valued contribution to the recent water law review process and provided the scientific foundation on which South Africa's new Water Act is being drafted. The provisions of this Act are such that they in themselves will create the need for further research. The recognition of the natural environment as part of the water resource has, for example, water quality management implications which will give additional impetus to the use of biological indicators of water quality.

A number of projects in this field are aimed at analysing the water quality situation, its causes, magnitude and impact on users. Other projects aim to improve our ability to predict system response to natural driving forces, disturbances, pollution incidents and management intervention or obtain a better understanding of the processes which operate in nature.

Poor water quality often manifests itself as specific problems. Projects that address problems in the field of salinity, eutrophication, other surface water quality studies and marine disposal are being funded by the WRC in support of water quality management.

Salinisation remains one of the consequences of water pollution which causes widespread problems in South Africa. However, most of these problems go unnoticed, or remain unconnected by consumers. Salinisation is the result of the addition of a variety of salts to the water environment which almost inevitably results from the increasing use and reuse of water associated with development. With increasing salinity the water becomes less fit for most users, who consequently incur additional costs.

Eutrophication is the enrichment of the water environment with plant nutrients and the consequent abundant growth of algae and aquatic plants. Serious problems pertaining to economics of water purification and defacement of the water environment are associated with eutrophication, while certain algae also excrete toxins.

The gradual deterioration of water

quality and the growing awareness of water quality as a factor which undermines the utilisation potential of water, have given rise to the identification of a number of research needs. **Water quality studies** are being conducted to address problems associated with microbial pollution, sediments and other water constituents, as well as to improve the means to cope with them.

Marine disposal often is more economical than the land-based treatment of effluents. However, the sea's limited assimilation capacity is increasingly being recognised. Because marine disposal is sometimes used for the disposal of substances detrimental to the marine environment, and because of the unfavourable publicity associated with such abuses and with pipelines which are poorly designed and operated, public resistance to marine disposal is increasingly being experienced world-wide. It is nevertheless a practice which is widely adopted by coastal communities (also in South Africa) to dispose of their effluents. The WRC finances projects in this field in order to establish criteria for using marine disposal as a responsible alternative to land-based disposal of effluents.

Completed projects

Phytoplankton blooms in the Vaal River and the environmental variables responsible for their development and decline

(No 359) Department of Genetics and Botany, University of the Orange Free State

The problems related to the over-abundance of algae (i.e. blooms) in rivers are well recognised, but poorly understood. The Vaal River is the most important and regulated river in South Africa. It is also eutrophic and highly productive, with massive developments of phytoplankton resulting in aesthetic problems, health hazards, interference with treatment processes and problems in water distribution systems. There was therefore a need to study the causes and consequences of the waxing and waning of phytoplankton assemblages and the effect of water transfer and stream regulation on algological and environmental variables in this river.

The phytoplankton populations with respect to quality and quantity were related to the physical and chemical environment in order to understand conditions responsible for the development and decline of specific algal blooms. It was found that at least 124 species and varieties occurred in the Vaal River with green algae showing the greatest diversity, while there was some seasonal variation of dominant species. The main result was the development of a model, taking into account light and silica effects on algal growth. This model was further developed in a separate project (No 536).

Cost: *R376 400*
Term: *1991-1995*

Development of a dynamic model for the growth and bloom of algae in the Vaal River

(No 536) Department of Applied Mathematics, University of the Orange Free State

A mathematical model aimed at water management was developed to predict the algal species and algal blooms likely to occur in a specific stretch along the Vaal River. The model takes into account six environmental factors having a major effect on algal growth, namely water temperature, underwater light, turbidity, dissolved silicon, dissolved nitrogen and dissolved phosphorus. A unique feature of the model is its ability to distinguish between different algal species, or at least different groups of algae, each consisting of species with similar properties. This makes it possible to predict not only an algal bloom, but also to give an indication of the type of algae which would be dominant. Two versions of the model are available: the one, a stationary model, does not take the river flow explicitly into account; the other, a more complex model, does take dynamic flow conditions of the river into account.

Cost: *R134 000*
Term: *1993-1995*

Guidelines for point-source pollution risk assessment as a decision-making tool for water quality management

(No 706) Corporate Risk Management (Pty) Ltd.

Although a number of studies have been carried out in the major catchment areas of South Africa to quantify the pollution contribution by the various point sources in a catchment, often little or no account has been taken of the relative **risks** posed by these pollution sources. For example, the larger water-using industries might not be posing the largest risk to the catchment, and vice versa.

The project aimed to produce a set of guidelines to assist water quality managers in the assessment of risk from point sources of pollution. The way in which the document has been written is deliberately general in that it intends to promote the methodology of risk assessment. It also describes a methodology which is applicable to broader environmental risk assessment as well as to the specifics of point-source pollution risk assessment. It is a practical document and provides a number of worked examples.

Cost: *R85 000*
Term: *1995-1996*

New projects

Holistic water quality management in catchments of South African harbours

(No 794) SRK (CE) Inc.

South Africa has numerous harbours along its coastline, six of which are associated with major coastal cities or development areas. These harbours are of vital importance to the economy of the country because of their role in the transport of imported and exported goods. Over the last decade South Africa's harbours have become of increasing importance as recreational, ecotourism and general commercial areas. As a result they are receiving increasingly high-profile public exposure. Many of South Africa's harbours receive water inflows from adjoining areas which are highly developed and with relatively poor water quality. Preliminary enquiries have indicated that water quality management concepts and operational systems

for harbour areas and their catchments are not well-defined.

This study will conduct a review and situational analysis of water quality issues pertinent to South African harbours, assess the current status of water quality management systems, highlight areas which require attention and contribute to the development of practical water pollution management guidelines.

Estimated cost: R140 500
Expected term: 1997-1998

Assessment of the quality of water supplies in the rural Western Cape with regard to agrichemical pollutants

(No 795) Department of Community Health, University of Cape Town

Expenditure on agrichemicals in South Africa has increased markedly over the past decade and a far greater variety of chemicals are used locally when compared to other developing countries. Despite the awareness that agrichemical exposure may be hazardous to human health, there is little systematic monitoring of the extent of environmental contamination by pesticides locally. In spite of the lack of clear evidence from surveillance data, there is some circumstantial evidence that exposure to agrichemicals via the environment may significantly affect the health of rural communities in South Africa. This project will conduct a thorough investigation to ascertain the presence of agricultural chemical pollution in water resources of the Western Cape. This is probably the area in the country with the highest use of these chemicals, and thus the most likely area in which to identify water resource contamination.

Estimated cost: R591 000
Expected term: 1997-1999

Feasibility of using low-cost modelling techniques to relate river water quality and diffuse loads to a range of land uses

(No 796) Stewart Scott (CE) Inc.

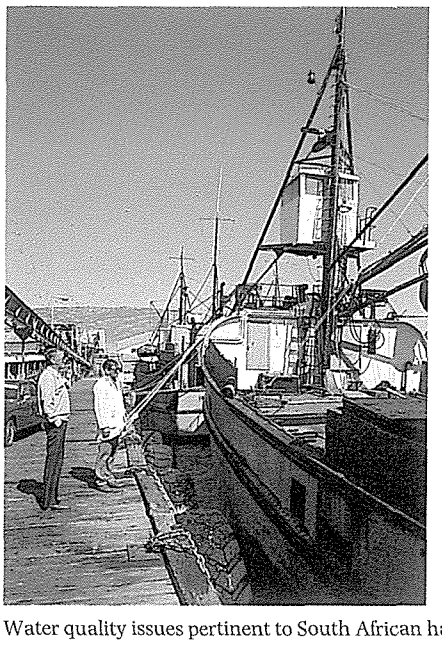
One of the major obstacles in quantifying and studying non-point source pollution is the high cost associated with conventional methods of monitoring diffuse source loads from different land uses. The conventional rigorous approach calls for continuous flow gauging in conjunction with high-frequency water quality sampling, both of which are usually extremely expensive and require a high level of technical competence to maintain equipment and process the large volumes of data. This raises the need to develop a low-cost, low-technology methodology that can be used to estimate diffuse source loads and develop useful relationships between instream river quality and land use. The research proposal is aimed at meeting this need.

Estimated cost: R120 000
Expected term: 1997

Identification of diatoms and their use in the assessment of water quality

(No 814) Department of Botany, University of Port Elizabeth

The maintenance of water quality is of cardinal importance in South Africa and we need a suite of tools with which to monitor it. These tools should range from the quick and inexpensive to the more sophisticated, and should include a range of organisms, as not all organisms are sensitive to the same stressors. It has been known for some time that individual species of benthic diatoms have specific and well-defined water quality tolerances, and that the dominant species in an assemblage will depend on the water quality. This makes them potentially good water quality indicators, except for the fact that their identification is difficult,



Water quality issues pertinent to South African harbours are being investigated.

and in the past has been the domain of expert scientists. This project aims to develop an electronic-based identification system based on dominant, simple characteristics presented in such a way that trained technicians may analyse samples for water quality indicators.

Estimated cost: R255 000
Expected term: 1997-1999

Use of *Daphnia* spp. and indigenous river invertebrates in whole effluent toxicity testing in the Vaal catchment

(No 815) Institute for Water Research, Rhodes University

Internationally, *Daphnia* spp. are the standard test organisms for water quality. *Daphnia* is, however, an organism of standing water and South Africa has very little natural standing water. If water quality managers are to be in a position to make informed decisions on the protection of the country's waters, it is necessary to know the relative sensitivity of the natural organisms to stressors in the environment. This project forms part of a thrust to obtain this information, and deals particularly with the toxicity of whole effluents, and in particular seeks to develop the methodology for investigating the effect of effluents using effluents discharged into the Vaal River in the region of the Vaal Triangle, and is being carried out in close co-operation with Rand Water.

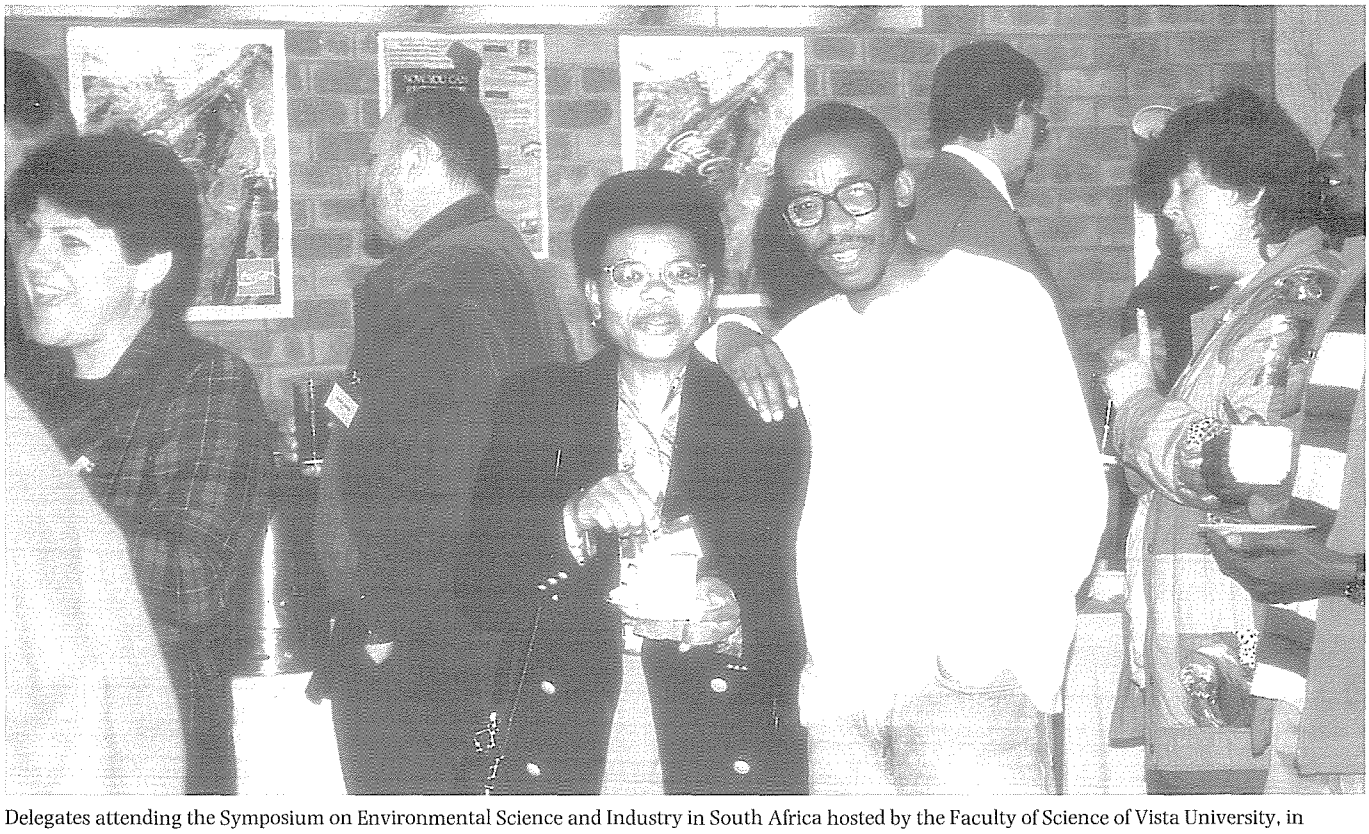
Estimated cost: R411 000
Expected term: 1997-1999

Selection of procedures for faecal pollution monitoring to describe health risks

(No 824) Division of Water, Environment and Forestry Technology, CSIR

The microbiological quality of South Africa's water resources has been under increasing threat from faecal pollution in recent years, due to rapid demographic changes and the lack of an appropriate sanitation infrastructure for much of the population. Using contaminated water for drinking, recreation, or irrigation poses a serious health risk of contracting waterborne diseases such as gastro-enteritis, salmonellosis, dysentery, cholera, typhoid fever and hepatitis. A national monitoring system to provide management information is thus needed to assess and manage the potential health risk related to faecal pollution of South Africa's water resources. Such a monitoring system should determine the status and trends in the microbiological quality of surface water in terms of faecal pollution, and assess the potential health risk associated with the use of the polluted water source. This project will evaluate the monitoring programme on a pilot scale, provide recommendations for modifications, and develop an implementation strategy.

Estimated cost: R600 000
Expected term: 1997-1998



Delegates attending the Symposium on Environmental Science and Industry in South Africa hosted by the Faculty of Science of Vista University, in association with the Division of Environmental Chemistry of the South African Chemical Institute, at the Mamelodi Campus on 23 July 1997.

Research projects

Completed

- **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 Genetics and Botany)
- **536** Development of a dynamic model for the growth and bloom of algae in the Vaal River (University of the Orange Free State – Department of Applied Mathematics)
- **706** Guidelines for point-source pollution risk assessment as a decision-making tool for water quality management (Corporate Risk Management (Pty) Ltd.)

Current

- **K8/32** Effect of urban stormwater runoff on the quality of South Africa's water resources (Wates, Meiring and Barnard (CE) Inc.)
- **195** Hydrosalinity studies in the Eastern Cape (Rhodes University – Institute for Water Research)
- **266** Extension of the management-orientated models for eutrophication control (CSIR – Division of Water, Environment and Forestry Technology)
- **369** Completion of research relating to the DISA model – A daily irrigation and salinity analysis system model (Ninham Shand (Cape) Inc.)
- **411** Coastal pollution: Pathogenic micro-organisms (University of Pretoria – Department of Medical Virology)
- **419** Water quality and quantity assessments in catchments with changing land uses in the Umzinto coastal area (SA Sugar Association Experiment Station)
- **421** Relationship between atmospheric deposition and water quality in a small upland catchment (CSIR – Division of Water, Environment and Forestry Technology)
- **447** Optimising diffuser design for off-shore pipelines – Laboratory experiments (CSIR – Division of Earth, Marine and Atmospheric Science and Technology)
- **465** Detergent phosphorus in South Africa: Impact on eutrophication with specific reference to the Umgeni catchment (University of Natal – Department of Chemical Engineering, and Umgeni Water)
- **498** Collection and evaluation of runoff water quality data from a disused feedlot in Natal (CSIR – Division of Water, Environment and Forestry Technology)
- **522** Pilot study to investigate alternative management options to enhance the use of saline water for irrigation purposes (University of Stellenbosch – Department of Soil and Agricultural Water Science)
- **633** Management of urban impoundments (Johannesburg City Council and Stewart Scott (CE) Inc.)
- **634** Quantifying the impact of the salinisation of South Africa's water resources with special reference to economic effects. Phase 1: Development of a generic model (DWAF and Urban-Econ, Development Economists)
- **696** Development of a guide to assess non-point source pollution of surface water resources in South Africa (Sigma Beta (CE) Inc. and the DWAF)
- **697** Modelling the long-term effect of atmospheric deposition on the salinity of catchment runoff with special reference to the Vaal Dam catchment (Stewart Scott (CE) Inc.)
- **717** Impact of urbanisation and industrialisation on the environment (Vista University – Department of Chemistry (Mamelodi Campus))
- **784** Rapid quantitative evaluation of water quality using a modified biological test – Phase II (University of the Witwatersrand – Department of Microbiology)
- **785** Validation of the modified MINLAKE model on Roodeplaat Dam (Stewart Scott (CE) Inc.)

New

- 794 Holistic water quality management in catchments of South African harbours (Steffen, Robertson and Kirsten (CE) Inc.)
- **795** Assessment of the quality of water supplies in the rural Western Cape with regard to agrichemical pollutants (University of Cape Town – Department of Community Health)
- **796** Feasibility of using low-cost modelling techniques to relate river water quality and diffuse loads to a range of land uses (Stewart Scott (CE) Inc.)
- **814** Identification of diatoms and their use in the assessment of water quality (University of Port Elizabeth – Department of Genetics and Botany)
- **815** Use of *Daphnia* spp. and indigenous river invertebrates in whole effluent toxicity testing in the Vaal catchment (Rhodes University – Institute for Water Research)
- **824** Selection of procedures for faecal pollution monitoring to describe health risks (CSIR – Division of Water, Environment and Forestry Technology)

CONTACT PERSONS

- **Mr HM du Plessis**
  (Salinisation, Eutrophication and Water Environment)
  e-mail: meiring@wrc.ccwr.ac.za
- **Mrs APM Oelofse**
  (Urban Runoff)
  e-mail: annatjie@wrc.ccwr.ac.za
- **Dr G Offringa**
  (Eutrophication)
  e-mail: offringa@wrc.ccwr.ac.za
- **Dr SA Mitchell**
  (Biomonitoring)
  e-mail: steve@wrc.ccwr.ac.za

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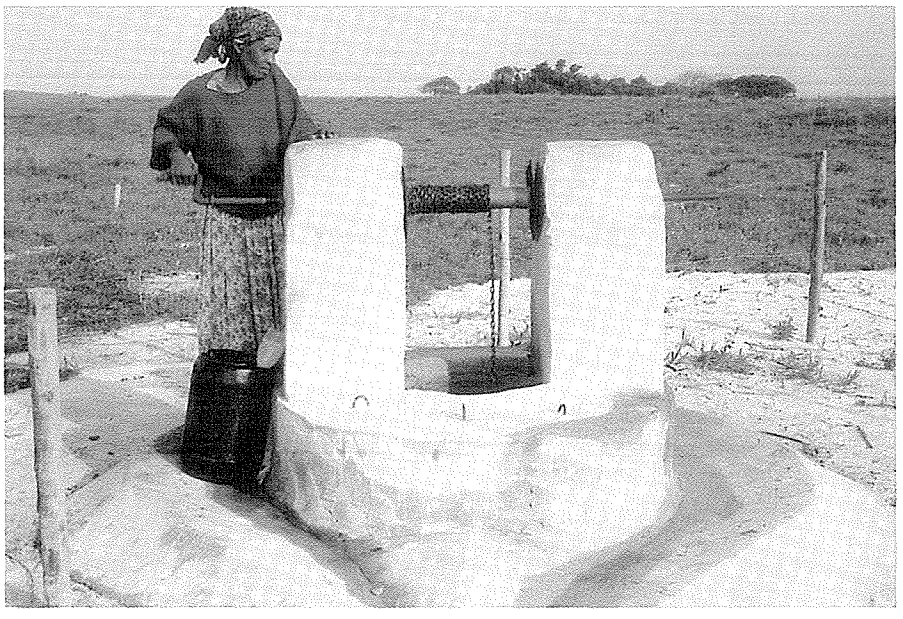
6 GROUNDWATER



The Co-ordinating Committee for Geohydrological Research (CCGR) has identified, as a priority, the need to investigate groundwater occurrence and development potential within hydrogeological regions/subregions for the purpose of meeting community water supply needs. This research need will be addressed by means of a programmed approach, which has proven very successful in co-ordinating fractured-rock aquifer research. Priority will be given to those areas reliant on groundwater for domestic purposes, and, in particular, areas underlain by complex hydrogeology. This programme will facilitate the integration of recently completed and current research with the ultimate goal of identifying exploitable groundwater resources and ensuring the sustainable development of these resources.

In the spirit of national water conservation, a study to ascertain the feasibility of artificially recharging secondary aquifers commenced in 1997. Although research has been carried out in primary aquifers, leading to a successful operational scheme at Atlantis, the potential of fractured-rock aquifers is yet to be tested. Fortunately South Africa can draw on the experience of, amongst others, Australia in this regard. Excellent opportunities for international co-operation exist in this field.

Completed projects

Development of a methodology and protocol for hydrochemical characterisation of South African aquifers

(No K8/97) Division of Water, Environment and Forestry Technology, CSIR and Directorate of Geohydrology, DWAF

There is a need for consistency when developing groundwater protection programmes. One way of achieving this consistency is through the use of a groundwater classification system, whereby current and potential sources and uses of groundwater can be identified and categorised. This then enables water quality standards to be set, forms a scientific foundation for the issuing of permits, and allows land-use controls to be developed to protect groundwater resources.

A system for the hydrochemical characterisation of South Africa's groundwaters was identified as a prerequisite for the classification of aquifers. Furthermore, it was envisaged that such a characterisation scheme would help deduce baseline values for the detection of pollution in aquifers. The main objective of this project was consequently to chemically characterise a hydrogeological region and develop a protocol for undertaking the hydrochemical characterisation of aquifers for the rest of South Africa.

Following a review of hydrochemical characterisation approaches, it was decided to perform the case study in the north-west Cape. However, once an evaluation of the National Water Quality and Groundwater Databases began, it became apparent that linking water quality information to borehole data was not trivial. Software routines had to be written to meet this requirement. A hydrochemical characterisation protocol has been proposed and has been developed further by the DWAF.

Cost: *R70 000*
Term: *1993-1995*

Undertaking of structural geological analyses of the KwaZulu-Natal Province for the purpose of aiding hydrogeological mapping

(No K8/158) Directorate of Geohydrology, DWAF

An analysis of the strike-frequency, distribution of lineaments, faults and dykes in KwaZulu- Natal was recently undertaken as part of a larger project by the DWAF to map the groundwater resources of the province.

The lineament strike data obtained from 1:250 000 geological maps, were

converted into digital form and statistically analysed using computer-based techniques.

The investigation provided insights into the extent of development of the various trends in the basement and cover rocks. The importance of north-south, west-northwest and east-northeast trends is clearly apparent.

An evaluation of the stress data to identify structures that are favourably oriented for groundwater development is included in the report. The approximate strike directions of structural discontinuities (faults, joints, dykes and veins) in each of the defined subdomains that appear to have developed at a high angle to a least principal compressive direction during the deformational history of the region, have been defined. These extensional structures may offer a higher potential for high-yielding boreholes.

Cost: R100 000
Term: 1994-1995

New projects

Bacterial pathogens in groundwater

(No 821) Department of Microbiology, University of Durban-Westville

Groundwater has historically been considered a reliable and safe source of water, protected from surface contamination by a "living filter", an upper soil mantel that removes pollutants as the water percolates downward through the soil. However, a number of well-documented outbreaks of microbially related diseases traced to contaminated groundwater, as well as numerous reports of chemical contamination, have destroyed the widely-held misconception that groundwater is safe from pollution. This has necessitated a reassessment of what is known about the fate of pathogenic micro-organisms in soil and groundwater.

The significance of microbiology as it relates to groundwater resides in the interactions of pollutants and micro-organisms in the subsurface and the effects of such interactions on the quality of groundwater.

This project aims to determine the fate of the pathogenic bacteria in the subsurface environment. The application of molecular methods for the detection of viable-but-non-culturable pathogens in surface and groundwater will be evaluated. The health risk posed by viable-but-non-culturable pathogens will be assessed as the advent of informal settlements in South Africa has the potential for disease transmission through microbial contamination of groundwater, viewed as the solution to addressing the immediate to short-term needs of over 12 m. South Africans who are without access to safe drinking water supplies.

Estimated cost: R250 000
Expected term: 1997-1998

Critical evaluation of groundwater monitoring in water resources evaluation and management

(No 838) Water Resources Evaluation and Management CC and DWAF

The availability of good, reliable data on groundwater levels and response to rainfall, water quality and areal estimates of groundwater recharge and aquifer storativity is vital for effective water resources management. Considerable financial resources are directed each year at groundwater monitoring programmes. These programmes gather data on both groundwater quality and quantity. The cost of running and maintaining monitoring networks in a country the size of South Africa is prohibitive. Consequently the number and selection of monitoring points and decisions on the frequency of monitoring are crucial in the hydrological data-gathering process.

Hydrological monitoring often results in the accumulation of records in data banks without there being any verification of the reliability of the data, the infilling of missing data and the extension of information based on limited data. Furthermore, the value of limited data is often under-estimated and the data are not utilised effectively. This can be attributed to a lack of understanding of the essence of monitoring programmes and the utilisation of ancillary information which can be geared to effective hydrological analysis and practical application in water resources evaluation and management.

Despite much work and many publications on different aspects of groundwater monitoring, there remains a need to carry out further research on this subject which forms the basis of all hydrological assessments and water resource evaluation.

Estimated cost: R195 000
Expected term: 1997-1998

Correlation of high uranium, arsenic and other chemical element values in groundwater with abnormal haematological values

(No 839) Toens and Partners CC

A recent study by the Department of Community Health, University of Stellenbosch, and Toens and Partners, recorded a high prevalence of haematological abnormalities in the Pofadder area of the north-west Cape. Statistical analysis of the hydrochemistry and haematological data has shown that a significant relationship exists between uranium, arsenic and zinc in groundwater and some haematological parameters.

The maximum limit for insignificant radiation risk in water is given by the Atomic Energy Corporation as 0,4 Bq/*l* gross alpha activity, which for uranium is equal to about 40 µg U/*l*. From the results available, it would seem that the background radiation levels in the area under discussion vary from about 30 to 75 µg U/*l*, with anomalous zones covering large areas, ranging from 150 µg U/*l* to maxima of 262 and 400 µg U/*l*.

The results are critical from health and groundwater resource management perspectives, as the further development of groundwater supplies in areas underlain by similar geological formations would need to be carefully investigated. The radioactivity level of groundwater, and the arsenic and zinc content are not routinely monitored.

The main aim of the project is to establish a correlation between the high prevalence of haematological abnormalities of long-term residents in the area around Pofadder and the radioactive and other chemical composition of the groundwater.

Estimated cost: R200 000
Expected term: 1997-1997

Investigation into a GIS-based methodology to determine the sustainable exploitability of South African aquifers

(No 840) Division of Water, Environment and Forestry Technology, CSIR

The National Groundwater Map of South Africa (TT 74/95) has provided water resource planners with enormous resources for selecting villages that will have to be targeted for groundwater supply. This potential has been recognised and the map in GIS format is currently being widely utilised. Furthermore the Directorate of Geohydrology, DWAF has produced a *Groundwater Harvest Potential Map*. The opportunity now exists to add further value to the work done on the Groundwater Map and the Harvest Potential Map, particularly as these are available in a GIS format. The next logical step will be the production of a semi-quantitative groundwater exploitation potential map, where aspects such as natural groundwater recharge and storage potential will be combined with the existing groundwater availability, transmissivity and quality maps. Such an exploitation potential map will provide water planners and managers with the information required for sustainable development of groundwater resources, targeted particularly at rural water supply projects.

The main aim of this feasibility study is to determine the data requirements in an assessment of sustainable exploitability and to test the approach in a "data-rich" area.

Estimated cost: R200 000
Expected term: 1997-1997

Assessment of ambient groundwater quality on a national scale in the Republic of South Africa

(No 841) Hydromedia Solutions and DWAF

The DWAF has for many years been gathering groundwater quality data from around the country as part of both ongoing groundwater monitoring programmes and *ad hoc* groundwater resource investigations. These data have been stored in the department's Water Quality Database. However, little interrogation of the data has taken place, except of that depicted on *The National Groundwater Map of South Africa*. The data-gathering drive has intensified over the past few years as a result of the regional groundwater mapping programme and the establishment of a national groundwater quality monitoring network.

It is very important that value be added to the national database. The differentiation between man-made and natural impacts on groundwater quality will in future have to be clarified. The further beneficiation of the data and its presentation in the form of a water quality atlas will affect numerous sectors, thus enabling them to efficiently plan their activities as well as address important issues from a national health and environmental point of view. Water quality information is essential in the planning and management of groundwater resources – the results of this project will consequently provide valuable data for the DWAF's community water supply initiative.

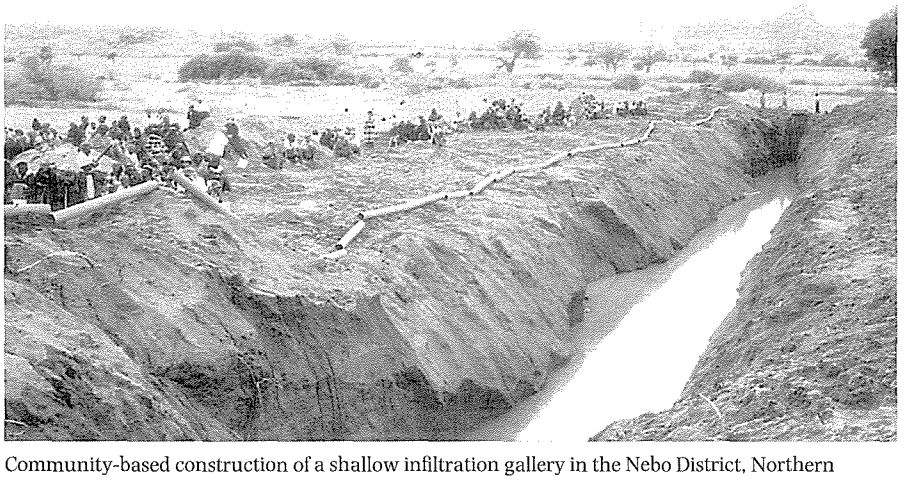
Estimated cost: R100 000
Expected term: 1997-1997

Artificial recharge, a technology for sustainable water resource development for community water supplies

(No 842) Division of Water, Environment and Forestry Technology, CSIR

Artificial recharge and the principle of conjunctive use offer valuable tools for augmenting South Africa's rather limited natural recharge. In large areas of the country precipitation occurs in the form of thunderstorms. These produce flash floods with most of the water rapidly leaving the catchment. Infiltration is minimal and recharge negligible. By capturing this surplus water and forcing it to infiltration, the groundwater resources would receive additional replenishment, thus boosting the amount of water available for later abstraction.

Many examples exist of operational artificial recharge schemes in the USA, Europe, Israel and Australia. These either use treated waste water or river water and are mainly intended for irrigation purposes. Only two large-scale operational schemes exist in Southern Africa, both of which involve unconfined primary aquifers that provide bulk water supply to urban communities along the arid west cost. Little, if any, attention has, however, been given to secondary aquifers that represent the source of water supply over much of the South African interior. Artificial recharge and conjunctive use could prove an invaluable tool in the current RDP water supply initiative, should it be found to be feasible in these areas. This feasibility study will be directed specifical-



Community-based construction of a shallow infiltration gallery in the Nebo District, Northern Province. The supply from the gallery is in the order of 2,0 l/s in an area where average yields are between 0,5 l/s to 1 l/s. The water is, in addition, free of fluoride, opposed to high fluoride concentrations from conventional boreholes located in the young granite.

ly at investigating this possibility by drawing on African and overseas experience, and will provide the country's water resource planners and managers with the information necessary to decide whether to adopt such a strategy or not.

Estimated cost: R186 000
Expected term: 1997-1997

Preparation of a handbook on the hydrogeology of the Karoo supergroup

(No 860) DWAF

Many towns and villages in the semi-arid western half of the country are totally dependent upon groundwater obtained from Karoo aquifers for their water supply. Furthermore, hundreds of villages in the rural areas of the Eastern Cape obtain their water supplies from boreholes located adjacent to or within the area of influence of dolerite dykes and sills, which have intruded into the Karoo sediments.

Over the past 20 years a number of research projects dealing with groundwater exploration, occurrence, development and management in fractured rock aquifers, and especially Karoo aquifers, have been completed. Of late, this research has been co-ordinated as part of the activities of the Fractured Rock Aquifer Task Group.

This information on Karoo aquifers is being sought by those responsible for the provision of water supplies in these regions. However, much of this information is in a form that is not easily accessible to water supply planners. Furthermore, recent findings from WRC research projects are altering the conceptual models of groundwater occurrence in Karoo sediments. All the past research is being synthesised and documented in a single handbook which will provide an excellent reference source for those responsible for developing groundwater for community water supplies, as well as providing guidance on future research needs in Karoo aquifers.

Estimated cost: R230 000
Expected term: 1997-1997

Integrated multidisciplinary approach to groundwater development in granitic aquifers

(No 862) Department of Geology, University of Pretoria

The use of geophysical techniques for the location of suitable targets for water supply boreholes is well understood. It is, however, in the application of these techniques in traditionally poor groundwater potential areas such as the Nebo granites of the Northern Province that the correct interpretation of the geophysical data becomes crucial in planning and developing community water supply projects. An integrated multidisciplinary approach is required whereby airborne geophysical techniques combined with ground geophysical surveys and detailed structural geological mapping are used in the siting of production boreholes.

As there is a serious need for a more effective approach to the exploration and development of groundwater resources for community water supply projects, it should be possible to apply the above integrated approach to other areas underlain by igneous and metamorphic rocks in South Africa.

The objectives of the study are to:

- Identify and classify the known aquifers of the Nebo granites, using existing data from the DWAF.
- Obtain the geophysical data used in the siting of these boreholes and incorporate the data into a database accessible to a GIS system.
- Develop an integrated approach to the siting of boreholes for the development of groundwater, using airborne and ground geophysics and detailed structural geological mapping.
- Develop an extensive geophysical database to be incorporated into the National Groundwater Database resident at the DWAF.

Estimated cost: R450 000
Expected term: 1997-1999

Hand-augering of shallow boreholes, Ubombo Region, KwaZulu-Natal. Hand-augered boreholes serve to identify the nature of the saturated alluvium prior to the sinking of hand-dug wells and will later serve as a pilot study for shallow screened boreholes to supply the communities.

CONTACT PERSONS

- **Mr AG Reynders**
  (Groundwater Resource Development and Pollution)
  e-mail: tony@wrc.ccwr.ac.za
- **Mr HM du Plessis**
  (Mining Pollution)
  e-mail: meiring@wrc.ccwr.ac.za

☎ **(012) 330-0340**

Research projects

Completed

- **K8/97** Development of a methodology and protocol for hydrochemical characterisation of South African aquifers (CSIR – Division of Water, Environment and Forestry Technology and DWAF – Directorate of Geohydrology)
- **K8/158** Undertaking of structural geological analyses of the KwaZulu-Natal Province for the purpose of aiding hydrogeological mapping (DWAF – Directorate of Geohydrology)

Current

- **291** Regional investigation into groundwater quality deterioration in the Olifants River catchment above the Loskop Dam, with specialised investigations in the Witbank Dam subcatchment (University of the Orange Free State – Institute for Groundwater Studies)
- **378** Development of techniques for risk analysis and groundwater management of Southern African aquifers (University of the Orange Free State – Institute for Groundwater Studies and CSIR – Division of Water, Environment and Forestry Technology)
- **481** Geochemistry and isotopes for resource evaluation in the fractured rock aquifers of the Table Mountain Group (CSIR – Division of Water, Environment and Forestry Technology)
- **487** Analysis and interpretation of aquifer tests in secondary aquifers (University of the Orange Free State – Institute for Groundwater Studies)
- **516** Application of seismic tomography and ground-penetrating radar for the detection of fractures and the determination of hydraulic properties of fractured rock aquifers (CSIR – Division of Water, Environment and Forestry Technology)
- **565** Hydrogeological, isotopic and hydrochemical assessment of the response of a fractured multi-layered aquifer to long-term abstraction (University of the Witwatersrand – Schonland Research Centre)
- **572** Investigation of the contaminant attenuation capacity of the soil/aquifer system with special emphasis on the vadose zone (CSIR – Division of Water, Environment and Forestry Technology and the University of Stellenbosch – Department of Soil and Agricultural Water Science)
- **640** Extension and refinement of the AQUAMOD computer software package (University of the Orange Free State – Institute for Groundwater Studies)
- **641** Assessment of the impact of agricultural practices on the quality of groundwater resources in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **653** Regional characterisation and mapping of Karoo fractured aquifer systems – An integrated approach using a geographical information system and digital image processing (DWAF – Directorate of Geo-hydrology, and the Council for Geoscience)
- **676** Preparation of a monograph on South Africa's groundwater resources (JR Vegter Esq.)
- **701** Relationship between the geotechnical and hydrogeological properties of residual soils and rocks in the vadose zone (University of Pretoria – Department of Geology)
- **702** Development of a Windows-based interpretation system for hydrogeologists (University of the Orange Free State – Institute for Groundwater Studies and the DWAF)
- **720** Geohydrological modelling of the Richards Bay area (University of Zululand – Department of Hydrology)
- **721** Groundwater supply assessment and strategy for the Western Karoo, Namaqualand and Bushmanland (University of the Western Cape – Department of Earth Sciences)
- **729** Modelling of groundwater flow in the Table Mountain Sandstone fractured aquifer in the Little Karoo region of South Africa (DWAF – Directorate of Geohydrology)
- **731** CFCs and groundwater age-dating in South Africa's fractured-rock aquifers (CSIR – Division of Water, Environment and Forestry Technology)
- **732** Cost-effective development of groundwater in problematic terrain and low- potential areas: The evaluation and assessment of current drilling and groundwater abstraction techniques and the modification of equipment and methods (Water Systems Management)
- **733** Utilisation of tracer experiments for the development of rural water supply management strategies for secondary aquifers (University of the Orange Free State – Institute for Groundwater Studies)

New

- **821** Bacterial pathogens in groundwater (University of Durban-Westville – Department of Microbiology)
- **838** A critical evaluation of groundwater monitoring in water resources evaluation and management (Water Resources Evaluation and Management CC and DWAF)
- **839** Correlation of high uranium, arsenic and other chemical element values in groundwater with abnormal haematological values (Toens and Partners CC)
- **840** Investigation into a GIS-based methodology to determine the sustainable exploitability of South African aquifers (CSIR – Division of Water, Environment and Forestry Technology)
- **841** Assessment of ambient groundwater quality on a national scale in the Republic of South Africa (Hydromedia Solutions and DWAF)
- **842** Artificial recharge, a technology for sustainable water resource development for community water supplies (CSIR – Division of Water, Environment and Forestry Technology)
- **860** Preparation of a handbook on the hydrogeology of the Karoo supergroup (DWAF)
- **862** Integrated multidisciplinary approach to groundwater development in granitic aquifers (University of Pretoria – Department of Geology)

7

AGRICULTURAL WATER MANAGEMENT

Population growth and rising income levels are putting pressure on agricultural and food production, but limitations are set by variable rainfall, available arable land and exploitable water resources. Given these constraints of natural resources, the relative decline of the contribution of agriculture to the gross domestic product and competition with alternative higher-valued uses in most other economic sectors, it is obvious that other options than increased water use for food production must be considered. This line of argument has led to promotion of the concept of "virtual water" (formulated by Prof JA Allan, University of London), i.e. the water required for or contained in food imports, especially staple food products. The question is whether the option of food trade or the availability of "virtual water", will allow balancing of water demand with supply in the water-scarce economy of South Africa?

An analysis of the situation in a regional context shows that better soils, higher rainfall and highest annual internal renewable water resources *per capita* are available in parts of countries such as Angola, Zambia, Moçambique and Tanzania. However, these areas of high natural potential do not coincide with the location of infrastructure and markets. In the case of grain trade, indications are that all countries in the region are producing for own consumption and projections by the International Food Policy Research Institute show that substantial cereal imports are required. It is clear, therefore, that at present no real prospects exist for South Africa to import "virtual water" in the form of cereals from SADC countries since all countries are dependent on the global grain trade. Considerable trade potential exists between these countries regarding import and export of certain industrial and horticultural crops, but the diversity and strength of the economy, with specific reference to the nett impact on the balance of payments, will determine the probability of relying on "virtual water".

Under these circumstances the implication is that some of the necessary growth in food production, particularly staple crops, will have to come from increased rain-fed or irrigated crop production. In addition, there are convincing counter-arguments against a preference for importing "virtual water" and in support of continued local production under irrigation. These are:

- The importance of economic linkages for development of rural economies
- Stabilisation of food production during seasonal or periodic droughts
- Utilisation of existing investments to full capacity
- Opportunities for employment, income-earning and food security
- Processing raw materials and value-adding on a local level
- Reduction of imports of staple crops with a comparative advantage
- Diversification to higher valued crops for exports.

Agriculture will without doubt have to contribute proportionally more to food production because of future higher standards of living and increased *per capita* consumption. At the same time it can be expected that competition will lead to a reduction in the quantity and quality of water available for production of pasture, grain, vegetable and fruit crops. Limited natural resources are not a constraint for economic growth, but if agriculture is to remain competitive, water resources will have to be used more productively. The twofold challenge to produce more food with less water requires, amongst others, creation of expertise through applied research. Opportunities exist for more efficient utilisation of water for both rain-fed and irrigated agriculture, as is demonstrated by the completed, ongoing and new projects funded by the WRC.

Completed projects

Effect of pre-programmed deficit irrigation on plant growth

(No 423) Department of Soil Science, University of the Orange Free State

Previous research resulted in the development of BEWAB, a computer program which can be used for irrigation planning and management at farm level. BEWAB produces pre-season irrigation schedules, depending both on the target yield appropriate for the amount of water available to the selected crop over the season, and on the desirable soil-water status at the beginning and end of the growing season. Prior to this project, BEWAB was being used to generate recommendations for both optimal and sub-optimal irrigation conditions, even though BEWAB development had been based on data for optimal (no water stress) conditions only. The aim of this project was to extend the capabilities of BEWAB and to test, and where necessary refine, its capacity to provide correct recommendations for conditions of controlled water stress.

As a result of this project, two more crop types (dry peas and potatoes) were added to the existing list of BEWAB options (wheat, maize and groundnuts). The best soil-water management option for controlled deficit irrigation included depletion of all available soil water by the end of the season. Longer (two-weekly, as compared with weekly) intervals between irrigations proved to be more effective for deficit irrigation; this longer interval also helped to combat the non-productive loss of water by evaporation from the soil surface. Finally, well-planned deficit irrigation resulted in crops adapting physiologically to the drier conditions; plants are shorter and leaves smaller, with reduced transpiration rates.

Cost: *R576 000*
Term: *1993-1996*

Determination of the relationship between transpiration rate and declining available water for *Eucalyptus grandis*

(No 441) Division of Water, Environment and Forestry Technology, CSIR

Previous studies of the water relations of *Eucalyptus* have taken place under conditions of adequate water supplies in the soil and subsoil. This project attempted to clarify at which level of soil-water content water stress would set in and transpiration begin to decline, whichother factors affect the onset and the intensification of water stress and associated decline in transpiration, and what the relative contributions of water held at various depths in the soil and subsoil are towards sustaining transpiration.

In attempting to answer these questions, elaborate measures were taken to induce plantation water stress by preventing rain from recharging soil-water. Soil-water measurements to a depth of 8 m confirmed that soil had dried out to at least that depth. Deep drilling revealed live tree roots 28 m below the surface, confirming that the accessibility of deep soil water to roots was preventing the development of material water stress, even after more than a year of withholding water.

While the results of this project did not provide answers to all questions implicit in the objectives, they did provide valuable new insights into the extent to which trees are able to access water in deep strata when grown on deep soils. Under such conditions new plantations may continue to use water at near-potential rates for several years after establishment, until all accessible stored water has been depleted.

Cost: *R458 000*
Term: *1992-1996*

Improved estimation of plant and soil evaporation from cropped lands

(No 507) Department of Agrometeorology, University of the Orange Free State

The partitioning of total crop evaporation into the transpiration (effective use) component and the soil evaporation (wastage) component is one of the weakest links in current crop growth and hydrological models. Recent evidence suggests that soil evaporation is a larger and more variable contributor to inefficient crop water use than previously realised. Practices which may intentionally result in sparser crop stands (e.g. deficit irrigation systems, appropriate technology systems for developing communities, dryland cropping systems) are particularly prone to having excessive proportions of irrigation or rain water being wasted through soil evaporation. This project was undertaken to acquire accurate field data to improve the ability of models to correctly partition total crop evaporation into plant and soil components.

An encountered difficulty, which ultimately proved insurmountable, was that of obtaining accurate, representative values of evaporation from soil in the presence of a transpiring crop. Such values could not be obtained either through direct measurement (microlysimeters) or by "difference". The "difference" method involved comparing total evaporation (measured lysimetrically or micrometeorologically) from two identical cropped surfaces, one of which had the soil surface covered to prevent soil evaporation. This procedure enhanced the energy load on the crop canopy over covered soil, thereby increasing plant evaporation and destroying comparability with plant evaporation in the presence of freely evaporating soil. Without the capacity to make key measurements, it was not possible to fully achieve the project's objectives. By way of consolation, however, the confirmed ability of currently available models to correctly simulate evaporation from bare, drying soils and to simulate the temperature of transpiring foliage could serve as a point of departure for future research.

Cost: *R118 000*
Term: *1993-1995*

Modelling the water balance on benchmark ecotopes

(No 508) Institute for Soil, Climate and Water, Agricultural Research Council

The soil-water balance is an important component of crop growth and hydrological models. Confidence in these models, which are potentially powerful tools for planning and management, would be greatly enhanced if they are shown to per-

form credibly over the wide range of typical soil, climate and land management conditions encountered in South Africa. There have been no previous attempts to systematically obtain representative data sets for typical land units (ecotopes) representing specific crop-soil-climate combinations. The aim of this project was therefore to acquire sufficient data pertaining to eight different benchmark crop ecotopes, to facilitate both widespread testing and adaptation of selected crop models and to promote their use in assessing production risks.

In testing models using the benchmark data sets, several weaknesses in their ability to simulate both water balances and crop yields were revealed. The sources of many of these weaknesses were also identified, providing model developers with useful direction for future model improvement. Weakness derived from, *inter alia*, failure to deal adequately with periods of waterlogging; unsatisfactory simulation of runoff regimes; excessive uptake of soil water towards the end of the growing season; and, most importantly, failure of one-dimensional models to account for commonly observed lateral movements of water in the root zone. Besides weaknesses, model strengths were also demonstrated, underlining their potential power as practical tools for agriculture.

Cost: *R296 000*
Term: *1993-1996*

New projects

Effect of water quality on irrigation farming along the lower Vaal River: The influence on soils and crops

(No 740) Department of Soil Science, University of the Orange Free State

It is foreseen that the water demand in Gauteng will continue to rise, thereby putting increasing pressure on the assuredness of water supply to irrigation farmers in the lower Vaal River. It is furthermore likely that the quality (especially the salinity) of water available for irrigation will continue to deteriorate. Under these conditions irrigated soils will become increasingly saline and the yields of high-income salt-sensitive crops will decrease. The irrigation percolate seeping back to the Vaal River will similarly be more saline, giving rise to an increasingly poor quality water even lower down the Vaal and Orange Rivers.

Most of the concepts by means of which the negative effect of a lower water quality on irrigation can be minimised, have not yet been applied or demonstrated in South Africa. This preliminary investigation will, *inter alia*, ascertain the observed change in Vaal River water quality and assess the effects these changes are likely to have, and have had, on irrigated soils and crops. Future research to address identified problems will be formulated.

Estimated cost: *R581 000*
Expected term: *1997-1999*

Quantification of the water balance on rehabilitated mine soils under rain-fed pastures on the Highveld of Mpumalanga

(No 798) Institute for Soil, Climate and Water, Agricultural Research Council

Water which infiltrates through the surface of land which has been rehabilitated following open-cast mining, artificially recharges the groundwater storage compartment which was created when coal was extracted. This water mostly becomes acid and/or saline as a result of the oxidation of pyrite present in the backfilled waste material. Depending on the seepage rate, it may take decades before the groundwater compartment fills up and the polluted water starts to decant into surface streams. One of the big uncertainties from a water quality management perspective is how much rainfall infiltrates to recharge the groundwater compartment, and thus how soon the compartment will fill up and start decanting. This proposal aims to determine the water balance of rehabilitated land under pasture at three sites over three growing seasons, and to use the results to calibrate available mathematical models which can be used to make long-term water balance predictions.

Estimated cost: *R363 000 with additional contributions of R491 000 by the National Department of Agriculture and R330 200 by the Agricultural Research Council*
Expected term: *1997-2000*

Mrs M-A Joska examining sample plates to determine invasion rates of *Cladophora glomerata* in the Kalkfontein Irrigation Canal in the south-west Free State.

Use of triploid grass carp for the biological control of excessive growth of water weeds in irrigation schemes

(No 816) Department of Zoology, Rand Afrikaans University

Excessive growth of water weeds, particularly the filamentous alga *Cladophora glomerata*, causes a substantial loss to irrigation as a result of flow reduction, and in bad cases overflow of water, in the canals. This is one in a suite of projects which is investigating ways of addressing this problem. The grass carp is a river fish able to live in strong currents, and is used extensively for the control of problem plants in earth-lined canals. This project will investigate their effectiveness in controlling unwanted algal growth in the concrete-lined canals and recommendations will be made regarding the use of grass carp in this situation.

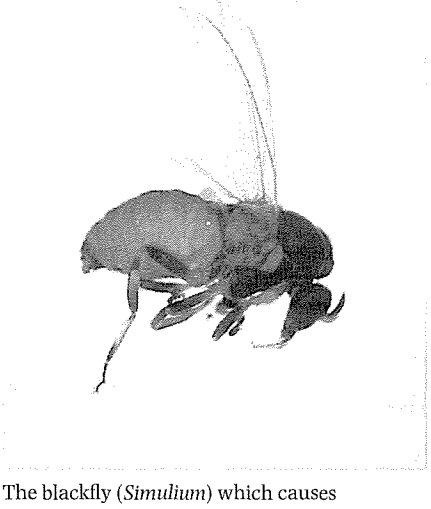
Estimated cost: *R281 000*
Expected term: *1997-2000*

Extension to and further refinement of a water quality guideline index system for livestock watering

(No 857) Department of Animal and Wildlife Sciences, University of Pretoria

The water quality guidelines for animal production published by the DWAF in 1996, although largely based on international guidelines, were the first to incorporate to some degree the problematic aspect of constituents having wide ranges of effects at the same concentration depending on site-specific factors. Significant shortcomings still exist, including not accounting sufficiently for factors which vary considerably between water sources and, therefore, not offering the flexibility required to assess a water source for different user groups. Nor do they offer solutions to problems of waters with contaminant levels which exceed the guidelines. Providing solutions is required, as water quality in many of the arid zones and informal settlements in Southern Africa does not comply with recommended standards.

During WRC project No 644 field trips to rural areas led to the identification of water-related production problems experienced by developing farmers and livestock owners in the immediate vicinity of towns and cities. Briefly these problems are the following:



The blackfly (*Simulium*) which causes substantial loss in agricultural areas adjacent to rivers with suitable breeding sites.

- Even if the developing farmers and livestock owners are aware of the fact that poor water quality has a negative impact on production, the Water Quality Guideline Index System (WQGIS) developed during project No 644, does not provide for livestock production systems found in rural and peri-urban communities. It is, therefore, necessary to extend the WQGIS by the addition of a new category, designed specifically to cater for extensive and communal ranges, and for intensive, semi-intensive and peri-urban production systems. In addition to the new category, new livestock types need to be included to provide for the production systems of these communities.
- A lack of knowledge within the agricultural advisory services (attending to the needs of developing and peri-urban communities) regarding the value of the WQGIS as an aid in developing animal production systems in rural and peri-urban areas. Furthermore, the data requirements for meaningful application of the WQGIS are also not fully understood. The need for a manual addressing livestock watering issues and providing guidelines on the adaptation of the WQGIS to specific conditions is, therefore, a very obvious one. The design and content of the manual would have to take cognizance of traditional practices, language constraints and the socio-economic role played by livestock in these communities.
- In the current WQGIS the unique conditions associated with wildlife watering are not being addressed. In large parts of the Northern and North-West Provinces wildlife is an integral part of stock farming, or it enjoys top priority in the case of numerous game farms and nature conservancies of varying sizes.

The livestock production of the small-scale sector has aims different to those of the large-scale commercial sector, ranging from sustainable household protein/milk production providing basic food requirements, to a significant contribution to the well-being of local communities. Frequently the water source must meet the needs of a variety of species of livestock, as well as human drinking needs. A species approach is, therefore, often not suited and a more integrated approach is required. Furthermore, new water quality constituents need to receive research attention as the conditions under which peri-urban livestock are produced tend to have a higher incidence of constituents which are normally problematic, but now enter the system, e.g. pathogens, parasites and various domestic chemicals.

The objective of the project is to establish water quality guidelines for livestock production on extensive and communal ranges, and for intensive, semi-intensive and peri-urban production systems, with a refinement of current water quality guidelines for livestock and development of a category for wildlife under extensive and semi-intensive management for incorporation into the WQGIS. It is also intended to develop a manual for rural and peri-urban communities enabling primarily extension officers to advise and assist on water quality issues ranging from household subsistence production and community kraals to small-scale production.

Estimated cost: R1 200 000
Expected term: 1997-1999

Influence of irrigation with gypsiferous mine water on soil properties and drainage water in Mpumalanga

(No 858) Chamber of Mines of South Africa

Huge quantities of acid mine drainage are presently being produced as a result of mining activities. These waters are mostly neutralised, either inadvertently, as a result of seepage through neutralising geological strata, or artificially, by the addition of lime. Mine drainage is, therefore, often saturated with gypsum. When released into the surface water environment, their high salinities are frequently responsible for unacceptable water quality degradation. On the other hand, irrigation provides for a novel approach to the utilisation and disposal of gypsum-rich water as demonstrated in a recently completed WRC project (No 582). Irrigation of neutralised acid mine water holds promise to significantly reduce the salt load emanating from mine drainage while at the same time extracting value from a water

which would otherwise be a polluting agent. This project aims to ascertain on a semi-operational scale whether gypsiferous mine water can be used on a sustainable basis for the irrigation of crops and/or the amelioration of acidic soils.

Estimated cost: *R1 185 000 with an additional contribution of R1 215 000 by the Chamber of Mines and major contributions in kind by Amcoal*
Expected term: *January 1997 to June 2000*

Optimising rainfall-use efficiency for developing farmers with limited access to irrigation water

(No 878) Institute for Soil, Climate and Water, Agricultural Research Council

Agriculture has the potential not only to provide work, but also to meet the food requirements of a large part of the underprivileged population. Achieving the objectives of supplying work and food, agriculture needs to be supported by wise land-use planning, application of modern technology and enabling policy decisions.

Food production is fundamentally determined by management of the atmosphere-plant-soil system, with water the main factor limiting productivity, especially in semi-arid and sub-humid areas. To achieve the objectives of food and employment, the focus of technology in these areas needs to be on the water balance in the atmosphere-plant-soil system, i.e. rainfall-use efficiency needs to be optimised.

Indications are that a large number of developing small-scale farmers are gaining access to land which can best be described as semi-arid or sub-humid. In many cases not even the requirements of limited irrigation will be met by the available water. Under these conditions optimisation of rainfall-use efficiency becomes vitally important.

This project intends making a contribution in the above regard by testing different production techniques on a number of benchmark ecotopes, thereby providing information to promote the rainfall-use efficiency. The careful selection of the benchmark ecotopes, together with the analysis of long-term climatic data and

Monitoring the soil-water balance of deciduous fruit trees with a neutron hydroprobe and tensiometers in a weighing lysimeter.

soil characteristics for such ecotopes, will enable results of the research to be applied widely beyond the confines of the actual experimental sites. The project would also provide data to improve the reliability of crop and water balance simulation models, resulting from a better understanding of the water regime dynamics of soil profiles in these regions under these conditions.

Against this background the objectives are to:

- Identify for selected benchmark ecotopes in a marginal cropping area, the crop production techniques that will result in optimum rainfall-use efficiency and sustainable productivity being achieved.
- Involve and develop pupil technicians with a view to their participation in extension activities in developing small-scale farmer communities.
- Embark on an effective technology transfer programme to ensure optimum application of research results by farmers, involving farmers' committees as role players in the project.

Estimated cost: R450 000
Expected term: 1997-1999

Research projects

Completed

- **423** Effect of pre-programmed deficit irrigation on crop reaction (University of the Orange Free State – Department of Soil Science)
- **441** Determination of the relationship between transpiration rate and declining available soil water for *Eucalyptus grandis* (CSIR – Division of Water, Environment and Forestry Technology)
- **507** Improved estimation of plant and soil evaporation from cropped lands (University of the Orange Free State – Department of Agrometeorology)
- 508 Modelling the water balance on benchmark ecotopes (Agricultural Research Council – Institute for Soil, Climate and Water)

Current

- **290** Flood and furrow irrigation: A critical evaluation of design procedures and the computerisation of the most suitable approaches (University of Pretoria – Department of Agricultural Engineering)
- **303** Use of saline water for irrigation purposes and an assessment of salt tolerance criteria of crops (University of Stellenbosch – Department of Soil and Agricultural Water Science)
- **372** Assessing the impacts of varying rainfall conditions on vegetation dynamics, production and certain hydrological properties of natural grassland, using a system modelling approach (Potchefstroom University for CHE – Department of Plant and Soil Sciences)
- **389** Scheduling irrigation of tuber crops with specific reference to potatoes (Agricultural Research Council – Vegetable and Ornamental Plant Institute)
- **417** Optimal water utilisation by turf (Potchefstroom University for CHE – Department of Plant and Soil Sciences)
- **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 soil already sealed due to cyclic irrigation (Potchefstroom University for CHE – Department of Plant and Soil Sciences)
- **573** Water-use efficiency of cultivated subtropical forage and pasture crops (University of Pretoria – Department of Plant and Soil Sciences)
- **578** Evaluation of irrigation techniques used by subsistence and emergent farmers (MBB (CE) Inc.)
- **581** Computerised weather-based irrigation water management system (University of the Orange Free State – Department of Agrometeorology)
- **600** Problem blooms of macro-algae: Investigation of causal factors, seasonality of recruitment and growth, and efficiency of control methods (University of Cape Town – Department of Botany)
- **624** Personal computer-based procedure for the estimation of irrigation requirements of crops in Southern Africa (MBB (CE) Inc.)
- **625** Use of computer models for agricultural water management at farm level (University of the Orange Free State – Department of Soil Science)
- **644** Quality of water for livestock production with emphasis on subterranean water and the development of a water quality guideline index system (University of Pretoria – Department of Animal and Wildlife Sciences)
- **645** Optimal management of uncertain water availability at farm and regional level with due allowance for risk and the environment (University of the Orange Free State – Department of Agricultural Economics)
- **646** Maximisation of economic water-use efficiency of processing tomatoes (University of Pretoria – Department of Plant Production)

AGRICULTURAL WATER MANAGEMENT

- **650** Integrated control of blackflies along the Orange River (Agricultural Research Council – Onderstepoort Veterinary Institute)
- **689** Irrigation water requirements of small-plot vegetable farmers (Agricultural Research Council – Institute for Soil, Climate and Water)
- **695** Establishing effects of saline irrigation water and managerial options on soil properties and plant performance (University of Stellenbosch – Department of Soil and Agricultural Water Science)
- **719** Investigation into food-plot production on irrigation schemes in the central region of the Eastern Cape Province (University of Fort Hare – Agricultural and Rural Development Research Institute)
- **725** Quantitative evaluation of the hydraulic properties of stony soils by means of laboratory simulations (Potchefstroom University for CHE – Department of Plant and Soil Sciences)
- **753** Facilitating irrigation scheduling by means of the soil water balance model (University of Pretoria – Department of Plant Production and Soil Science)
- **768** Evaluation of the appropriateness and management requirements of micro-irrigation systems in small-scale farming (MBB (CE) Inc.)
- **774** Development of guidelines for appropriate training levels and content in support of sustainable small-scale irrigation development (MBB (CE) Inc.)
- **780** Effect of the introduction of agroforestry species on the soil moisture regime of traditional cropping systems in rural areas (CSIR – Division of Water, Environment and Forestry Technology)

New

- **740** Effect of water quality on irrigation farming along the lower Vaal River: The influence on soils and crops (University of the Orange Free State – Department of Soil Science)
- **798** Quantification of the water balance on rehabilitated mine soils under rain-fed pastures on the Highveld of Mpumalanga (Agricultural Research Council – Institute for Soil, Climate and Water)
- **816** Use of triploid grass carp for the biological control of excessive growth of water weeds in irrigation schemes (Rand Afrikaans University – Department of Zoology)
- **857** Extension to and further refinement of a water quality guideline index system for livestock watering (University of Pretoria – Department of Animal and Wildlife Sciences)
- **858** Influence of irrigation with gypsiferous mine water on soil properties and drainage water in Mpumalanga (Chamber of Mines)
- **878** Optimising rainfall-use efficiency for developing farmers with limited access to irrigation water (Agricultural Research Council – Institute for Soil, Climate and Water)

CONTACT PERSONS

- **Dr GR Backeberg**
  (Agricultural Water Management)
  e-mail: gerhard@wrc.ccwr.ac.za
- **Mr DS van der Merwe**
  (Irrigation and Animal Husbandry)
  e-mail: david@wrc.ccwr.ac.za
- **Dr GC Green**
  (Agrometeorology and Plant Physiology)
  e-mail: george@wrc.ccwr.ac.za
- **Mr HM du Plessis**
  (Salinisation)
  e-mail: meiring@wrc.ccwr.ac.za

☎ **(012) 330-0340**

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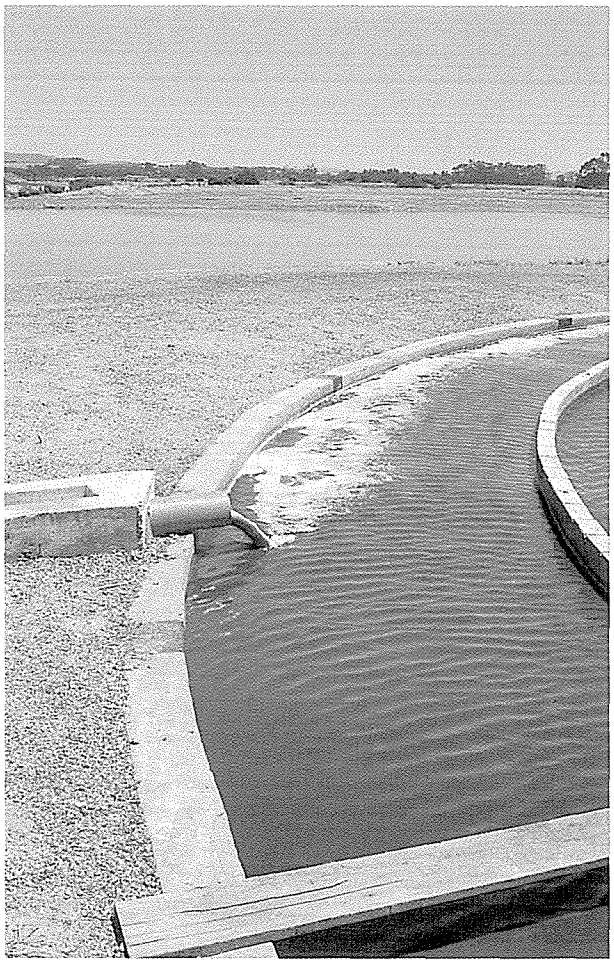
INDUSTRIAL WATER MANAGEMENT



The use of water by industry often includes the potential for rapid degradation of water quality due to contamination by raw materials, semi-processed materials, products or by-products involved in the production process. Historically, this potential has been viewed as a threat to the environment and the public water supply. The opportunity implicit in this scenario has also been recognised, and management techniques have been developed to conserve water, minimise waste, prevent pollution and control environmental impacts, and thereby contribute to an improved sustainability and quality of life.

Analysis of the life cycle of water used by industry for processing purposes shows a complex set of interactions which draws on all aspects of water engineering from supply to treatment and disposal, in which the industry effectively "rents" the water for a short period as a small part of the cycle. The quality of the water taken in (generally "good", often potable) is usually degraded to some extent during the production process, resulting in an aqueous effluent discharge of lower quality which often requires treatment for further beneficial use or discharge to the environment. The quantity of water used for industrial processing in the RSA is relatively low (estimated at around 8% of total national water use) and is largely non-consumptive, but the pollutant load generated is proportionally significantly greater (a characteristic feature of industrial water use). It is only when viewed against such a holistic backdrop that the "true cost" and correspondingly the "true value" of the water used by industry can be determined, and resource management considerations require that all the impacts concerned be quantitatively measured to determine the overall cost/benefits of the industrial use of water. Scientific and engineering disciplines provide both the techniques for quantitative situation analysis and the technological tools for effective management, implementation and treatment process unit operations.

Over the years of its existence, a retrospective view of research funded by the WRC into effective management of the industrial use of water indicates that the focus has progressively shifted from end-of-pipe effluent treatment solutions, through waste characterisation and surveying by sectoral and national industrial water and waste-water management studies, to water conservation and waste minimisation procedures including cascading, regenerative recycling, regenerative reuse and process modifications. Currently, increasing attention is being given to the development and implementation of cleaner production and cleaner technology protocols which intrinsically incorporate the application and integration of all the above related aspects and contribute thereby to improving the sustainability of production. Appropriate research attention is nevertheless still paid to the development of treatment technologies for managing the impacts caused by residual or recalcitrant effluent contamination.

Examples of current and new research areas which incorporate various aspects of technology development and resource management are:

- The application of process engineering techniques such as pinch technology for developing a rational means of managing water demand and effluent generation in an industrial complex.

- A biotechnological approach using fungi and enzymes to reduce the use of chemicals such as chlorine and sulphur dioxide for treating and detoxifying pulp and paper effluents.
- The assessment of the operating and process advantages of a baffled (compartmentalised) anaerobic digester for treating high-strength and toxic organic industrial effluents.
- The optimisation of bioreactor design, including efficient retention and separation of the biomass, for the treatment of effluents containing heavy metals.
- The application of algal pond technology to the removal of sulphates and heavy metals from large volumes of acid mine drainage effluents.

Completed projects

Biological treatment of industrial water with the simultaneous production of single-cell protein

(No 263) Department of Chemical Engineering, University of Pretoria

Some carbon-rich waste waters may be utilised for the production of useful products, such as single-cell proteins, thereby offsetting the costs of treatment of these waters. A shortage of animal feed protein renewed the interest in single-cell protein. The aim of this project was to evaluate a combination of a cross-flow sieve and filamentous fungi (*Geotrichum candidum* and *Aspergillus fimigatus*) for the biological degradation of a high-carbon effluent (pulp-mill effluent) with the simultaneous production of a protein suitable for animal feed supplement.

It was found that *Aspergillus fimigatus* was the most suitable organism. It was able to break down the pulp-mill effluent biodegradable COD by 84%. Projecting the pilot-plant results to the main pulp mill, the process would potentially be able to produce 120 000 t/a of protein (30% of South Africa's estimated protein deficit in the year 2000) from the 84 Ml/d pulp-mill effluent stream.

Cost: *R67 100*
Term: *1989-1996*

Removal of suspended solids from pulp and paper effluents by employing a combined sedimentation, flotation and sand filtration process

(No 333) Division of Water, Environment and Forestry Technology, CSIR

Pulp and paper effluents contain both lighter particles (fibres) and heavier particles (grit and ash). Dissolved air flotation is more successful in removing the lighter particles, whereas settling tanks are more appropriate for removing the heavier particles. The aim of the project was to evaluate a combination of inclined-plate sedimentation and dissolved air flotation for the treatment of a pulp and paper effluent.

It was found that good solids removal is obtained with the process, but that the chemical oxygen demand (COD) was not significantly reduced. During the settling stage, however, most of the suspended solids were removed and the COD was reduced, the dissolved air flotation stage only making a minor contribution. The conclusion drawn is that it will be more cost-effective to simply provide a somewhat bigger settler, without a subsequent flotation stage.

Cost: *R55 000*
Term: *1991-1993*

Regional treatment of textile and industrial effluents

(No 456) Department of Chemical Engineering, University of Natal

Colour and auxiliary chemicals from the processing of textiles persist through conventional waste-water treatment plants and enter the receiving water body. If there is not sufficient dilution, either at the waste-water treatment plant or in the receiving water body, the colour and chemicals affect both the aesthetic quality and the downstream beneficial use of the water. Work undertaken on the in-house treatment of textile effluents has emphasised the recycling of water, chemicals and energy while the problems of removing the colour and of concentrate disposal have not been addressed, which is of particular concern to inland textile mills. This project therefore aimed at studying the fate of textile effluent fractions discharged to sewer by inland textile mills in mixed domestic and industrial effluent at sewage works. The effect of specific textile and industrial effluents on sewage treatment processes was investigated, and the addition of polymers and the incorporation of further process steps within a sewage works to improve the removal of specific pollutants was evaluated. The treatment of specific textile effluent concentrates, which had been segregated at source and transported to the sewage works, was also investigated.

In anaerobic studies conducted at laboratory scale, pilot scale and full scale on reactive dyes and dye effluents, the main results found were that:

- Reactive dye concentrates can be treated in a conventional anaerobic digester.
- Prior exposure of the biomass to the dye did not increase the rate of decolourisation, but did increase the tolerance of the micro-organisms to previously inhibitory concentrations of the dye.
- The rate of decolourisation was first-order with respect to dye concentration and an additional carbon source (e.g. glucose) was found to be necessary to maintain the microbial metabolic state.
- The presence of nitrate in the system resulted in inhibition of decolourisation whereas sulphate had no effect on the decolourisation rate; decolourisation only occurred once all the nitrate in the system had been reduced and a potential of less than -450 mV (saturated calomel electrode) was conducive to rapid decolourisation.
- Adsorption of the dye to the biomass did play a role in the initial stages of decolourisation, but the adsorbed dye was subsequently decolourised and therefore no distinction was made between abiotic and biological decolourisation.
- The degradation products of the dye after anaerobic digestion were isolated and identified and found to be consistent with reduction of the azo bond, and these metabolites were not degraded further under anaerobic conditions.

Cost: *R489 400*
Term: *1992-1995*

Development of management strategies and recovery systems for heavy metal wastes

(No 589) SRK (CE) Inc.

Discharge of heavy metals to sewer can have significant detrimental effects on the efficiency of the municipal sewage treatment, directly by their inherent toxicity, or indirectly by accumulating in sewage sludges limiting sludge disposal opportunities, or by passing directly through the treatment system to be discharged to the receiving aquatic environment.

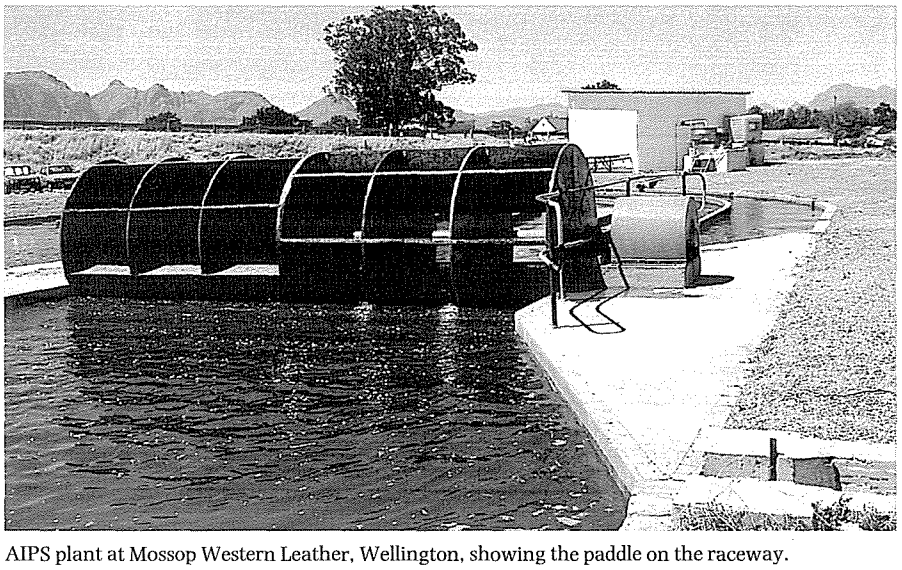
Many municipalities do have industrial discharge standards promulgated to limit discharges to sewer, but the operation of industries and limitations on the ability of municipalities to practically monitor and control discharges continue to result in significant metal loads arriving at the sewage treatment plants in an unaccounted manner.

It has also been identified that stringent control through excessive penalties and restrictive practices may not be appropriate in encouraging the responsible handling of the wastes generated by industry. An integrated approach to heavy metal waste control through waste minimisation, pretreatment and waste management programmes is believed to offer a mutually acceptable and effective mechanism for managing and controlling metal wastes whilst optimising resource utilisation and relationships between industry and control authorities.

Waste Minimisation identifies opportunities to reduce the wastes generated and to optimise reuse and recovery where practical. Where waste minimisation alone cannot reliably achieve a desired discharge metal load, the **Pretreatment Programme** identifies opportunities for pretreating effluent on-site to meet required qualities. Associated with the approach would be the provision of a dedicated **Centralised Waste Treatment (CWT) facility** which would receive, treat and dispose of, or recover for reuse, the metal wastes in a well-regulated manner, and a **Waste Management Programme** to monitor and control the movement of contaminated wastes from their point of production to the final destination, and to ensure that the industry programmes and the **CWT** operate responsibly and economically.

This Report (WRC Report No 589/1/97) reviews local and international practices in the management of heavy metal sewer discharges, handling of metal wastes, and utilised the Johannesburg Municipal Area to assess and demonstrate the feasibility for a **CWT** facility and associated **Waste Management Programme** opportunities.

Cost: *R69 200*
Term: *1994-1995*



AIPS plant at Mossop Western Leather, Wellington, showing the paddle on the raceway.

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

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

Scale formation in cooling systems leads to increased energy consumption and increased make-up water requirements. Magnetic scale control has been known since before the Second World War but results were erratic and researchers were not able to prove beyond any reasonable doubt if, and under what conditions, these magnetic units could control scale formation. The main aim of the project was to identify whether, and under which conditions, these units could control scale successfully in industrial-type cooling circuits.

Because the study was executed on such a micro-chemistry scale, it was discovered that it was not the magnetic units *per se* which controlled scale formation, but micro-quantities of certain metals freshly dissolved into the water from the bodies of the magnetic units which interfere with the crystal structure. This interference results in the formation of the aragonite crystal form of calcium carbonate, which does not adhere to surfaces as does the normal, scaling, calcite form of crystal. The concept has been patented.

Cost: *R349 600*
Term: *1994-1997*

Role played by *Shewanella* and sulphide-producing bacteria in metallic corrosion in industrial water systems

(No 661) Department of Microbiology, University of the Western Cape

Industrial waters generally contain higher concentrations of dissolved and suspended salts and solids than drinking water. The higher nutrient levels are conducive to microbial growth, with an emphasis on attached bacterial growth (i.e. biofilms). Bacterial biofilms are known to harbour various bacterial populations and are the main cause of microbially induced corrosion (MIC) in industrial water systems.

The main aim of this study was to determine the role played by non-sulphate-reducing bacteria (non-SRB) sulphide-

producing bacteria in MIC in industrial water systems, in particular to:

- Study quantitatively the occurrence and location within biofilms, in industrial water systems, of non-SRB sulphide-producing bacteria (i.e. *Shewanella*) as well as of SRB.
- Determine the role played by *Shewanella* in the corrosion of ferrous metals and to investigate three aspects of the metabolic capabilities of *Shewanella* as possible contributors to MIC.

The results obtained demonstrated clearly that apart from *S. putrefaciens*, a variety of the *Aeromonas* species occurring in industrial cooling-water systems have true sulphidogenic properties, producing hydrogen sulphide from sulphite. *S. putrefaciens* was shown to reduce both sulphite and ferric iron using cathodic hydrogen from steel as electron donor, and also corroded mild steel in pure culture at three times the rate of corrosion in the absence of bacteria. The *S. putrefaciens* isolates reduced sulphite at dissolved oxygen concentration levels under 1,5 mg/*l*, explaining why hydrogen sulphide is often detected in highly aerated industrial cooling-water systems, even where biofilm growth is kept to a minimum and biofilms are consequently thin, with few anaerobic zones. A simulated model cooling-water system, inoculated with *S. putrefaciens*, *Desulfovibrio vulgaris* (true SRB) and *Pseudomonas aeruginosa*, yielded biofilms in which the SRB did not survive well. *S. putrefaciens* dominated the biofilm together with the aerobic *P. aeruginosa*, showing that the former is better suited to growth in biofilms, growing in sulphidogenic/aerated environments, than are the SRB. The results have shown that *S. putrefaciens* possesses the metabolic capabilities required to induce MIC, that it accelerates the corrosion rate of mild steel and that it outperforms the true SRB in biofilms in sulphidogenic/aerated cooling systems. It was concluded that *S. putrefaciens* is a powerful agent of MIC, probably more detrimental than are the true SRB, and that it is vital for operators of industrial cooling-water systems to monitor its presence.

Cost: *R100 800*
Term: *1995-1996*

New projects

Operation and monitoring of the WRC/LIRI waste-water treatment pilot plant for industrial effluent research and training of waste-water treatment personnel

(No 826) LIRI Technologies

The WRC has made substantial investments in previous projects for the construction of a pilot plant at LIRI Technologies (Grahamstown) for research into industrial effluent treatment and the education and training of waste-water treatment plant personnel. The pilot plant provides a unique facility in terms of industrial effluent research, and the linkage between LIRI Technologies and Rhodes University offers the opportunity to co-ordinate research into the treatment of industrial effluents and the corresponding training of personnel. Technologies which are developed or improved at this facility will very quickly find their way into general use, providing effective technology transfer.

The project objectives are to:

- Monitor performance of the pilot plant and its application in evaluating industrial effluent treatment options
- Complete current studies of high-rate biofiltration treatment of tannery and other industrial effluents
- Evaluate the algal high-rate oxidation ponding system as a tertiary treatment to the WRC/LIRI pilot plant
- Evaluate the role of algal biomass in enhancing conventional biological systems in treating industrial effluent
- Report on the use of the plant in the training of waste-water treatment personnel and the development of course material associated with its use.

Estimated cost: *R350 000*
Expected term: *1997-1998*

Detection methods for studying the ecology of *Legionella* in cooling-water systems

(No 827) Department of Microbiology and Plant Pathology, University of Pretoria

Legionella are the causative agents of *Legionella* pneumonia (Legionnaires disease) and non- pneumonic legionellosis. *Legionella* species are ubiquitous in aquatic environments, including cooling towers and potable water supplies, and are frequently isolated from industrial water systems in South Africa. Moreover, water shortage forces factories to recycle and reutilise water and microbiological quality control is therefore important to industry.

Nationally, various laboratories are testing water samples for the presence of *Legionella* using different analytical methods, with inconsistent results. The development of a quick, standardised, reliable method for identification and enumeration of *Legionella* in both industrial water and biofilm samples is therefore essential.

No official guidelines or standards exist in South Africa for *Legionella* in water. This study will be the first ecological survey of *Legionella* in industrial cooling-water systems. This research is necessary to determine the health risk of *Legionella* in the working environment and to formulate guidelines for *Legionella* in water systems to improve environmental health.

Estimated cost: *R121 000*
Expected term: *1997-1998*

Development of bioreactor systems for the treatment of heavy metal containing effluents

(No 845) Department of Biochemistry and Microbiology, Rhodes University

The contamination of waste waters by heavy metals is a major source of environmental pollution and represents a loss of a vital resource since water availability and quality will be a significant factor in the future socio-economic growth of South Africa. The unsuitability of metal-contaminated water for reuse in industrial processing is also an important economic consideration for many industries because of the escalating cost of freshwater supplies.

Numerous studies have shown that

biotechnology-based processes can provide an effective and inexpensive means of removing heavy metals from water when compared to more traditional methods such as ion-exchange and chemical precipitation. Previous studies on such bioprocesses have largely focused on the use of yeast as a biosorbent and were carried out using mainly laboratory solutions containing selected heavy metals. While yeast biomass was shown to be an effective biosorbent it would appear that its practical application is likely to be limited to low-volume, high-metal concentration effluents since the amount of biomass required for large volume effluents (e.g. mining) makes it economically impractical for such wastes.

For more widespread application in metal removal and/or recovery from waste waters, alternative forms of biomass are algae and the water fern, *Azolla*. This fern is widely distributed in South African water systems, grows particularly well in the Eastern Cape, and represents a readily available and inexpensive form of biomass for metal-removal applications.

The objectives of the project are to:

- Evaluate the potential of algae and the water fern, *Azolla* to accumulate heavy metals from effluents which are relatively low in volume but high in metal content, e.g. electroplating and battery industry waste waters.
- Exploit the exopolysaccharide production by a number of algae as a means of enhancing metal-removal efficiencies.
- Optimise bioreactor design including biomass retention and separation systems for direct on-site application of the technology developed above.
- Embark on a capacity-building programme as part of the project by involving staff and students from the University of Fort Hare and the University of the North in these studies.

Estimated cost: R598 000
Expected term: 1997-1999

Application of pinch technology as a strategic tool in the rational management of water and effluent in an industrial complex

(No 851) Pollution Research Group, University of Natal

The conservation of water has been recognised as an essential aspect in the management of the country's water resources. While the industrial sector is not a large water user, it can be an important effluent producer. Industry requires water of different qualities and produces a range of effluents. Technical expertise in industry allows for different process options to be selected which will have an impact on the resulting water quality. Technologies need to be promoted to enable strategic decisions to be made from the large range of options available. Pinch technology is a technique which was first used for assessing the overall interrelated energy needs of a complex industrial plant or cluster of such plants. In a similar way this technology may be applied in the field of industrial effluent treatment in South Africa.

The Pollution Research Group at the University of Natal has the opportunity to participate in an effluent reduction project at such a complex near Durban. By applying pinch technology and using their extensive knowledge of industrial effluent treatment techniques, it is anticipated that an optimal solution will be facilitated. The resulting experience and knowledge gained by all parties will ensure that the techniques would be more widely used in the future.

The objectives are to:

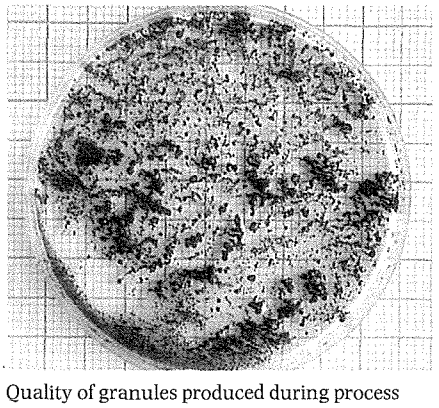
- Apply and assess pinch technology as an approach for promoting water and effluent conservation in large chemical or industrial complexes.
- Develop procedures for the integration of water quantity and quality requirements of individual unit operations into the overall optimal use of water in such industrial complexes.
- Establish guidelines for and promote the use of pinch technology as a planning tool for water quality management (national, local and factory level).
- Transfer the technology to water authorities, consultants, academics and engineers for application in industrial water conservation surveys.

Estimated cost: R907 000
Expected term: 1997-1999

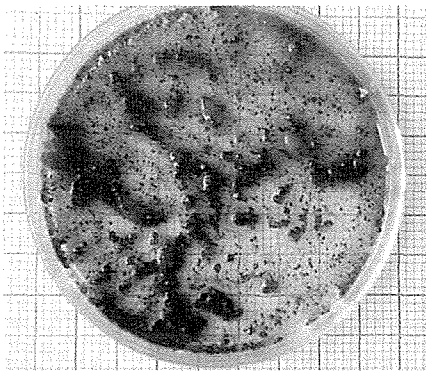
Assessment of baffled (compartmentalised) anaerobic digester for the treatment of high- strength and toxic organic industrial effluents

(No 853) Pollution Research Group, University of Natal

The predicted high industrial growth rate in South Africa, coupled with limited water resources, will in certain situations necessitate the implementation of advanced and sophisticated effluent-treatment systems. The organic effluents arising from the agri-industrial, food and beverage, textile and fine chemical sectors are generally problematic in terms of their concentrated, variable intermittent and sometimes toxic nature. Many such effluent streams would, however, be amenable to treatment by anaerobic digestion, pro-



Quality of granules produced during process induction and lactate and canning fruit effluent as microbial growth stimulants. Granule sizes vary from pin-point to 2 mm.



Quality of granules produced during process induction and glucose as microbial growth stimulants. Granule sizes vary from pin-point to 3 mm.

vided that the toxicity of the particular effluent stream is identified at an early stage and that the microbial populations concerned can be acclimated to the organic constituents concerned, in a suitably designed reactor.

Anaerobic treatment of large volumes of industrial waste waters has been facilitated by the development of high-rate reactors that can achieve good separation between the hydraulic retention time and the solids retention time. The anaerobic baffled tank reactor is one such example. Attributes are a high rate of hydraulic throughput with very little loss of biomass from the reactor, a high reaction rate per unit volume, a low fraction of dead space compared to other types of anaerobic reactors and the ability to withstand intermittent loads and toxic shocks caused by constituents of the industrial waste water being treated.

These operating advantages compared to a completely mixed system are due to the very high efficiency by means of which the active biomass is retained in the system, while the efficiency with which substrates are metabolised is achieved by the compartmentalisation of different microbial associations which have been acclimated to the range of constituents in the effluent. The series of microbial associations allow specialised bacteria to break down the effluent in a stepwise fashion, producing degradation products that may otherwise have been toxic or inhibitory to a mixed culture.

One of the effluents targeted for treatment in the proposed baffled reactor is textile scouring and dye effluent. The necessary background work was undertaken by the Pollution Research Group during the course of an earlier WRC project, entitled **The Regional Treatment of Textile and Industrial Effluents** (Project No 456).

The objectives of this programme are to design, construct, operate and assess the suitability of an efficient and cost-effective reactor for the treatment of a high-strength, refractory and/or toxic organic industrial effluent.

Estimated cost: R1 218 000
Expected term: 1998-2000

Biological sulphate desalination and heavy metal precipitation in industrial and mining effluents using the algal integrated ponding system (AIPS)

(No 869) LIRI Technologies, Rhodes University

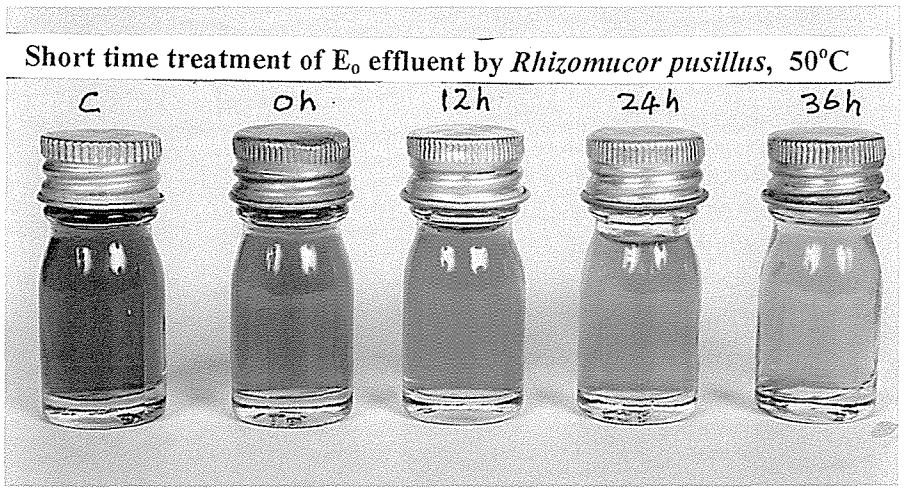
The acute problems of accumulating salinities within the public water system in the inland regions of South Africa are well known. Recently attention has been focused on the pumping of large volumes of sulphate and heavy metal containing mine water into the environment, water which eventually finds its way into the public water system. Moreover, other industries, such as tanneries, also produce effluent high in sulphate and heavy metals and so contribute to the problem.

Biodesalination through biological sulphate reduction followed by metal sulphide precipitation offers the potential to address the above problem and to make available significant volumes of treated water for public supply. Laboratory- and pilot-plant research findings in previous and ongoing WRC projects have demonstrated the potential of the AIPS for adaptation to the treatment of high-volume waste waters containing sulphate and heavy metal. The study is now being extended to the construction of a demonstration-scale AIPS pilot plant at Nigel Municipality's Grundling Sewage Works. The pilot plant will initially be fed tannery effluent and later mine drainage water.

The project aims are to:

- Construct and operate an AIPS pilot plant adapted for sulphate biodesalination and heavy metal precipitation
- Evaluate the efficiency of COD-containing effluent (e.g. tannery waste water or sewage solids) as the carbon source for sulphate reduction
- Demonstrate the potential contribution to carbon source of algal biomass produced in the AIPS process
- Evaluate sulphide and heavy metal recovery in the system
- Monitor algal biomass production and evaluate the feasibility of its recovery as a by-product.

Estimated cost: R673 000
Expected term: 1997-1998



Fungal decolourisation of bleach plant effluent E_0 from SAPPI SAICCOR mill using *Rhizomucor pusillus* RM7 for various treatment times.

Research projects

Completed

- **263** Biological treatment of industrial water with the simultaneous production of single-cell protein (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, Environment and Forestry Technology)
- **456** Regional treatment of textile and industrial effluents (University of Natal – Department of Chemical Engineering)
- **589** Development of management strategies and recovery systems for heavy metal wastes (SRK (CE) Inc.)
- **612** Reduction of scaling in industrial water-cooling circuits by means of magnetic and electrostatic treatment (Rand Afrikaans University – Energy Laboratory and Department of Chemistry)
- **661** Role played by *Shewanella* and sulphide-producing bacteria in metallic corrosion in industrial water systems (University of the Western Cape – Department of Microbiology)

Current

- **239** Transfer of waste-water management technology to the meat processing industry (SRK (CE) Inc. and Abakor Ltd.)
- **241** Dewatering of compressible filter cakes (University of Natal – Department of Chemical Engineering)
- **308** Recovery of water and chemicals from ion-exchange regeneration effluents (University of Natal – Department of Chemical Engineering)
- **315** Utilisation of the fungus *Geotrichum* in waste water (University of Pretoria – Department of Chemical Engineering)
- **331** Improved oxygen transfer for high biosludge concentrations (University of Pretoria – Department of Chemical Engineering)
- **342** Improvement in water usage control and waste-water treatment in the sorghum beer industry (University of Pretoria – Department of Chemical Engineering)
- **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)
- **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)
- **453** Development of procedures to assess whole effluent toxicity (CSIR – Division of Water, Environment and Forestry Technology)
- **455** Anaerobic digestion of dairy factory effluents (Irene Animal Production Institute, Agricultural Research Council)
- **457** Monitoring and optimisation study of high-rate biofiltration, aerobic biological treatment processes for tannery and fellmongery waste water (LIRI Technologies)
- **458** Development of an expert systems approach to water management in the fruit and vegetable processing industry (SRK (CE) Inc.)
- **495** Biotechnological approach to the removal of organics from saline effluents (Rhodes University – Department of Biochemistry and Microbiology)
- **535** Use of filamentous micro-organisms for the purification of industrial effluents (University of Pretoria – Department of Chemical Engineering, Division of Water Utilisation Engineering)
- **546** Development and demonstration of effluent treatment systems appropriate to the needs of the red meat abattoir industry (SRK (CE) Inc.)
- **551** Evaluation of the potential quantity of methane gas from 85 anaerobic household digesters (BE La Trobe)
- **552** Evaluation of immobilised semi-conductor particles for the photo-catalytic oxidation of organic pollutants in industrial and municipal waste water (University of Stellenbosch – Department of Chemistry)
- **616** Use of algal and yeast biomass to accumulate toxic and valuable heavy metals from waste water (Rhodes University – Department of Biochemistry and Microbiology)
- **652** Purification of abattoir effluents by means of the protein reclamation process (Abakor Ltd.)
- **657** Course development for the education and training of industrial waste-water treatment plant operators and managers (Rhodes University – Department of Biochemistry and Microbiology)
- **658** Algal high-rate oxidation ponding for the treatment of abattoir effluents (Rhodes University – Department of Biochemistry and Microbiology)
- **659** Purification of high organic effluent by means of a tent-type anaerobic digester (Abakor Ltd. – Multilog Division)
- **660** Development and implementation of biological cleaning techniques for ultrafiltration and reverse osmosis membranes for industrial effluents with a high organic content (University of Stellenbosch – Department of Biochemistry)
- **667** Enhanced granulation in upflow anaerobic sludge-bed digesters (UASB) by process induction and microbial stimulation (University of Stellenbosch – Department of Food Science)
- **673** Complete treatment of dairy factory effluents by means of primary anaerobic digestion and secondary algal protein production (Agricultural Research Council – Animal Nutrition and Animal Production Institute)
- **674** On-site evaluation of an anion-free flocculant for industrial cooling systems (University of Natal – Pollution Research Group and Eskom)

INDUSTRIAL WATER MANAGEMENT

- **687** Membrane-based biotechnological systems for treatment of organic pollutants (Rhodes University – Department of Microbiology)
- **759** NATSURV: Water and waste-water management in the petrochemical industry (CSIR – Division of Water, Environment and Forestry Technology)
- **760** Waste minimisation and effluent treatment guide for the textile industry (University of Natal – Pollution Research Group)
- **761** Extraction of ionic and chemical species from water by capsulated membrane extraction (Potchefstroom University for CHE – Department of Chemical Engineering)
- **762** Survey of anaerobic digesters in the KwaZulu-Natal region in order to assess their availability for the treatment of high strength or toxic organic effluents (University of Natal – Pollution Research Group)
- **763** Biotechnological approach to the management of effluents from the pulp and paper industry (University of the Orange Free State – Department of Microbiology and Biochemistry)
- **766** Utilisation of earthworms and associated systems for treatment of effluent from red meat abattoirs (Abakor Ltd. – Multilog Division)
- **778** Total recycling of effluent from the protein recovery process appropriate to the red meat and poultry abattoir industries (Abakor Ltd. – Multilog Division)

New

- **826** Operation and monitoring of the WRC/LIRI waste-water treatment pilot plant for industrial effluent research and training of waste-water treatment personnel (LIRI Technologies)
- **827** Detection methods for studying the ecology of *Legionella* in cooling-water systems (University of Pretoria – Department of Microbiology and Plant Pathology)
- **845** Development of bioreactor systems for the treatment of heavy metal containing effluents (Rhodes University – Department of Biochemistry and Microbiology)
- **851** Application of pinch technology as a strategic tool in the rational management of water and effluent in an industrial complex (University of Natal – Pollution Research Group)
- **853** Assessment of a baffled (compartmentalised) anaerobic digester for the treatment of high-strength and toxic organic industrial effluents (University of Natal – Pollution Research Group)
- **869** Biological sulphate desalination and heavy metal precipitation in industrial and mining effluents using the algal integrated ponding system (AIPS) (Rhodes University – LIRI Technologies)

CONTACT PERSONS

- **Mr GN Steenveld**
  (Industrial and Municipal Waste-Water Treatment)
  e-mail: greg@wrc.ccwr.ac.za
- **Dr G Offringa**
  (Membrane Applications)
  e-mail: offringa@wrc.ccwr.ac.za
- **Dr SA Mitchell**
  (Bioassaying)
  e-mail: steve@wrc.ccwr.ac.za

☎ **(012) 330-0340**

9 MEMBRANE TECHNOLOGY

Membranes used by a number of institutes in South Africa for research on membrane bioreactors.

It is envisaged that membranes will fulfil an ever-increasing role in the South African water sector. Membranes have emerged as effective unit processes which may be used in a wide range of applications, including desalination of sea water and brackish water, the purification of surface and polluted waters for potable use, and the treatment of industrial and municipal effluents. Membrane separation processes are not only relevant to First-World conditions, but also have great potential for water supply to rural and peri-urban communities. Both reverse osmosis and ultrafiltration-based plants have been proven capable of supplying water to small communities in South Africa.

The growing tendency towards co-operative research between various research institutions, is increasingly becoming a distinctive feature of South African membrane research. For example, joint research and general co-operation between the Universities of Stellenbosch, Rhodes, Western Cape, South Africa, and the Technikons ML Sultan, Cape and Peninsula, have not only resulted in exciting technical developments, but have also created a core of skilled scientists and technologists in this field. Co-operation with private membrane manufacturers and supply organisations has resulted in increased local and foreign application of local membrane research and development.

Technical innovations over the past year, most of which have been patented, include the following (see also **Year under Review**):

- A novel membrane chemical treatment method was developed by the Department of Chemistry, University of the Western Cape. The chemicals are easily applied and drastically reduce membrane fouling in ion-exchange membranes (Funding for this work is provided by both the WRC and Eskom).
- Using the outer-skinless, hollow-fibre ultrafiltration membrane developed by the Institute for Polymer Science, University of Stellenbosch, the Department of Microbiology and Biochemistry at Rhodes University developed a novel "defouling on demand" approach to ultrafiltration membrane defouling. An "activatable" enzyme is immobilised on the membrane and triggered at will by the operator in order to degrade the fouling layer and restore membrane flux.
- A simple but exciting method of analysing for phenols and other organic foulants in water was developed by the Department of Microbiology and Biochemistry at Rhodes University as part of their bioreactor research. This method uses a "dipstick" consisting of a membrane on which an enzyme is immobilised with a colour reagent. A colour change is effected which is proportional to the concentration of the organics.
- A new method of applying polymer groups to polysulphone membranes to render the membrane surface less hydrophobic was developed by the Department of Chemistry at the University of South Africa.
- Results of development done at the Institute for Polymer Science (IPS), University of Stellenbosch to improve the performance of local membranes indicated the following:

- Ultra-thin film tubular membranes were made from poly-2-vinylimidazoline and polyvinyl alcohol, cross-linked with 3,5-dichlorosulphonyl benzoylchloride and were successfully housed and tested in commercially available modules.
- A coating procedure was developed for the regeneration of substandard or degraded cellulose acetate membranes.
- Chemical oxidation-resistant fluorinated polyvinylidene fluoride was fabricated for possible use with oxidising chemicals such as ozone.
- Polypropylene surfaces were modified to make them more glueable with epoxy glues. Assistance was given to Hoechst in the USA to make their membranes more amenable to gluing.
- Using a new carbonisation procedure, mechanically and chemically stable, asymmetrical, carbon membranes were produced for use as bioreactors.
- Novel, electro-conducting, polymeric membranes have been produced for the separation of certain gases.
- Preliminary results show that the Institute succeeded in producing a new, sponge-type UF membrane, providing three times the flux and double the bursting strength of the previous, outer-skinless, membrane. It is to be evaluated as a dual purpose, biofilm reactor and potable water treatment membrane. (Full reporting will be done in next year's *WRC Technical Report*).

Completed projects

Investigation into the upgrading of Orange River water and secondary sewage effluent by means of ultra- and nanofiltration

(No 548) Institute for Polymer Science, University of Stellenbosch

The study was aimed at determining to what extent low-pressure membrane filtration is capable of producing water of a better quality to consumers in the Uitenhage area. Both Orange River water and secondary sewage effluent were used as feed for capillary ultrafiltration and tubular nanofiltration investigations. The emphasis of the study was on long-term performance evaluation of the membranes for secondary sewage reclamation.

It was found that nanofiltration of secondary sewage effluent yielded a quality water suitable for industrial use. The cellulose acetate nanofilters were, however, prone to hydrolysis under the high prevailing pH conditions, indicating a requirement to use acid. The ultrafiltration polyethersulphone membranes were found to be more robust and the modules performed well. These results indicated that both methods could be used successfully to purify secondary sewage effluent for reuse in industrial processes.

Cost: *R62 400*
Term: *1993-1994*

Tolerant membranes

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

The main aim of the project was to improve the performance of locally-produced membranes in general. Results from the study include the following:

Ultra-thin film tubular membranes were made of poly-2-vinylimidazoline and polyvinyl alcohol, cross-linked with 3,5-dichlorosulphonyl benzoyl chloride and were successfully housed and tested in commercially available modules. A coating procedure was developed for the regeneration of substandard or degraded cellulose acetate membranes. Chemical oxidation-resistant fluorinated polyvinylidene fluoride was fabricated for possible use with oxidising chemicals such as ozone. Polypropylene surfaces were modified to make them more glueable with epoxy glues. Assistance was given to Hoechst in the USA to make their membranes more amenable to gluing. Using a new carbonisation procedure, mechanically and chemically stable, asymmetrical, carbon membranes were produced for use as bioreactors. Significant manpower development took place since the project was executed by researchers from a number of institutions in the country.

Cost: *R473 100*
Term: *1994-1997*

Capillary membrane production development

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

The aim of this project was to further the technology of locally developed micro- and ultrafiltration capillary membranes, while simultaneously rendering them more cost-effective.

The project produced the following results: An internally-skinned membrane with narrow-bore microvoids, extending the full width of the capillary wall, and with no external skin layer, was produced from polysulphone and polyethersulphone. These externally-skinless membranes are able to produce filtered water at a trans-membrane pressure of only 3 to 5 m of water. The membranes were successfully incorporated into both axial-flow tube-in-shell-type modules and transverse-flow modules. Because of the trumpet-shaped pores in the membrane capillary wall, these membranes can also be used for immobilising useful organisms, thereby opening the way to various membrane bioreactor applications.

Cost: *R804 000*
Term: *1994-1997*

New projects

Development of a fabrication protocol for the production of capillary membranes and special modules for the low-cost treatment of contaminated water

(No 769) Institute for Polymer Science, University of Stellenbosch

In this project the existing narrow-bore membrane production facilities at the Institute for Polymer Science will be extended to include hollow fine-fibre membrane production. Membranes that will be produced include polyvinylidene fluoride and "Teflon"-type membranes for ozone contactors, Nafion membranes, co-polymer carbon membranes for removal of pollutants from water, silicon rubber-coated membranes for trihalomethane removal and catalytic membranes for nitrate removal. In addition, improved fabrication protocols will be developed for high-speed spinning of dense-porous hol-

low fine-fibre membranes, transverse-flow modules and bioreactor and catalytic contact modules. The project will increase both the scope and efficiency of South African membranes for both water and waste-water treatment.

Estimated cost: R1 407 000
Expected term: 1997-1999

Defouling of ultrafiltration membranes

(No 791) Department of Biochemistry and Microbiology, Rhodes University

The project aims at the defouling of high-flux, low-pressure ultrafiltration membranes by linkage of defouling enzymes to these membranes for the purpose of low-cost, low-maintenance ultrafiltration of water in rural areas for potable use. Techniques will be developed for the attachment of enzymes to the membranes. For this purpose, various enzymes will be investigated in terms of their ability to attach to the membrane surfaces and their efficiency in breaking down fouling layers on the membrane. The research will be performed on fouling layers consisting of organic components, such as proteins, tannins, fats and carbohydrates. It is hoped that membranes will be produced with attached enzymes, exhibiting self-cleaning capabilities and reduced fouling owing to removal of the gel layer by these degradative enzymes.

Estimated cost: R48 000
Expected term: 1997

Polymeric and ceramic-based membranes for use in electromembrane reactors

(No 844) Department of Applied Chemistry, University of the Western Cape

The fouling of ion-exchange membranes by large organic anions together with their low chemical, mechanical and thermal stability, imposes serious limitations on electromembrane separation processes and effluent reactors. This results in lower process efficiency and increased energy expenditure. Chemical and electrochemical pretreatment techniques could be developed to reduce these problems. The use of high-flux modified membranes could result in great savings with regard to both capital and operating costs.

The objectives of the research programme are as follows:

- The development of new chemical and electrochemical pretreatment methods to improve the anti-fouling characteristics of existing ion-exchange membranes and production techniques for novel non-fouling membranes.
- The development of cation-exchange membranes with increased transfer number for monovalent ions.
- The production of polymeric and ceramic ion-exchange membranes with increased chemical stability and incorporation of these novel membranes into electrodialysis and electromembrane reactor units.

Estimated cost: R192 000
Expected term: 1997-1999

Development of a continuous-flow membrane bioreactor

(No 846) Department of Microbiology, University of the Western Cape

The biodegradation of hydrophobic pollutants is extremely difficult. Surfactant addition enhances the solubility of hydrophobic organic compounds in aqueous phase, mobilising them into a form more readily available for conventional pump-and-treat strategies. Surfactants of biological origin have distinct advantages over synthetic surfactants due to their biodegradability and their effectiveness at extreme temperature, pH and salinity.

This project is aimed at developing new bioreactor technology for the stabilisation of hydrophobic pollutants in aqueous phase for subsequent biodegradation by a fungal system. *Pseudomonas aeruginosa* will be grown as a biofilm on a permeable membrane with hydrophilic surface properties. The biofilm will be perfused with hydrophobic pollutant and with water to yield an oil-in-water emulsion for biodegradation by the fungal system. The fungal system consists of *Phanerochaete chrysosporium* seeded into the trumpet-shaped wall of the outer-skinless ultrafiltration membrane developed by the Institute for Polymer Science of the University of Stellenbosch.

Estimated cost: R176 000
Expected term: 1997-1999

Development of transverse-flow membrane modules for use in bioreactors

(No 847) Institute for Polymer Science, University of Stellenbosch

Transverse-flow membrane modules are required for many commercial and industrial applications, because of their higher mass-transfer coefficient, modular design, individual stacking freedom and possible uses as bioreactors. Good progress has been made so far in the existing module development programme which has shown much promise with regard to the initial construction and design. A WRC-owned SA Patent protects the development carried out to date and further applications for patents on the improvements and scaling-up will be filed.

The objectives of the research programme are to:

- Design, develop and produce single-spacer layers with capillary membranes cast in position. Sealing gaskets will be used between layers to build a module.
- Compound an epoxy-compatible polymer with good chemical resistance for injection-moulding of spacers.
- Design, develop and fit manifold end-plates with suitable feed distributors to ensure an even flow over the membranes.
- Evaluate system performance as a membrane contactor device.

Estimated cost: R217 000
Expected term: 1997

Use of tolerant membranes for preparing drinking water as well as for water reuse, using solar power and electro-induced driving forces

(No 852) Institute for Polymer Science, University of Stellenbosch

Many diseases in South Africa are caused by drinking contaminated water. Therefore, a major challenge is the achievement of disinfected water and the removal of toxic materials. A possible answer lies in the use of novel electrolysis processes, consisting of package plants, using small, inexpensive solar cells and pumps, which can operate relatively trouble-free for long periods of time. Electrolysis effects the removal of organics and salts, the creation of peroxides and oxichlorides for sterilisation and the formation of metal coagulants.

The aim of this project is to hybridise the electrolysis process by incorporating the further process of electro-pervaporation in the same unit. In this way, waters containing bromides, chlorides or nitrates may be treated and these ions removed as bromine, chlorine and nitrogen gas. The system is intended for use by rural households, communities and industries as a simple, low-maintenance, low-power requirement process.

Estimated cost: R928 000
Expected term: 1997-1999

CONTACT PERSON

- **Dr G Offringa**
(Development and Application of Membranes)
e-mail: offringa@wrc.ccwr.ac.za
☎ **(012) 330-0340**

Research projects

Completed

- **548** Investigation into the upgrading of Orange River water and secondary sewage effluent by means of ultra- and nano-filtration (University of Stellenbosch – Institute for Polymer Science)
- **619** Tolerant membranes (University of Stellenbosch – Institute for Polymer Science)
- **632** Capillary membrane production development (University of Stellenbosch – Institute for Polymer Science)

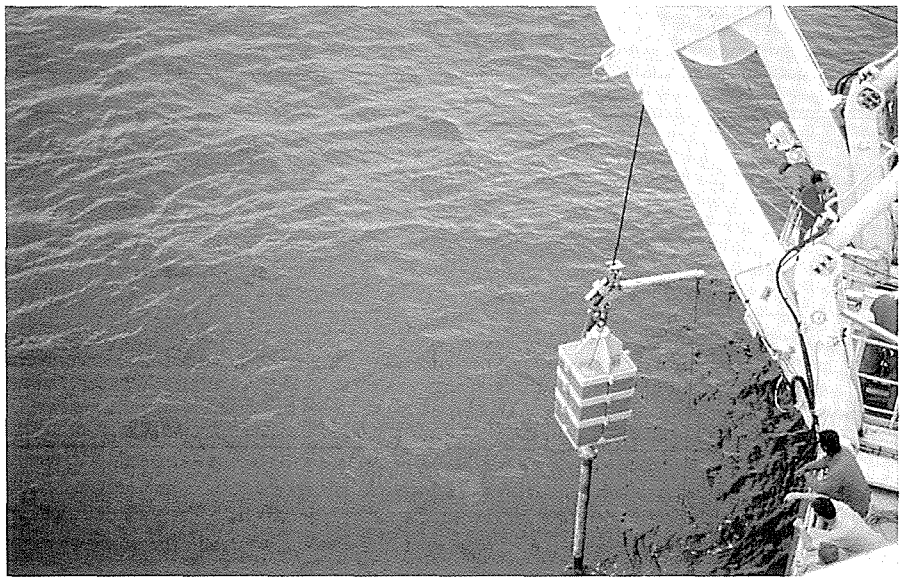
Current

- **201** Treatment of inorganic brines and concentrates (University of Natal – Pollution Research Group)
- **238** Design criteria for cross-flow microfiltration (University of Natal – Pollution Research Group)
- **618** Development of specialised cross- and transverse-flow capillary membrane modules (University of Stellenbosch – Institute for Polymer Science)
- **723** Designed functionalised polymers by anionic macromolecular engineering for membrane development (Vista University – Department of Chemistry (Port Elizabeth Campus))
- **728** Computer program for cross-flow module and potable water plant design (University of Stellenbosch – Institute for Polymer Science)

New

- **769** Development of a fabrication protocol for the production of capillary membranes and special modules for the low-cost treatment of contaminated water (University of Stellenbosch – Institute for Polymer Science)
- **791** Defouling of ultrafiltration membranes (Rhodes University – Department of Biochemistry and Microbiology)
- **844** Polymeric and ceramic-based membranes for use in electromembrane reactors (University of the Western Cape – Department of Applied Chemistry)
- **846** Development of a continuous-flow membrane bioreactor (University of the Western Cape – Department of Microbiology)
- **847** Development of transverse-flow membrane modules for use in bioreactors (University of Stellenbosch – Institute for Polymer Science)
- **852** Use of tolerant membranes for preparing drinking water as well as for water reuse, using solar power and electro-induced driving forces (University of Stellenbosch – Institute for Polymer Science)

10 HYDROCLIMATOLOGY



The research field, hydroclimatology, includes all weather- and climate-based research and development which can contribute meaningfully to the assessment and management of South Africa's water resources. In practice this translates mainly into researching ways of coping with rainfall variability and dealing with extremes of weather and climate which can place water resources systems and dependent communities under severe risk.

Precipitation enhancement through hygroscopic seeding of warm-based summer convective cloud systems is an emerging technology which has developed as a result of strong research support by the WRC, in collaboration with the Weather Bureau, since 1983. The technology is firmly grounded on an understanding of the microphysical and dynamic factors which influence the efficiency of thunderclouds as producers of rainfall. It depends on the use of a novel pyrotechnic seeding flare designed to dispense hygroscopic particles of appropriate sizes and concentrations required to accelerate the growth of cloud droplets by enhancing the collision-coalescence process. The immediate focus has now shifted away from further development of the technology towards assessing the benefits of area-scale pilot hygroscopic seeding operations. This shift in emphasis has coincided with the cessation of direct funding by the WRC. Funding is being taken over by prospective users of the technology, while the WRC will continue to be involved in a co-ordinating capacity during the remainder of the technology evaluation phase.

The **adequate monitoring of precipitation** is fundamental to water management in a country such as South Africa where precipitation is the dominant water resource. For some time there has been grave concern about the steadily diminishing number of reporting rain gauges in South Africa, at a time when the density of rain gauges should in fact be sharply increasing in response to the need for greater precision in the management of a resource being subjected to ever-increasing demands. Fortunately, the advent of weather radar as a device for quantitative rainfall measurement provides the potential of more than compensating for the reduced number of rain gauges. Radars have the additional capability of providing continuous areal coverage, whereas rain gauges provide point measurements only. Innovative research by the Weather Bureau and the University of Pretoria using the WRC's MRL-5 dual wavelength radar situated near Bethlehem, has shown clearly that supplementing rain gauges with a weather radar network for the continuous monitoring of precipitation in space and time should be fully realisable in South Africa. The pilot phase in the development of such a network is about to commence.

South Africa's rain-gauge records include many valuable daily time series, several stretching over many decades. Because of the large distances between rain gauges, there is a lack of information on spatial variability which makes it extremely difficult to interpret these rain-gauge data in terms of daily areal rainfall, a quantity which water resource engineers need to know in order to plan and design with confidence. Recently acquired radar maps of daily rainfall are starting to reveal typical spatial rainfall patterns associated with different weather systems. **Stochastic space-time models of daily rainfall**, are under investigation as a means of reproducing typical spatial rainfall patterns and solving the long-standing problem of spatial interpolation of rain-gauge data and of reducing point measurements to areal values.

The ability of water resource managers

to cope with extreme climatic situations and systematic climate change depends greatly on the degree of foreknowledge of such potentially serious extremes and trends. The WRC has been one of the main South African sponsors of research in this area over the past ten years. Statistical models for the **prediction of seasonal rainfall** have been developed and are under continuous refinement; outputs from these models contribute to the suite of seasonal forecasts available to the public from members of the South African Long-Lead Forecast Forum. The fact that forecasts are not always in agreement is a reflection of both the complexity of the climate system and the deficient understanding of the intricate mechanisms involved. Research projects which attempt to improve the understanding of mechanisms (**the role of the oceans** included) associated with periods of deficient and/or heavy rainfall, are being supported; results will hopefully be reflected in better and more consistent forecasts in future. Better forecasts are also ultimately expected from the use of numerical atmospheric circulation models, although statistical models at present still have the better forecasting skill. Research to develop the use of general circulation models for this purpose is now getting under way.

The outputs from general circulation models, which model the global atmosphere, are generally of too coarse a resolution to be used directly for regional applications, such as predicting either seasonal rainfall for zones within the region or the impacts of climate change on water resources of the region's catchments. The links between the global and regional scales must first be established. Extensive research on **downscaling techniques** supported at the University of Cape Town, has recorded most promising progress.

In April 1997, three of the developing technologies with which the WRC has been closely involved came under the spotlight when the WRC was co-organiser of the International Workshop on Weather- and Climate-based Technologies to Benefit Water Resource Management. The workshop, which was held in Pretoria, was sponsored by the USA's National Oceanographic and Atmospheric Administration (NOAA), the South African Government and the World Meteorological Organisation. The technologies which were the focus of the workshop were seasonal forecasting, monitoring and enhancement of precipitation. The goal of the workshop was to bring together atmospheric scientists and water resource practitioners to spell out further development needs for ensuring that these technologies realise their full potentials within the context of water resources management.

Completed projects

Evaporation measurements above vegetated surfaces using micrometeorological techniques

(No 349) Department of Agronomy, University of Natal

Besides rainfall, the most important factor affecting water supply from a catchment is the evaporation (including transpiration) from the catchment's vegetation, whether it be climax grassland or commercial forest. Prior to this project, there was no capability of obtaining direct measurements of catchment evaporation. The aim of this project was to develop certain micrometeorological methodologies, specifically based on Bowen ratio energy balance (BREB) and eddy correlation (EC) techniques, for measuring evaporation, or water use, by catchment vegetation. Further aims were to study and account for all sources of error, test methods rigorously for accuracy and precision and assess their potential for routine use in catchment water balance quantification.

This project succeeded well in identifying the strengths and limitations of the micrometeorological techniques under investigation. BREB and EC techniques were successfully used over climax grassland in the Drakensberg, a maize canopy, a vineyard site and bare soil. A sound foundation has been laid for wider use of the techniques in catchment water balance studies. Indeed, based on preliminary results of this project, there have already been successful applications of especially the BREB technique in several other hydrological investigations.

Cost: R349 000
Term: 1991-1995

Assessment of the potential for using stable carbon isotope ratios of wood charcoal as a climate indicator

(No 437) South African Museum, Cape Town

This project followed on from a previous project undertaken by the South African museum which revealed that physical dimensions of xylem vessels in wood (either natural or charcoaled) of *Protea* and *Combretum* spp. growing over a wide range of climatic conditions correlated well with seasonal rainfall totals. Xylem anatomy of charcoal of the same species in archaeological deposits was then used to contribute information towards the reconstruction of South Africa's palaeoclimatic record. The project now completed aimed at establishing whether stable carbon isotope ratios of the archaeological charcoal samples could provide further information for palaeoclimatic record reconstruction. Unfortunately, significant correlations between stable carbon isotope ratios of wood cellulose and rainfall were lost when wood was charcoaled, probably because of a variable isotope fractionation factor. The conclusion reached was that the use of stable carbon isotope ratios of charcoal in archaeological deposits has limited potential for climate reconstruction. Useful findings did, nevertheless, emerge from earlier steps in the investigation. Firstly, *Widdringtonia cedarbergensis* from the Cedarberg in the Western Cape was shown to have considerable potential for dendrochronological analysis; secondly, the water consumption of *Eucalyptus* cuttings grown under a range of conditions correlated well with stable carbon isotope ratios of wood cellulose.

Cost: R389 000
Term: 1992-1996

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

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

Anthropogenic increases of atmospheric CO_2 and other so-called greenhouse gases are almost certain to be reflected in a trend towards global warming. This will be accompanied by shifts in precipitation

patterns and probably also enhanced precipitation variability. Whereas general circulation models (GCMs) provide a means of predicting these changes on a global scale, the inability to translate global-scale predictions into regional-scale predictions has greatly limited any attempts to carry out assessments of climate change impacts on South Africa's water resources. The aims of this project were, therefore, to validate GCM simulations of atmospheric controls on South African precipitation and temperature patterns, to develop a new non-linear methodology for deriving cross-scale climate relationships and to develop preliminary estimates of regional climate changes suitable for use as input to hydrological and agricultural models. The down-scaling procedure developed was based on artificial neural nets. Both short- and long-term variabilities in current regional climates were successfully captured as a function of both the larger-scale observed circulation and the GCM-modelled circulation. Once tested in this manner, the down-scaling procedure was applied to GCM-simulated circulations under double the present-day CO_2 conditions, thereby generating preliminary scenarios of expected temperature and rainfall changes for different parts of South Africa.

Cost: *R113 300*
Term: *1994-1996*

Modelling rainfall-producing systems over Southern Africa

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

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

The aim of the project was to model the thermodynamic and kinematic structure of tropical-temperate troughs and their rainfall production over Southern Africa using the Colorado State University Regional Atmospheric Modelling System (CSU RAMS).

The RAMS model provided accurate simulations of circulation conditions for tropical-temperate troughs in Southern Africa. It also provided new insights into the structure and evolution of tropical-temperate troughs and of the characteristics of the Walker Cell circulation. Hypotheses concerning large-scale circulation controls over tropical-temperate troughs as well as the moisture sources and rainfall distributions of these systems were confirmed. The major sources of moisture for the development of large-scale synoptic features were further highlighted by Lagrangian trajectory modelling of rain days and no-rain days.

Cost: *R449 000*
Term: *1994-1996*

Development of an objective system to forecast summer rainfall over Southern Africa

(No 672) Department of Oceanograpy, University of Cape Town

Previous research had shown seasonal rainfall forecasts to be both feasible and potentially beneficial for managing water resources, planning crop production and minimising risks associated with year-to-year fluctuations in rainfall. This project was undertaken to introduce a greater degree of objectivity into the forecasting process by identifying atmospheric and oceanic precursor patterns which anticipate summer rainfall, to formulate reliable predictors of summer rainfall and associated impacts, to develop multivariate algorithms to skilfully predict area-rainfall and associated impacts, and to further analyse dynamic interactions underlying seasonal rainfall.

Multivariate linear regression models were developed for both summer rain and for certain climate impacts, using standard statistical software.

The number of predictors per model was restricted to four or five, out of an initial 100 candidate predictors. For nine rainfall models, typical predictors included global indices such as the Southern Oscillation Index (SOI) as well as sea surface temperatures, convection indices and surface and upper air winds associated with various oceanic areas. The multivariate models were validated using the jack-knife technique and were found to possess acceptable skill.

Cost: *R600 000*
Term: *1995-1996*

National precipitation research programme with a view to rainfall enhancement

(No 726) Company for Research on Atmospheric Water Supply (CRAWS) and Department of Environment Affairs (Weather Bureau), subcontracting CloudQuest (Pty) Ltd and Unisa

The national precipitation research programme commenced in 1990 and a final report for the period 1990 to 1993 has already been issued. The key development during that period was the initiation of a randomised hygroscopic seeding experiment based on insights gained during preceding research into the potential of enhancing rainfall through the seeding of warm-based summer convective clouds.

The objectives for the current reporting period (1994 to 1996) comprised the following:

- To continue and complete the randomised hygroscopic seeding experiment.
- To obtain further confirmation of the hygroscopic seeding hypothesis with the help of microphysical measurements, chemical sampling and numerical modelling.
- To improve the utilisation potential of radar for real-time storm tracking and areal rainfall measurements.
- To undertake pilot studies and planning activities needed prior to the initiation of an areal rainfall enhancement experiment.

The randomised hygroscopic seeding experiment was successfully concluded. Storms which were seeded produced statistically significantly larger amounts of rain (on average 30%) than clouds not seeded. Microphysical measurements and numerical modelling confirmed that

hygroscopic seeding greatly accelerated the collision-coalescence growth of cloud particles to precipitation sizes. Chemical sampling, intended to provide information on the dispersal of seeding material throughout the storm, was unfortunately less successful. Excellent progress was made with the use of radar for both storm tracking and areal rainfall measurement in real time. Finally, the initiation of an emergency cloud-seeding operation in the Northern Province in March 1995 gave enormous impetus to the planning of a pilot operational areal rainfall enhancement project, due to commence in the 1997/98 summer. WRC support for rainfall enhancement research came to an end in March 1997, with most of the objectives successfully achieved.

Cost: *R24 181 000*
Term: *1990-1997*

Palaeoclimatic database for Southern Africa

(No K8/178) Climatology Research Group, University of the Witwatersrand

Partial support was provided by the WRC for an initiative to compile a palaeoclimatic database for Southern Africa, as part of an international project on Palaeoclimates of the Southern Hemisphere. Using information in the database, trends in hydrological and thermal parameters have been compiled on maps of Southern Africa using the ARC/Info GIS. While the data available span the period from 130 000 years ago to the present, inferences relating to the most recent 12 000 years are particularly interesting. For the first time, thanks to the detailed maps made possible by the development of this large database, distinctive patterns of prehistoric wetting and drying in different regions in South Africa are being revealed.

Cost: *R28 000*
Term: *1995-1996*

New projects

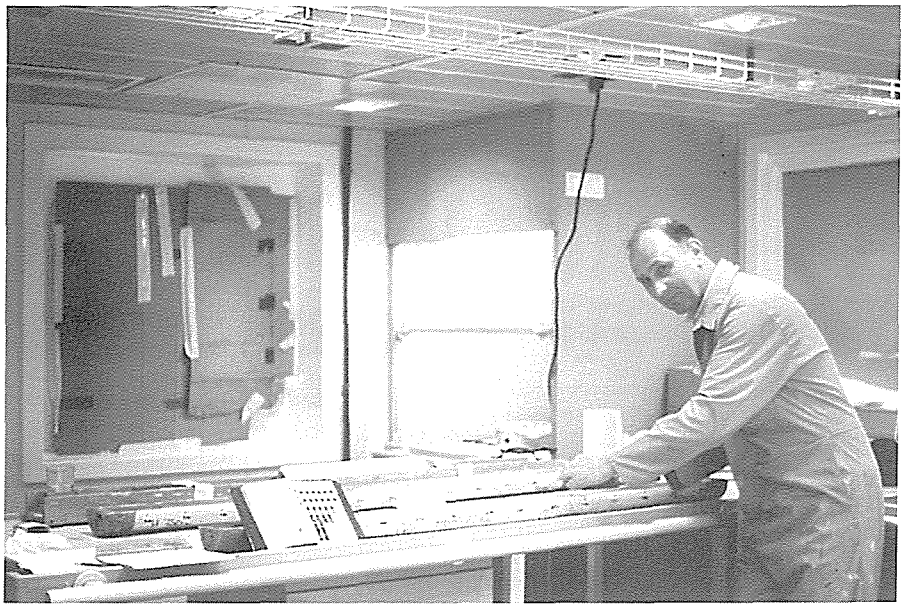
Acquisition of off-shore marine sediment samples for palaeoclimatic and hydrological record reconstruction

(No 804) Climatology Research Group, University of the Witwatersrand

It is now widely accepted that recent world-wide changes in climate are beyond the limits of natural variability and are probably due to a century-and-a-half of industrial activity and other human influences. In order to complement general circulation modelling in developing the best scenarios of possible future climate change, which will in all probability impact on water resources and food security, it is essential to obtain regional records of past climatic and hydrological changes and variability.

An opportunity recently arose for the WRC to facilitate a major new thrust in this direction by assisting South African scientists in obtaining research material of great potential value for augmenting current records of past hydroclimatic variability. As part of an international research programme, a French research ship, capable of collecting off-shore marine sediment

Thirty-metre corepipe used to obtain sediment samples on the continental shelf.



John Rogers of the University of Cape Town's Department of Geological Sciences, describing piston cores aboard the *Marion Du Fresne*.

cores in excess of 30 m deep, was due to cruise through the Benguela Current areas off the coast of Southern Africa. This presented a uniquely valuable and inexpensive opportunity for a South African investigator to participate in the cruise in order to locate and obtain samples of cores from key locations near the land. Preserved in the sediments to be sampled are unique records of palaeohydrological changes. Samples obtained will be available for in-depth study by a wide range of South African scientists over many years.

Estimated cost: R140 000
Expected term: 1997

Modelling of extreme rainfall over Southern Africa

(No 805) Climatology Research Group, University of the Witwatersrand

Heavy rainfall events can be life-threatening or life-saving, or both. For sound planning and sufficiently early warning, early recognition of conditions which give rise to such events is vitally important. This importance may even increase over the next few decades, given strong indications that one of the effects of changing global climate is an increase in variability and frequency of extreme conditions. Extremely wet conditions may span a wide range of time scales, from the event scale (a few days) through seasonal to multi-seasonal scales. A WRC project completed by Wits University concentrated on the multi-day event and the development of mesoscale modelling techniques to explain mechanisms associated with such relatively short-lived rain-producing systems. The modelling approach proved successful but needs to be applied and evaluated for more test cases – something which could not be done prior to the conclusion of that project.

This new project is expected to fulfil this need and will also investigate and clarify mechanisms associated with wet periods of longer duration (such as those of the 1995/96 summer) which have not, up to now, been adequately explained or predicted.

Estimated cost: R538 000
Expected term: 1997-1999

Dynamic modelling to investigate the regional climate response to global change

(No 806) Department of Environmental and Geographical Science, University of Cape Town

It is becoming increasingly clear that to ignore the threats (or opportunities) global climate change poses to different sectors of Southern African society, would be very irresponsible. While predictions of a range of general circulation models (GCMs) are beginning to converge and provide greater confidence in predictions at a global (coarse resolution) scale, many countries, including South Africa, are grappling with the problem of interpreting likely global changes in terms of what can be expected locally within their own regions.

Some years ago the WRC started providing support to the University of Cape Town to initiate work on the problem of regionalising GCM forecasts of global climate change, specifically as far as precipitation patterns are concerned. Initial work adopted an empirical approach in terms of which variations in the global atmospheric circulation patterns at typical GCM scales are linked to regional precipitation patterns using an artificial neural net approach. Linkages which have been established appear to be satisfactory and are currently being used to establish a set of regional climate change scenarios which will form the basis for immediate hydrological and agricultural impact analyses.

However, the main weakness of the empirical approach is that linkages are not based on an understanding of the complex physical and dynamic processes underlying the climate system. Through enhanced international networking, advances in computing power and recent refinements in limited-domain, high-resolution models, it has become possible for the new project to adopt the more mechanistic, modelling approach to the question of regionalising global change predictions.

Estimated cost: R339 000
Expected term: 1997-1999

Modelling variability in the Agulhas current system and its influence on South Africa's climate

(No 868) Department of Oceanography, University of Cape Town

In recent years there has been increasing recognition of the importance of ocean processes in regulating South Africa's weather and climate and good progress has been made in identifying key ocean areas where temperature anomalies correlate well with rainfall variability over South Africa.

Associated with this progress has been the recognition of certain ocean-based predictors which are useful in generating long-range precipitation forecasts for South Africa.

While most research to date has been based on exploring statistical linkages between historical records of oceanic, atmospheric, satellite-derived and precipitation variables, there is also an ongoing process study involving actual measurements of heat and water vapour additions to the atmosphere in the important Agulhas Current region. Modelling studies have, as yet, received very little attention.

This project proposes to introduce a strong modelling component to the ocean-climate interaction programme and, more specifically, to investigate the relationships between Agulhas system processes and conditions which favour the evolution and positioning of important rain-producing weather systems over South Africa.

Estimated cost: R621 000
Expected term: 1997-2000

Research projects

Completed

- **349** Evaporation measurements above vegetated surfaces using micro-meteorological techniques (University of Natal – Department of Agronomy)
- **437** Assessment of the potential for using stable carbon isotope ratios of wood charcoal as a climate indicator (South African Museum – Cape Town)
- **594** Regional climate change scenarios for precipitation and temperature from general circulation models (University of Cape Town – Department of Environmental and Geographical Science)
- **595** Modelling rainfall-producing systems over Southern Africa (University of the Witwatersrand – Climatology Research Group)
- **672** Development of an objective system to forecast summer rainfall over Southern Africa (University of Cape Town – Department of Oceanography)
- **726** National precipitation research programme with a view to rainfall enhancement (Company for Research on Atmospheric Water Supply (CRAWS) and Department of Environment Affairs (Weather Bureau), subcontracting CloudQuest (Pty) Ltd. and Unisa)
- **K8/178** Palaeoclimatic database for Southern Africa (University of the Witwatersrand – Climatology Research Group)

Current

- **374** Southern Agulhas current and its influence on the weather and climate of Southern Africa (University of Cape Town – Department of Oceanography)
- **550** Development of models to stochastically generate spatially distributed daily rainfields (University of Natal – Department of Civil Engineering)
- **596** Development of a real-time non-conventional rainfall mapping system for coastal zone cloud systems (University of Pretoria – Department of Civil Engineering)
- **693** Weather radar measurement of rainfall as well as hydrological applications of weather radar (University of Pretoria – Department of Civil Engineering)
- **751** Analysis of regional precipitation and water resource impacts from GCM-derived regional climate change scenarios (University of Cape Town – Department of Environmental and Geographical Science)
- **752** Spatial and temporal modelling of rainfields using fractals (University of Natal – Department of Civil Engineering)

New

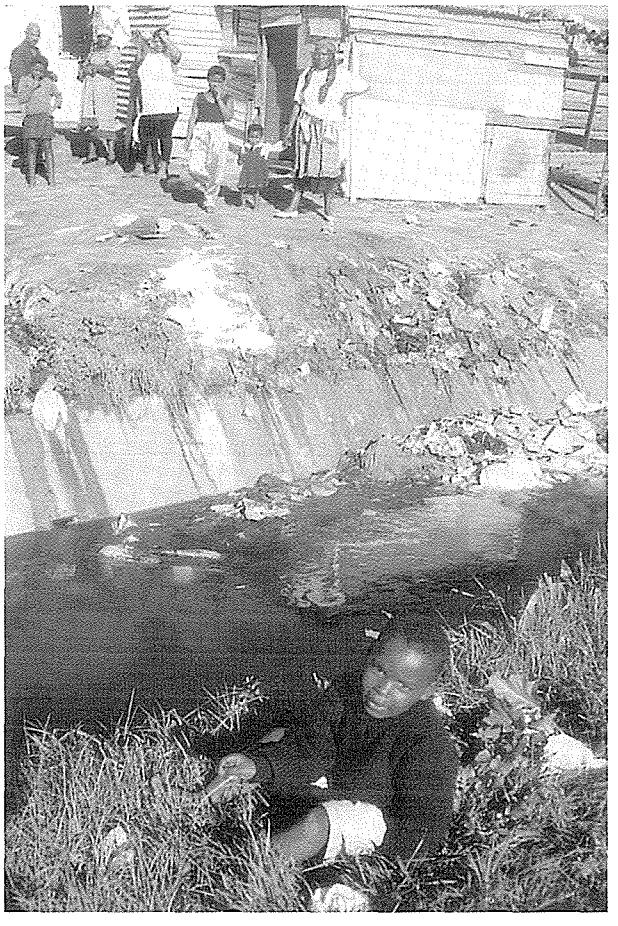
- **804** Acquisition of off-shore marine sediment samples for palaeoclimatic and hydrological record reconstruction (University of the Witwatersrand – Climatology Research Group)
- **805** Modelling of extreme rainfall over Southern Africa (University of the Witwatersrand – Climatology Research Group)
- **806** Dynamic modelling to investigate the regional climate response to global change (University of Cape Town – Department of Environmental and Geographical Science)
- **868** Modelling variability in the Agulhas current system and its influence on South Africa's climate (University of Cape Town – Department of Oceanography)

CONTACT PERSON

- **Dr GC Green**
  e-mail: george@wrc.ccwr.ac.za
  ☎ **(012) 330-0340**

11

INTEGRATED WATER RESOURCE MANAGEMENT



The year 1997 will be remembered as the year in which the new Water Act took final shape. Few could have predicted some years ago that a Water Act would soon employ terms such as: "water management areas", "water resource classification", "determination of the reserve", "resource quality objectives", "water allocation plans", "integrated catchment management strategy" and "catchment management agencies".

The meaningful implementation of the new Act will create enormous challenges for the water resources community and the adequacy of our hydrological information, knowledge and management skills (wisdom) will be tested over a wide front. At the same time our future research activity will also be judged by the way it supports the successful implementation of many aspects of the new Water Act. This Act will also enable the research community to achieve greater harmony in setting research objectives.

The number of directly involved stakeholders is about to increase. More than ever before it is necessary to ask whether water research and data collection efforts provide enough appropriate information to enable sound, wise and comprehensive water management to be practised nationwide.

Research into motivating human behaviour and achieving public participation in the best way will require additional attention. Research to develop procedures which should enable a diverse community of water resource stakeholders to reach consensus on at least the main issues in their area has become of vital importance.

Completed projects

Development of a distributed hydrological modelling system to assist with water quantity and quality management in the Mgeni catchment, Phase II

(No 375) Department of Agricultural Engineering, University of Natal

The ACRU hydrological model was configured for the Umgeni catchment upstream of Inanda Dam to simulate daily streamflow for 137 subcatchments for a 34-year period from 1 January 1960 to 31 January 1993.

Specific attention was paid to the following scenarios:

- Streamflow under current conditions
- Streamflow under pristine (Acocks veld type) conditions
- Streamflow under impact of some current land uses
- Impact of possible future land-use scenarios.

Simulated streamflows were verified against observed data for a limited number of subcatchments. All verifications gave a coefficient of determination above 78%. In all cases simulated streamflow was within 6% of the observed values.

It was found that the simulated impact of present land uses compared with pristine conditions can be highly significant. In highly urbanised catchments runoff can double while extensive forest development can decrease streamflow by more than 60%.

The model used a recently modified universal soil loss equation on a grid of 250 x 250 m using GIS-based digital terrain models. The mean annual sediment yields for the 137 subcatchments varied from 2 to 629 t/km^2, the highest to be found in the degraded parts of the Valley of a Thousand Hills. Simulations also highlighted how rare single and even local events dominate long-term sediment delivery.

Based on the previous approaches a phosphorus pollution potential map was produced with values ranging between 250 to more than 4 800 kg/km^2.a. In one modelling scenario, an increase in subsistence type farming and informal settlement in the Mzundizi catchment caused sediment delivery to increase by 17%, phosphorus to increase by 76% and *E. coli* concentrations by 40%.

Cost: *R1 228 908*
Term: *1991-1994*

Groundwater abstraction in the Port Elizabeth municipal area

(No 515) SRK (CE) Inc. and the Municipality of Port Elizabeth

The drought experienced in the Eastern Cape during the latter part of the 1980s and the early 1990s resulted in an acceleration in the drilling of new private boreholes in the Port Elizabeth municipal (PEM) area. Port Elizabeth is situated mainly on the sandstones of the Table Mountain Group (TMGS) which, by South African standards, can be considered a major fractured rock aquifer. However, its close proximity to the sea poses a real threat in terms of sea-water intrusion into the aquifer which may, in turn, render it useless as a source of high quality drinking water.

The primary aim of the research project was consequently to determine the distribution of boreholes and volume of groundwater abstracted from the TMGS aquifer in the PEM area and to formulate suitable guidelines for the control of groundwater development and protection of the aquifer in terms of groundwater quality and volumes of water abstracted. In particular the potential for saline intrusion to the aquifer is to be investigated.

Contrary to popular belief, it was estimated that only some 300 boreholes are utilised in the PEM area. Total groundwater abstraction was estimated to be 370 000 m^3/a.

There is sporadic and short-lived intrusion of saline water in those boreholes closest to the sea in the Summerstrand area. This is currently a local and non-permanent phenomenon but there is potential for a deep incursion of saline water into the aquifer under higher pumping conditions, should drought conditions return.

There is evidence of groundwater contamination in many areas on the basis of conductivity, chloride and nitrate levels, especially when compared to groundwater quality in TMGS aquifers found elsewhere in the country. The contamination is attributed to urbanisation and, specifically old waste dumps, fertilizer application, irrigation with treated effluent, leaking sewers and stormwater runoff.

Cost: *R191 000*
Term: *1993-1995*

Integrated catchment management approaches for South Africa

(No 682) Division of Water, Environment and Forestry Technology, CSIR

A report entitled *The Philosophy and Practice of Integrated Catchment Management: Implications for Water Resource Management in South Africa* has been produced as a Water Law Review discussion document. The document has proved to be a concise, clear guide for a range of organisations interested in integrated resource management.

Ideally, South Africa should aim to shift gradually from a situation where integrated catchment management (ICM) is regulated and controlled at central and regional government levels to the community-based self-regulatory approach aimed for in Australia. This would allow sufficient time for learning and the development of an appropriate skills base to enable expansion of ICM from the present relatively small core of skilled people at central and regional government level. A gradual approach would also enable different models used in other countries to be assessed and the best facets to be applied locally in a logical and structured manner.

On the ground, this would take the form of identifying priority catchments, and working initially with a catchment forum, or some similar participatory organisation. The forum could be gradually developed into a catchment committee, taking more responsibility and accountability as local capabilities are developed and enhanced. The next step could be the development and constitution of a catchment board or authority, whose legal, executive and fund-raising status would depend on the needs of the local situation.

Cost: *R188 580*
Term: *1995-1997*

New projects

Multi-level decision support for the control of alien invasive plants in South Africa

(No 807) Division of Water, Environment and Forestry Technology, CSIR

Fast-growing exotic trees under cultivation and alien invader species are significant users of water resources, and there is a pressing need for decision support in their management and control. South Africa is currently spending in the region of R100m./a on the control of invasives and decision-makers in the present "Working for Water" programme have expressed the need for the development of such a decision-support system (DSS) to allocate this funding most effectively.

This project will synthesise knowledge and expertise gained through past and current research on vegetation/water interactions and on alien invasive plants to produce practical decision support for their control. The aim is to structure the DSS in such a way that it will stimulate necessary co-operation at various levels and also serve as a framework for policy-making and implementation of institution and organisational solutions related to the national control of invasives.

At the one extreme, presenting the broader issues renders the product of value to policy-makers and the public; at the other, researchers studying the detailed biological mechanisms in this area would have access to background information and be able to experiment with models of growth, spread and water usage. The system will highlight research needs, facilitate careful selection of variables and indicate what data to collect at what resolutions.

Three types of target audience have been identified, each with their own specific interest:

- Policy-makers: generally operating at a national scale but recognised at lower levels.
- Landowners/managers and catchment agencies: for the effective management of water resources at a catchment scale.

- Research and educational organisations: for use in appropriate educational and awareness programmes.

Estimated cost: R353 000
Expected term: 1997-1998

Econometric and institutional economic analysis of water use in the Crocodile River catchment, Mpumalanga Province, South Africa

(No 855) Economics Unit, European Science and Environment Forum

The use of water in South Africa has in the past been inextricably linked to land. Water supply services have also been subsidised and, consequently, land prices have been artificially high. This has rendered entry into e.g. farming unnecessarily expensive, sent out the market signal that water was abundant and cheap, while the inability to trade in water rights led to water wastage and distorted water allocation patterns.

As a result, users do not know what the true costs of water supply are and there is no appreciation of real opportunity costs. Therefore, it is unlikely that water is being used or reallocated efficiently. Policy-makers in the past relied on engineering solutions to water problems, transferring water from one location to another to meet the demand for that water. There is often an over-estimation of the benefits of water development, of which government irrigation projects are a prime example.

This research will provide an objective estimate of the value of water to the local community. It is anticipated that with the measurement of the value of water to different users and, with policy based on this analysis, a more efficient and sustainable allocation of water will result. This should lead to greater prosperity for the region, as water will be used for the highest valued uses (subject to social considerations), as well as to empowerment of local people who will be entitled to obtain the benefits of their share.

Estimated cost: R112 000
Expected term: 1997-1998

Development of group decision-support methods to facilitate participative water resource management

(No 863) Department of Statistical Sciences, University of Cape Town

It is widely accepted that water resources planning must increasingly involve public participation in the decision-making process. Such participation implies a two-way flow of information. On the one hand the public participation must inform planners and political decision-makers as to the goals, preferences and aspirations of the groups or communities they represent. On the other hand the public needs to be informed of the consequences of different policy options, as established by research, in order that the preferences they express be fully informed. This creates the need for DSSs and procedures to facilitate this process. Although specific problems may require specifically designed DSSs, the aim of the proposed project is to develop a general framework for the design of such systems, as well as a decision support "shell" which can be used for rapid development of specific DSSs.

Techniques to assist different interest groups in evaluating different "policy scenarios" for water resource planning, particularly from the point of view of the more intangible criteria, have been developed in a previous project. While these techniques are already operationally usable, the increasing need for involvement by ever-widening sectors of the society requires further enhancements.

Key issues which need to be addressed are:

- Facilitation of the process of identifying alternative courses of action: Although the previous work did give some attention to this issue, it was still implicit that planners would propose alternatives, which would then be evaluated and modified by interested and affected parties. True public participation implies that all such parties should have the opportunity to generate feasible options, and this requires additional support to facilitate the process of learning and understanding (by community representatives) the consequences of alternative actions.
- Facilitation of the process of identifying relevant criteria or points of view for evaluating alternative policies: Many groups will enter the evaluation process with uncertainty regarding even their own goals, and the support systems need to help them reach greater clarity regarding the criteria according to which they may best be able to make comparisons between alternative policy options.

Estimated cost: R628 000
Expected term: 1997-1998

Integrated catchment management in an urban context: The Great and Little Lotus Rivers, Cape Town

(No 864) Abbott Grobicki (Pty) Ltd.

Integrated catchment management (ICM) is a concept which offers the analytical tools for dealing with the conflicting needs of water and effluent management, water quality, river ecology, and the communities and economic activities within the catchment area. It has not yet found much application or resonance in South Africa, especially within the urban context. Most catchment management work done to date in urban areas has focused on stormwater management.

The catchment area of the Little and Great Lotus Rivers, both draining into Zeekoeivlei and from there into False Bay, has been shown by numerous studies to exhibit many of the characteristics of polluted and degraded rivers. Bacteriological counts and nutrient levels are very high and rising, especially in the Great Lotus River, and there are problems with litter and solid waste. The inflow of raw sewage poses a health hazard to inhabitants of the area adjacent to the river. The extent of chemical and industrial pollution has not been quantified.

The catchment contains an area of intensive agriculture, as well as densely populated urban areas with both formal and informal settlements. There are thus both point sources and diffuse sources of pollution, which have contributed towards the notorious situation developing of Zeekoeivlei becoming a hypertrophic coastal lake.

The purpose of this project is to provide a blueprint for urban catchment manage-

ment in South Africa. In particular, the approach developed in this project focuses on water quality and on rehabilitation strategies, as well as on the involvement of the local communities in the catchment area. The improvement of water quality from the Lotus catchment and Zeekoevlei will in turn have a beneficial impact on the water quality in False Bay. The development of strategies for community management of the catchment is essential to ensure that the improvement and upgrading of the catchment are sustainable.

Estimated cost: R1 000 000
Expected term: 1997-1999

Operational model of the Orange River

(No 865) BKS (CE) Inc.

A recent BKS study highlighted the importance of the evaporation losses from the Orange River as well as the problem of releasing the correct volume of water from Vanderkloof Dam to ensure that the demands associated with the downstream users can be supplied without allowing too much spillage from the system into the Atlantic Ocean. The problem of estimating the river losses is currently the subject of a study being funded by the WRC.

The releases from Vanderkloof Dam into the Orange River have not been considered a problem until quite recently. Prior to 1992, there was always excess water in the system with the result that water, well in excess of other downstream demands, could be released primarily for power generation. This resulted in considerable spillage from the Orange River into the Atlantic Ocean which was also significantly in excess of the environmental requirements at the river mouth.

A sharp increase in competing water demands and a period of below-average runoff have changed the situation dramatically, giving rise to a need for operational modelling of the Orange River. It is envisaged that by using the modelling approach to schedule river releases from the Vanderkloof Dam, annual savings in the order of 200 million m^3/a will be achieved.

Estimated cost: R968 000
Expected term: 1997-1998

The development of strategies for community management of the catchment is essential to ensure that the improvement and upgrading of the catchment are sustainable.

Community-based integrated catchment management programme with special reference to sustainable resource use in the Mlazi catchment

(No 866) Farmer Support Group, University of Natal

The Ntshongweni catchment, located between Durban, Pietermaritzburg and the Hammarsdale/Mpumalanga industrial/residential complex, is a microcosm of South Africa. Virtually all of the problems encountered in the various communities and activities around the country are found in this catchment.

In 1995 the WRC contracted the Farmer Support Group of the University of Natal to undertake a pilot project aimed at involving all communities living in the catchment in activities aimed at rehabilitation and integrated management of the catchment. The pilot project is drawing to a close, but has demonstrated the feasibility and potential value of a larger project to develop a framework for community-based ICM in South Africa, with special reference to sustainable resource use in the greater Mlazi catchment.

The aims of this project are to:

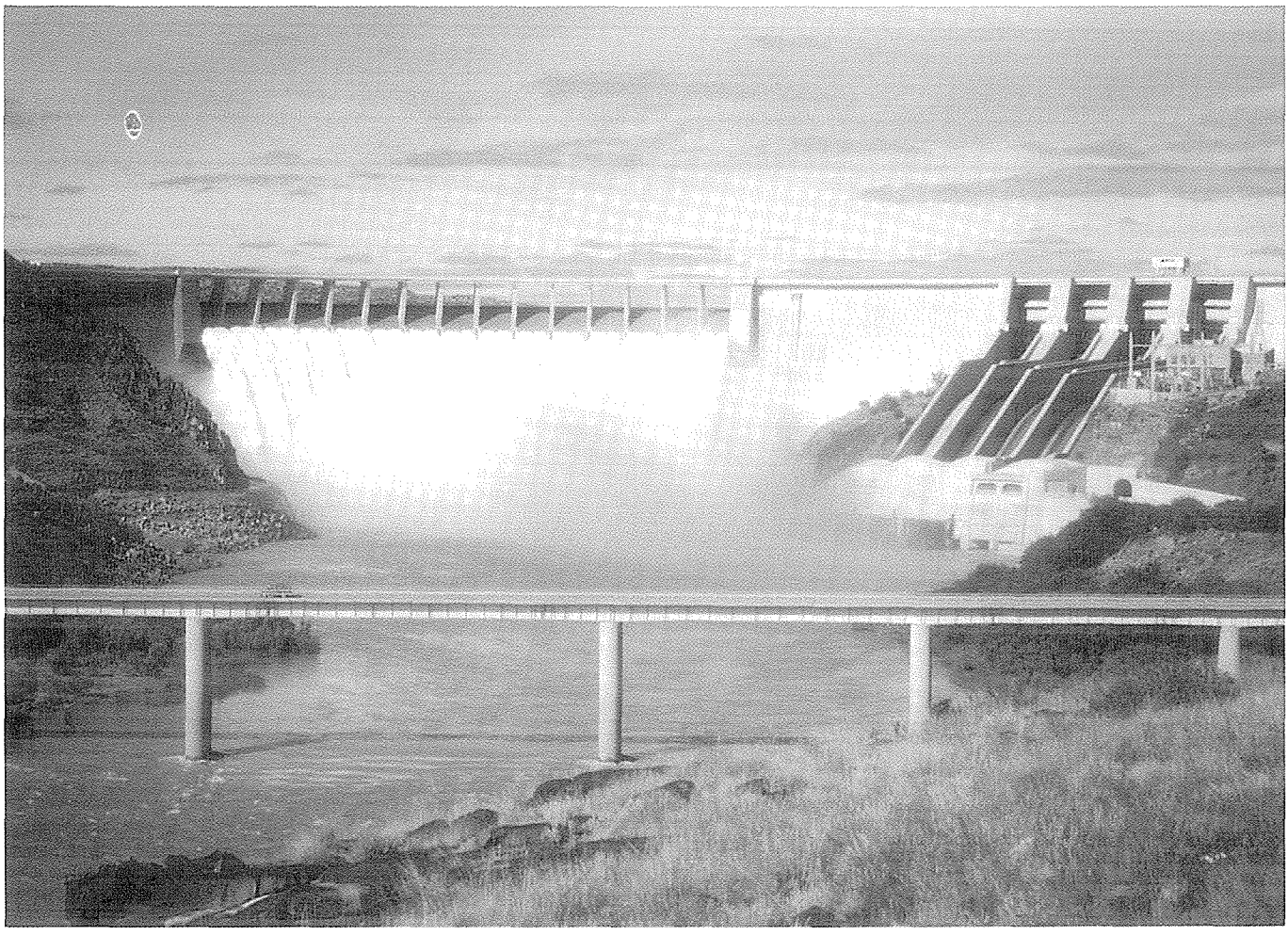
- Help build the institutional capacity needed for informed local control of the planning and exploitation of natural resources in the catchment.
- Help appropriate agencies to understand local people's current attitudes to the catchment and its resources, and help the agencies develop educational programmes which will improve aspects of catchment management.
- Assist local people in implementing ecologically and economically sound land-use practices.
- Monitor biophysical factors such as water and vegetation, and also monitor participation of people in the management of selected areas of the catchment in order to evaluate the effectiveness of the programme, and to plan future interventions on a catchment-wide scale.

The pilot project has been a learning exercise in how to involve local people in the effective management of all seven of the major land uses encountered in the area (commercial forestry, grazing, commercial arable agriculture, subsistence agricul-

ture, conservation, urban development and industry). Major emphasis in the rural areas is on developing viable ecological farm and forestry management systems, with special attention to the management of wetlands and vegetation. Similarly, in areas of urban and industrial activity, the development of an environmental ethic among the people is proving to be necessary.

The project requires a practical engagement on the ground aimed at supporting local activities, strengthening local institutions, helping to educate people living in the catchment and monitoring the whole process to learn as much as possible about the nature of participatory catchment management. Strengthening local interest groups is a prerequisite to the establishment of an Mlazi Catchment Management Committee. Reconstruction and development in South Africa require a broadening of access to resources. Within the context of a catchment such as this, there are unique possibilities for building synergies based on the dual economy of the area. The development of an "Mlazi Catchment Identity" will result in people sharing expertise which will benefit the catchment as a whole.

Estimated cost: R1 700 000
Expected term: 1997-1999



Vanderkloof Dam spilling, taken during a field trip which formed part of the study on the Orange River.

Research projects

Completed

- **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)
- **515** Groundwater abstraction in the Port Elizabeth municipal area (SRK (CE) Inc. and the Municipality of Port Elizabeth)
- **682** Integrated catchment management approaches in South Africa (CSIR – Division of Water, Environment and Forestry Technology)

Current

- **526** Distribution of fluoride-rich groundwater in the eastern and Mogwase regions of Bophuthatswana: Influence of bedrock and soils and constraints on utilisable drinking-water supplies (University of Cape Town – Department of Geology)
- **640** Extension and refinement of the AQUAMOD computer software package (University of the Orange Free State – Institute for Groundwater Studies)
- **642** Development of a water information management database system for data capture and processing at local authority level (University of the Orange Free State – Institute for Groundwater Studies and DWAF)
- **666** Holistic, catchment-scale, comparison of water-use efficiency of crops, focusing on the comparison between forest plantations and key irrigated agricultural crops (CSIR – Division of Water, Environment and Forestry Technology)
- **690** Continued research on flood damage functions, models and computer programs for irrigation and urban areas in South Africa (University of the Orange Free State – Department of Agricultural Economics and the DWAF)
- **702** Development of a Windows-based interpretation system for hydrogeologists (University of the Orange Free State – Institute for Groundwater Studies and the DWAF)
- **748** Impacts of exotic plants on the water resources of South Africa, with special reference to economics and policy options for effective management of the problem (CSIR – Division of Water, Environment and Forestry Technology)
- **749** Modelling benefits of integrated catchment management (University of Natal – Department of Agricultural Engineering)

New

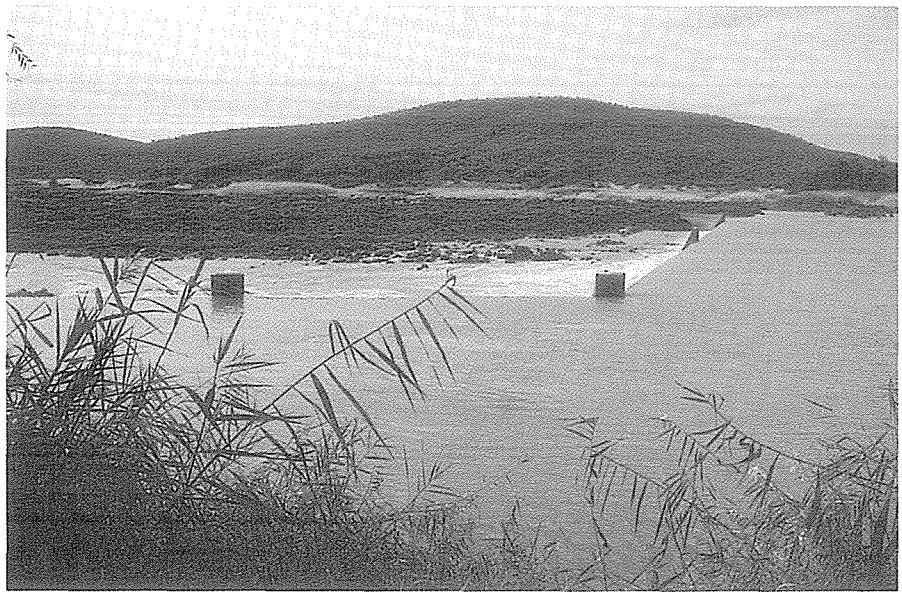
- **807** Multi-level decision support for the control of alien invasive plants in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **855** Econometric and institutional economic analysis of water use in the Crocodile River catchment, Mpumalanga Province, South Africa (European Science and Environment Forum – Economics Unit)
- **863** Development of group decision-support methods to facilitate participative water resource management (University of Cape Town – Department of Statistical Sciences)
- **864** Integrated catchment management in an urban context: The Great and Little Lotus Rivers, Cape Town (Abbott Grobicki (Pty) Ltd.)
- **865** Operational model of the Orange River (BKS (CE) Inc.)
- **866** Community-based integrated catchment management programme with special reference to sustainable resource use in the Mlazi catchment (University of Natal – Farmer Support Group)

CONTACT PERSONS

- **Mr H Maaren**
  (Hydrology and Water Management)
  e-mail: hugo@wrc.ccwr.ac.za
- **Mr JN Bhagwan**
  (Urban Water Balance)
  e-mail: jbhagwan@wrc.ccwr.ac.za
- **Mr AG Reynders**
  (Groundwater Aspects)
  e-mail: tony@wrc.ccwr.ac.za
- **Dr GR Backeberg**
  (Aspects Related to Agriculture)
  e-mail: gerhard@wrc.ccwr.ac.za
- **Mr HM du Plessis**
  (Pollution Aspects)
  e-mail: meiring@wrc.ccwr.ac.za

☎ **(012) 330-0340**

12 SURFACE HYDROLOGY



Research priorities and programmes in the field of surface hydrology will undoubtedly be strongly influenced by two recent developments. The first is the new Water Act, which recognises all water, irrespective of where it occurs in the hydrological cycle, as a single resource. The second is the emerging emphasis on integrated catchment management (ICM) which, besides diverting some research funding from "pure" surface hydrology, could also influence the nature of hydrology projects which are funded in future.

Both developments tend to create research needs which would be better accommodated within a single broad discipline of hydrological science than in traditionally separate disciplines such as hydrology, geohydrology, plant water relationships or irrigation. Questions concerning groundwater recharge, water use of crops under irrigation or rain-fed conditions, water use of indigenous forests or exotic plantations are interrelated facets of ICM and impact on the single resource, water.

In recent years policy research, dealing more with the behaviour of people, has necessarily become part of and tended to dilute hydrological science. The need for sound knowledge and factual understanding of the dynamics of water is, however, as great as ever before. At a recent hydrological workshop the development of an atlas of classified hydrological landscapes or hydrotopes for South Africa was conceptualised. Such hydrotopes would convey important information about the three-dimensional and non-linear behaviour of water to a wide range of stakeholders. If, for example, managers were to divide South Africa into water management areas and hydrologists could make headway with the demarcation and characterisation of hydrotopes within such areas, there will have been good progress in making sound science accessible to decision-makers.

Completed projects

Development of an urban component for the ACRU model

(No 424) Department of Geography, University of Durban-Westville

It was established that by incorporating the WASHMO model into the ACRU model, it is possible to generate realistic hydrographs from urban catchments. The WASHMO model was altered to accommodate runoff from pervious as well as connected (adjunct) and unconnected (disjunct) impervious areas. The ACRU model was also changed to be used in conjunction with the WASHMO section as a single-event storm model. This enables ACRU to be used for design storm purposes similar to the SCS models. It was further established that the ACRU model in its existing form can simulate runoff on a daily basis from fully urbanised catchments. After the inclusion of accumulation and washoff equations, ACRU is also capable of simulating non-point pollution from urban areas, with a higher degree of accuracy from fully reticulated urban areas than from natural streams. This is due to the fluctuations in chemical loads in the baseflow component of the streamflow.

Further testing over a wider range of catchments is, however, needed to exclude any bias towards a particular catchment. This will improve the model's capacity to do realistic simulations in terms of hydrograph development and water quality. Further refinement is also necessary to be able to represent natural streams more accurately in terms of water quality loads in the baseflow component as well as to accommodate chemical constituents attached to sediments. This will enable the model to give more accurate water quality simulations from urban catchments with natural streams.

Cost: *R143 275*
Term: *1992-1995*

Classification and hydrological modelling of low flows in Southern Africa

(No 494) Institute for Water Research, Rhodes University

This project surveyed the various low-flow measures and indices currently used in hydrology, aquatic sciences, engineering and water resource management. It defined the South African community of users of low-flow information and their specific requirements in this regard. A package developed under HYMAS (hydrological modelling application software) included methods for flow-duration curve construction, analysing frequency, magnitude and duration of continuous low-flow events, baseflow separation, calculation of recession properties of a stream and low-flow frequency analysis. The software has been applied to daily flow data from 240 streamflow gauges representing the unregulated flow regimes in South Africa. The variable time interval (VTI) hydrological model has been evaluated in terms of low flow and a new set of criteria for model performance has been developed. A spatial interpolation algorithm was developed together with a low-flow patching method in order to fill the gaps in incomplete observations. Methods have been developed and tested to generate daily flow data at ungauged sites using regional flow characteristics. One method generates daily flow from monthly data, again using regional parameters.

Problem areas mostly relate to the availability of daily streamflow information rather than to the low-flow estimation techniques themselves. It is generally possible to develop a picture of the low-flow conditions in large catchments through the combined use of observed and simulated data. A better understanding is, however, required of how to regionalise the relationships between monthly and daily flow duration curves. The logical extension of the low-flow studies would be to continue with the detailed investigation of low-flow processes in different parts of the country, paying more attention to the behaviour of the natural water systems (streams, wetlands) under drought conditions.

Cost: *R1 061 000*
Term: *1993-1995*

Hydrological implications of afforestation in the North-Eastern Cape

(No 511) Division of Water, Environment and Forestry Technology, CSIR

Baseline information assembled in this project included existing streamflow records, spatial distribution of areas afforested and immediately planned for afforestation, land-cover classification and information on land-cover types, the location of wetlands, and the distribution of alien invasives. Additional socio-economic data have been assembled in order to put the potential impacts of afforestation into the regional context. A "biological" water quality baseline has been established at 15 monitoring sites on the major rivers in the district (the Wildebees, Mooi, Pot and Antelope Spruits). This methodology entailed a survey of the biological health of the river and can easily be repeated either at regular or at event-driven intervals. Rivers are biologically in a good condition at present.

The CSIR's "flow reduction curves" were used to estimate impacts of afforestation on the expected virgin yield from 10 quaternary catchments. Peak (maximum) impacts of all current and planned afforestation (i.e. 53 395 ha), on mean annual runoff within the 10 quaternary catchments vary between 2 and 18%. Worst impacts on low flows range from 5 to 31%. Mean annual impacts (impacts distributed over the length of the rotation) would be considerably lower than this – with the peak impacts reduced by an estimated 35%. The maximum total impact of afforestation at the level of the tertiary catchment is 5%, at the secondary catchment about 1%, and <0,5% at the level of the primary catchment. This situation would be reached in 2009 or 2010 and is also a function of the compacted age class distribution.

Cost: *R600 000*
Term: *1993-1996*

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

(No 635) Institute for Water Research, Rhodes University

This was the first WRC-funded contribution to UNESCO's International Hydrological Programme (IHP).

The Report (WRC Report No 235/1/97) outlines the background to the development of the Southern African FRIEND daily-flow time-series database and provides some further information about the South African stations (290 in total) that have been included.

The main results are presented in some detail in 11 Appendices, one for each country and an additional one for the simulations of the impacts of land-use change.The "Results", "Summary" and "Discussion" chapters are designed to provide a succinct overview of the main results obtained from the application of the two main models (Pitman and VTI).

Some of the more important conclusions were:

- The project has highlighted a well-known and understood (and obvious) problem experienced when applying any hydrological model. This problem relates to the quality and resolution of the input data and it is clear that without adequate rainfall data, either the simulation results can be expected to be poor, or even if the results are adequate they may be achieved for the wrong reason which suggests that the calibrated parameter set may not be transferable to other periods or catchments.
- A lack of information about levels of water abstraction and catchment land-use changes presented a problem for both models but is more relevant to the daily model. There were some catchments where the observed flow regimes suggested that such influences were present, but without more data these could not be quantified and were therefore difficult to properly account for in the calibration procedures.

The Patching model developed in this project represents a very simple tool to extrapolate daily flows gauged at a site to other periods at the same site, or to ungauged sites using regional flow-duration curves. The model was applied in several areas during this project and the results were very encouraging.

Cost: *R901 000*
Term: *1994-1996*

New projects

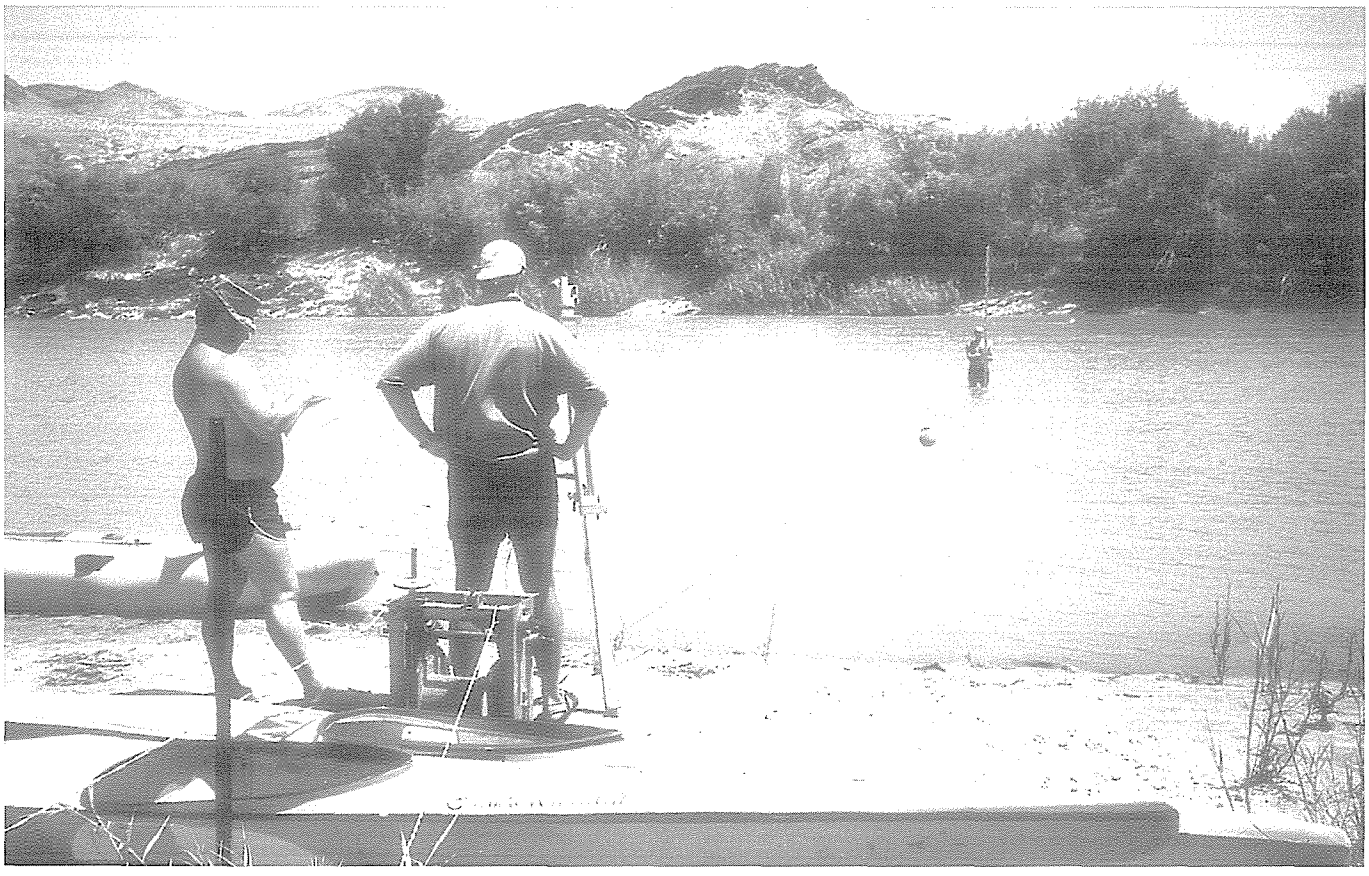
Comparison of the water use of selected invasive and indigenous riparian plant communities

(No 808) Division of Water, Environment and Forestry Technology, CSIR

Current and anticipated future investment of funds by government water boards and forestry companies towards clearing riparian zones of exotic invader trees involves many millions of rands. The primary motivation for this large-scale effort is to enhance the flow of water in streams and rivers to the benefit of downstream users. Some South African experimental data are available to support this assertion, but are nowhere near sufficient to permit an overview of the hydrological benefit of the extensive clearing operations now in progress. If the current momentum and enthusiasm for the removal of riparian exotic trees is to be maintained, it is vital to obtain a clear picture of the increase in water flowing in our streams and rivers under a variety of management options and conditions.

Accurate estimates are required of the annual water use of a range of the most common invader tree communities, as well as of the most common indigenous riparian communities which will be established after clearing operations are completed. These comparative data will be used to estimate the reduction in evaporative loss following clearing of invasive trees and to quantify the annual water use of a range of post-clearfelling plant community options, to assist in choosing the community to be established.

Estimated cost: *R421 000*
Expected term: *1997-1999*



Cross-section of the Orange River at Brand Karos (just upstream of the river mouth) being surveyed during a flow-gauging exercise for **Studies on river losses: Phase 2** (Project No 638).

Feasibility of using trunk growth increments to estimate water use of *Eucalyptus grandis* plantations

(No 809) Division of Water, Environment and Forestry Technology, CSIR

Predicting the hydrological impacts of *Eucalyptus grandis* plantations remains an important research objective in South Africa, in view of the rising demand for both water and wood products. Regression models predicting the water use of different age classes of trees have been developed, but apply only to trees experiencing no water stress. Many plantations of this species occur in relatively marginal sites where regular drought stress is experienced, and where existing models will over-estimate water use. Establishment of new plantations is likely to occur more frequently in such areas as prime sites become more scarce.

A previous WRC project revealed a high degree of correlation between annual trunk volume growth increment and cumulative annual water use ($R^2 = 0.89$). This close correlation raises the possibility that the water use of plantations of *E. grandis* can be conveniently estimated from simple growth measurements, opening the way for the practical assessment of *Eucalyptus* water use over the entire forestry region of South Africa. An additional and important benefit will be a much improved understanding of the water-use efficiency of *Eucalyptus* wood production, enabling comparisons to be made with alternative forms of land use. The purpose of this study is to examine the correlation in more detail in trees representing a wide range of age, site quality and management regime, and to determine the precision with which water use may be estimated from growth data.

Estimated cost: R302 000
Expected term: 1997-1998

Afforestation effects: A re-analysis of the South African catchment afforestation experimental data

(No 810) Division of Water, Environment and Forestry Technology, CSIR

Research into the water use of timber plantations commenced in 1937 with the establishment of the most comprehensive network of catchment experiments. These experiments have been analysed individually over the last half century by a variety of methods. The results have been of great use in regulating further afforestation and in providing the scientific basis for such regulation.

However, the methods used in these analyses were often limited. Outmoded statistical techniques were used, weak correlations with rainfall were the basis of some predictions, and conservative bounds were placed on predictions which may have under-estimated afforestation effects. The various sets of results are therefore not strictly comparable. There is a need to treat all the data in a standard and unified way.

Documented findings from these experiments are also inadequate to answer specific and detailed questions which are currently being asked of planners and water regulators. Furthermore, with models such as ACRU and HYMAS being proposed for use in predicting afforestation effects, there is a need for a real baseline against which the performance of the models can be tested. A thorough understanding of the real effects of afforestation is needed before one can truly evaluate the performance of simulation models.

The above-mentioned afforestation experiments remain the most comprehensive set of data on the effects of forestry on water yield, and much information remains untapped within these data.

The aim of this project is to re-work all the data in order to:

- Clarify many of the issues around forestry effects on streamflow which are currently still being debated
- Provide a baseline against which modelling efforts can be tested.

Cost: R400 000
Term: 1997-1998

Long-duration design rainfall estimates for Southern Africa

(No 811) Department of Agricultural Engineering, University of Natal

A significant number of engineering and conservation design decisions, involving costs of many millions of rands, are made annually in South Africa utilising medium- to long-duration (1 to 7 d) design rainfall information. Currently used medium- to long-duration design rainfalls are based on daily rainfall data up to the late 1970s.

Subsequently a large number of extreme rainfall events have occurred (e.g. 1987/1988 floods in Natal and the Orange-Vaal system). Currently available daily rainfall records are now 25 years longer than those used previously and thus many stations whose length of record was too short for extreme value analysis in previous studies now qualify to be included in the analysis.

When estimating design flood hydrographs from a catchment it is necessary to convert the point rainfall measurements to areal rainfall depths. These so-called area reduction factor (ARF) relationships need to be re-investigated in the light of recent extreme events and the longer period of record now available for analysis.

New techniques for use in extreme value analysis reported in the literature will be investigated for possible adoption in the study. Furthermore, the basic assumption about the annual maximum series being stationary with respect to time needs to be tested.

While it is accepted that design rainfall values and point-to-areal rainfall relationships need to regenerated periodically as new techniques are developed, and as longer records become available for analysis, it is also the intention of this project to develop a processing system that will enable future updates to be performed in a relatively short time period.

Estimated cost: R274 000
Expected term: 1997-1998

Integration and application of daily flow analysis and simulation approaches within Southern Africa

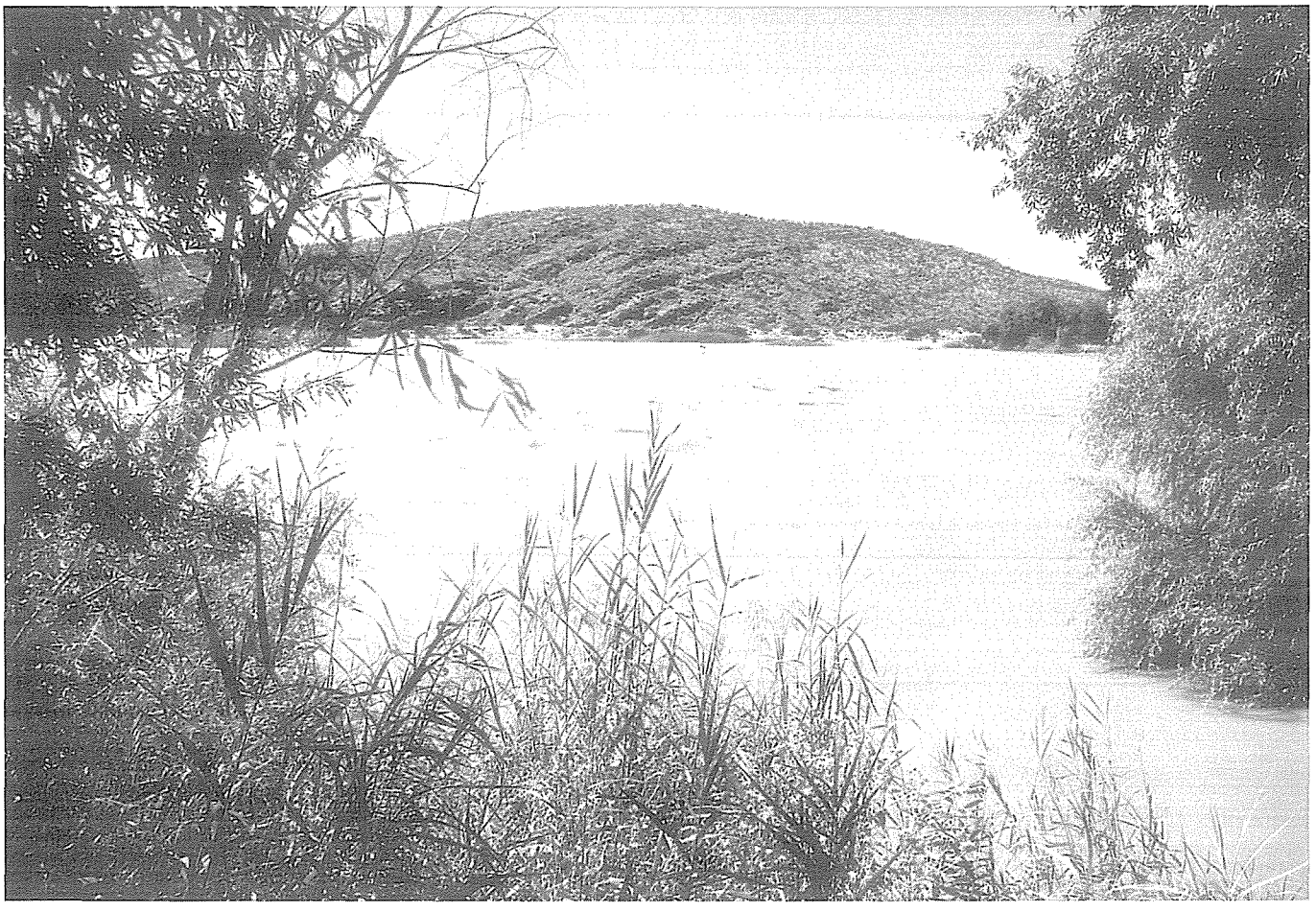
(No 867) Institute for Water Research, Rhodes University

This project follows on from previous projects, notably the Southern African FRIEND project (No 635), which revealed definite needs within the broad field of daily flow analysis and estimation in Southern Africa. These needs fall into three broad categories, viz. technique development, technique application and technology transfer (including training and capacity-building), which are nevertheless best addressed in an integrated manner. This project aims to strengthen analysis expertise within the SADC region and to assist in developing capacity in countries which have previously relied on outside help.

It is proposed to apply a combination of low-flow techniques to the Incomati River and tributaries (Sabie, Crocodile and Komati, for example) within South Africa, Swaziland and Moçambique. As many of these rivers fall within the Kruger National Park, co-operation with the KNP Rivers Research Programme will be established. While the question of essential water resource development of international rivers is a very sensitive issue, there is little doubt that future planning and distribution of water must be based on a sound scientific understanding. In seeking to contribute to that understanding, the project team will co-operate with the Moçambique National Directorate for Water, the Swaziland Water Resources Branch and the South African DWAF.

With regard to capacity-building, the project team has already established links with the University of Dar-Es-Salaam, University of Swaziland and various national hydrology agencies, and has contributed to a regional course on the subject of rainfall-runoff modelling. Project personnel will continue to contribute to training courses and will host visiting scientists at Rhodes University to co-operate on various components of the project.

Estimated cost: R1 135 000
Expected term: 1997-1999



Zeekoeibaart Weir (just downstream of Boegoeberg Dam) at high flow, in contrast with the photo on p. 88 which illustrates the change in surface area with low flow.

Research projects

Completed

- **424** Development of an urban component for the ACRU model (University of Durban-Westville – Department of Geography)
- **494** Classification and hydrological modelling of low flows in Southern Africa (Rhodes University – Institute for Water Research)
- **511** Hydrological implications of afforestation in the North-Eastern Cape (CSIR – Division of Water, Environment and Forestry Technology)
- **635** Flow regimes from international experimental and network data (FRIEND) for Southern Africa (Rhodes University – Institute for Water Research)

Current

- **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)
- **348** Root development and water usage of commercial timber species (University of Natal – Department of Agronomy)
- **492** Effect of the agricultural environment on water resources (University of Natal – Department of Agricultural Engineering)
- **493** Development and testing of a water balance model for a grassland catchment in the summer rainfall area of South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **636** Hydrological systems modelling research programme: ACRU model development and user support (University of Natal – Department of Agricultural Engineering)
- **637** Hydrological systems modelling research programme: Hydrological process research (University of Natal – Department of Agricultural Engineering)
- **638** Studies on river losses: Phase 2 (BKS (CE) Inc.)
- **681** Short-duration design rainfall estimates for Southern Africa (University of Natal – Department of Agricultural Engineering)
- **683** Evaporation from the Orange River: Quantifying open water resources (CSIR – Division of Water, Environment and Forestry Technology)
- **730** Development of a research strategy on the interaction between vegetation and groundwater (CSIR – Division of Water, Environment and Forestry Technology)
- **744** Experimentation and laboratory measurement for hydrological processes research (University of Natal – Department of Agricultural Engineering)
- **746** Development of a hydrological model of the Upper and Middle Limpopo River (University of Stellenbosch – Department of Civil Engineering)
- **747** Assessment of the MIKE SHE hydrological model for application in South African catchments (Rhodes University – Institute for Water Research)
- **781** Long-term monitoring of streamflow and weather in the Cathedral Peak catchments (CSIR – Division of Water, Environment and Forestry Technology)

New

- **808** Comparison of the water use of selected invasive and indigenous riparian plant communities (CSIR – Division of Water, Environment and Forestry Technology)
- **809** Feasibility of using trunk growth increments to estimate water use of *Eucalyptus grandis* plantations (CSIR – Division of Water, Environment and Forestry Technology)
- **810** Afforestation effects: A re-analysis of the South African catchment afforestation experimental data (CSIR – Division of Water, Environment and Forestry Technology)
- **811** Long-duration design rainfall estimates for Southern Africa (University of Natal – Department of Agricultural Engineering)
- **867** Integration and application of daily flow analysis and simulation approaches within Southern Africa (Rhodes University – Institute for Water Research)

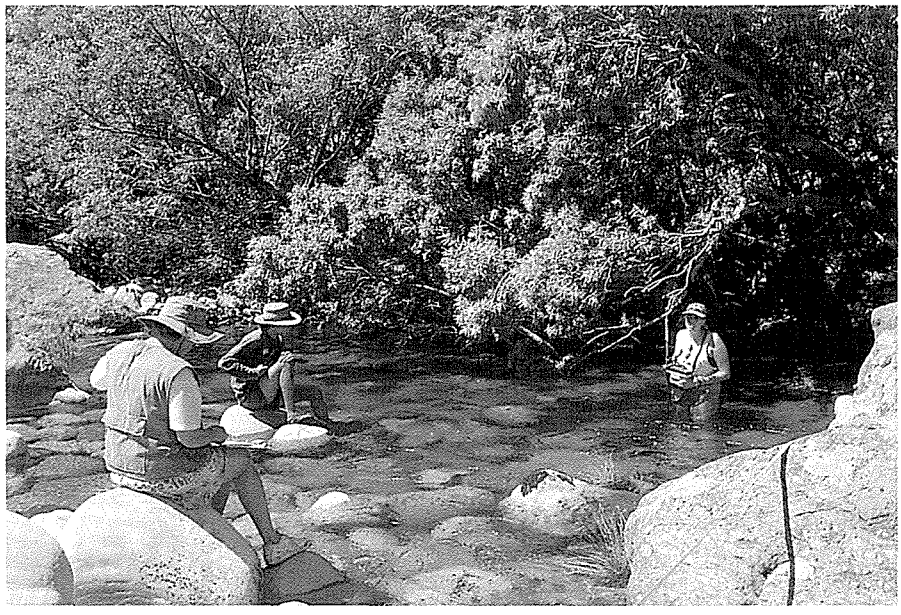
CONTACT PERSONS

- **Mr H Maaren**
  (Hydrology and Water Management)
  e-mail: hugo@wrc.ccwr.ac.za
- **Mr JN Bhagwan**
  (Urban Water Balance)
  e-mail:
  jbhagwan@wrc.ccwr.ac.za
- **Mr DS van der Merwe**
  (Flow Measurement and Sediment)
  e-mail: david@wrc.ccwr.ac.za

☎ **(012) 330-0340**

13

CONSERVATION OF WATER ECOSYSTEMS



The National Aquatic Ecosystem Biomonitoring Programme is being established under the auspices of the DWAF, the WRC and the Department of Environment Affairs and Tourism. This Programme is based on the SASS (South African Scoring System) test using invertebrates to monitor water quality and combined with other tests giving other indicators of ecosystem health. A WRC-funded project, started at the beginning of 1997, will pilot the Programme in Mpumalanga, and preliminary surveys have already shown results both in terms of the water quality of the first rivers tested as well as involvement from industries based in the area.

The draft National Water Bill makes provision for an ecological water reserve which provides sufficient water to protect aquatic ecosystems. Research nearing completion is addressing methods to determine this reserve for data-poor waters.

Recently completed projects on the management and water use of riparian vegetation have indicated the importance of the correct management of these systems, not only for the stability of the river channel, but also for the consumptive use of water. Projects started this year will refine our knowledge of riparian systems and management strategies will be developed from the results.

The estuaries of the former Transkei are the least known on the South African coastline and a project started this year will begin to redress that.

The Co-ordinating Committee for Water Ecosystems Research revised the Research Master Plan during the year, although, following the major revision made during 1996, the changes were in details only. However, one point which was firmly made was that the Research Master Plan should be linked to relevant policies of the departments which have responsibilities for aquatic ecosystems.

Completed projects

Standard laboratory organisms for water quality studies

(No 545) Institute for Water Research, Rhodes University

This project is part of a thrust to develop methods of ecotoxicological testing using indigenous organisms from flowing waters. The aim of this particular project was to screen riverine organisms for species suitable for laboratory maintenance, develop a pilot programme for the maintenance of laboratory populations, and to establish a supply of suitable taxa for experimental purposes. The criteria on which the organisms were selected include their sensitivity, aspects of their ecology and life history, physiology and the ease with which they can be cultured and handled. The organism most successfully cultured was the freshwater limpet *Burnupia stenochorias*. The mayflies *Adenophlebia auriculata* and *Choroterpes elegans* were also reared successfully in the laboratory, but have not yet been bred successfully artificially.

Cost: *R561 700*
Term: *1993-1995*

Establishment of an effective information management system for the Kruger National Park Rivers Research Programme (KNPRRP)

(No 655) National Parks Board in collaboration with the Institute of Natural Resources, University of Natal

This project set out, in the context of Phase II of the KNPRRP, with the objective of making all relevant information pertaining to the KNPRRP easily traceable and readily accessible for general purpose usage, for integrative studies and as a basis for the other facets of the KNPRRP.

A network of all information sources relevant to the programme was established, expanded and maintained. Information was defined in its widest sense to embrace documents, digital data sets (including GIS data layers), videos, photos and museum collections. The approach taken was to set up meta data files (data files describing data sets) for all of these, classify the contents in multiple evidently useful ways, and develop extensive research mechanisms and cross-referencing capability. The catalogue included references to all rivers flowing through the Kruger National Park (KNP), but excluded the less relevant material for the Olifants River upstream of the top of the escarpment. An attempt was also made to include data from the full Moçambican reaches downstream of the Lowveld.

Upon announcing the availability of the first draft hard-copy data catalogue, the demand for abstracts became clear. This need was met by generating or obtaining as many of the highest-priority abstracts as funding would allow. Furthermore, the long time series of fixed-point photographs of KNP rivers were digitally captured for distribution on CD-ROM.

A suite of programs was written which allows any future collator to capture new meta data records, integrate these into the full collection (updating cross-references and linkages) and at any point print a catalogue in final word-processor format. Future distribution of catalogues will be in neatly typeset digital word-processor format, leaving printing and binding as optional for the recipient.

Cost: *R285 000*
Term: *1994-1996*

Abiotic-biotic links in the Sabie River: The responses of riverine biota to changing hydrology and geomorphology

(No 777) Institute for Water Research, Rhodes University

The KNP, a world-famous tourist destination, is dependent upon several rivers for its water supply. All these rivers rise outside the Park and are increasingly affected by agricultural, forestry and industrial development and development of water supplies for a growing human population. These developments affect water quality and quantity in the KNP rivers and place riparian ecosystems under threat.

Against this background the objectives of this project were to draw together the abiotic and biotic information and knowledge, generated by the KNPRRP, into a suite of models which will enable researchers and resource managers to predict response to geomorphological and hydrological changes in the Sabie River; and to use the synthesised information to launch an implementation phase of the KNPRRP.

During the course of the project several innovative methods and techniques were explored, including the use of qualitative models to simulate geomorphology, fish and riparian vegetation; the development of new techniques for relating fish habitat to river channel morphology; the development of a geomorphology-based riparian vegetation model; and the use of recent computing advances to aid the transfer of data and information and the visualisation of model results.

The final product of this project is a suite of models which consists of a hydrological model and three qualitative rule-based models (QRBM) to describe the geomorphic function, fish response and riparian vegetation response of the Sabie River. The ACRU agrohydrological modelling system is used to simulate catchment hydrological processes in order to provide daily streamflow and sediment yield information to the QRBMs.

The geomorphological model has a baseline geomorphological template consisting of the distribution of channel types along the Sabie River, and these are used as the basis on which to route sediment inputs from the subcatchments. Internally, the changing sediment balance within each channel type causes a change in the geomorphological composition at the scale of morphologic unit, and these are simulated with rules developed by geomorphologists with detailed knowledge of the Sabie River.

As far as the fish model is concerned, a rule-based approach is used to predict the response of specific fish groups, characteristic of the shallow Lowveld sections of the Sabie-Sand River system, to varying flow conditions in the catchment and potential changes in the channel type of the representative reach at which it operates. The changing patterns of abundance established for these species, both for normal and extreme seasonal conditions, form the basis of this predictive model. To facilitate interpretation, the eleven shallow-water species important in the Lowveld are, where possible, grouped according to shared lifestyles largely based on their taxonomic and life-history traits. A habitat-suitability index, to allow for the incorporation of information relating a change in fish habitat depending upon geomorphic change, has been developed for inclusion in the model.

The riparian vegetation model is a QRBM that predicts a riparian vegetation response to geomorphic change, in response to an altered hydrological regime. Vegetation distribution patterns and the relationship of these patterns with fluvial geomorphology formed the background to the definition of rules that govern vegetation response in the model. Five functional groupings of geomorphological units, grouped according to their functionality in terms of their ability to support vegetation, are the model inputs. Model outputs are five geomorphic states which were defined for each functional grouping of geomorphological units. Six vegetation types were selected as response units for the model. Vegetation states, defined for each of the vegetation types, are predicted according to geomorphic states of each functional group of geomorphological units.

The suite of models was used to simulate the effects of various flow scenarios in the Sabie River. The results from scenarios where the models were used to simulate the effects of the construction of a large dam on the Sabie, reflect the overriding

response of the fish to seasonal hydrological conditions. The geomorphic response is one of increasing sedimentation. The riparian vegetation response is a slow increase in the abundance of the phragmites vegetation type. As expected, the riparian vegetation response is the least dynamic of all those simulated.

Cost: R253 000
Term: 1996-1997

New projects

Botanical importance rating of estuaries in the former Ciskei and Transkei

(No 812) Department of Botany, University of Port Elizabeth

The estuaries of the former Ciskei and Transkei are not only poorly known but also fall in the transitional area between the subtropical (KwaZulu-Natal) and cooler (southern Cape) estuaries. They already form the basis of ecotourism in the area and this is likely to expand, and development of the water resources in the region is likely to affect the estuaries as well. This project aims to extend the botanical importance rating system to the estuaries in this transitional zone, to provide baseline data on the structure and distribution of the plant community in relation to freshwater input in an area where few data currently exist, and to translate this into management tools to be used in a decision-support system.

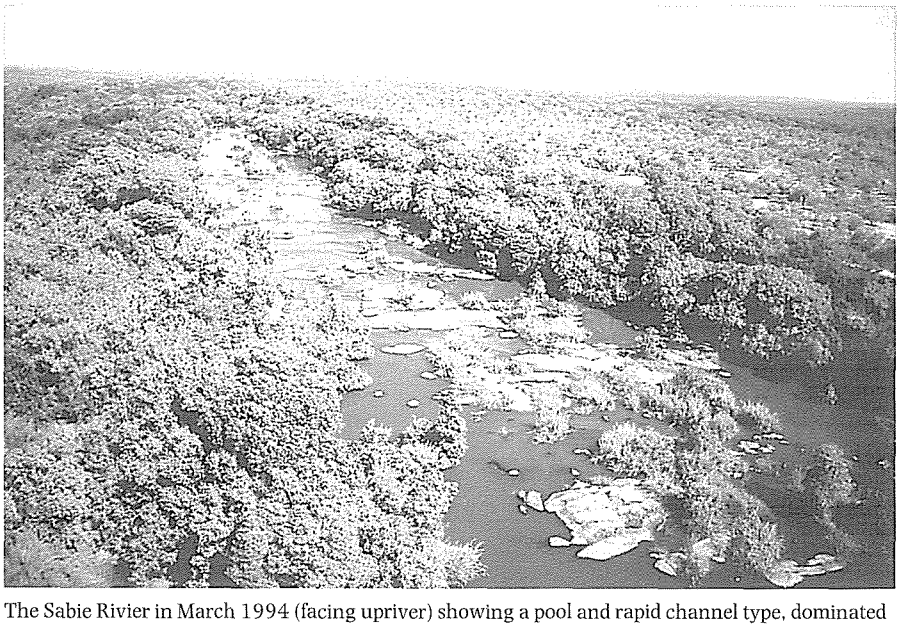
Estimated cost: R155 000
Expected term: 1997-1999

Rule-based modelling for management of riparian systems

(No 813) Department of Botany, University of the Witwatersrand

Knowledge of riparian vegetation in South Africa is limited. In particular we lack the ability to predict the response of vegetation to changes in flow and geomorphology. This project forms a part of the KNPRRP, and the model developed will make an important contribution to the management of these systems. In the KNP particularly there is an urgency to improve the ability to manage riparian vegetation, as both the change in the elephant management policy as well as the imminent closure of Injaka Dam are likely to impact on the riparian fringe. The project aims to improve the national ability to manage the response of riparian systems to changes in flow regime and geomorphology. The recent severe drought and subsequent high flood in the Sabie River will provide valuable data for the project.

Estimated cost: R470 000
Expected term: 1997-1998



The Sabie Rivier in March 1994 (facing upriver) showing a pool and rapid channel type, dominated by bedrock influence. This slide was taken upstream of the confluence between the Sabie and the Sand Rivers.

Geomorphological research for the conservation and management of Southern African rivers

(No 849) Department of Geography, Rhodes University

The estimation of minimum flow requirements of a river requires multidisciplinary inputs, and fluvial geomorphology is one of the disciplines that is required. Geomorphologists are in the position to make both long-term predictions on the effect of altered flow patterns as well as being able to define the habitats available to stream-dwelling organisms. The broad aim of this project is to implement geomorphological research as an integral component in the conservation of Southern African river systems. Specifically, it will refine the geomorphological component of the instream flow requirement methodology, develop indices and monitoring procedures to assess channel condition and refine the hydraulic biotope concept.

Estimated cost: R690 000
Expected term: 1997-1999

Develop procedures for regional implementation and maintenance of the DWAF's national biomonitoring programme

(No 850) Division of Water, Environment and Forestry Technology, CSIR

Effective resource management is dependent on the information available, and with the DWAF moving away from the "end-of-pipe" management of effluents to integrated ecosystem management, monitoring techniques need to focus on the overall response of ecosystems to stressors. The DWAF has taken the decision to develop and implement a National Aquatic Ecosystem Biomonitoring Pro-

gramme. Following the country's move to devolve decision-making to the provinces, the programme is designed to be managed at regional level, and it is, thus, necessary to develop the capacity to manage the programme at regional level. The aims of this project are to establish monitoring networks, protocols for the storage, transfer and management of data, formats and procedures for the dissemination of information and to ensure that the capacity exists to maintain the programme after the project is completed.

Estimated cost: R976 000
Expected term: 1997-1999

Interaction of reed distribution, hydraulics and geomorphology in semi-arid rivers

(No 856) Centre for Water in the Environment, University of the Witwatersrand

Environmental management of rivers requires consideration of, *inter alia*:

- Dynamic morphological characteristics
- Local hydraulic conditions
- Biotic-abiotic links
- Consumptive water use by riverine vegetation.

A previous project (No 376), carried out by the Centre for Water in the Environment (CWE), has shown that the interaction of reeds with sediment is an important process in fluvial morphological change. River morphology is determined largely by the quantities and patterns of sediment storage, and current research in the USA confirms that a significant proportion of sediment stored in rivers is associated with vegetation. The geomorphic influence of reeds and other instream vegetation is dynamic and highly interactive: reeds induce sediment deposition and sediment deposits in turn provide habitat for reedbed establishment and expansion.

This interaction has been neglected in the past because conventional modelling approaches cannot effectively incorporate vegetation dynamics. A new modelling approach being developed at the CWE has potential for doing this, but requires more detailed knowledge of hydraulic and sediment processes. The proposed project will enhance the predictive capability achieved in the previous WRC project by incorporating vegetation-sediment interaction.

Another recently completed WRC project (No 474), also carried out by the CWE, has shown that reeds account for the major proportion of transpiration loss along the Sabie River. Specification of instream water requirements, therefore, requires reliable estimation of future changes in reed cover. It was also shown that reedbeds play an important role in the establishment of woody riparian vegetation along the Sabie River. Furthermore the research has shown that the occurrence of reeds in the Sabie River is highly dynamic, and is tending to increase – with important consequences for both morphological change and consumptive water use. Reedbeds, therefore, are an important consideration in the management of riparian vegetation.

With an overall objective of improving the ability to model reedbed dynamics and the associated morphological change and hydraulic effects in semi-arid rivers, this project intends to investigate the characteristics of reedbed dynamics, hydraulics and sedimentation that influence their mutual interaction, and to formulate a model to describe this interaction.

Specific facets to be attended to are, *inter alia*, the following:

- Determine the local hydraulic conditions and sedimentation states conducive to reedbed establishment, maintenance, expansion and contraction.
- Determine the flow resistance of a reedbed and how it is influenced by reed life history characteristics and water stage.
- Determine the effect on overall resistance in a channel of the distribution pattern of reed cover, and propose a method for predicting overall resistance in a channel with a mixture of surface types.
- Determine the effectiveness of a reedbed in trapping coarse and fine sediment, and the influence on trapping of reedbed distribution pattern, flow condition and reed life history characteristics.
- Determine the stabilising effect of reeds on a sediment deposit and the conditions required for sediment remobilisation.
- Construct a rule-based model to describe the reedbed dynamics and associated morphological change.

Estimated cost: R800 000
Expected term: 1997-2000

Instream flow assessments: Technology transfer of the building-block methodology

(No 874) Department of Zoology, University of Cape Town

The building block methodology (BBM) was developed during an earlier project (No 476) as a means of estimating the instream flow required to maintain ecological functioning of a river. This has been developed to a useful methodology, but has really only been used at the prefeasibility stage of water resource development. The need for the methodology, and hence people experienced in its use, is set to increase rapidly as, on the one hand, the DWAF begin to use it in the feasibility phase of resource water development. On the other hand, with the new Water Law requiring an environmental reserve, it is likely that this process will be applied in this context as well. The aims of this project are to transfer the BBM from the realms of scientific research to water resource management and to continue development into the feasibility phase.

Estimated cost: R96 000
Expected term: 1997-1998

Verification of estimates of water use by riverine vegetation on the Sabie River in the KNP

(No 877) Division of Water, Environment and Forest Technology, CSIR

The flow regimes of the vast majority of South African rivers have been affected to a large extent as a result of agricultural and anthropogenic developments in the catchments of these rivers. In a number of cases these pressures resulted in rivers being changed from perennial to seasonal and even ephemeral systems. Consequently, for example, reduced winter base-flows are resulting in increased stress levels amongst the natural river biota. The viability of riverine ecosystems is, where relevant, dependent on the effective manage-

ment of water supplies.

With the natural riverine biota a recognised and legitimate water demand sector, effective management implies an in-depth knowledge of *inter alia* consumptive water use by natural riparian vegetation under various meteorological and river-flow conditions. Maintaining riparian vegetation is important in view of its contribution to the habitat of invertebrates, fish, reptiles, amphibians, birds and mammals. It is, therefore, an indispensable link in the whole water-ecosystem chain.

The dearth of information and data in the above regard, was attended to in a previous WRC research project (No 474). In addition to information concerning consumptive water use by riparian vegetation, the project also attended to the development of mathematical models which would provide resource managers with a predictive capability. The result was two linked models: a bank storage model, modelling subterranean water movement; and a riverine vegetation transpiration model, modelling the evaporation of water abstracted from the alluvium. In both cases it was not possible to verify or validate the results of these models, but it would appear that, as far as riverine trees are concerned, the calculated estimates tend to be conservative. By contrast, the reed transpiration model simulated very high evaporation rates for certain periods.

The principal aim of the new project will be to verify the consumptive water use of trees and reeds on the banks of Sabie River in the KNP. The contention is that verification of the models to predict water use by riparian trees and reeds, would result in revised consumptive water-use estimates for riverine vegetation, thereby providing resource managers and vegetation ecologists with a capability applicable also in other situations where, for example, reeds are an important component of the vegetation.

Estimated cost: R600 000
Expected term: 1997-1999

Development of a classification system for rivers of the KNP and a model for analysing trends in the condition of these rivers

(No 881) Institute for Water Research, Rhodes University

Although much information is available on the rivers of the KNP, there is at present no clarity as to how this information can be extrapolated from one river to the others. This is particularly true for the Sabie River, which has been the focus of research during Phase II of the KNPRRP. The monitoring programme for the KNP rivers, which is the main aim of the monitoring subprogramme of Phase III, will be designed to collect comparable data for all the KNP rivers with the possibility that there may be an emphasis on particular issues for individual rivers. A classification system is, therefore, required to define the similarities and differences between all the main rivers, thereby allowing comparisons, extrapolations and predictions involving these rivers.

Survey in dense riparian vegetation in the vicinity of Penge (Northern Province).

The proposed national classification system is too broad for application to the KNP rivers, but does provide guidelines at finer resolutions. For the purposes of the KNPRRP monitoring subprogramme, the classification system should be based on the following criteria:

- Physical structure of the rivers (size, geology, climate, geomorphology)
- Ecological integrity and causes of degradation
- Desired future state.

As far as the model for analysing trends in the condition of KNP rivers is concerned, the situation is that much of the data currently being collected in monitoring activities are unreported. The concept of "threshold of probable concern (TPC)" provides warning markers against which to check the condition of rivers. What is required is a simple model into which monitoring data could routinely be fed to analyse and present trends in relation to TPCs. A pilot exercise is to be undertaken to develop a model which would analyse and present the fish data currently collected on a routine basis.

Estimated cost: R63 000
Expected term: 1997-1998

Prediction of flow modification effects in the rivers of the KNP

(No 882) Centre for Water in the Environment, University of the Witwatersrand

A previous project on the abiotic-biotic links in the Sabie River (No 777) has been successful in developing largely prototype models of ecological response to catchment abiotic factors. This project also attended to the development of a model of geomorphological response to varying hydrological conditions. In the limited time available for the project, it has been impossible to adequately test and refine the models developed. The models are currently largely in the prototype phase, and further refinement and testing are needed in order that the model results may be used with confidence in catchment planning exercises. Furthermore, during the course of project No 777, several innovative methodologies were employed, but could not be fully explored due to time constraints. In particular, it will be beneficial to further explore the process of linking fish habitat to a template provided by the geomorphological structure of the river.

In addition to the above, this project will also serve as a planning phase for continuation of the research, especially as far as *inter alia* the following is concerned:

- Reassessment of the prototype fish and geomorphology models in the context of management's goals of "desired future state" and monitoring needs.
- Assessment of the consequences of the long-term implementation of the instream- flow-requirement (IFR) recommendations on management scenarios for the KNP rivers.
- Assessment of the applicability of the models to other rivers of the KNP and possibly other rivers in Southern Africa.

Estimated cost: R50 000
Expected term: 1997

Maintenance and updating of the KNPRRP meta data catalogue

(No 883) Institute for Natural Resources, University of Natal

The necessity for a well-organised and indexed repository of meta data of all available sources of information regarding the KNP rivers has been emphasized and attended to during Phase II of the KNPRRP. The intention during Phase III is explicitly to keep the meta database functioning, up-to-date and responsive to the needs of researchers and managers in the KNPRRP. To sustain the initiatives begun in Phase II, it is necessary that adequate contact with and interest amongst data custodians be maintained. Furthermore, consolidation and broadening of avenues of distribution should be furthered by liaison with other agencies involved in water-related meta data.

The objectives, therefore, are to:

- Maintain a viable network of co-operating custodians of data
- Be able to produce on request and at short notice a fully up-to-date digital copy on diskette of the catalogue in any standard word-processor format

The penetration structures of a *Pythium* sp. in a strand of *Cladophora glomerata* 12 h after inoculation.

- Liaise constructively with other meta data and data-providing agencies so that data sets are easily accessible to those audiences targeted by the KNPRRP.

Estimated cost: R31 000
Expected term: 1997-1998

Hydrological modelling to manage the environmental reserve within the KNP

(No 884) Department of Agricultural Engineering, University of Natal

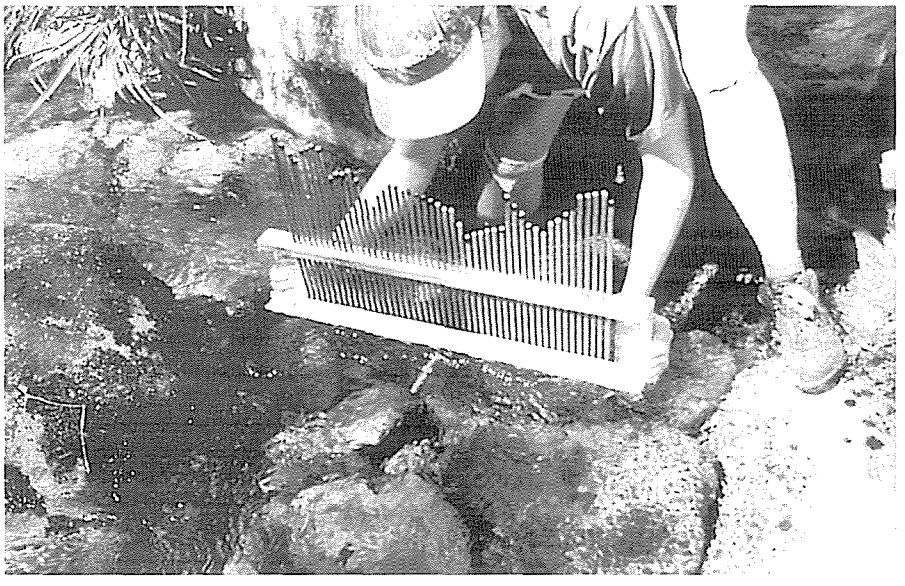
South Africa is faced by the challenge of equitable distribution of its limited water resources and ensuring that conflicts over water are addressed and resolved objectively and timeously. This situation is exacerbated by deteriorating water quality from increased sediment yield resulting from unsuitable land-use management in the catchment and enhanced loadings of point and non-point pollutants resulting from increased levels of industry and from agricultural practices. There has for the past decade been an increasing awareness of the environmental water requirements and the KNPRRP is an example of a programme to develop methodologies to address these issues. Furthermore the KNPRRP has recognised that since over 90% of the water flowing through the park rises in the catchments to the west of the reserve, it is imperative to develop modelling systems to understand the hydrological system dynamics outside as well as inside the KNP. The KNPRRP has also recognised that the management of the environmental reserve is going to require ongoing and dynamic systems to assist the process of day-to-day management and the conflicts which will inevitably arise over environmental allocations of water.

One method of objectively and explicitly dealing with the multi-sectoral demands for water is to develop and configure a credible hydrological and water quality modelling system which can simulate the various sectoral demands for water and which is also capable of modelling aspects of the quality of water. Once configured, simulated streamflow from the model can be used by other research projects and modelling efforts which are dependent on the flow of water. Stakeholders also have the opportunity of utilising the model and thus appreciate the complexities of modelling natural systems. Consequently objective and credible results are obtained from such an installed dynamic, operational modelling system.

Against this background the objectives are to:

- Refine, re-configure where necessary and verify a dynamic, land-use sensitive, spatially distributed hydrological model for the Sabie River system in South Africa, which will provide historical sequences of daily time series of streamflow and sediment yield at any point of interest/conflict to other modellers involved in the KNPRRP and to relevant stakeholders in the catchments.
- Establish an active operational hydrological modelling framework for use in current and future water resource conflict resolution.
- Provide a modelling infrastructure capable of modelling water quality and thus facilitate the use of this modelling system by water quality modellers.

Estimated cost: R200 000
Expected term: 1997-1998



Measuring the heterogeneity of the river bed of a Cape mountain stream – the Eerste River, Stellenbosch.

Research projects

Completed

- **545** Standard laboratory organisms for water quality studies (Rhodes University – Institute for Water Research)
- **655** Establishment of an effective information management system for the Kruger National Park Rivers Research Programme (KNPRRP) (National Parks Board in collaboration with the University of Natal – Institute of Natural Resources)
- **777** Abiotic-biotic links in the Sabie River: The responses of riverine biota to changing hydrology and geomorphology (Rhodes University – Institute for Water Research)

Current

- **376** Geomorphological response to changing flow regimes of the Sabie and Letaba River system (University of the Witwatersrand – Department of Botany)
- **422** Rapid biological assessment of water quality impacts in streams and rivers (CSIR – Division of Water, Environment and Forestry Technology)
- **428** Overview of the pesticide and heavy metal levels present in populations of the larger indigenous fish species of selected South African rivers (CSIR – Division of Water, Environment and Forestry 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)
- **497** Geomorphological classification system for South African river systems (Rhodes University – Department of Geography)
- **505** Environmental status of the Orange River mouth as reflected by the fish community (University of the Orange Free State – Department of Zoology and Entomology)
- **525** Natural and unnatural factors regulating the structure and functioning of estuarine systems (University of Natal – Institute of Natural Resources)
- **576** Effects of different magnitude flows on riverine ecosystems (University of Cape Town – Freshwater Research Unit)
- **577** Decision support system for the integrated management and conservation of estuaries (University of Natal – Institute of Natural Resources)
- **601** Freshwater requirements of plant communities in different types of estuaries (University of Port Elizabeth – Department of Botany)
- **608** Lethal and sublethal effects of metals on fish physiology in the Republic of South Africa (Rand Afrikaans University – Department of Zoology)
- **626** Water quality requirements for riverine biotas (University of Cape Town – Department of Zoology)
- **627** Integrated modelling system for predicting the impacts of changes in water quantity and quality brought about by upstream development (Sigma Beta (CE))
- **663** System-related scale study to determine the function of the riparian vegetation of the Olifants River, Transvaal (Agricultural Research Council – Roodeplaat Grassland Institute)
- **664** Water quality modelling of estuaries (CSIR – Division of Water, Environment and Forestry Technology)
- **665** Assessment of the ecological impacts of inter-basin transfer schemes in dryland environments (University of Cape Town – Department of Zoology)
- **669** Survey for potential biological control agents for the troublesome alga *Cladophora glomerata* (Agricultural Research Council – Plant Protection Research Institute)
- **686** Application of an artificial stream system to investigate macro-invertebrate water quality tolerances (Rhodes University – Institute for Water Research)
- **716** Water quality and aquatic faunal studies in the Umzimvubu catchment, Eastern Cape, with particular emphasis on species as indicators of environmental change (University of the Transkei – Department of Zoology)
- **718** Tadpoles as bio-indicators of stream quality (University of the Western Cape – Department of Biochemistry)
- **722** Effect of inter-basin transfer on the hydrochemistry, benthic invertebrates and ichthyofauna of the Mhlatuze Estuary and Lake Nseze (University of Zululand – Department of Zoology)
- **754** Linking abiotic and biotic data on South African Rivers (University of Cape Town – Department of Zoology)
- **755** Development of a production facility for test organisms to be used in flowing water ecotoxicological research (Rhodes University – Institute for Water Research)
- **756** Decision support for the management and conservation of estuarine systems: Phase 2 (University of Natal – Institute for Natural Resources)
- **782** Scenario modelling for the Kruger National Park Rivers Research Programme (KNPRRP) decision support system (University of the Witwatersrand – Centre for Water in the Environment)
- **783** Tolerances of selected macro-invertebrates from the Buffalo River (Eastern Cape, South Africa) to components and dilutions of textile effluent (Rhodes University – Institute for Water Research)

New

- **812** Botanical importance rating of estuaries in the former Ciskei and Transkei (University of Port Elizabeth – Department of Botany)
- **813** Rule-based modelling for management of riparian systems (University of the Witwatersrand – Department of Botany)
- **849** Geomorphological research for the conservation and management of Southern African rivers (Rhodes University – Department of Geography)

- **850** Develop procedures for regional implementation and maintenance of the DWAF's National Biomonitoring Programme (CSIR – Division of Water, Environment and Forestry Technology)
- **856** Interaction of reed distribution, hydraulics and geomorphology in semi-arid rivers (University of the Witwatersrand – Centre for Water in the Environment)
- **874** Instream flow assessments: Technology transfer of the building-block methodology (University of Cape Town – Department of Zoology)
- **877** Verification of estimates of water use by riverine vegetation on the Sabie River in the KNP (CSIR – Division of Water, Environment and Forest Technology)
- **881** Development of a classification system for rivers of the KNP, and a model for analysing trends in the condition of these rivers (Rhodes University – Institute for Water Research)
- **882** Prediction of flow modification effects in the rivers of the KNP (University of the Witwatersrand – Centre for Water in the Environment)
- **883** Maintenance and updating of the KNPRRP meta data catalogue (University of Natal – Institute for Natural Resources)
- **884** Hydrological modelling to manage the environmental reserve within the KNP (University of Natal – Department of Agricultural Engineering)

CONTACT PERSONS

- **Dr SA Mitchell**
  (Stream Fauna and Flora and Aquatic Ecosystems)
  e-mail: steve@wrc.ccwr.ac.za
- **Mr HM du Plessis**
  (Irrigation Return Flow)
  e-mail: meiring@wrc.ccwr.ac.za
- **Mr JN Bhagwan**
  (Natural Wetlands)
  e-mail: jbhagwan@wrc.ccwr.ac.za
- **Mr DS van der Merwe**
  (Facets of the Kruger National Park Rivers Research Programme)
  e-mail: david@wrc.ccwr.ac.za
- **Dr GR Backeberg**
  (Resource Economics)
  e-mail: gerhard@wrc.ccwr.ac.za

☎ **(012) 330-0340**

14

MINE-WATER MANAGEMENT

The relative scarcity of South Africa's water resources and relative abundance of our mineral resources have been responsible for the country's past development and progress being intimately linked to the development of these two resources. Although less so than in the past, our national economy is still much affected by the fortunes of the mining industry – a feature which is expected to continue for the foreseeable future.

By its very nature and scale, mining makes a marked and visual impact on the environment. Fortunately, overall use of our national water resources by mining is relatively low and unlikely to increase significantly because of the combined effects of a decline in mining activities and the degree of reuse within the industry. Mining is, however, implicated as a significant contributor to water pollution – the prime reason being that most of our geological formations which are mined, contain pyrites, which oxidise to form sulphuric acid when exposed to air and water. Additional pollution originates from the metallurgical refinement and other beneficiation activities on mines. Mines frequently use underground seepage to supplement outside sources. The quality of this water is often poor, which has a detrimental effect on the quality of water which mines ultimately have to dispose of.

Most of mining's impact on the water environment is diffuse in nature and thus difficult to quantify and control. It is only fairly recently that the regulating authorities began to give serious attention to the problem of how to regulate this impact. Agreement was subsequently reached between government and the mining industry that the acceptance by Government of an Environmental Management Programme as proposed by a mine and the subsequent execution of this programme by the mine would satisfy Government's rehabilitation requirements. Hereby the mining industry accepted environmental rehabilitation as an integral part of their operations. By keeping to the letter and spirit of their environmental management programmes, it is expected that individual mines will keep the negative environmental impact of their operations to within acceptable limits.

Mining-related water research sponsored by the WRC is aimed at addressing the high priority needs emanating from mining activities. Research activities are being co-ordinated by the Co-Ordinating Committee for Mining Related Water Research (CCMRWR) comprising representatives and individuals from Government, mining and the research communities. At a workshop held during April 1997 the CCMRWR reviewed research progress during the past number of years and assessed the present water-related research and technology transfer needs of the industry.

The following six problem areas were identified as those in which technology is either not available or inadequate to deal with the water-related problems being experienced:

- Water treatment options
- Water management options
- Tools and techniques for predicting environmental impacts at source level on a mine
- Quantification of the effect of mining operations on surface and groundwater resources
- Data acquisition systems, databases and information systems
- Policy with regard to the effect of mining on the water environment.

The workshop formulated and prioritised the research and technology transfer needs for those areas where problems were being experienced as a result of either inadequate knowledge to deal with them, or as a result of a lack of technology transfer. These needs were made available to interested and affected parties and are expected to guide research and technolo-

gy transfer activities over the next three years.

As a result of past initiatives taken by the CCMRWR, duplication of the national mining-related water research effort has largely been eliminated and research is being conducted more cost-effectively than previously. Since 1993 the WRC has spent about R7,5 m. on mining-related water research projects. The expenditure by industry and other parties during 1996 (the only year for which comprehensive data are available) was up to four times that of the WRC.

Completed projects

Optimisation of mine service water disinfection

(No 471) Department of Chemical and Environmental Engineering, University of Pretoria

The main aim of the project was to evaluate the cost-effectiveness of using ozone as disinfectant for nitrate-containing mine service water. Normally chlorine is used for this purpose, but the nitrate-rich water results in a high chlorine demand, which renders the disinfection process very costly. The service water used in this project was a potable water supply, augmented by direct cooling water and water used for dust suppression. At 10 mg/l the ozone demand of this water was found to be quite high. Results from the study were not sufficiently conclusive to enable concrete conclusions to be drawn with regard to the relative cost-efficiency of ozone vs. chlorine in this specific case study.

Cost: *R55 000*
Term: *1992-1994*

Prediction of pollution loads from coarse sulphide-containing rock materials

(No 559) SRK (CE) Inc.

Acid mine drainage from coarse materials in mine dumps is a significant contributor to pollution of South Africa's water resources. A predictive mathematical model was developed as part of this project, to estimate the waste quality issuing from proposed or existing waste rock dumps, and to enable mine management to evaluate options (blending, stacking) for waste rock disposal and dump composition. The project also aimed to evaluate kinetic laboratory test methods which determine the propensity of coarse discards to cause acid mine drainage and the practicability of inundation of acid-generating materials as a control technology under local conditions.

The *Salmine* model which was developed is a useful tool to evaluate the effect of alternative control options on the characteristics of mine drainage. *Salmine* is complemented by a physical model to simulate processes for which the development of a rigorous mathematical model is not an achievable objective, or, for which the requirements of data collection are potentially too onerous to be of practical use to industry. Several practical methods to inundate sulphide-containing wastes for both open-cast and underground mines have been proposed.

Cost: *R661 853*
Term: *1993-1996*

New projects

Suitability and impact of power station fly ash in mining rehabilitation

(No 745) Institute for Groundwater Studies, University of the Orange Free State

About 3 m. t of fly ash are being produced annually by each of the larger power stations. There appear to be several potentially advantageous applications for fly ash to ameliorate the potentially negative effects of coal-mining activities. It could be used as an alternative to agricultural lime, be a suitable material with which to fill the final void that is formed during open-cast mining, or, because of its low permeability, significantly reduce the ingress of rain and surface water into open-cast mines when inserted between open-cast spoil material and the soil cover. However, there are also potentially negative effects that need to be considered. Several undesirable trace elements can, for example, be released from fly ash in an acid environment. The scope of this project is to investigate the various ways in which power station fly ash can be applied for mine rehabilitation, without a risk to the environment.

Estimated cost: *R507 000*
Expected term: *1997-1998*

The anaerobic contact bed / anoxic limestone drain (ACB/ALD) train which was used to neutralise acid mine water for use in additional experiments, conducted at Arnot Colliery, to develop integrated passive water treatment systems for mine effluent streams.

Preliminary assessment of pollution contained in the unsaturated and saturated zones beneath reclaimed mine dumps

(No 797) Geo-Hydro Technologies

Sand dumps and slimes dams have been implicated in earlier studies as sources of water pollution. Because of the thickness of these dumps it is practically impossible to determine the exact extent of seepage beneath dumps and how it is affected by different construction methods, size and other variables. Many of the older dumps in Gauteng are now being reprocessed in order to extract gold which could not be extracted with earlier extraction procedures. Because contaminants which have been leached from the mine dumps are retained in the underlying soil, sites where dumps are being removed present a unique opportunity to study (in retrospect) the extent, nature and areal or spatial distribution of contaminants underneath mine dumps. This study of these sites aims to identify the nature and extent of contamination in the unsaturated and saturated zones beneath reclaimed slimes dams and sand dumps. It will also endeavour to evaluate and define the existing state of knowledge with regard to the long-term environmental effects of mine waste deposits and define the need for, and scope of, further studies.

Estimated cost: R345 600
Expected term: 1997-1998

Economic and technical evaluation of regional treatment options for point-source gold-mine effluents entering the Vaal Barrage catchment

(No 800) Stewart Scott (CE) Inc.

Indications are that four gold mines are contributing about 25% of the salt load to the Vaal Barrage by way of their point-source discharges. The costs associated with this salt load are felt by several users and direct abstractors from the Vaal River system. The effluents from three of the mines are largely derived from mining operations undertaken during the last 100 years. Their effluents should thus be seen as a regional, if not a national problem, which requires a co-ordinated management strategy, with inputs by the mining industry and the regulating authorities.

The study aims to define conceptual strategies which could cost-effectively be employed to manage/treat point-source gold-mine effluents, confirm the current contribution of these point-source discharges to the salt load entering the Vaal Barrage, and estimate the cost to users. A report detailing strategies that show promise for cost-effectively managing or treating the point-source gold-mine effluents will be generated.

Estimated cost: R319 000
Expected term: 1997-1998

Generic water balance for the South African coal-mining industry

(No 801) Pulles, Howard and De Lange Inc.

In order to manage and ameliorate water quality and hydrological impacts during coal-mine commissioning, operation and specifically post-closure situations, the expected water use and discharge need to be studied and characterised under varying conditions in different catchments as well as for different mining methods. Typical uses of a generic balance include a holistic view of coal-mining contributions to surface water pollution, a holistic view of water use in the coal-mining industry, and placing the water use and pollution from coal mining in a regional context.

The study aims to develop a generic water balance that can be used by the mining industry, catchment authorities and parties affected by coal-mining water use and discharge. The generic water balance will be developed for the following coal mining operations, viz. open-cast, underground board-and-pillar and underground total extraction conditions, as well as mining with and without coal beneficiation plants.

Estimated cost : R106 000
Expected term: 1997

Determination of the suitability of alternative carbon sources for sulphate reduction in the passive treatment of mine waters

(No 802) Division of Water, Environment and Forestry Technology, CSIR

A suitable and/or sustainable carbon source is essential for the long-term operation and cost-effectiveness of passive bio-

The experimental set-up at the Arnot Colliery site in which six different carbon sources were used in experiments to supplement results obtained with pilot-scale integrated passive water treatment systems for mine effluent streams.

logical sulphate reduction. Carbon sources used in a current pilot-scale study are cow manure, sewage sludge, mushroom compost and hay. Carbon sources such as mushroom compost, which is often recommended internationally, or domestic sewage sludge, may not be readily available at a specific location and it is, therefore, necessary to seek alternatives. The overall aim of the project is to identify suitable low-cost carbon sources for sulphate reduction in the passive treatment of mine waters. Specific aspects that will be addressed include the identification of the range of carbon sources available in the country, development of a test procedure to obtain sulphate reduction kinetics for the different carbon sources under passive treatment conditions, testing the developed procedure on a model carbon source mixture which should provide carbon over a short-, medium- and long-term period, and summarising the test procedures in preliminary guidelines.

Estimated cost: R264 000
Expected term: 1997-1998

CONTACT PERSONS

- **Mr HM du Plessis**
  (Impact Studies and Mitigation of Effects)
  e-mail: meiring@wrc.ccwr.ac.za
- **Mr AG Reynders**
  (Groundwater Pollution)
  e-mail: tony@wrc.ccwr.ac.za
- **Dr G Offringa**
  (Mine-water Treatment)
  e-mail: offringa@wrc.ccwr.ca.za

☎ **(012) 330-0340**

Research projects

Completed

- **471** Optimisation of mine service water disinfection (University of Pretoria – Department of Chemical and Environmental Engineering, Division of Water Utilisation)
- **559** Prediction of pollution loads from coarse sulphide-containing rock materials (SRK (CE) Inc.)

Current

- **413** Use of vegetation in the amelioration of the impact of mining on water quality – An assessment of species and water use (CSIR – Division of Forest Science and Technology)
- **454** Occurrence of bacteria causing acid mine drainage in the outer layers of coal waste dumps (University of Stellenbosch – Department of Microbiology)
- **528** Development of an integrated and generic water quality simulation model for open-cast coal mining water circuits (Wates, Meiring and Barnard (CE) Inc.)
- **575** Calibration of models for the design of covers for open-cast mine and waste dump rehabilitation (Wates, Meiring and Barnard (CE) Inc.)
- **582** Screening of crop, pasture and wetland species for tolerance of polluted water originating in coal mines (University of Pretoria – Department of Plant and Soil Science)
- **647** Application of isotope chemistry to quantify the contribution of gold and coal mines to salt pollution load in groundwater and rivers (CSIR – Division for Earth, Marine and Atmospheric Science and Technology)
- **699** Prediction techniques and preventative measures relating to the post-operational impact of underground mines on the quality and quantity of groundwater resources (University of the Orange Free State – Institute for Groundwater Studies, Chamber of Mines of South Africa and the DWAF)
- **700** Pilot-scale development of integrated passive water treatment systems for mine effluent streams (Pulles, Howard and De Lange Inc., The Chamber of Mines of South Africa, Eskom and Sasol Coal)
- **750** Development of an information transfer, extraction and management system for mine-water management and treatment (Pulles, Howard and De Lange Inc.)

New

- **745** Suitability and impact of power station fly ash in mining rehabilitation (University of the Orange Free State – Institute for Groundwater Studies)
- **797** Preliminary assessment of pollution contained in the unsaturated and saturated zones beneath reclaimed mine dumps (Geo-Hydro Technologies)
- **800** Economic and technical evaluation of regional treatment options for point-source gold-mine effluents entering the Vaal Barrage catchment (Stewart Scott (CE) Inc.)
- **801** Generic water balance for the South African coal-mining industry (Pulles, Howard and De Lange Inc.)
- **802** Determination of the suitability of alternative carbon sources for sulphate reduction in the passive treatment of mine waters (Division of Water, Environment and Forestry Technology – CSIR)

15 WATER POLICY

The water economy in South Africa has developed from an expansionary to a maturing phase. This means that a situation of **water scarcity** exists, i.e. more water is needed than can be delivered at a given time, place and quality. Accordingly, the water management approach must change from being supply-driven to being demand-driven. Attention must, therefore, focus on design of appropriate institutions, organisations and policy instruments to achieve objectives of more efficient and equitable conservation and reallocation of available water resources.

Water allocation has gained prominence on the public policy agenda because of a combination of occurrence of extreme droughts, unequal access to water in rural areas, shifts in the contribution of water-use sectors to economic growth and sharing of rivers with neighbouring countries. Awareness is further heightened by skewed distribution of surface water resources between catchment areas of the inland plateau relative to those of the escarpment and coast of South Africa, and relatively low internal renewable water resources *per capita* in comparison with other countries in the Southern African Development Community (SADC). With total annual available water resources of approximately 1 200 m^3 *per capita* South Africa is already water-stressed, and is near the limit of 1 000 m^3 *per capita*/a below which countries are considered to be water-scarce. However, it must be realised that this is an average with cyclical variations being experienced, and that only an estimated 740 m^3 *per capita*/a is utilisable with current technology, of which approximately 85,8% is already exploited. Nonetheless, if current water-use patterns with distorted price and tariff signals continue in future, absolute water scarcity and resulting conflicts between water uses will certainly increase.

The problem of water scarcity is essentially one of conflict between different uses and users in or between catchment areas; conflict between present and future generations of people; conflict between application of human and capital resources for water resource development relative to other investments; and conflict between economic prosperity and preservation of ecosystems. The experience of countries which have successfully reformed water allocation policies, clearly indicates that a mix of market and administrative procedures is necessary to resolve conflicts over water. The best possible information is required if these policy options are to achieve the goal of decreasing the quantity demanded or shifting the demand for water. This information includes the following:

- Quantification of basic human needs and instream flow requirements of water- stressed river systems
- Measurement of existing water use, runoff for different land uses and possible water quality changes
- Specification of water rights or water licences in terms of percentage of flow or volume and the expected long-term variation
- Valuation of water resources for domestic, irrigation, forestry, industrial and power generation purposes in different catchment areas
- Determination of the impact of higher water tariffs on the level of consumption in various water-use sectors
- Maintaining or improving the quality of water through incentive-based pollution and effluent charges.

The projects funded in this research field all aim to improve the information base for effective water management policies.

Completed projects

Arrangements for regulating water services in South Africa

(No 788) Palmer Development Group

Since 1994 a number of activities have been initiated by the DWAF to ensure that all South Africans have access to basic water services. A Community Water Supply and Sanitation Programme has been established and implemented within the wide powers given under the Water Act of 1956. While this legislation gives extensive powers of intervention to the Minister, it has important deficiencies.

The policy outlined in the report on this project is intended to remedy these deficiencies. After defining the nature of water services, the report makes a number of proposals whose effect, when translated into legislation, will be to:

- Recognise the rights of consumers of water services and provide mechanisms to protect and promote their interests.
- Distinguish between service authorities (usually local government) and service providers (which may include local government, water boards, private companies and NGOs) thus providing a framework within which responsibilities can be clearly attributed and private sector service provision can be regulated.
- Promote a developmental approach to the regulation of services by requiring water service authorities to produce a development plan with clear targets and strategies which outline how they and their service providers will achieve their objectives.
- Empower DWAF, as the central government agency responsible for regulating water supply and sanitation services, to establish basic norms and standards for service provision.
- Enable DWAF, where needed, to establish a family of public service providers (regional utilities such as water boards and local water committees) to support local government in providing equitable and sustainable access to water services.
- Provide financial and other support to local governments to assist them to achieve Government's objectives of equitable and sustainable access to water services.
- Continue to provide services directly where this is required to meet minimum standards.
- Promulgate regulations to promote the efficient, equitable and sustainable provision of water services and the conservation of water resources.

Cost: *R80 000*
Term: *1997*

New projects

Development of a legal framework to provide for the effective management and sustainable utilisation of South Africa's groundwater resources

(No 789) DWAF

In reviewing South Africa's Water Law, the review team has found it necessary to examine the implementation of the various Water Law principles through a series of directed, short-term research projects. This project, to explore the development of a legal framework which would provide for the effective management and sustainable utilisation of South Africa's groundwater resources, forms part of the series.

The legal framework to be developed would address the following aspects:

- Institutional structures to provide for groundwater allocation under conditions of uncertainty
- Information systems to support groundwater management
- A scientifically-based allocation system
- Mechanisms to encourage sustainable management practices
- Support mechanisms to facilitate groundwater management at local level under conditions of uncertainty
- Mechanisms to ensure co-operation between diverse institutions involved with land-use activities which impact on groundwater resources.

It is envisaged that this project, besides suggesting an appropriate legal framework for consideration by the Water Law drafting team, will produce a report which outlines various legislative and management scenarios, appropriate for South Africa, drawn from comparative international legislative practice regarding groundwater regulation and management.

Estimated cost: R120 000
Expected term: 1997

Estimation of the residential price elasticities of demand for water by means of a contingent valuation approach

(No 790) Economic Project Evaluation (Pty) Ltd.

An important factor in being able to manage the demand for water effectively is knowledge of water's price elasticities of demand. This fact has been highlighted in an ongoing study being conducted by the DWAF concerning the future tariff structure for water in South Africa. In the household sector indications are that demand is inelastic with respect to price. Based on international studies, the evidence is that elasticities vary between -0,29 and -0,6, i.e. a 10% increase in tariffs will result in 2,9% to 6,0% reduction in water use. No recent research effort has, however, been undertaken into price elasticities for water in South Africa. The need for an understanding of the price elasticity of demand of water is clear, since it determines the extent to which water tariffs as a policy instrument can be applied to reduce water use.

The objective of the project is, therefore, to estimate the residential price elasticities of demand for water for different income groups by means of a contingent valuation method (CVM), i.e. using willingness-to-pay as a measure of behavioural intention.

Estimated cost: R473 400
Expected term: 1997-1999

Development of a philosophy and methodology for the implementation of "the polluter pays" principle in the context of receiving water quality objectives

(No 793) Stewart Scott (CE) Inc.

Internationally it is increasingly accepted that the traditional (command-and-control) approach to the control of environmental pollution, is not cost-effective. The discipline of environmental economics suggests supplementary flexible economic measures which can achieve acceptable levels of environmental benefits with simpler administration and lower control costs. The introduction of "the polluter pays" principle in water quality management is attractive not only because it is claimed to be more cost-effective, but also because of the inherent fairness it embodies. There are, however, several practical issues which need to be resolved before its implementation can be considered. This project will address many of these issues, such as the development of a philosophy for the implementation of "the polluter pays" principle in water quality management, the design of pollution tax/emission charges systems, determining the optimum level of tax/charge, identification of the most suitable institution to impose tax/charges systems, defining the extent and fate of revenues and recommending implementation options.

Estimated cost: R355 000
Expected term: 1997

Review of industrial effluent tariff structures in South Africa and guidelines on the formulation of an equitable effluent tariff structure

(No 854) DA Kerdachi, Private Consultant

General experience in South Africa is that effluent charges are so unrealistically low, that there is no incentive for industrialists to allocate funds towards improving the quality of their effluent. It is far more convenient to discharge effluents into a sewerage system and let the local authority or any other controlling authority incur expenditure. Inevitably this expenditure is never fully recovered. If the true cost for effluent discharges is borne by industry, it will relieve the burden on the domestic consumer and allow money normally directed to cover the financial shortfall, to be used for the benefit of the poorer sections of the community.

The charging system must allow for an equitable proportion of finance to be provided by industry for their contribution towards the cost of effluent treatment to the standard required by the DWAF and for the installation of an adequate sewerage system. This mode of operation is essential and preferable to the system of punitive measures that are not easily enforceable, usually ending up in a no-win situation after months and years of protracted legal proceedings.

A correct formulation applicable on a national scale will minimise the environmental and social impact; will help indus-

try to minimise water usage and become more conscious of effluent management; and reduce the financial burden of all domestic users while assuring that industries pay their proportion according to their hydraulic load and carbon strength. If proper effluent-charging systems and formulae are in place, industrialists will pay more attention to effluent management, resulting in financial benefit to all users.

Estimated cost: R175 000
Expected term: 1997-1998

Pricing of water resources in South Africa with specific reference to riparian surface water

(No 870) Department of Agricultural Economics, University of Natal

South Africa is a semi-arid country with limited and variable water resources, and increasingly competing demands for water. In the past, resolving water scarcity was directed to the development of additional supplies. The institutions that evolved for water management were based largely on a commitment to the construction of large storage and conveyance facilities with the aid of significant public subsidies. Under these institutional arrangements, water has not been considered an economically scarce resource because water rights were not generally transferable among users separate from land. This non-transferability eliminated the attachment of an opportunity cost to water, providing users with the incentive to over-use water.

This approach to water management is no longer rational since conflicts among water users are escalating as water needs outstrip the natural availability of water. The water scarcity problem requires institutions that reflect the ultimate economic scarcity of water, and allocate limited water supplies among various competing demands in a flexible manner.

The study aims to:

- Identify the institutional arrangements that have facilitated or hindered the operation of a water-rights market along the Orange and Pongola Rivers
- Quantify the efficiency gains and advantages achieved through water market transactions
- Determine the requirements for institutional and legal reform to establish tradable water rights
- Evaluate the likely influence of the new water policy and the National Water Bill on the operation of the water market
- Make policy proposals to improve allocative efficiency through tradable water rights.

Estimated cost: R50 000
Expected term: 1997-1998

CONTACT PERSONS

- **Dr GR Backeberg**
(Economics)
e-mail: gerhard@wrc.ccwr.ac.za
- **Mr H Maaren**
(Decision Support)
e-mail: hugo@wrc.ccwr.ac.za

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Research projects

Completed

- **788** Arrangements for regulating water services in South Africa (Palmer Development Group)

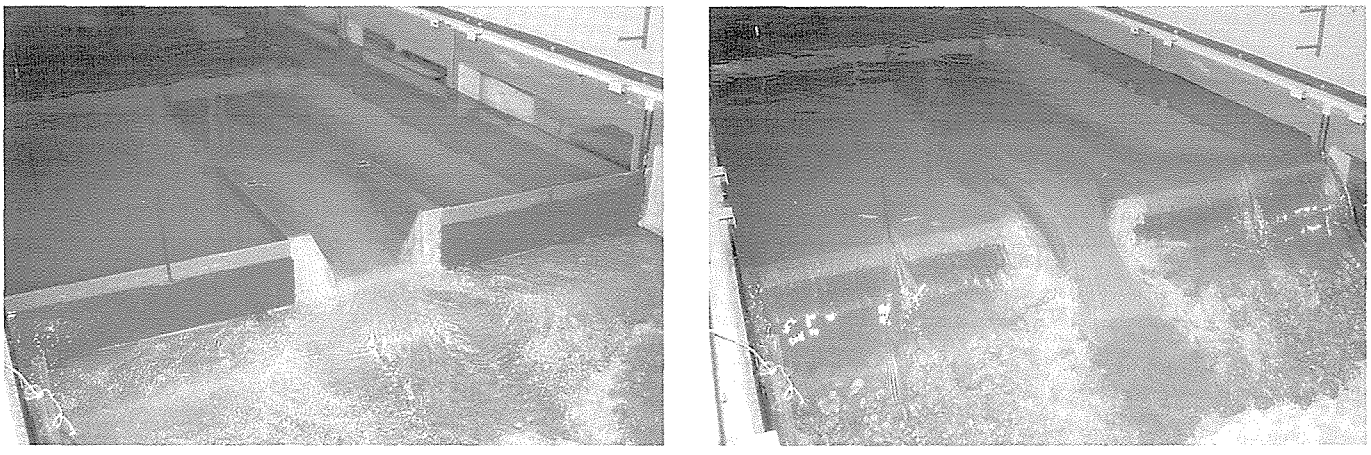
Current

- **512** Development of procedures for decision support in water resources management (University of Cape Town – Department of Statistical Sciences)
- **678** Pricing water as an economic resource (Palmer Development Group)
- **758** Establishment of a research framework for local authorities and the preparation of the first part of a series of management guidelines for water and waste departments in local authorities (Palmer Development Group)

New

- **789** Development of a legal framework to provide for the effective management and sustainable utilisation of South Africa's groundwater resources (DWAF)
- **790** Estimation of the residential price elasticities of demand for water by means of a contingent valuation approach (Economic Project Evaluation (Pty) Ltd.)
- **793** Development of a philosophy and methodology for the implementation of "the polluter pays" principle in the context of receiving water quality objectives (Stewart Scott (CE) Inc.)
- **854** Review of industrial effluent tariff structures in South Africa and guidelines on the formulation of an equitable effluent tariff structure (DA Kerdachi, Private Consultant)
- **870** Pricing of water resources in South Africa with specific reference to riparian surface water (University of Natal – Department of Agricultural Economics)

16 HYDRAULICS



With reference to Project No 442, the above photographs illustrate models investigating flow measurement utilising the sluicing flume in combination with an existing weir.

In terms of the Water Research Act (Act No 34 of 1971, as amended) the WRC is charged to, *inter alia*, promote research in respect of "the occurrence, preservation, conservation, utilization, control, supply, distribution, purification, pollution or reclamation of water supplies and water; and the use of water for agricultural, industrial or urban purposes". Examined closely, hydraulics, being that branch of science and technology concerned with the mechanics of fluids (especially liquids), to a greater or lesser extent forms an integral part of all of these facets of water.

It is not very often that a research project addresses a need that could be described as a singularly hydraulic problem. Most of the times the hydraulics component of the problem is dealt with as a subsection of the overall objective of the research project, thereby not giving hydraulics the recognition it deserves as a research field in its own right. In view of the important role of hydraulics as indicated above, and in order to promote it as a research field qualifying for WRC research funding, the situation, as far as the WRC is concerned, was rectified by establishing this chapter in the *WRC Technical Report*, dedicated to hydraulics-related research projects.

During the year under review no new research projects commenced which qualify for inclusion in this chapter. However, certain developments regarding two of the current projects occurred during 1997 which warrant mentioning at this stage.

Development of improved flow-gauging structures for South African rivers

(No 442) Sigma Beta (CE)

This project commenced in 1992 with the objectives to upgrade existing gauging stations and the standardisation thereof, as well as to develop a gauging structure which requires minimum maintenance but ensures flow gauging of adequate accuracy. In 1995 the research team reported on the development of the so-called sluicing flume with the characteristics of being able to deal with extreme variations in discharge magnitudes, and of integrating a Crump weir with the flume, thus providing for a smooth transition between low-notch measurements and the established practices for discharge measurements over different weir sections at higher water levels (WRC Report No 442/2/95).

The sluicing flume has been well received by the DAWF and a number of these flumes have already been constructed. The Department, however, identified two further needs as far as this flume is concerned, and in order to attend to these needs without a loss in research momentum, the term of this project has been extended to 31 December 1997. During the additional period the research team will concentrate on the above-mentioned needs, i.e. optimising of the structure and gauging points for additional depth: width ratios, and a critical evaluation of the flume's gauging characteristics under submerged conditions.

Removal of floating and suspended materials from streams

(No 691) Department of Civil Engineering, University of Stellenbosch

Poor litter control in river catchments, resulting in an unacceptable type of pollution of rivers, vleis and beaches, forms the background to this research project which commenced in 1995. As is indicated by the title, the project also addresses the problem of sediment removal, especially as far as pumping stations and diversion structures are concerned.

Originally it was planned to have the project completed during 1997 but it has now been extended to 31 December 1998. This extension will allow more in-depth

research to improve the current understanding of the behaviour of water-borne trash (particularly plastics) in the vicinity of trapping structures, thereby contributing to the development of in-line, self-cleaning screens requiring lower capital and running costs, yet displaying a high trap efficiency and a low head loss. Furthermore, the need for a catchment management study regarding the control of littering is to be investigated due to the fact that the trash loading rate in South Africa is two orders of magnitude (100) more than in Australia – currently considered to be the world leaders as far as removal of floating trash is concerned.

In the sediment removal part of the project, the intention is to prepare guidelines for the extraction of water from sediment-laden rivers – a document for which there is an urgent need under South African conditions. Extensive model studies at the Universities of Stellenbosch and of Cape Town are being attended to in support of the development of the above-mentioned guidelines.

Research projects

Current

- **433** Engineering properties of important Southern African rock types with special reference to the shearing strength of concrete dam wall foundations (Technikon Pretoria – School for Civil Engineering)
- **442** Development of improved flow-gauging structures for South African rivers (Sigma Beta (CE))
- **502** Plunge pool scour reproduction in hydraulic models (CSIR – Division of Water, Environment and Forestry Technology)
- **580** The control of dam siltation in South Africa (BKS (CE) Inc.)
- **643** Development of rigorous engineering methodology for designing vegetable erosion protection systems: Phase 2 (SRK (CE) Inc.)
- **691** Removal of floating and suspended materials from streams (University of Stellenbosch – Department of Civil Engineering)

CONTACT PERSONS

- **Mr DS van der Merwe**
  (Hydraulics)
  e-mail: david@wrc.ccwr.ac.za
- **Mr H Maaren**
  (Sedimentation)
  e-mail: hugo@wrc.ccwr.ac.za
- **Mr AG Reynders**
  (Geological Aspects)
  e-mail: tony@wrc.ccwr.ac.za

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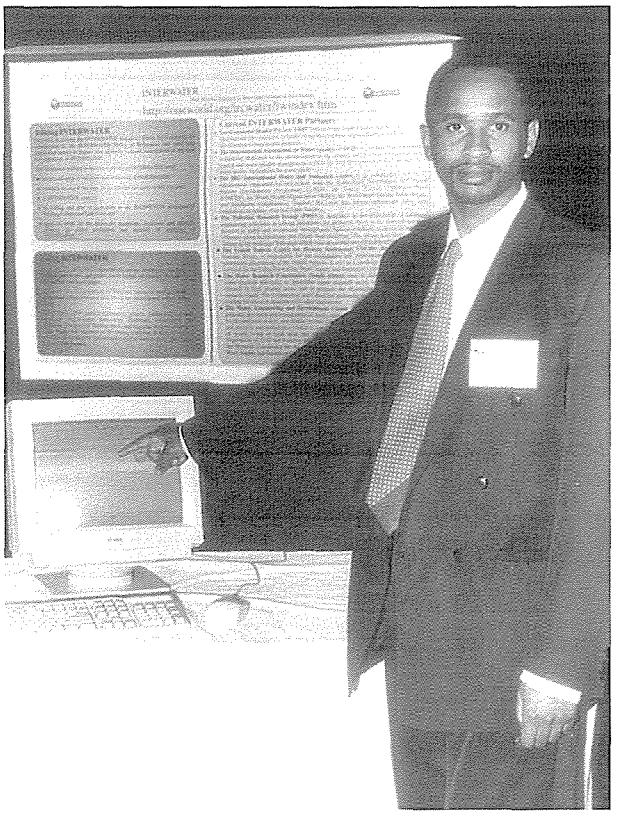
INFORMATION TECHNOLOGY AND RESEARCH SUPPORT SERVICES



Mr Ndirangu Wa Kibata demonstrating Internet pages from the Interwater Website during the WEDC Conference held in Durban in September 1997.

Up to the end of 1996, the South African Water Information Centre (SAWIC), located at the CSIR, was funded by the WRC as a support service to the South African water research and practitioner community. SAWIC's main task had been to build and maintain the bibliographic database, WATERLIT, and to provide the necessary user support for WATERLIT. The beginning of 1997 saw a new arrangement come into being: WATERLIT is now being run as an independent research-support project and senior personnel from SAWIC have relocated to the WRC to form a new information technology (IT) group within the WRC. SAWIC, as such, has ceased to exist. The WRC's other major research service, the Computing Centre for Water Research (CCWR) continues to operate independently.

Information Technology (IT)

The main tasks of the IT group are to assist the WRC with its internal information management and in fulfilling a major part of its mission, viz. the effective transfer of information and technology to users outside the WRC. This includes the development and population of the WRC's Website on the Internet, to make it the single entry-point to water-related information in South Africa.

The WRC's Website was launched on 1 April 1997. The site aims to reflect, *inter alia*, the activities of the WRC, together with the results of projects funded by the WRC. The development of the site is a dynamic process, with new items constantly being added.

Current contents may be viewed at http://www-wrc.ccwr.ac.za.

Besides populating the website, the IT group further supports the water research community by managing information output and providing user support in respect of the WATERLIT database. Finally, it has been tasked with redesigning and developing a database for water-related research projects in South Africa, covering projects funded not only by the WRC, but all other organisations as well.

Research networks to enable an unlimited number of individuals, who share the same interest but are located in different parts of the world, have been co-developed with the WRC. The organisation plans to set up many more such networks in the near future based on the success of the existing information network groups, i.e. Interwater, Emily and the KwaZulu-Natal Water Research Network (KZNWRN).

WATERLIT

The building of the WATERLIT database will continue under contract to the CSIR. User support will be provided by the WRC's IT group.

WATERLIT continued its steady growth during 1997. The total number of references in the database now exceeds 285 000 and the growth rate remains at around 1 200 items per month. The drastic increase in journal subscriptions has forced the developers of the database to utilise information resources located outside the CSIR, e.g. the Universities of Pretoria and Stellenbosch, etc. Almost 40% of the journal titles covered are now obtained from sources outside the CSIR:

CSIR journals	314
Non-CSIR journals	190
Total	**504**

The thesaurus, listing the controlled terminology used to describe the contents of publications when referenced in the database, was revised and published in 1997. A total of 10 000 terms are now available to indexers to describe the contents of every publication added to WATERLIT.

The rapid development of IT has opened up new ways for making the database available to users world-wide. WATERLIT will be available for free usage by local users via the WRC's website on the Internet. Non-South African users have to subscribe on an annual basis. Sabinet On-line (Pty) Ltd, the local on-line information provider enabling electronic access to a wide variety of local and international databases, is also in the process of linking WATERLIT to their system. Publication of the database on CD-ROM by two international companies still continues. A selection of health-related references from WATERLIT was combined with contributions from other databases and published on CD-ROM by NISC under the title: African Health Anthology (AHA).

The use of the Internet as a mechanism to manage information provision and retrieval has had a dramatic impact on the use of computerised databases. With direct access to the database via the Internet now in place, WATERLIT is sharing the lead with information providers in the rest of the world.

Computing Centre for Water Research (CCWR)

The CCWR was established jointly by the WRC, IBM South Africa and the University of Natal in 1986 and has been supported by the WRC since that time. The WRC views the CCWR as a strategic initiative to support four key elements of the WRC's overall strategy which are 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 technological knowledge.

These strategic actions support and simultaneously depend on one of the key principles of the proposed new Water Law, namely, integrated catchment management (ICM). The WRC's establishment and continued support of the CCWR is an embodiment of the WRC's belief that integrated science is an essential foundation for ICM.

South Africa has a number of world-class water scientists and their supporting groups. However, they are separated geographically, organisationally and in terms of their disciplines. This separation has both advantages and disadvantages for these experts need to specialise but at the same time they also need to integrate their highly complex, multi-faceted and interdependent fields of water science. The CCWR's activities are one of the many actions which the WRC supports in order to creatively and cost-effectively minimise the disadvantages and maximise the advantages. The incredible growth in wide-area computer networking technology has enabled the WRC to create a virtual centre, in the CCWR, where intellect from throughout Southern Africa and indeed the world can interact to co-create new perspectives which in turn lead to more effective actions.

Effective actions are certainly required in the management of water issues in Southern Africa. Fully 70% of the land area in the Southern African Development Community (SADC) is comprised of shared river basins. There is thus a need to broaden participation and thereby democratise the process of ICM for sustainable water resources development. This need is fundamental to peaceful, holistic and equitable progress in Southern Africa, a region so racked with conflict and riven with inequalities which exacerbate the already complex situation surrounding the sustainable development of scarce water resources.

The above gives the philosophical and business rationale for the continued support of the CCWR. A key question, however, is what of the CCWR's performance? Its involvement in all aspects of water research and practice in South Africa continues to be reliable, innovative and extensive. The CCWR's small staff of 6 professionals serves the on-line, medium- and long-term needs of 353 registered users who are based at no fewer than 127 departments within 86 institutions including 17 overseas institutions in the USA, Britain, Germany, Australia and New Zealand. A further breakdown of users reveals approximately 63% from universities, 17% from state or parastatal institutions, 15% from private consulting firms and 5% from what could be termed direct stakeholders in water issues.

These users are working on every conceivable aspect of water. Selected achievements and initiatives of these users in which the CCWR has been involved in the year under review are:

- Assisting with the development of an Internet home page and wide-area communications for a number of developing community initiatives e.g. National Community Water and Sanitation Training Institute, the University of the North (Sovenga); Ndumiso Environmental Society; Sobantu Environmental Desk; and Greater Edendale Environmental Network (GREEN).
- Interaction with various river management forums which are potential forerunners of the catchment management agencies as envisaged in the new Water Law.
- Continued involvement in the Kruger National Park Rivers Research Programme (KNPRRP) which has already taken on an international dimension.
- Further excellent progress has been made in facilitating the co-operation of

key user groups in developing a software shell for ICM systems and a common standard for the management of complex time-series data within models.
- To ensure the cost-effective development of world class systems products the CCWR is continuing its policy of strengthening international contacts with *inter alia* the US Environmental Protection Agency (EPA), the Water Resources Division of the US Geological Survey and with various scientific groupings working on European Union-funded programmes in Southern Africa.
- A number of the researchers to whom the CCWR directs special attention are working at historically disadvantaged universities, e.g. University of Zululand, University of Fort Hare, University of the North, University of the Western Cape and University of Transkei.
- Primarily through the person of the manager of the CCWR but also through other staff members the CCWR serves on 22 steering and co-ordinating committees as part of the WRC's strategy to facilitate inter-disciplinary interaction.
- Several groups of CCWR users are collaborating to jointly estimate the effects of the El Niño phenomenon on crop yields and water resources in the region. Collaboration in these endeavours has a strong international connection in most cases.

The CCWR strives to work in a complimentary and facilitatory relationship with all the WRC-funded research which potentially requires collaborative computing.

The overall annual total benefit of the CCWR to users is estimated at R6 350 000. The average annual cost over the last five years (adjusted to 1996 levels) has been R1 840 000, which translates to a benefit/cost ratio of about 3.56.

New project

Implementation of appropriate information technologies for the WRC, for the more effective transfer of research results. Phase 3

(No 843) Division of Information and Communications Technology, CSIR

This project is the third in a series, of which the first two were:

- A pilot study to develop an information system to improve the accessibility and usability of research results and reports, through the application of information technology (No 703) 1995.
- Development and implementation of a plan for the WRC, using information technology for the more effective transfer of research results (No 736) 1996.

Results of these projects are implemented in-house, as they become available.

The aims of the present project are to:

- Support the WRC in the development of an Internet site for the organisation
- Develop an information protocol for the submission of research reports as well as for the electronic publishing of official WRC publications
- Provide training to the IT group for the continued development of the Internet site in future.

The official site of the WRC on the Internet was launched on 1 April 1997 as one of the deliverables of this project. At that stage, only basic information about the background of the WRC and its activities was provided. It is planned to add a number of additional features during the rest of the project term.

The development of a WRC Internet site provided the organisation with an opportunity to present the results of its research initiatives to the widest possible audience. As a direct result, copies of WRC research reports have been requested in increasing numbers from all over the world.

Estimated cost: R181 000
Expected term: 1997

Research projects

Current

- **K6/1** Ongoing development and maintenance of the WATERLIT bibliographic database (CSIR – Division of Information and Communications Technology)
- **K6/3** Computing Centre for Water Research (University of Natal – CCWR)
- **735** Promotion of the Internet as a source of information on water and sanitation (University of Natal – Department of Chemical Engineering)

New

- **843** Implementation of appropriate information technologies for the WRC, for the more effective transfer of research results. Phase 3 (CSIR – Division of Information and Communications Technology)

CONTACT PERSONS

- **Mr H Maaren**
  (CCWR)
  e-mail: hugo@wrc.ccwr.ac.za
- **Mr AH du Toit**
  (Network Manager)
  e-mail: arno@wrc.ccwr.ac.za
- **Mrs MM Pretorius**
  (Group Co-ordinator)
  e-mail: mpretori@wrc.ccwr.ac.za
- **Ms F Myburgh**
  (WATERLIT and Webmaster)
  e-mail: fmyburgh@wrc.ccwr.ac.za
- **Ms J Shelwell**
  (Database Design)
  e-mail: jshelwel@wrc.ccwr.ac.za

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TRANSFER OF INFORMATION AND TECHNOLOGY

The promotion of information and technology transfer is one of the most important objectives of the WRC. This is very clearly defined in the Water Research Act, namely to "accumulate, assimilate and disseminate knowledge in regard to the results of such research and the application thereof, and promote development work for the purpose of such application".

For the promotion of its programme of information and technology transfer, the WRC has developed a number of activities. Although some of these activities are directed at the transfer of information, the emphasis falls mainly on technology transfer, i.e. the application of research results, since this will always represent the final dividend of the research investment.

Partnership research

Partnership research is regarded as a very effective method of enhancing technology transfer. The partnership principle is incorporated, as far as possible, in research projects, and means that the end user of the results participates in the planning and execution of the research.

Publications

The WRC's publications cater for three levels, viz. pure scientific, popular scientific and practical scientific.

Water SA

Water SA is the WRC's scientific journal which contains original research articles and review articles on all aspects of water science, technology and engineering. The journal appears quarterly and the first edition was launched in April 1975.

Water SA has a strict refereeing system whereby all articles submitted for publication are first referred to referees, whereafter a decision is taken on publication.

Water SA has an extensive local as well as overseas readership. It also enjoys world-wide coverage in the sense that it is covered by more than 20 international abstracting services who publish and distribute summaries of articles which appear in *Water SA*.

SA Waterbulletin

SA Waterbulletin is a bilingual bi-monthly periodical. Within the broad spectrum of water research it aims to:

- Furnish information on water and water research in a popular scientific manner to the different interest groups in the water field
- Promote the transfer of technology by announcing the availability of reports, manuals, guides etc. which emanate from water research
- Promote communication between the WRC and authorities and individuals, such as researchers, engineers, technicians, government departments, local authorities and the industrial and agricultural sectors
- Convey social news and matters of interest (e.g. about conferences and personalities) to the water research community.

Manuals, guidelines and reports

At the conclusion of a project, and also while research is still under way, results are evaluated in respect of possible use and application and depending on the nature of the results a decision is taken on publication, dissemination and application thereof. More information on these publications appears in the relevant chapters and in the **Annexure**.

List of Commission publications

The **Annexure** to this annual report contains a list of publications (articles, papers and published reports) which appeared during 1996 and which emanated from research supported wholly or in part by the WRC.

Conferences, seminars, workshops and demonstrations

From time to time the WRC, on its own or in co-operation with other organisations, arranges such meetings. These afford ideal opportunities for promoting personal contact between research scientists or between research scientists and the users of research results. In this way the transfer of information and technology is greatly enhanced. More information on meetings held during the year is contained in the individual chapters.

Mass media

In this regard the accent falls on information transfer, and press releases, radio and television are used to this end.

Utilisation of overseas expertise

It is in the national interest that overseas expertise and knowledge be used where these are not available locally, and the WRC has developed various methods to achieve this. Overseas specialists, for example, are engaged as consultants and the WRC from time to time sends personnel and other experts overseas in order to obtain information on a particular problem area. More information in this regard appears in the individual chapters.

Commercialisation

In the future the WRC will focus increasingly on a further aspect of technology transfer, which is in progress already, viz. the commercialisation of research results by e.g. the private sector. The patenting of research results and the sale of publications and computer programs would be classified as such. In this way the WRC earns royalties, locally as well as abroad.

Software

The development of software to support research or to process information and data, is one of the goals of the WRC. Updates will in future be made available for downloading via the WRC's Internet Website.

CONTACT PERSONS

- **Mrs IG Buchan**
  (Editor: *Water SA*)
  e-mail: ingrid@wrc.ccwr.ac.za
- **Mrs HAJ van Rensburg**
  (Assistant Editor: *Water SA*)
  e-mail: drinie@wrc.ccwr.ac.za
- **Mr JP du Plessis**
  (Editor: *SA Waterbulletin*)
  e-mail: jan@wrc.ccwr.ac.za
- **Ms HS Joubert**
  (Assistant Editor: *SA Waterbulletin*)
  e-mail: helene@wrc.ccwr.ac.za
- **Mrs T van der Schyff**
  (Librarian)
  e-mail: tineke@wrc.ccwr.ac.za
- **Ms CA Human**
  (Editorial Secretary: *Water SA and SA Waterbulletin*)
  e-mail: rina@wrc.ccwr.ac.za

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ANNEXURE

Publications emanating from research financed wholly or partially by the WRC

This **Annexure** contains a list of publications released in 1997, as well as a complementary list of 1996. Requests for articles and papers should be directed to the authors.

DEVELOPING COMMUNITIES

Articles and papers (1997)

- Bruwer JW, Sipamla AM, Van der Linde HJ and Frank H (1997) Research on the environmental impact of a rapidly urbanizing community – HPLC as a technique for polyaromatic hydrocarbon detection. Paper presented at Symp. on Environ. Sci. and Ind. in S. Afr., Vista Univ./SA Chem. Inst., Pretoria. July.
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- Grabow WOK (1997) Overcoming new challenges in controlling waterborne diseases. Invited paper: Water Manage., Ownership and Distribution Summit, Inst. for Int. Res., BIFSA Conf. Centre, Midrand. 16-18 July.
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- Taylor MB (1997) Molecular epidemiology of South African strains of hepatitis A virus: 1982-1996. *J. Med. Virol.* **51** 273-279.
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MISSION STATEMENT

To contribute effectively to the best possible quality of life for the people of South Africa, and to the protection of the water environment, 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.*